TN Science Standards Reference

Suggestions for Implementing Three-dimensional Science Instruction

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Introduction

Document Purpose

In October 2016, the Tennessee State Board of Education approved the new Tennessee Academic Standards for Science. The standard recommendation committee authored these standards using the research presented in *A Framework for K-12 Science Education*[1] as guidance. The principal recommendation of the framework was a shift away from a strict adherence to the apparent linearity of the scientific method and towards implementing **three dimensions of science instruction: crosscutting concepts, science and engineering practices, and disciplinary core ideas**.

The intent of this document is to connect the new Tennessee Academic Standards for Science with the framework to provide an enhanced view of related content for each standard. Standards authors took deliberate measures to ensure that content, concepts, and practices follow a progression which parallels the cognitive development of a student from kindergarten through high school.

The first three sections of this document provide reference material that allows individuals to quickly evaluate the appropriate cognitive processes for learners in any grade band. The fourth section provides elaboration on each standard. Depending on course and grade level, this support may include background content knowledge, suggestions for approaches to presenting the content, or background information linking backwards to the conceptual path that a student followed to reach their present grade-level understanding. In this document, each standard is connected to a component idea within the framework, where further context can be found. Additionally, suggestions are made to link each standard to an applicable crosscutting concept and science and engineering practice.

Suggestions for Use

This guide should act as a reference document. The content has been arranged for easy navigation to and from the table of contents. There are suggestions presented for crosscutting concepts and practices that may pair well with each standard, but the intent is not to limit instruction by specifying connections: Many standards have connections to multiple concepts or practices. Additionally, this guide is not intended to provide information related to assessment, but rather to support and elaborate on the content and progressions of science instruction in Tennessee.

[1] National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13165.

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Disciplinary Core Idea Learning Progression: Physical Sciences

The content of the new Tennessee science standards is organized into four different disciplinary core ideas: physical sciences, life sciences, earth and space science, and engineering, technology, and applications of science. Throughout a student's academic career, they will move in and out of each disciplinary core idea in a manner designed to parallel their own capacity for understanding. This section reorganizes the K-8 standards, which allows for a side-by-side comparison of the standards to follow the progression of each disciplinary core idea.

PS1: Matter and its interactions		
K	K.PS1.1	Plan and conduct an investigation to describe and classify different kinds of materials including wood, plastic, metal, cloth, and paper by their observable properties (color, texture, hardness, and flexibility) and whether they are natural or human-made.
	K.PS1.2	Conduct investigations to understand that matter can exist in different states (solid and liquid) and has properties that can be observed and tested.
	K.PS1.3	Construct an evidence-based account of how an object made of a small set of pieces (blocks, snap cubes) can be disassembled and made into a new object.
3	3.PS1.1	Describe the properties of solids, liquids, and gases and identify that matter is made up of particles too small to be seen.
	3.PS1.2	Differentiate between changes caused by heating or cooling that can be reversed and that cannot.
	3.PS1.3	Describe and compare the physical properties of matter including color, texture, shape, length, mass, temperature, volume, state, hardness, and flexibility.
5	5.PS1.1	Analyze and interpret data from observations and measurements of the physical properties of matter to explain phase changes between a solid, liquid, or gas.
	5.PS1.2	Analyze and interpret data to show that the amount of matter is conserved even when it changes form, including transitions where matter seems to vanish.
	5.PS1.3	Design a process to measure how different variables (temperature, particle size, stirring) affect the rate of dissolving solids into liquids.
	5.PS1.4	Evaluate the results of an experiment to determine whether the mixing of two or more substances result in a change of properties
7	7.PS1.1	Develop and use models to illustrate the structure of atoms, including the subatomic particles with their relative positions and charge.
	7.PS1.2	Compare and contrast elemental molecules and compound molecules.
	7.PS1.3	Classify matter as pure substances or mixtures based on composition
	7.PS1.4	Analyze and interpret chemical reactions to determine if the total number of atoms in the reactants and products support the Law of Conservation of Mass
	7.PS1.5	Use the periodic table as a model to analyze and interpret evidence relating to physical and chemical properties to identify a sample of matter.
	7.PS1.6	Create and interpret models of substances whose atoms represent the states of matter with respect to temperature and pressure

PS2: Motion and Stability: Forces and Interactions		
2	2.PS2.1	Analyze the push or the pull that occurs when objects collide or are connected
	2.PS2.2	Evaluate the effects of different strengths and directions of a push or a pull on the motion of an object.
	2.PS2.3	Recognize the effect of multiple pushes and pulls on an object's movement or non-movement.
3	3.PS2.1	Explain the cause and effect relationship of magnets.
	3.PS2.2	Solve a problem by applying the use of the interactions between two magnets.
5	5.PS2.1	Test the effects of balanced and unbalanced forces on the speed and direction of motion of objects.
	5.PS2.2	Make observations and measurements of an object’s motion to provide evidence that a pattern can be used to predict future motion.
	5.PS2.3	Use evidence to support that the gravitational force exerted by Earth on objects is directed toward the Earth’s center.
	5.PS2.4	Explain the cause and effect relationship of two factors (mass and distance) that affect gravity.
	5.PS2.5	Explain how forces can create patterns within a system (moving in one direction, shifting back and forth, or moving in cycles), and describe conditions that affect how fast or slowly these patterns occur
8	8.PS2.1	Design and conduct investigations depicting the relationship between magnetism and electricity in electromagnets, generators, and electrical motors, emphasizing the factors that increase or diminish the electric current and the magnetic field strength.
	8.PS2.2	Conduct an investigation to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.
	8.PS2.3	Create a demonstration of an object in motion and describe the position, force, and direction of the object.
	8.PS2.4	Plan and conduct an investigation to provide evidence that the change in an object’s motion depends on the sum of the forces on the object and the mass of the object.
	8.PS2.5	Evaluate and interpret that for every force exerted on an object there is an equal force exerted in the opposite direction.

PS3: Energy		
1	1.PS3.1	Make observations to determine how sunlight warms Earth's surfaces (sand, soil, rocks, and water).
2	2.PS3.1	Demonstrate how a stronger push or pull makes things go faster and how faster speeds during a collision can cause a bigger change in the shape of the colliding objects
	2.PS3.2	Make observations and conduct experiments to provide evidence that friction produces heat and reduces or increases the motion of an object.
3	3.PS3.1	Recognize that energy is present when objects move; describe the effects of energy transfer from one object to another.
	3.PS3.2	Apply scientific ideas to design, test, and refine a device that converts electrical energy to another form of energy, using open or closed simple circuits.
	3.PS3.3	Evaluate how magnets cause changes in the motion and position of objects, even when the objects are not touching the magnet.
4	4.PS3.1	Use evidence to explain the cause and effect relationship between the speed of an object and the energy of an object.
	4.PS3.2	Observe and explain the relationship between potential energy and kinetic energy.
	4.PS3.3	Describe how stored energy can be converted into another form for practical use.
6	6.PS3.1	Analyze the properties and compare sources of kinetic, elastic potential, gravitational potential, electric potential, chemical, and thermal energy.
	6.PS3.2	Construct a scientific explanation of the transformations between potential and kinetic energy.
	6.PS3.3	Analyze and interpret data to show the relationship between kinetic energy and the mass of an object in motion and its speed.
	6.PS3.4	Conduct an investigation to demonstrate the way that heat (thermal energy) moves among objects through radiation, conduction, or convection.

PS4: Waves and their applications in technologies for information transfer		
1	1.PS4.1	Use a model to describe how light is required to make objects visible. Summarize how Illumination could be from an external light source or by an object giving off its own light.
	1.PS4.2	Determine the effect of placing objects made with different materials (transparent, translucent, opaque, and reflective) in the path of a beam of light.
2	2.PS4.1	Plan and conduct investigations to demonstrate the cause and effect relationship between vibrating materials (tuning forks, water, bells) and sound.
	2.PS4.2	Use tools and materials to design and build a device to understand that light and sound travel in waves and can send signals over a distance.
	2.PS4.3	Observe and demonstrate that waves move in regular patterns of motion by disturbing the surface of shallow and deep water.
4	4.PS4.1	Use a model of a simple wave to explain regular patterns of amplitude, wavelength, and direction.
	4.PS4.2	Describe how the colors of available light sources and the bending of light waves determine what we see.
	4.PS4.3	Investigate how lenses and digital devices like computers or cell phones use waves to enhance human senses.
8	8.PS4.1	Develop and use models to represent the basic properties of waves including frequency, amplitude, wavelength, and speed.
	8.PS4.2	Compare and contrast mechanical waves and electromagnetic waves based on refraction, reflection, transmission, absorption, and their behavior through a vacuum and/or various media.
	8.PS4.3	Evaluate the role that waves play in different communication systems.

Disciplinary Core Idea Learning Progression: Life Sciences

LS1: From Molecules to Organisms: Structure and Process		
K	K.LS1.1	Use information from observations to identify differences between plants and animals (locomotion, obtainment of food, and take in air/gasses).
	K.LS1.2	Recognize differences between living organisms and non-living materials and sort them into groups by observable physical attributes.
	K.LS1.3	Explain how humans use their five senses in making scientific findings.
1	1.LS1.1	Recognize the structure of plants (roots, stems, leaves, flowers, fruits) and describe the function of the parts (taking in water and air, producing food, making new plants).
	1.LS1.2	Illustrate and summarize the life cycle of plants.
	1.LS1.3	Analyze and interpret data from observations to describe how changes in the environment cause plants to respond in different ways.
2	2.LS1.1	Use evidence and observations to explain that many animals use their body parts and senses in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water, and air.
	2.LS1.2	Obtain and communicate information to classify animals (vertebrates-mammals, birds, amphibians, reptiles, fish, invertebrates-insects) based on their physical characteristics
	2.LS1.3	Use simple graphical representations to show that species have unique and diverse life cycles.
3	3.LS1.1	Analyze the internal and external structures that aquatic and land animals and plants have to support survival, growth, behavior, and reproduction.
5	5.LS1.1	Compare and contrast animal responses that are instinctual versus those that that are gathered through the senses, processed, and stored as memories to guide their actions.
7	7.LS1.1	Develop and construct models that identify and explain the structure and function of major cell organelles as they contribute to the life activities of the cell and organism.
	7.LS1.2	Conduct an investigation to demonstrate how the cell membrane maintains homeostasis through the process of passive transport.
	7.LS1.3	Evaluate evidence that cells have structural similarities and differences in organisms across kingdoms
	7.LS1.4	Diagram the hierarchical organization of multicellular organisms from cells to organism
	7.LS1.5	Explain that the body is a system comprised of subsystems that maintain equilibrium and support life through digestion, respiration, excretion, circulation, sensation (nervous and integumentary), and locomotion (musculoskeletal).
	7.LS1.6	Develop an argument based on empirical evidence and scientific reasoning to explain how behavioral and structural adaptations in animals and plants affect the probability of survival and reproductive success.
	7.LS1.7	Evaluate and communicate evidence that compares and contrasts the advantages and disadvantages of sexual and asexual reproduction.

	7.LS1.8	Construct an explanation demonstrating that the function of mitosis for multicellular organisms is for growth and repair through the production of genetically identical daughter cells.
	7.LS1.9	Construct a scientific explanation based on compiled evidence for the processes of photosynthesis, cellular respiration, and anaerobic respiration in the cycling of matter and flow of energy into and out of organisms.

LS2: Ecosystems: Interactions, Energy and Dynamics		
1	1.LS2.1	Conduct an experiment to show how plants depend on air, water, minerals from soil, and light to grow and thrive.
	1.LS2.2	Obtain and communicate information to classify plants by where they grow (water, land) and the plant's physical characteristics.
	1.LS2.3	Recognize how plants depend on their surroundings and other living things to meet their needs in the places they live.
2	2.LS2.1	Develop and use models to compare how animals depend on their surroundings and other living things to meet their needs in the places they live.
	2.LS2.2	Predict what happens to animals when the environment changes (temperature, cutting down trees, wildfires, pollution, salinity, drought, land preservation).
3	3.LS2.1	Construct an argument to explain why some animals benefit from forming groups
4	4.LS2.1	Support an argument with evidence that plants get the materials they need for growth and reproduction chiefly through a process in which they use carbon dioxide from the air, water, and energy from the sun to produce sugars, plant materials, and waste (oxygen); and that this process is called photosynthesis.
	4.LS2.2	Develop models of terrestrial and aquatic food chains to describe the movement of energy among producers, herbivores, carnivores, omnivores, and decomposers.
	4.LS2.3	Using information about the roles of organisms (producers, consumers, decomposers), evaluate how those roles in food chains are interconnected in a food web, and communicate how the organisms are continuously able to meet their needs in a stable food web.
	4.LS2.4	Develop and use models to determine the effects of introducing a species to, or removing a species from, an ecosystem and how either one can damage the balance of an ecosystem.
	4.LS2.5	Analyze and interpret data about changes (land characteristics, water distribution, temperature, food, and other organisms) in the environment and describe what mechanisms organisms can use to affect their ability to survive and reproduce.
6	6.LS2.1	Evaluate and communicate the impact of environmental variables on population size.
	6.LS2.2	Determine the impact of competitive, symbiotic, and predatory interactions in an ecosystem.
	6.LS2.3	Draw conclusions about the transfer of energy through a food web and energy pyramid in an ecosystem.
	6.LS2.4	Using evidence from climate data, draw conclusions about the patterns of abiotic and biotic factors in different biomes, specifically the tundra, taiga, deciduous forest, desert, grasslands, rainforest, marine, and freshwater ecosystems.
	6.LS2.5	Analyze existing evidence about the effect of a specific invasive species on native populations in Tennessee and design a solution to mitigate its impact.
	6.LS2.6	Research the ways in which an ecosystem has changed over time in response to changes in physical conditions, population balances, human interactions, and natural catastrophes.
	6.LS2.7	Compare and contrast auditory and visual methods of communication among organisms in relation to survival strategies of a population.
7	7.LS2.1	Develop a model to depict the cycling of matter, including carbon and oxygen, including the flow of energy among biotic and abiotic parts of an ecosystem.

LS3: Heredity: Inheritance and Variations of traits		
K	K.LS3.1	Make observations to describe that young plants and animals resemble their parents.
2	2.LS3.1	Use evidence to explain that living things have physical traits inherited from parents and that variations of these traits exist in groups of similar organisms
5	5.LS3.1	Distinguish between inherited characteristics and those characteristics that result from a direct interaction with the environment. Apply this concept by giving examples of characteristics of living organisms that are influenced by both inheritance and the environment.
	5.LS3.2	Provide evidence and analyze data that plants and animals have traits inherited from parents and that variations of these traits exist in a group of similar organisms.
7	7.LS3.1	Hypothesize that the impact of structural changes to genes (i.e., mutations) located on chromosomes may result in harmful, beneficial, or neutral effects to the structure and function of the organism.
	7.LS3.2	Distinguish between mitosis and meiosis and compare the resulting daughter cells.
	7.LS3.3	Predict the probability of individual dominant and recessive alleles to be transmitted from each parent to offspring during sexual reproduction and represent the phenotypic and genotypic patterns using ratios.

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LS4: Biological Change: Unity and Diversity		
3	3.LS4.1	Explain the cause and effect relationship between a naturally changing environment and an organism's ability to survive.
	3.LS4.2	Infer that plant and animal adaptations help them survive in land and aquatic biomes.
	3.LS4.3	Explain how changes to an environment's biodiversity influence human resources.
4	4.LS4.1	Obtain information about what a fossil is and ways a fossil can provide information about the past.
5	5.LS4.1	Analyze and interpret data from fossils to describe types of organisms and their environments that existed long ago. Compare similarities and differences of those to living organisms and their environments. Recognize that most kinds of animals (and plants) that once lived on Earth are now extinct.
	5.LS4.2	Use evidence to construct an explanation for how variations in characteristics among individuals within the same species may provide advantages to these individuals in their survival and reproduction.
6	6.LS4.1	Explain how changes in biodiversity would impact ecosystem stability and natural resources.
	6.LS4.2	Design a possible solution for maintaining biodiversity of ecosystems while still providing necessary human resources without disrupting environmental equilibrium.
8	8.LS4.1	Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change in life forms throughout Earth's history
	8.LS4.2	Construct an explanation addressing similarities and differences of the anatomical structures and genetic information between extinct and extant organisms using evidence of common ancestry and patterns between taxa
	8.LS4.3	Analyze evidence from geology, paleontology, and comparative anatomy to support that specific phenotypes within a population can increase the probability of survival of that species and lead to adaptation.
	8.LS4.4	Develop a scientific explanation of how natural selection plays a role in determining the survival of a species in a changing environment.
	8.LS4.5	Obtain, evaluate, and communicate information about the technologies that have changed the way humans use artificial selection to influence the inheritance of desired traits in other organisms.

Disciplinary Core Idea Learning Progression: Earth and Space Sciences

ESS1: Earth's Place in the Universe		
1	1.ESS1.1	Use observations or models of the sun, moon, and stars to describe patterns that can be predicted.
	1.ESS1.2	Observe natural objects in the sky that can be seen from Earth with the naked eye and recognize that a telescope, used as a tool, can provide greater detail of objects in the sky.
	1.ESS1.3	Analyze data to predict patterns between sunrise and sunset, and the change of seasons
2	2.ESS1.1	Recognize that some of Earth's natural processes are cyclical, while others have a beginning and an end. Some events happen quickly, while others occur slowly over time
3	3.ESS1.1	Use data to categorize the planets in the solar system as inner or outer planets according to their physical properties.
4	4.ESS1.1	Generate and support a claim with evidence that over long periods of time, erosion (weathering and transportation) and deposition have changed landscapes and created new landforms.
	4.ESS1.2	Use a model to explain how the orbit of the Earth and sun cause observable patterns: a. day and night; b. changes in length and direction of shadows over a day
5	5.ESS1.1	Explain that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from the Earth.
	5.ESS1.2	Research and explain the position of the Earth and the solar system within the Milky Way galaxy, and compare the size and shape of the Milky Way to other galaxies in the universe.
	5.ESS1.3	Use data to categorize different bodies in our solar system including moons, asteroids, comets, and meteoroids according to their physical properties and motion.
	5.ESS1.4	Explain the cause and effect relationship between the positions of the sun, earth, and moon and resulting eclipses, position of constellations, and appearance of the moon.
	5.ESS1.5	Relate the tilt of the Earth's axis, as it revolves around the sun, to the varying intensities of sunlight at different latitudes. Evaluate how this causes changes in day-lengths and seasons.
	5.ESS1.6	Use tools to describe how stars and constellations appear to move from the Earth's perspective throughout the seasons.
	5.ESS1.7	Use evidence from the presence and location of fossils to determine the order in which rock strata were formed.
8	8.ESS1.1	Research, analyze, and communicate that the universe began with a period of rapid expansion using evidence from the motion of galaxies and composition of stars.

	8.ESS1.2	Explain the role of gravity in the formation of our sun and planets. Extend this explanation to address gravity's effect on the motion of celestial objects in our solar system and Earth's ocean tides.

ESS2: Earth's Systems		
K	K.ESS2.1	Analyze and interpret weather data (precipitation, wind, temperature, cloud cover) to describe weather patterns that occur over time (hourly, daily) using simple graphs, pictorial weather symbols, and tools (thermometer, rain gauge).
	K.ESS2.2	Develop and use models to predict weather and identify patterns in spring, summer, autumn, and winter.
2	2.ESS2.1	Compare the effectiveness of multiple solutions designed to slow or prevent wind or water from changing the shape of the land.
	2.ESS2.2	Observe and analyze how blowing wind and flowing water can move Earth materials (soil, rocks) from one place to another, changing the shape of a landform and affecting the habitats of living things.
	2.ESS2.3	Compare simple maps of different land areas to observe the shapes and kinds of land (rock, soil, sand) and water (river, stream, lake, pond).
	2.ESS2.4	Use information obtained from reliable sources to explain that water is found in the ocean, rivers, streams, lakes, and ponds, and may be solid or liquid
3	3.ESS2.1	Explain the cycle of water on Earth.
	3.ESS2.2	Associate major cloud types (cumulus, cumulonimbus, cirrus, stratus, nimbostratus) with weather conditions.
	3.ESS2.3	Use tables, graphs, and tools to describe precipitation, temperature, and wind (direction and speed) to determine local weather and climate.
	3.ESS2.4	Incorporate weather data to describe major climates (polar, temperate, tropical) in different regions of the world
4	4.ESS2.1	Collect and analyze data from observations to provide evidence that rocks, soils, and sediments are broken into smaller pieces through mechanical weathering (frost wedging, abrasion, tree root wedging) and are transported by water, ice, wind, gravity, and vegetation.
	4.ESS2.2	Interpret maps to determine that the location of mountain ranges, deep ocean trenches, volcanoes, and earthquakes occur in patterns.
	4.ESS2.3	Provide examples to support the claim that organisms affect the physical characteristics of their regions.
	4.ESS2.4	Analyze and interpret data on the four layers of the Earth, including thickness, composition, and physical states of these layers.
6	6.ESS2.1	Gather evidence to justify that oceanic convection currents are caused by the sun's transfer of heat energy and differences in salt concentration leading to global water movement.
	6.ESS2.2	Diagram convection patterns that flow due to uneven heating of the earth.
	6.ESS2.3	Construct an explanation for how atmospheric flow, geographic features, and ocean currents affect the climate of a region through heat transfer.
	6.ESS2.4	Apply scientific principles to design a method to analyze and interpret the impact of humans and other organisms on the hydrologic cycle.
	6.ESS2.5	Analyze and interpret data from weather conditions, weather maps, satellites, and radar to predict probable local weather patterns and conditions.
	6.ESS2.6	Explain how relationships between the movement and interactions of air masses, high and low pressure systems, and frontal boundaries result in weather conditions and severe storms.

8	8.ESS2.1	Analyze and interpret data to support the assertion that rapid or gradual geographic changes lead to drastic population changes and extinction events.
	8.ESS2.2	Evaluate data collected from seismographs to create a model of Earth's structure
	8.ESS2.3	Describe the relationship between the processes and forces that create igneous, sedimentary, and metamorphic rocks.
	8.ESS2.4	Gather and evaluate evidence that energy from the earth's interior drives convection cycles within the asthenosphere which creates changes within the lithosphere including plate movements, plate boundaries, and sea-floor spreading.
	8.ESS2.5	Construct a scientific explanation using data that explains the gradual process of plate tectonics accounting for A) the distribution of fossils on different continents, B) the occurrence of earthquakes, and C) continental and ocean floor features (including mountains, volcanoes, faults, and trenches)

ESS3: Earth and Human Activity		
k	K.ESS3.1	Use a model to represent the relationship between the basic needs (shelter, food, water) of different plants and animals (including humans) and the places they live.
	K.ESS3.2	Explain the purpose of weather forecasting to prepare for, and respond to, severe weather in Tennessee.
	K.ESS3.3	Communicate solutions that will reduce the impact from humans on land, water, air, and other living things in the local environment.
3	3.ESS3.1	Explain how natural hazards (fires, landslides, earthquakes, volcanic eruptions, floods) impact humans and the environment.
	3.ESS.3.2	Design solutions to reduce the impact of natural hazards (fires, landslides, earthquakes, volcanic eruptions, floods) on the environment.
4	4.ESS3.1	Obtain and combine information to describe that energy and fuels are derived from natural resources and that some energy and fuel sources are renewable (sunlight, wind, water) and some are not (fossil fuels, minerals).
	4.ESS3.2	Create an argument, using evidence from research, that human activity (farming, mining, building) can affect the land and ocean in positive and/or negative ways.
6	6.ESS3.1	Differentiate between renewable and nonrenewable resources by asking questions about their availability and sustainability.
	6.ESS3.2	Investigate and compare existing and developing technologies that utilize renewable and alternative energy resources.
	6.ESS3.3	Assess the impacts of human activities on the biosphere including conservation, habitat management, species endangerment, and extinction.
7	7.ESS3.1	Graphically represent the composition of the atmosphere as a mixture of gases and discuss the potential for atmospheric change.
	7.ESS3.2	Engage in a scientific argument through graphing and translating data regarding human activity and climate.
8	8.ESS3.1	Interpret data to explain that earth's mineral, fossil fuel, and groundwater resources are unevenly distributed as a result of geologic processes.
	8.ESS3.2	Collect data, map, and describe patterns in the locations of volcanoes and earthquakes related to tectonic plate boundaries, interactions, and hotspots.

Disciplinary Core Idea Learning Progression: Engineering, Technology, & Applications of Science

ETS1: Engineering Design		
K	K.ETS1.1	Ask and answer questions about the scientific world and gather information using the senses.
	K.ETS1.2	Describe objects accurately by drawing and/or labeling pictures.
1	1.ETS1.1	Solve scientific problems by asking testable questions, making short-term and long-term observations, and gathering information.
2	2.ETS1.1	Define a simple problem that can be solved through the development of a new or improved object or tool by asking questions, making observations, and gather accurate information about a situation people want to change
	2.ETS1.2	Develop a simple sketch, drawing, or physical model that communicates solutions to others.
	2.ETS1.3	Recognize that to solve a problem, one may need to break the problem into parts, address each part, and then bring the parts back together
	2.ETS1.4	Compare and contrast solutions to a design problem by using evidence to point out strengths and weaknesses of the design
3	3.ETS1.1	Design a solution to a real-world problem that includes specified criteria for constraints.
	3.ETS1.2	Apply evidence or research to support a design solution.
4	4.ETS1.1	Categorize the effectiveness of design solutions by comparing them to specified criteria for constraints.
5	5.ETS1.1	Research, test, re-test, and communicate a design to solve a problem.
	5.ETS1.2	Plan and carry out tests on one or more elements of a prototype in which variables are controlled and failure points are considered to identify which elements need to be improved. Apply the results of tests to redesign the prototype.
	5.ETS1.3	Describe how failure provides valuable information toward finding a solution.
6	6.ETS1.1	Evaluate design constraints on solutions for maintaining ecosystems and biodiversity.
	6.ETS1.2	Design and test different solutions that impact energy transfer.
8	8.ETS1.1	Develop a model to generate data for ongoing testing and modification of an electromagnet, a generator, and a motor such that an optimal design can be achieved.
	8.ETS1.2	Research and communicate information to describe how data from technologies (telescopes, spectroscopes, satellites, and space probes) provide information about objects in the solar system and universe.

ETS2: Links Among Engineering, Technology, and Science on Society and the Natural World		
K	K.ETS2.1	Use appropriate tools (magnifying glass, rain gauge, basic balance scale) to make observations and answer testable scientific questions.
1	1.ETS2.1	Use appropriate tools (magnifying glass, basic balance scale) to make observations and answer testable scientific questions.
2	2.ETS2.1	Use appropriate tools to make observations, record data, and refine design ideas.
	2.ETS2.2	Predict and explain how human life and the natural world would be different without current technologies.
3	3.ETS2.1	Identify and demonstrate how technology can be used for different purposes.
4	4.ETS2.1	Use appropriate tools and measurements to build a model.
	4.ETS2.2	Determine the effectiveness of multiple solutions to a design problem given the criteria and the constraints.
	4.ETS2.3	Explain how engineers have improved existing technologies to increase their benefits, to decrease known risks, and to meet societal demands (artificial limbs, seatbelts, and cell phones).
5	5.ETS2.1	Use appropriate measuring tools, simple hand tools, and fasteners to construct a prototype of a new or improved technology.
	5.ETS2.2	Describe how human beings have made tools and machines (X-ray cameras, microscopes, satellites, computers) to observe and do things that they could not otherwise sense or do at all, or as quickly or efficiently.
	5.ETS2.3	Identify how scientific discoveries lead to new and improved technologies.
7	7.ETS2.1	Examine a problem from the medical field pertaining to biomaterials and design a solution taking into consideration the criteria, constraints, and relevant scientific principles of the problem that may limit possible solutions.

Progression of Crosscutting Concepts

Across all disciplines, there are crosscutting concepts which unify all of the disciplines of science. Crosscutting concepts represent one of the three dimensions of science instruction. As a student's science schemas become increasingly complex, so does their ability to see the connections between seemingly dissociated ideas. These seven crosscutting concepts will look different depending on the development of the student. Growth in math ability and scientific literacy promote discussions of more complex connections.

Crosscutting Concept 1

Patterns: Observation and explanation			
Framework Description: *Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them. (NRC, p.84)*			
Early Elementary (K-2)	**Upper Elementary (3-5)**	**Middle Grades (6-8)**	**High School (9-12)**
• Students recognize, classify, and record patterns they observe in nature or man-made objects.	• Students recognize, classify, and record patterns involving rates of change. • Students use patterns as evidence in an argument or to make predictions, construct explanations, and engage in arguments.	• Students recognize, classify, and record patterns for macroscopic phenomena based on microscopic structure. • Students recognize, classify, and record patterns in data, graphs, and charts. • Students infer and identify cause and effect relationships from patterns.	• Students recognize, classify, and record patterns in quantitative data from empirical research and mathematical representations. • Students recognize that different patterns for the same system may be present depending on the scale at which the system is analyzed.

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Crosscutting Concept 2

Cause and Effect: Relationships can be explained through a mechanism.			
Framework Description: *Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts. (NRC, p.84)*			
Early Elementary (K-2)	**Upper Elementary (3-5)**	**Middle Grades (6-8)**	**High School (9-12)**
• Students identify cause and effect relationships through observable patterns, utilizing simplistic tests to provide evidence to support or refute their ideas.	• Students routinely search for cause and effect relationships in systems they study. • Students identify conditions required for specific cause and effect interactions to occur through investigation.	• Students begin to connect their explanations for cause and effect relationships to specific scientific theory. • Students use cause and effect relationships to make predictions. • Students recognize that some cause and effect explanations are merely a correlation of factors.	• Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales. • Students use and evaluate empirical evidence to classify causation vs. correlation. • Students design a system to produce a desired outcome.

Crosscutting Concept 3

Scale, Proportion, and Quantity: That integrate measurement and precision of language.			
Framework Description: *In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance*. *(NRC, p.84)*			
Early Elementary (K-2)	**Upper Elementary (3-5)**	**Middle Grades (6-8)**	**High School (9-12)**
• Students make comparisons using relative scales (e.g., bigger or smaller, closer or further, sooner or later).	• Students become familiar with sizes immensely large or small or durations extremely short or long. • Students make measurements of physical properties of objects using base units.	• Students recognize that phenomena are not necessarily observable at all scales. • Students develop models to investigate scales that are beyond normal experiences. • Students make and evaluate derived/proportional measurements. • Students create proportional and algebraic relationships from graphical representations.	• Students recognize that the presence of patterns can be dependent on the scale at which a system is observed. • Students use proportional relationships to predict how changing one property will affect another in a system.

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Crosscutting Concept 4

Systems and System Models: with defined boundaries that can be investigated or characterized by the next three concepts.			
Framework Description: *Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering. (NRC, p.84)*			
Early Elementary (K-2)	**Upper Elementary (3-5)**	**Middle Grades (6-8)**	**High School (9-12)**
• Students identify and describe the parts and their roles in the inner workings as part of a larger system/object.	• Students group and describe interactions of the components that define a larger system.	• Students develop models for systems which include both visible and invisible inputs and outputs for that system. • Students evaluate the sub-systems that may make up a larger system. • Students include relevant and exclude irrelevant factors when defining a system.	• Students design or define systems in order to evaluate a specific phenomenon or problem. • Students create and manipulate a variety of different models: physical, mathematical, computational. • Students make predictions from models, taking into account assumptions and approximations.

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Crosscutting Concept 5

Energy and Matter: Conservation through transformations that flow or cycle into, out of, or within a system			
Framework Description: *Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations. (NRC, p.84)*			
Early Elementary (K-2)	**Upper Elementary (3-5)**	**Middle Grades (6-8)**	**High School (9-12)**
• Students understand that objects can be deconstructed and reassembled in the same or different ways to form a foundation for understanding transformations of energy and matter.	• Students recognize that large objects are made up of collections of particles. • Students track transformations of matter to demonstrate the law of conservation of mass. • Students begin to recognize types of energy present in a system and the ability to transfer this energy between objects.	• Students give general descriptions of different forms and mechanisms for energy storage within a system. • Students demonstrate conservation of mass in physical and chemical changes. • Students track energy through transformations in a system.	• Students demonstrate and explain conservation of mass and energy in systems, including systems with inputs and outputs. • Students explain the conservation of energy by discussing transfer mechanisms between objects or fields as well as into or out of a system. • Students reconcile conservation of mass in nuclear processes.

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Crosscutting Concept 6

Structure and Function: of systems and their parts			
Framework Description: *The way in which an object or living thing is shaped and its substructure determine many of its properties and functions. (NRC, p.84)*			
Early Elementary (K-2)	**Upper Elementary (3-5)**	**Middle Grades (6-8)**	**High School (9-12)**
• Students investigate how the roles of specific components of a system affect the functioning of the larger system.	• Students begin to recognize that objects and systems have smaller sub-structures, which determine the property of a material or system. • Students begin to attribute the shapes of sub-components to the function of the part.	• Students begin to attribute atomic structure and interactions between particles to the properties of a material. • Students design systems, selecting materials for their relevant properties.	• Students apply patterns in structure and function to unfamiliar phenomena. • Students infer the function of a component of a system based on its shape and interactions with other components.

Crosscutting Concept 7

Stability and Change: of systems			
Framework Description: *For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study. (NRC, p.84)*			
Early Elementary (K-2)	**Upper Elementary (3-5)**	**Middle Grades (6-8)**	**High School (9-12)**
• Students begin to track and describe changes in a system using relative scales. • Students begin to question causes for stability and change and why some systems do not change.	• Students begin to describe changes in terms of the time over which they occur—their rate. • Students recognize that even apparently stable systems may be undergoing imperceptible changes.	• Students make explanations of stability and change discussing molecular components of a system. • Students explain that systems in motion or dynamic equilibrium can be stable.	• Students provide examples and explanations for sudden and gradual changes.

[2] Crosscutting concept summary tables adapted from National Science Teachers Association

Progression of Science and Engineering Practices

Rigid adherence to teaching the scientific method as the dogma of scientific activity presents an incomplete representation of the activities of a scientist. At any moment of time, it is likely that the activities of a scientist are described by at least one of these eight, named practices. These practices should not be seen as a linear series of steps, but rather a group of snapshots. The science and engineering practices are one of the three dimensions of three-dimensional science instruction. There are two ways that the practices are divided. First, each practice is separated into applications to science and applications to engineering. The practices are then divided to describe how the practice evolves on pace with a student's learning.

Asking questions (for science) and defining problems (for engineering) to determine what is known, what has yet to be satisfactorily explained, and what problems need to be solved	
Framework: *Application to Science*	*Application to Engineering*
While questioning and curiosity are innate human behaviors, scientists must develop questions that can be answered empirically.	Beyond noticing problems, an engineer is able to structure a problem in a task-oriented manner, identifying conditions for successful remediation as well as limitations on solutions, prior to engaging solution design.

Progression	**Early Elementary (K-2)**	**Late Elementary (3-5)**	**Middle Grades (6-8)**	**High School (9-12)**
Science	• Students develop questions based on their experiences and begin to form testable questions.	• Questions generated by students are still based on experiences, and begin to incorporate relationships between two things.	• Questions originate based on experience as well as need to clarify and test other explanations. • Questions are asked that lead to explicit relationships between variables.	• Questions facilitate empirical investigation. • Questions about arguments and interpretations elicit further elaboration or investigation.
Engineering	• Students explicitly describe a design problem that can be solved using a new tool or improvement to an existing tool.	• Building on their ability to define design problems, students can incorporate constraints (such as time, cost, materials) and a limited number of criteria for solutions into their problem definitions.	• Students define design problems, invoking scientific background knowledge to define multiple criteria and constraints for solutions.	• Students define increasingly complex design problems for systems with interacting parts and include societal, technical, and environmental considerations.

Developing and using models to develop explanations for phenomena, to go beyond the observable and make predictions or to test designs				
Framework:				
Application to Science			*Application to Engineering*	
Scientific models can make the invisible world tangible, be improved as understandings develop, and be used to make predictions. Models may be physical or mathematical.			Models, simulations, and prototypes can illuminate flaws in design approaches.	
Progression				
	Early Elementary (K-2)	**Late Elementary (3-5)**	**Middle Grades (6-8)**	**High School (9-12)**
Science	• Students make drawings, displays, and simple representations for events they experience through their senses, incorporating relative scales when appropriate.	• Student models begin to become abstract and metaphorical, incorporating relationships between events and predictive aspects for recurring events. • Students can identify specific limitations of their models.	• Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled system. • Students can use identified limitations of their model to make improvements.	• Students can create models for the interactions of two separate systems. • Students can test the predictive abilities of their models in a real-world setting and make comparisons of two models of the same process or system.
Engineering	• Students develop a model, plan, or drawing representing a device.	• Students create a design plan or prototype of a tool or object, which incorporates cause and effect behaviors within the device.	• Student models are designed and scale appropriately to generate data regarding the functioning of their device.	• Student models are functioning prototypes and able to generate data useful for both computation and problem solving.

Planning and carrying out controlled investigations to collect data that is used to test existing theories and explanations, revise and develop new theories and explanations, or assess the effectiveness, efficiency, and durability of designs under various conditions.				
Framework:				
	Application to Science		*Application to Engineering*	
	Scientists must develop experiments which isolate portions of a system and permit control over experimental variables to investigate the behavior of dependent factors.		Investigations serve to test designs as well as collect information about factors which would influence the design of solutions.	
Progression				
	Early Elementary (K-2)	**Late Elementary (3-5)**	**Middle Grades (6-8)**	**High School (9-12)**
Science	• Students carry out investigations in groups and make decisions about suitable measurements for data collection in order to answer a question.	• Students carry out investigations in groups, where conditions and variables are controlled, utilize appropriate instruments, and deliberately perform multiple trials.	• Students begin to investigate independently, select appropriate independent variables to explore a dependent variable, and recognize the value of failure and revision in the experimental process.	• Students plan and perform investigations to aid in the development of a predictive model for interacting variables, consider the quantity of data with respect to experimental uncertainty, and select methods for collection and analysis of data.
Engineering	• Students determine whether a proposed object or tool will meet criteria for success based on past experiences, observations, or measurements.	• Students make measurements for the purpose of testing and comparing competing design solutions or understanding the effects of modifications to an existing device.	• Students design tests which determine the effectiveness of a device under varying conditions.	• Students design tests for their device which focus on exposing potential failure points.

Analyzing and interpreting data with appropriate data presentation (graph, table, statistics, etc.), identifying sources of error and the degree of uncertainty. Data analysis is used to derive meaning or evaluate solutions.				
Framework:				
	Application to Science		*Application to Engineering*	
	Scientists must decide how to organize data to be evaluated in such a way that patterns in investigated systems will manifest, as well as consider uncertainty and precision in their investigations.		Data collection affords engineers the ability to compare competing designs in terms of both their adherence to limitations invoked by constraints, and the degree to which they meet the criteria for a solution.	
Progression				
	Early Elementary (k-2)	**Late Elementary (3-5)**	**Middle Grades (6-8)**	**High School (9-12)**
Science	• Students set a foundation for data analysis by recording their thoughts and observations about patterns and events in a way that can be shared with others	• Students organize data (observations and measurements) in a way that facilitates further analysis and comparison.	• Students create and analyze graphical presentations of data to identify linear and non-linear relationships, consider statistical features within data, and evaluate multiple data sets for a single phenomenon.	• Students derive proportionalities and equalities for dependent variables which include multiple independent variables; considering uncertainty, and limitations of collected data.
Engineering	• Students analyze observations and measurements for a device to ensure it satisfies specifications.	• Students use data to refine engineering problems or proposed solutions.	• Students evaluate multiple sets of performance data to determine the optimal conditions for operation and use of a device.	• Students use data to revise and optimize devices already in operation.

<table>
<tr><td colspan="5">Using mathematics and computational thinking
as tools to represent variables and their relationships in models, simulations, and data analysis in order to make and test predictions</td></tr>
<tr><td colspan="5">Framework:</td></tr>
<tr><td colspan="3">Application to Science</td><td colspan="2">Application to Engineering</td></tr>
<tr><td colspan="3">In addition to algebraic problem solving, scientists use mathematics to construct simulations and graphical representations for use in prediction and illuminating proportionalities, as well as evaluate the significance of correlations.</td><td colspan="2">Engineers use mathematical formulae to evaluate the suitability of designs and materials. Additionally, the development of computational models allows for testing of a device prior to physical construction.</td></tr>
<tr><td colspan="5">Progression</td></tr>
<tr><td></td><td>Early Elementary (K-2)</td><td>Late Elementary (3-5)</td><td>Middle Grades (6-8)</td><td>High School (9-12)</td></tr>
<tr><td>Science</td><td>• Students recognize patterns and make comparisons using counting and number lines.</td><td>• Students organize experimental data to reveal patterns and utilize data using simple graphs to form explanations.</td><td>• Students use computing to process large amounts of data in order to develop mathematical representations (ratios, percentages, rates) that will help evaluate a scientific explanation.</td><td>• Students differentiate between the appropriateness of quantitative and qualitative data.
• Students create computational or mathematical models for interactions in the natural world, utilizing unit equivalencies.</td></tr>
<tr><td>Engineering</td><td>• Students compare two different solutions to a problem from collected data.</td><td>• Students interpret simple graphs to compare a set of solutions to a problem.</td><td>• Students create ordered series of steps to evaluate the function of a device or understand a process.</td><td>• Students apply and test computational models for the function of a device.</td></tr>
</table>

Constructing explanations and designing solutions to explain phenomena or solve problems				
Framework:				
Application to Science			*Application to Engineering*	
Scientific theories are explanations for patterns present in nature (scientific laws). In science, theories are used to create scientific explanations for events or phenomena in the natural world and are accepted by consensus based on empirical evidence.			There is seldom a single solution to an engineering problem, but rather a number of solutions that may be evaluated based on their adherence to constraints and degrees to which they meet specified criteria.	
Progression				
	Early Elementary (K-2)	**Late Elementary (3-5)**	**Middle Grades (6-8)**	**High School (9-12)**
Science	• Students generate explanations for natural phenomena that incorporate relevant evidence.	• Students create evidence-based explanations for relationships seen in the natural world as well as identify evidence that supports other explanations.	• Students form explanations using sources (including student-developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and support or spark revisions to a particular conclusion.	• Students form explanations that incorporate sources (including models, peer-reviewed publications, their own investigations), invoke scientific theories, and evaluate the degree to which data and evidence support a given conclusion.
Engineering	• Students design and/or build a device that solves a specific given problem and evaluate competing solutions.	• Students design a device utilizing scientific ideas as well as compare competing solutions based on constraints and criteria for success.	• Students design as well as test devices meant to meet specific design criteria, with the objective of increasing the effectiveness of multiple solutions.	• Students evaluate complex designed systems and select the optimal solution-based tests they design and conduct, taking into account a prioritization of multiple constraints.

Engaging in argument from evidence to identify strengths and weaknesses in a line of reasoning, to identify best explanations, to resolve problems, and to identify best solutions	
Framework: *Application to Science*	*Application to Engineering*
Argumentation in science requires effective application and analysis of other processes to present and defend a claim based on evidence, taking into consideration relevant scientific ideas.	With the possibility of multiple viable solutions for a single design problem, engineers must be able to evaluate competing solutions to determine the best possible design and defend their decisions.

Progression	Early Elementary (K-2)	Late Elementary (3-5)	Middle Grades (6-8)	High School (9-12)
Science	• Students create and identify evidence-based arguments and consider the degree to which an argument is supported by evidence.	• Students create and identify evidence-based arguments and consider whether an argument is supported by evidence or relies on opinions or incomplete representations of relevant evidence.	• Students critique and consider the degree to which competing arguments are supported by evidence. • Students present an argument based on empirical evidence, models, and scientific reasoning.	• Students critically evaluate evidence supporting an argument and create written or oral arguments which invoke empirical evidence, scientific reasoning, and scientific explanations.
Engineering	• Students make and support claims about a proposed device or solution.	• Students make and support claims about a proposed device or solution.	• Students present evaluations of a solution or device that include student-designed tests and give consideration to constraints and criteria for success.	• Students present evaluations of a solution or device that incorporate scientific knowledge and results from student-designed tests, as well as real-world factors (e.g. societal, environmental).

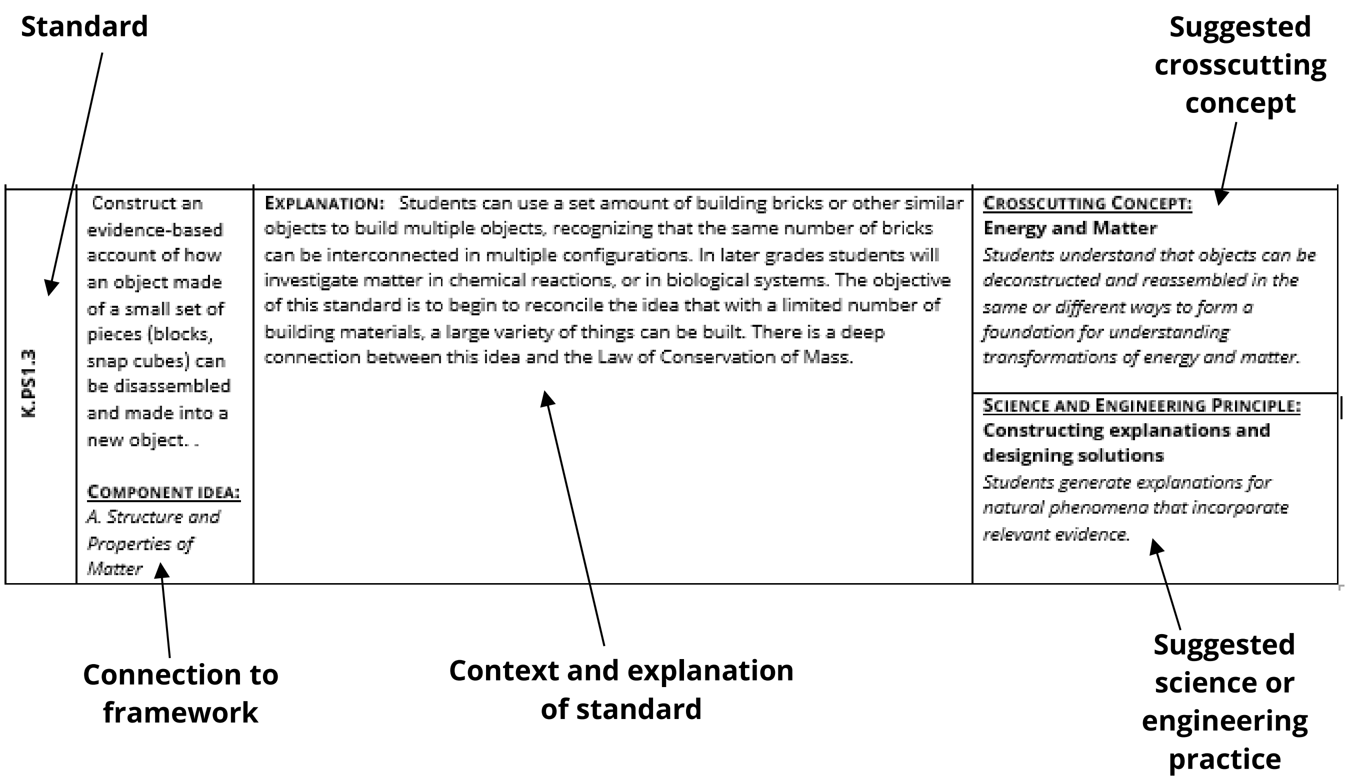
Obtaining, evaluating, and communicating information from scientific texts in order to derive meaning, evaluate validity, and integrate information				
Framework:				
Application to Science			*Application to Engineering*	
Progression of science is dependent on generating consensus and understanding for new theories and ideas. To be able to move an idea forward, scientific ideas must be effectively communicated through various means including: data tables, graphs, graphics, text, or other media.			Selection of a specified design solution requires the ability to present a justification and rationale for the decision. Additionally, engineers must often rely on information gathered by both scientists and engineers to guide design and analysis decisions.	
Progression				
	Early Elementary (K-2)	**Late Elementary (3-5)**	**Middle Grades (6-8)**	**High School (9-12)**
Science	• (Obtain/Evaluate) Students read and utilize the information, features, and structure of grade-appropriate texts and media to obtain scientific information useful in forming or supporting a scientific claim. • (Communicate) Students utilize writing, drawing, and modeling to communicate information.	• (Obtain/Evaluate) Students read and summarize text and embedded, non-text elements (including tables, figures, and graphs) from multiple sources synthesizing an understanding on a scientific idea. • (Communicate) Students communicate scientific information in writing utilizing embedded tables, charts, figures, and graphs.	• (Obtain/Evaluate) Students evaluate text, media, and visual displays of information with the intent of clarifying claims and reconciling conflicting explanations. • (Communicate) Students communicate scientific information in writing utilizing embedded tables, charts, figures, and graphs.	• (Obtain/Evaluate) Students critically read scientific literature, integrating, extracting, and accurately simplifying main ideas from multiple sources while maintaining accuracy and validating data when possible. • (Communicate) Students provide written or oral explanations for phenomena and multipart systems using models, graphs, data tables, and diagrams.
Engineering	• Students use images or diagrams to identify scientific principles utilized in the design of a device.	• Students communicate technical information about proposed design solutions using tables, graphs, and diagrams.	• Students communicate technical information about proposed design solutions using tables, graphs, and diagrams.	• Students communicate technical information about multi-part design solutions using tables, graphs, and diagrams.

[3] *Science and engineering practices progression tables adapted from National Science Teachers Association.*

Standards Overview

Usage

The standards are divided into grade-level groups by disciplinary core idea (DCI). Each DCI is color coded for ease in navigation. The standard number is listed in the left column followed by a column containing the full text of the standard as well as the component idea. This component idea can be used to connect each standard to a specific grade band endpoint within the framework that inspired the standard. The final column offers suggestions for how a standard might become part of a three-dimensional approach to instruction. This should only be seen as a suggestion, as there are many possible connections between concepts and related crosscutting concepts and science practices.



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Kindergarten:

K.PS1: Matter and Its Interactions			
K.PS1.1	Plan and conduct an investigation to describe and classify different kinds of materials including wood, plastic, metal, cloth, and paper by their observable properties (color, texture, hardness, and flexibility) and whether they are natural or human-made. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** Students can make observations of different materials in groups, utilizing a graphic organizer to track and organize their observations. Being able to describe materials based on physical properties allows students to make determinations about appropriate uses for materials, as well as consider whether. In later grades, students can use such records of the initial physical properties of a material to determine whether or not a chemical reaction has occurred. Care should be taken that the objects selected for grouping permit a wide variety of groupings. For example, some groups may form groupings based on color, others by texture, size, or even smell. Evidence collected during the investigation should allow students to answer the question about whether a material is man-made or naturally occurring. *(Making measurements is not a grade-appropriate skill. Discussions of size should be relative comparisons of size.)*	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record the patterns they observe in nature or man-made objects.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students carry out investigations in groups, making decisions about suitable measurements for data collection in order to answer a question.*

K.PS1.2	Conduct investigations to understand that matter can exist in different states (solid and liquid) and has properties that can be observed and tested. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** Examples may include water occurring as a solid or a liquid depending on whether it is kept cold or allowed to warm, as well as considering other materials that may look like water but not behave similarly (e.g., methanol and other alcohols will not be a solid under the same conditions even though they may look like water). Students may use properties above as well as considering other physical properties whether objects float or sink in water, may have characteristic smells, are attracted to magnets. *(Temperature should be treated in a relative fashion (hotter/colder) as the use of a thermometer is not a grade-appropriate skill. Discussion of gases as a phase of matter is not grade appropriate, since this is not a visible form of matter.)*	**CROSSCUTTING CONCEPT:** **Structure and Function** *Students begin to track and describe changes in a system using relative scales* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students carry out investigations in groups, making decisions about suitable measurements for data collection in order to answer a question.*
K.PS1.3	Construct an evidence-based account of how an object made of a small set of pieces (blocks, snap cubes) can be disassembled and made into a new object. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** Students can use a set amount of building bricks or other similar objects to build multiple objects, recognizing that the same number of bricks can be interconnected in multiple configurations. In later grades, students will investigate matter in chemical reactions or in biological systems. The objective of this standard is to begin to reconcile the idea that with a limited number of building materials, a large variety of things can be built. There is a deep connection between this idea and the Law of Conservation of Mass.	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students understand that objects can be deconstructed and reassembled in the same or different ways to form a foundation for understanding transformations of energy and matter.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students generate explanations for natural phenomena that incorporate relevant evidence.*

K.LS1: From Molecules to Organisms: Structures and Processes			
K.LS1.1	Use information from observations to identify differences between plants and animals (locomotion, obtainment of food, and take in air/gasses). **COMPONENT IDEA:** *A. Structure and Function*	**EXPLANATION:** Students should begin to consider the external features of living organisms. The purpose of this standard is to emphasize that all living organisms have external structures that aid in processes such as seeing, hearing, moving, grasping, providing protection, and locating and taking in food, water, and air. Students should be led to patterns such as: plants are often anchored to the ground while animals are free to move, plants are able to make their own food, or both plants and animals have external structures used in gas exchange.	**CROSSCUTTING CONCEPT:** **Structure and Function** *Students investigate how the roles of specific components of a system affect the functioning of the larger system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider degree to which an argument is supported by evidence.*
K.LS1.2	Recognize differences between living and non-living materials and sort them into groups by observable physical attributes. **COMPONENT IDEA:** *A. Structure and Function*	**EXPLANATION:** Students should be given the opportunity to make observations of sets of living and non-living things in order to create a classification system based on their observations. The focus should be on the idea that living organisms all go through a basic life cycle which includes: birth, growth and reproduction, and death.	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record the patterns they observe in nature or man-made objects.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data** *Students set a foundation for data analysis by recording their thoughts and observations about patterns and events in a manner that can be shared with others.*

K.LS1.3	Explain how humans use their five senses in making scientific findings. **COMPONENT IDEA:** *D. Information Processing*	**EXPLANATION:** Senses allow living organisms to collect information about their surroundings and communicate it to others. While many organisms use this information for purposes limited to survival and reproduction, humans undertake scientific endeavors to gain an understanding of the natural world. Students should be aware that specific body parts are associated with each sense. (e.g., eyes, ears, skin, etc.) An example may include using a graphic organizer with pictures of eyes, ears, nose, mouth, and hand at the top with space for students to draw their observations below. They see a pencil, smell vanilla, hear a bell, and feel sandpaper.	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record the patterns they observe in nature or man-made objects.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *(Obtain/Evaluate) Students read and utilize the information, features, and structure of grade-appropriate texts and media to obtain scientific information useful in forming or supporting a scientific claim. (Communicate) Students utilze writing, drawing, and modeling to communicate information.*

K.LS3: Heredity: Inheritance and Variation of Traits			
K.LS3.1	Make observations to describe that young plants and animals resemble their parents. **COMPONENT IDEA:** *A. Inheritance of Traits*	**EXPLANATION:** This standard provides an opportunity for students to begin to compile observations that living organisms resemble their parents. It is important to note that the offspring will not look identical to their parents, but will have similarities. Observations might resemble comparisons of different leaf arrangements in species of beech tree vs walnut tree or similar activities in which student look for small differences in otherwise similar organisms. Gene expression and mechanisms for passing DNA from parent to offspring are not discussed until middle school, these early observations can compel students to search for explanations as their content knowledge increases.	**CROSSCUTTING CONCEPT:** **Structure and Function** *Students investigate how the roles of specific components of a system affect the functioning of the larger system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider degree to which an argument is supported by evidence.*

K.ESS2: Earth's Systems			
K.ESS2.1	Analyze and interpret weather data (precipitation, wind, temperature, cloud cover) to describe weather patterns that occur over time (hourly, daily) using simple graphs, pictorial weather symbols, and tools (thermometer, rain gauge). **COMPONENT IDEA:** *D. Weather and Climate*	**EXPLANATION:** The focus of kindergarten investigations into weather is to begin to allow students to see that there are changes in the weather and there are patterns within these changes. The patterns should also include phenomena which are concurrent (e.g., The temperature drops when there is cloud cover, or it is very windy before a large temperature change.) The focus at this grade level is on gathering information and recognizing the patterns. These discussions set the foundation for later grades where students will investigate the underlying cause and effect relationships for these patterns as well as be able to differentiate weather from climate. Examples may include analyzing weather data over a period of time and making a class chart to illustrate findings. *(Students are not required to make readings. Students should be able to make comparisons of two thermometers: The higher the mercury rises, the greater the temperature.)*	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record the patterns they observe in nature or man-made objects.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Using mathematics and computational thinking** *Students recognize patterns and make comparisons using counting and number lines.*
K.ESS2.2	Develop and use models to predict weather and identify patterns in spring, summer, autumn, and winter. **COMPONENT IDEA:** *D. Weather and Climate*	**EXPLANATION:** Students are introduced to weather patterns that accompany the changing seasons. At this grade, students are not expected to fully grasp that time can be considered at different scales (e.g., a number of days makes up a season). Instead, students should focus on making comparisons of weather at different times throughout the year. An example may include constructing a class chart to discuss seasons and the different weather that happens in each.	**CROSSCUTTING CONCEPT:** **Scale, Proportion, and Quantity** *Students make comparisons using relative scales. (e.g., bigger or smaller, closer or further, sooner or later).* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students make drawings, displays, and simple representations for events they experience through their senses, incorporating relative scales when appropriate.*

K.ESS3: Earth and Human Activity			
K.ESS3.1	Use a model to represent the relationship between the basic needs (shelter, food, water) of different plants and animals (including humans) and the places they live. **Component Idea:** *A. Natural Resources*	**Explanation:** Organisms will live in places that give them access to the materials that are needed to meet their basic needs. Humans utilize natural resources in everything they do. This extends from common needs such as food and clothing to the complex devices such as computers that humans have developed. The focus of this standard is only on basic needs for survival, not modern conveniences. Examples of relationships may include that deer eat buds and leaves, therefore, they usually live in forested areas; and, grasses need sunlight, so they often grow in meadows. Plants, animals, and their surroundings make up a system. Humans use soil and water to grow food, wood to burn to provide heat or build shelters, and materials such as iron or copper extracted from Earth to make cooking pans. Life is far more abundant near water sources. Examples of humans using natural resources should be limited to processes where the resources are used in a nearly raw form. This standard might pair well with design challenges asking students to evaluate potential habitation sites.	**Crosscutting Concept:** **Cause and Effect** *Students identify cause and effect relationships through observable patterns, utilizing simple tests to provide evidence that supports or refutes their ideas.* **Science and Engineering Principle:** **Developing and using models** *Students make drawings, displays, and simple representations for events they experience through their senses, incorporating relative scales when appropriate.*
K.ESS3.2	Explain the purpose of weather forecasting to prepare for, and respond to, severe weather in Tennessee. **Component Idea:** *B. Natural Hazards*	**Explanation:** Severe weather is a phenomenon that can adversely affect, yet is largely beyond the control of, humans. Because of its geographic location, there are certain types of severe weather that might directly affect Tennessee, while others may not occur. As with other natural hazards, understanding severe weather can help alleviate damages and losses associated with severe weather. Weather forecasting can help make short-term preparations, or long-term construction decisions to minimize effects.	**Crosscutting Concept:** **Stability and Change** *Students begin to question causes for stability and change and why some systems do not change.* **Science and Engineering Principle:** **Developing and using models** *Students make drawings, displays, and simple representations for events they experience through their senses, incorporating relative scales when appropriate.*

K.ESS3.3	Communicate solutions that will reduce the impact from humans on land, water, air, and other living things in the local environment. **COMPONENT IDEA:** *C. Human Impacts on Earth Systems*	**EXPLANATION:** Humans develop land and utilize resources for survival and to be more comfortable. Identifying the effects of these uses can help to minimize cumulative effects of their decisions. Choosing to re-use and recycle materials can decrease additions to landfills, which can contaminate ground-water resources, reduce wildlife habitat, or release dangerous/unpleasant gases (such as ammonia) into the air.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students identify and describe parts and their roles in the inner workings as part of a larger system/object.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *(Obtain/Evaluate) Students read and utilize the information, features, and structure of grade-appropriate texts and media to obtain scientific information useful in forming or supporting a scientific claim. (Communicate) Students utilze writing, drawing, and modeling to communicate information.*

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K.ETS1: Engineering Design			
K.ETS1.1	Ask and answer questions about the scientific world and gather information using the senses. **<u>Component idea:</u>** *A. Defining and Deliminating and Engineering Problems*	**Explanation:** Engineering leads to improvements in our daily lives and begins with the recognition of situations to be improved. Students should begin to explore how the observations they make can be helpful in thinking about design problems. In later grades, students will learn how to combine these observations in order to define problems which can be resolved through engineering.	**<u>Crosscutting Concept:</u>** **Systems and System Models** *Students identify and describe parts and their roles in the inner workings as part of a larger system/object.* **<u>Science and Engineering Principle:</u>** **Developing and using models** *Students make drawings, displays, and simple representations for events they experience through their senses, incorporating relative scales when appropriate.*
K.ETS1.2	Describe objects accurately by drawing and/or labeling pictures. **<u>Component idea:</u>** *B. Developing Possible Solutions*	**Explanation:** In early stages, the design process involves actively developing solutions in brainstorming sessions. To participate in collaborative settings, students must be able to make a physical representation of their ideas early in the design process in order to receive feedback from others. In later grades, students will transition from such preliminary drawings to the creation of detailed models and prototypes. The process of labeling such images allows students to recognize that their device consists of a number of smaller parts whose interactions must be considered and planned.	**<u>Crosscutting Concept:</u>** **Systems and System Models** *Students identify and describe parts and their roles in the inner workings as part of a larger system/object.* **<u>Science and Engineering Principle:</u>** **Developing and using models** *Students develop a model, plan, or drawing representing a device.*

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K.ETS2: Links Among Engineering, Technology, Science, and Society			
K.ETS2.1	Use appropriate tools (magnifying glass, rain gauge, basic balance scale) to make observations and answer testable questions. **COMPONENT IDEA:** *A. Defining and Deliminating and Engineering Problems*	**EXPLANATION:** Student number fluency is still developing, so this standard appears in a similar manner in both kindergarten and first grade. The interplay between science and engineering is cyclic. Innovations in engineering create tools that advance the field of science. Such advances produce new technologies permitting new observational capabilities. Tools aligned to this standard and grade level should permit relative measurement, and activities involving measurement should consider students' math and numeric abilities.	**CROSSCUTTING CONCEPT:** **Scale, Proportion, and Quantity** *Students make comparisons using relative scales. (e.g. bigger or smaller, closer or further, sooner or later)* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *Students use images or diagrams to identify scientific principles utilized in the design of a device.*

First Grade:

1.PS3: Energy			
1.PS3.1	Make observations to determine how sunlight warms Earth's surfaces (sand, soil, rocks, and water). **<u>Component idea:</u>** *B. Conservation of Energy and Energy Transfer*	**Explanation:** This standard represents a student's first exposure to energy. Examples of observations may include feeling how warm or cool different materials (placed in similar containers), like light-colored sand, potting soil, water, red clay and similar colored rocks, feel. Additionally, objects can be placed directly in sunlight or out of sunlight. The objective of this standard is to prepare students for the idea that the Sun is doing something to the surface of the Earth. This will be a challenging concept to truly grasp because the Sun does not physically touch the Earth, nor is there visible transfer of any substance causing the warming. (Teacher background: It should be understood that the energy itself is not a physical substance, but rather a substance-like quantity that can be stored in an object or transferred from one object to another. In this case, energy from the sun is transferred through space via light (a form of electromagnetic radiation). This energy is then stored in objects as thermal energy. Thermal energy can be thought of as a "bank account" for energy, and light is a way that a "deposit" or transfer of energy is made to this account.) *(Observations about temperature should be limited to relative observations such as "feels warmer" or "feels cooler.")*	**<u>Crosscutting Concept:</u>** **Pattern** *Students recognize, classify, and record the patterns they observe in nature or man-made objects.* **<u>Science and Engineering Principle:</u>** **Analyzing and interpreting data** *Students set a foundation for data analysis by recording their thoughts and observations about patterns and events in a manner that can be shared with others.*

1.PS4: Waves and Their Applications in Technologies for Information Transfer			
1.PS4.1	Use a model to describe how light is required to make objects visible. Summarize how illumination could be from an external light source or by an object giving off its own light. **COMPONENT IDEA:** *B. Electromagnetic Radiation*	**EXPLANATION:** Objects become visible when light from an external light source is reflected off the surface of an object. In the absence of any external light source, no light reflects off the surface of the object, and we cannot detect the object using our sense of sight. Some objects (such as fires, or the Sun) get hot enough that they can give off their own sources of light. Example experiences may include the inability to observe objects in a completely dark room. Pinhole viewers may be constructed using tubes from paper towel rolls or empty tubes from chips and used to observe a candelabra light bulb or trees or objects outdoors. Students can then diagram the events necessary to create the image projected on the back of the pinhole camera/viewer. *(The speed of light and wave properties should not be discussed, merely the idea that light travels in straight paths.)*	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record the patterns they observe in nature or man-made objects.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students make drawings, displays, and simple representations for events they experience through their senses, incorporating relative scales when appropriate.*
1.PS4.2	Determine the effect of placing objects made with different materials (transparent, translucent, opaque, and reflective in the path of a beam of light). **COMPONENT IDEA:** *B. Electromagnetic Radiation*	**EXPLANATION:** Some objects may appear invisible (such as glass) when they do not absorb any light, others may absorb all light and therefore be easier to see, while others can redirect the pathway of light allowing the otherwise straight path to be diverted. If pinhole viewers are constructed, students can place these materials in front of the pinhole and observe the effects. Shadows are created when the path of light is blocked before it strikes a surface, but mirrored surfaces can be used to redirect a beam of light around obstacles. *(The scattering of light by rough surfaces may be discussed but is not a principle part of this standard.)*	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students identify cause and effect relationships through observable patterns, utilizing simple tests to provide evidence that supports or refutes their ideas.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data** *Students set a foundation for data analysis by recording their thoughts and observations about patterns and events in a manner that can be shared with others.*

1.LS1: From Molecules to Organisms: Structures and Processes			
1.LS1.1	Recognize the structure of plants (roots, stems, leaves, flowers, fruits) and describe the function of the parts (taking in water and air, producing food, making new plants). **COMPONENT IDEA:** *A. Structure and Function*	**EXPLANATION:** All organisms have external structure with specific functions which aid in their survival. The focus of this standard is to examine these structures in plants exclusively, and builds on kindergarten investigations where students compared the structural differences between plants and animals. Examples may include: the roots anchor the plant and take in water and nutrients, the stem takes water and nutrients to the rest of the plant, the leaves make food for the plant and take in air through openings in the leaves, the flower makes plant seeds, and the fruit protects the plant seeds.	**CROSSCUTTING CONCEPT:** **Structure and Function** *Students investigate how the roles of specific components of a system affect the functioning of the larger system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students generate explanations for natural phenomena that incorporate relevant evidence.*
1.LS1.2	Illustrate and summarize the life cycle of plants. . **COMPONENT IDEA:** *B. Growth and Development of Organisms*	**EXPLANATION:** There are predictable changes that accompany each stage of life, and these changes are similar across unrelated organisms. Adult organisms can reproduce and have their own young. For example, plants sprout with one or two leaves emerging first, or a flower will wither and fall off a plant after being pollinated. Further examples may include different ways plants: grow (e.g., increase in size, produce new part), reproduce (e.g., develop seeds and spores, root runners), and die (e.g., length of life). There are also characteristics of adults and offspring that aid in their reproductive successes, such as producting of hardened seeds, attracting pollinators, germinating under favorable conditions, or flower buds opening at during the same times as other related plants.	**CROSSCUTTING CONCEPT:** **Stability and Change** *Students begin to track and describe changes in a system using relative scales* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students make drawings, displays, and simple representations for events they experience through their senses, incorporating relative scales when appropriate.*

1.LS1.3	Analyze and interpret data from observations to describe how changes in the environment cause plants to respond in different ways. **<u>Component idea:</u>** *D. Information Processing*	**Explanation:** Due to their lack of mobility, students may have the misconception that plants cannot sense or respond to changes in their environment. The focus of this standard is to uncover responses that plants may have to changes in their environment. Keep in mind: These responses are changes initiated by the plant and result from chemical signals and pathways within the plant. Examples may include plants leaning towards sunlight, leaves wilting from lack of water, leaves changing color in autumn, and trees shedding leaves. (The focus of this standard is on responses a single plant may have to changes in its environment, not changes to a species over time.)	**<u>Crosscutting Concept:</u>** **Cause and Effect** *Students identify cause and effect relationships through observable patterns, utilizing simple tests to provide evidence that supports or refutes their ideas.* **<u>Science and Engineering Principle:</u>** **Analyzing and interpreting data.** *Students set a foundation for data analysis by recording their thoughts and observations about patterns and events in a manner that can be shared with others.*

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1.LS2: Ecosystems: Interactions, Energy, and Dynamics			
1.LS2.1	Conduct an experiment to show how plants depend on air, water, minerals from soil, and light to grow and thrive**.** **<u>Component idea:</u>** *A. Interdependent Relationships in Ecosystems*	**Explanation:** Plants are unique in an ecosystem because they are able to sustain life without eating. Plant roots prevent them from moving to more favorable locations so certain plants will survive better in different settings with varying amounts of water, minerals, and light. Understanding why specific organisms survive only in certain areas requires that students understand the reliance of plants on air, water, and minerals from the soil. Experiments with plants may include comparing results of a variable such as growth with and without air, or light, or water, or minerals from soil (e.g., nitrogen, phosphorous, etc.).	**<u>Crosscutting Concept:</u>** **Energy and Matter** *Students understand that objects can be deconstructed and reassembled in the same or different ways to form a foundation for understanding transformations of energy and matter.* **<u>Science and Engineering Principle:</u>** **Planning and carrying out controlled investigations** *Students carry out investigations in groups, making decisions about suitable measurements for data collection in order to answer a question.*

1.LS2.2	Obtain and communicate information to classify plants by where they grow (water, land) and the plant's physical characteristics. **Component idea:** *A. Interdependent Relationships in Ecosystems*	**Explanation:** Recognizing that plants have requirements for life, students can then explore how different availabilities of sunlight, water, and nutrients define ecosystems. Students can then relate these differences in ecosystems to physical characteristics of plants in those ecosystems. Examples of plants growing in water may include phytoplankton in the ocean, algae in lakes, cattail in ponds, and river grasses. Examples of plants growing on land may include cacti in the desert, wildflowers on mountains, mosses toward mountain tops, and deciduous trees in forests.	**Crosscutting Concept:** **Pattern** *Students recognize, classify, and record the patterns they observe in nature or man-made objects.* **Science and Engineering Principle:** **Obtaining, evaluating, and communicating information** *(Obtain/Evaluate) Students read and utilize the information, features, and structure of grade-appropriate texts and media to obtain scientific information useful in forming or supporting a scientific claim. (Communicate) Students utilze writing, drawing, and modeling to communicate information.*
1.LS2.3	Recognize how plants depend on their surroundings and other living things to meet their needs in the places they live. **Component idea:** *A. Interdependent Relationships in Ecosystems*	**Explanation:** Interactions between living organisms in an ecosystem provide energy and matter. The materials needed for plant survival are used and re-used by plants and animals. Examples may include earthworms to aerate the soil, animals to disperse seeds, bees and other insects to help pollinate, and surroundings that offer the right amount of sunlight, water, and type of soil.	**Crosscutting Concept:** **Structure and Function** *Students investigate how the roles of specific components of a system affect the functioning of the larger system.* **Science and Engineering Principle:** **Developing and using models** *Students make drawings, displays, and simple representations for events they experience through their senses, incorporating relative scales when appropriate.*

1.ESS1: Earth's Place in the Universe			
1.ESS1.1	Use observations or models of the sun, moon, and stars to describe patterns that can be predicted. **COMPONENT IDEA:** *A. The Universe and Its Stars*	**EXPLANATION:** This is the first point in their education where students will consider events in space. The focus should be on making observations that reinforce that celestial bodies are changing and in motion. Examples of patterns may include the sun and moon appearing to rise in one part of the sky move across the sky and set, the shape and presence of the moon changing in a manner different than the sun, stars twinkling, and stars other than the sun are visible at night but not the day. *(Students should focus on patterns for the shapes of the moon, rather than rote memorization of the names of lunar phases.)*	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record the patterns they observe in nature or man-made objects.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students set a foundation for data analysis by recording their thoughts and observations about patterns and events in a manner that can be shared with others.*
1.ESS1.2	Observe natural objects in the sky that can be seen from Earth with the naked eye, and recognize that a telescope, used as a tool, can provide greater detail of objects in the sky. **COMPONENT IDEA:** *A. The Universe and Its Stars*	**EXPLANATION:** Students should be led to the realization that observations with their naked eye are limited and that the vastness of space can be revealed to an even greater degree using a telescope. Examples may include students journaling their findings by observing the night sky with their naked eye. Telescopes have two primary benefits, they allow us to distinguish light from stars that might otherwise go unnoticed with the naked eye, and also allow us to perceive details in the surface of the moon or other celestial bodies. A field trip to an observatory or setting up a simple telescope may help students learn that a telescope will help them see objects in the sky in greater detail.	**CROSSCUTTING CONCEPT:** **Scale, Proportion, and Quantity** *Students make comparisons using relative scales. (e.g., bigger or smaller, closer or further, sooner or later)* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data** *Students set a foundation for data analysis by recording their thoughts and observations about patterns and events in a manner that can be shared with others.*

1.ESS1.3	Analyze data to predict patterns between sunrise and sunset and the change of seasons. **<u>COMPONENT IDEA:</u>** *B. Earth and the Solar System*	**EXPLANATION:** This standard can build on observations from kindergarten where students observed temperature variations across the seasons. Coupled with physical science investigations on energy, students are prepared to explain the temperature variations observed in kindergarten. The emphasis of this standard should be on a relative comparison of the length of daylight hours in each season. Students can collect this data on an on-going basis. This can be accomplished through direct observation during some parts of the year, or through daily news publications . *(In first grade, students should infer that there is some cause for the patterns in their data, but discussions of a mechanism for seasonal changes in daylight hours due to the tilt of the earth's axis will be addressed in fourth grade.)*	**<u>CROSSCUTTING CONCEPT:</u>** **Pattern** *Students recognize, classify, and record the patterns they observe in nature or man-made objects.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Planning and carrying out controlled investigations** *Students carry out investigations in groups, making decisions about suitable measurements for data collection in order to answer a question.*

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1.ETS1: Engineering Design			
1.ETS1.1	Solve scientific problems by asking testable questions, making short-term and long-term observations, and gathering information. **<u>Component idea:</u>** *A. Defining and Deliminating and Engineering Problems*	**Explanation:** As part of the design process, students should begin to understand that there can be multiple solutions to a single problem. In later grades, students will evaluate competing solutions based on their ability to work with criteria for success and constraints. In first grade, students should be preparing for this process by making observations before they begin to design a solution. Students can be given a problem to solve and tasked with making relevant observations. An example could be "How long does it take an ice cream bar to melt?" Students would observe the ice cream bar every 30 minutes.	**<u>Crosscutting Concept:</u>** **Systems and System Models** *Students identify and describe parts and their roles in the inner workings as part of a larger system/object.* **<u>Science and Engineering Principle:</u>** **Analyzing and interpreting data** *Students analyze observations and measurements for a device to ensure it satisfies specifications.*

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1.ETS2: Links Among Engineering, Technology, Science, and Society			
1.ETS2.1	Use appropriate tools (magnifying glass, basic balance scale) to make observations and answer testable questions. **<u>Component idea:</u>** *A. Defining and Deliminating and Engineering Problems*	**Explanation:** The interplay between science and engineering is cyclic. Innovations in engineering create tools that advance the field of science. Such advances produce new technologies permitting new observational capabilities. Tools aligned to this standard and grade level should permit relative measurement, and activities involving measurement should consider students' math and numeric abilities.	**<u>Crosscutting Concept:</u>** **Scale, Proportion, and Quantity** *Students make comparisons using relative scales. (e.g. bigger or smaller, closer or further, sooner or later)* **<u>Science and Engineering Principle:</u>** **Obtaining, evaluating, and communicating information** *Students use images or diagrams to identify scientific principles utilized in the design of a device.*

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Second Grade:

2.PS2: Motion and Stability: Forces and Interactions			
2.PS2.1	Analyze the push or the pull that occurs when objects collide or are connected. **COMPONENT IDEA:** *A. Forces, Fields, and Motion*	**EXPLANATION:** Students should consider that when two objects are in contact, they act with equal forces on one another. Analysis of the push or pull should include considering that forces have both a size (called "magnitude" in later grades) and a direction. This is true for objects at rest or in motion. Evidence for this observation can be collected by placing two bathroom scales between a pair of students and having them push off of one another, or two students pulling backwards on a pair of spring scales. Even in instances where one student may be seated in a rolling chair or on a skateboard, the two scales will give the same readings. *(Students should only focus on relative values of the scale readings, which will always be equal.)*	**CROSSCUTTING CONCEPT:** **Scale, Proportion, and Quantity** *Students make comparisons using relative scales. (e.g., bigger or smaller, closer or further, sooner or later)* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data** *Students set a foundation for data analysis by recording their thoughts and observations about patterns and events in a manner that can be shared with others.*
2.PS2.2	Evaluate the effects of different strengths and directions of a push or a pull on the motion of an object. **COMPONENT IDEA:** *A. Forces, Fields, and Motion*	**EXPLANATION:** Students may use different systems and methods to create pushes and pulls from different directions. The same size force may be applied to large and small objects, considering differences in outcome. In addition to forces which cause an object to begin to move, forces applied to objects already in motion may also be addressed and their changes to speed and direction of travel. Forces parallel to an object's motion cause the object to speed up or slow down, while forces perpendicular to an object's motion change the direction of the object's motion. Objects that are at rest on a surface or sliding across a surface experience friction forces that always oppose their own motion. Avoid discussions of friction related to rolling objects due to the difficulty in differentiating between static friction that causes rolling motion and rolling resistance with opposes the motion of a rolling object. *(Forces that are not either parallel or perpendicular to an object's motion are beyond the scope of this standard due to the complexity of resolving such forces.)*	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students identify cause and effect relationships through observable patterns, utilizing simple tests to provide evidence that supports or refutes their ideas.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students carry out investigations in groups, making decisions about suitable measurements for data collection in order to answer a question.*

2.PS2.3	Recognize the effect of multiple pushes and pulls on an object's movement or non-movement. **<u>COMPONENT IDEA:</u>** *C. Stabilitiy and Instability in Physical Systems*	**EXPLANATION:** Students should consider instances of objects at rest and in motion and form explanations for causes of rest or motion. Force diagrams are a powerful model which can be used to help student create explanations for why some objects may slide down a slope, while other objects might remain at rest on the same slope. Objects might also include those suspended from vertical wires or those resting against a wall. Using the bristled portion of a broom, sweep across the top of a bowling ball to change its motion and observe the forces/sweeps required to cause the bowling ball to follow certain paths (e.g., around a circle, through a maze). *(Students can use symbols such as arrows of different sizes/lengths to represent relative sizes of forces without actual measurements.)*	**<u>CROSSCUTTING CONCEPT:</u>** **Stability and Change** *Students begin to question causes for stability and change and why some systems do not change.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Constructing explanations and designing solutions** *Students generate explanations for natural phenomena that incorporate relevant evidence.*

2.PS3: Energy			
2.PS3.1	Demonstrate how a stronger push or pull makes things go faster and how faster speeds during a collision can cause a bigger change in the shape of the colliding objects. **COMPONENT IDEA:** *C. Relationship Between Energy and Forces and Fields*	**EXPLANATION:** Students are setting a foundation to understand that forces are a method to transfer energy from one object to another. At this grade level, specific types of energy (e.g., kinetic energy) are not appropriate so it is sufficient to simply describe the effects of forces on the motion or shape. Building on the first grade metaphor of energy as a substance-like quantity that can be stored or transferred, students have the opportunity to consider that objects store different amounts of energy as they move at different speeds. Transferring more energy to an object by pushing it harder results in greater changes to the objects motion. Energy transfer during a collision results in a greater deformation to the objects involved in the collision. Examples of this behavior can be observed by dropping small balls (e.g., golf balls) into beds of play dough and observing the different amounts of deformation of the play dough based on the speed of the golf ball at the time of the collision. *(Measurements can be relative comparisons of the degree to which an object is deformed during a collision.)*	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students identify cause and effect relationships through observable patterns, utilizing simple tests to provide evidence that supports or refutes their ideas.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data** *Students set a foundation for data analysis by recording their thoughts and observations about patterns and events in a manner that can be shared with others.*

2.PS3.2	Make observations and conduct experiments to provide evidence that friction produces heat and reduces or increases the motion of an object. **COMPONENT IDEA:** *D. Energy in Chemical Processes and Everyday Life*	**EXPLANATION:** In first grade, students see that transferring energy causes the temperature of a surface to increase. Building on this understanding, students can understand that processes such as rubbing their hands together which cause a surface to warm up must be the result of energy transfer to the surface of your hands. Recognizing that rubbing and warming their hands increases the thermal energy stored in their hands can be used to facilitate discussions of where that energy was transferred from, and where the energy is transferred as their hands cool back down. These ideas also explain how friction can cause a sliding object to come to rest, and have energy conserved. Design challenges associated with this standard might ask students to minimize the effects of friction, or evaluate two similar devices that have varying degrees of effectiveness due to frictional losses. Examples may also include investigating how changes to an object's motion correlate with surfaces warming or cooling. *(Observations of temperature changes can be limited to qualitative observations.)*	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students identify and describe parts and their roles in the inner workings as part of a larger system/object.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students make drawings, displays, and simple representations for events they experience through their senses, incorporating relative scales when appropriate.*

2.PS4: Waves and Their Applications in Technologies for Information Transfer			
2.PS4.1	Plan and conduct investigations to demonstrate the cause and effect relationship between vibrating materials (tuning forks, water, bells) and sound. **COMPONENT IDEA:** *A. Wave Properties: Mechanical and Electromagnetic*	**EXPLANATION:** All waves are repeating patterns of highs and lows that transfer energy from one place to another. Investigations of waves moving across the surface of a pool of water should result in students noting that objects (such as corks) floating on the surface of the water move up and down as the wave passes beneath them, but the objects do not travel along with the wave. Students might note that surfers or objects caught near the shore move back and forth. Such instances are not exceptions and can be explained by differentiating between waves in relatively deep or shallow water. In the case of sound, it is a variation between high pressure pockets of air and low pressure pockets of air. Students should focus on the connection that when objects vibrate back and forth, they make sound. Stopping the vibration causes the sound to end. Examples of vibrating materials that make sound may include a tuning fork or plucking a stretched rubber band or guitar string. To observed sound making an object vibrate, hold a piece of paper next to a speaker playing loud music.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students identify cause and effect relationships through observable patterns, utilizing simple tests to provide evidence that supports or refutes their ideas.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students carry out investigations in groups, making decisions about suitable measurements for data collection in order to answer a question.*
2.PS4.2	Use tools and materials to design and build a device to understand that light and sound travel in waves and can send signals over distances. **COMPONENT IDEA:** C. Information Technologies and Instrumentation	**EXPLANATION:** Since early times, humans have been communicating over long distances through systems such as smoke signals or Morse code. There are several historical lessons on information theory, such as those found on Khan Academy, which discuss unique approaches to sending messages over distance. Now, digital signals can be sent using waves. Students might devise a device which is capable of transmitting a message (spoken or encoded) over a distance. Options may include, flashes of light in a darkened room, two cups joined by a string, or even a focused light source shining on a solar cell connected to an amplified speaker. Challenges to this activity to inspire creativity might include increasing the complexity of the message, or using the device to conduct a two-way exchange resulting in some action taken from the recipients at either end.	**CROSSCUTTING CONCEPT:** **Structure and Function** *Students identify and describe parts and their roles in the inner workings as part of a larger system/object.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students design and/or build a device that solves a specific given problem and evaluate competing solutions.*

2.PS4.3	Observe and demonstrate that waves move in regular patterns of motion by disturbing the surface of shallow and deep water. **COMPONENT IDEA:** *A. Wave Properties: Mechanical and Electromagnetic*	**EXPLANATION:** Deep or shallow waters are relative to the height of a wave, not an absolute measured depth. Water can be described as deep whenever its depth is greater than half the wave amplitude. Waves moving through deep water cause the surface of the water to move up and down as the wave passes. Individual water molecules don't travel away from their original position; they move in place, in a circular pattern. An object floating on the surface of this water will bob up and down and shift right to left in the same pattern as the water particles beneath it. However, over a period of time, it can be seen that the object never travels across the surface of the water. Table tennis balls and under-bed storage bins can be used as demonstrations. If a wave travels into shallow water (water that is <1/2 of the wave's amplitude), it will topple (e.g., waves rolling onto beaches, or a boat wake at the edge of a river or lake.	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record the patterns they observe in nature or man-made objects.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students make drawings, displays, and simple representations for events they experience through their senses, incorporating relative scales when appropriate.*

2.LS1: From Molecules to Organisms: Structures and Processes			
2.LS1.1	Use evidence and observations to explain that many animals use their body parts and senses in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water, and air. **<u>Component idea:</u>** *A. Structure and Function*	**Explanation:** Early in their life sciences education, students should be making the connection that external structures on organisms have specific functions to aid in their survival. In later grades, this idea will be extended to internal organs, and finally to cellular structures. Examples may include grizzly bears using their long claws to dig winter dens and break apart logs to find insects to eat; the eyes and nose of crocodiles stick up above its head so it can hide under water and still keep a lookout for prey; and rhinos use their ears like radar because they have poor eyesight. *(Both first-hand observations and texts can be used as evidence.)*	**<u>Crosscutting Concept:</u>** **Systems and System Models** *Students identify and describe parts and their roles in the inner workings as part of a larger system/object.* **<u>Science and Engineering Principle:</u>** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider degree to which an argument is supported by evidence.*

2.LS1.2	Obtain and communicate information to classify animals (vertebrates-mammals, birds, amphibians, reptiles, fish, invertebrates-insects) based on their physical characteristics. **COMPONENT IDEA:** *A. Structure and Function*	**EXPLANATION:** Organisms survive in their habitat because they have features that provide them advantages. By examining a variety of different animals facing different environmental pressures, students can begin to identify common adaptations that have developed over time. Examples may include that vertebrates have backbones and invertebrates do not, birds have beaks, reptiles have scales, amphibians have permeable skin, and fish have gills. *(Criteria for classification should be limited to observable differences in anatomy or life cycle and address anatomical features, but not physiological functions.)*	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record the patterns they observe in nature or man-made objects.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *(Obtain/Evaluate) Students read and utilize the information, features, and structure of grade appropriate texts and media to obtain scientific information useful in forming or supporting a scientific claim. (Communicate) Students utilize writing, drawing, and modeling to communicate information.*
2.LS1.3	Use simple graphical representations to show that species have unique and diverse life cycles. **COMPONENT IDEA:** *B. Growth and Development of Organisms*	**EXPLANATION:** Organisms can appear remarkably similar to or unimaginably different from other organisms. Despite differences in appearance, organisms pass through a common progression of birth, growth and reproduction, and death. At different points along this progression there are common characteristics and abilities, such as the ability to reproduce marking entrance to adulthood. Examples may include different ways animals are born (live birth, from an egg), grow (increase in size and weight, produce new parts through metamorphosis), reproduce (mate and lay eggs that hatch) and die (e.g., length of life).	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record the patterns they observe in nature or man-made objects.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students make drawings, displays, and simple representations for events they experience through their senses, incorporating relative scales when appropriate.*

2.LS2: Ecosystems: Interactions, Energy, and Dynamics

2.LS2.1	Develop and use models to compare how animals depend on their surroundings and other living things to meet their needs in the places they live. **COMPONENT IDEA:** *A. Interdependent Relationships in Ecosystems*	**EXPLANATION:** To survive, animals must find sources of food, as well as protection from other animals or the environment. In first grade, students learned that plants need sunlight, water and air to grow. Animals must eat plants or other animals to fulfill their needs. Some examples may include: a picture of a bear with a stream near its home with arrows pointing to the cave, stream, and bushes (eating and dispersing seeds) labeling shelter and food, a group of fish schooling together to avoid being eaten; and bees using nectar from flowers and flowers being pollinated by bees.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students identify and describe parts and their roles in the inner workings as part of a larger system/object.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider degree to which an argument is supported by evidence.*

2.LS2.2	Predict what happens to animals when the environment changes (temperature, cutting down trees, wildfires, pollution, salinity, drought, land preservation) **<u>COMPONENT IDEA:</u>** *C. Ecosystem Dynamics, Functioning, and Resilience*	**EXPLANATION:** The organisms in an environment thrive because they have adaptations suitable to particular conditions. Changes in environmental conditions may cause an organism to move into or out of a region or cause changes in the relative sizes of different populations within that system. Examples of what might happen to animals when the environment changes may include animals adjusting to temperature changes by changing their location, such as fish changing depth in the water or reptiles sunning themselves on rocks on cool days. When trees are cut down or wildfires occur animals lose their homes, they have to compete with other animals for survival, they relocate changing the makeup of an area, or they don't survive.	**<u>CROSSCUTTING CONCEPT:</u>** **Stability and Change** *Students begin to question causes for stability and change and why some systems do not change.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Constructing explanations and designing solutions** *Students generate explanations for natural phenomena that incorporate relevant evidence.* *(Communicate) Students utilize writing, drawing, and modeling to communicate information.*

2.LS3: Heredity			
2.LS3.1	Use evidence to explain that living things have physical traits inherited from parents and that variations of these traits exist in groups of similar organisms **COMPONENT IDEA:** *B. Variation of Traits*	**EXPLANATION:** The complicated understanding of inheritance that students will gain by high school explains mechanisms by which parents are able to pass on genetic information to offspring. These molecular understandings grew out of a need to explain why offspring look like their parents, and why some organisms that are not related by birth still look similar to each other. At this grade level, students should be presented opportunities to uncover patterns in appearance. Examples of physical traits may include a baby giraffe has its parent's long neck, long legs, and fur color. Also that there are still similarities between two giraffe that are not related by birth. Similarly, oak tree offspring inherit leaf type, bark type, and the ability to produce acorns for reproduction. However, different types of oak trees may have different types of acorns.	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record the patterns they observe in nature or man-made objects.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider degree to which an argument is supported by evidence.*

2.ESS1: Earth's Place in the Universe			
2.ESS1.1	Recognize that some of Earth's natural processes are cyclical while other have a beginning and an end. Some events happen quickly, while others occur slowly over time. **COMPONENT IDEA:** *C. The History of Planet Earth*	**EXPLANATION:** Some processes taking place on the Earth occur within a single day. However, the age of the Earth is so much greater than our lifespans that gradual changes to the Earth often go undetected, yet their cumulative effects have led to the variety of Earth's surface features, such as canyons and mountain ranges. Events such as earthquakes that occur quickly can contribute to gradual changes to Earth. It is essential that students begin to build an understanding for these prolonged changes to grasp discussions of other standards in second grade and beyond. Cyclic events might include day turning to night, compared to non-cyclic events such as volcanic eruptions or other natural hazards.	**CROSSCUTTING CONCEPT:** **Scale, Proportion, and Quantity** *Students make comparisons using relative scales (e.g., bigger or smaller, closer or further, sooner or later).* **SCIENCE AND ENGINEERING PRINCIPLE:** **Using mathematics and computational thinking** *Students recognize patterns and make comparisons using counting and number lines.*

2.ESS2: Earth's Systems			
2.ESS2.1	Compare the effectiveness of multiple solutions designed to slow or prevent wind or water from changing the shape of the land. **COMPONENT IDEA:** *E. Biogeology*	**EXPLANATION:** Carrying out this activity is designed to introduce students to the impact that humans can have on the Earth's geologic processes. Producing models of their solutions can be used to introduce the students to a qualitative sense of scale as they consider appropriate selections of materials to test their solutions. In later grades, students will explore the role that living organisms have in producing soils or transforming Earth's atmosphere. Solutions to be compared may include different designs of dikes/windbreaks and different designs for using shrubs, grass, or trees to prevent erosion.	**CROSSCUTTING CONCEPT:** **Scale, Proportion, and Quantity** *Students make comparisons using relative scales (e.g., bigger or smaller, closer or further, sooner or later).* **SCIENCE AND ENGINEERING PRINCIPLE:** **Using mathematics and computational thinking** *Students compare two different solutions to a problem from collected data.*
2.ESS2.2	Observe and analyze how blowing wind and flowing water can move Earth materials (soil, rocks) from one place to another, changing the shape of a landform and affecting the habitats of living things. **COMPONENT IDEA:** *A. Earth Materials and Systems*	**EXPLANATION:** The focus of this standard is to begin a discussion of how Earth's systems interact and cause changes over time. This standard explores interactions within the atmosphere, hydrosphere, geosphere, and biosphere. Over long periods of time, such interactions have contributed to the diversity of organisms on Earth. Examples of types of landforms may include hills, river banks, valleys, and dunes.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students identify and describe parts and their roles in the inner workings as part of a larger system/object.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students generate explanations for natural phenomena that incorporate relevant evidence.*

2.ESS2.3	Compare simple maps of different land areas to observe the shapes and kinds of land (rock, soil, sand) and water (river, stream, lake, pond). **<u>Component idea:</u>** *B. Plate Tectonics and Large-Scale Systems Interactions*	**Explanation:** In later grades, students will begin to examine evidence that supports tectonic theory. Due to the scale of tectonic activity, students will need to have some prior experience with maps and recognizing that maps are representations of their physical world. The function of a map is to show the location of objects on earth's surface and that maps can provide information about terrain or availability of water. Activities with this standard might pair well with life science standards examining the needs of living organisms.	**<u>Crosscutting Concept:</u>** **Scale, Proportion, and Quantity** *Students make comparisons using relative scales. (e.g. bigger or smaller, closer or further, sooner or later)* **<u>Science and Engineering Principle:</u>** **Developing and using models** *Students make drawings, displays, and simple representations for events they experience through their senses, incorporating relative scales when appropriate.*

2.ESS2.4	Use information obtained from reliable resources to explain that water is found in the ocean, rivers, streams, lakes, and ponds, and may be solid or liquid. **COMPONENT IDEA:** *C. The Roles of Water in Earth's Surface Processes*	**EXPLANATION:** Water is present in a multitude of scales on earth. The roles of water on earth include transport of soil and rocks from one place to another and also determine the types of organisms that are found in a given region. Part of this standard is comparing the size of these different water sources and their interconnected nature. Resources might include examinations of various different examples of each hydrologic feature from around the world.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students identify cause and effect relationships through observable patterns, utilizing simple tests to provide evidence that supports or refutes their ideas.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *(Obtain/Evaluate) Students read and utilize the information, features, and structure of grade appropriate texts and media to obtain scientific information useful in forming or supporting a scientific claim.*

2.ETS1: Engineering Design			
2.ETS1.1	Define a simple problem that can be solved through the development of a new or improved object or tool by asking questions, making observations, and gathering accurate information about a situation people want to change **COMPONENT IDEA:** *A. Defining and Deliminating and Engineering Problems*	**EXPLANATION:** In earlier grades, students have been presented with a problem and worked to make observations that were relevant to the process of formulating that problem. Students should now be presented the opportunity to take a situation or object that can be improved and create a design problem around this improvement. Asking questions, making observations, and gathering accurate data to come up with a solution for a new or improved tool to solve problems may include examples arising from what happens to animals when the environment changes due to temperature fluctuations, cutting down trees, wildfires, pollution, salinity changes, and the effects of drought. Computers or tablet devices are effective tools to research accurate data from reliable resources, and programs may be used to help organize the data found.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students identify and describe parts and their roles in the inner workings as part of a larger system/object.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Asking questions (for science) and defining problems (for engineering)** *Students explicitly describe a design problem that can be solved using an new object or device.*

2.ETS1.2	Develop a simple sketch, drawing, or physical model that communicates solutions to others. **Component idea:** *B. Developing Possible Solutions*	**Explanation:** Working in a collaborative setting requires that students communicate preliminary solutions effectively. Examples for developing a simple sketch, drawing, or physical model that show part and whole to communicate the solution to others may include conducting an investigation or determining if a design solution works as intended to explain how a stronger push or pull makes things go faster and how faster speeds during a collision can cause a bigger change in the shape of the colliding objects. Colliding objects can be made using interlocking pieces to create a vehicle. Ramps made from wood or cardboard, and varying sizes of rubber bands may be used to create the push/pull at different strengths causing differences in the collisions that will allow the students to make observations and draw conclusions regarding these variances.	**Crosscutting Concept:** **Systems and System Models** *Students identify and describe parts and their roles in the inner workings as part of a larger system/object.* **Science and Engineering Principle:** **Obtaining, evaluating, and communicating information** *(Communicate) Students utilze writing, drawing, and modeling to communicate information.*
2.ETS1.3	Recognize that to solve a problem, one may need to break the problem into parts, address each part, and then bring the parts back together. **Component idea:** *B. Developing Possible Solutions*	**Explanation:** The process of developing a solution requires that students recognize interacting factors which may all impact the design of more complex solutions. In order to carry out such system level evaluation, a student must first be able to deconstruct their problem. The large solution may require addressing a series of smaller problems independently, then recombining the solutions to these smaller problems. Examples of this may be experienced in simple coding exercises such a navigating around obstacles to work through a maze.	**Crosscutting Concept:** **Energy and Matter** *Students understand that objects can be deconstructed and reassembled in the same or different ways to form a foundation for understanding transformations of energy and matter.* **Science and Engineering Principle:** **Planning and carrying out controlled investigations** *Students determine whether a proposed object or tool will meet criteria for success based on past experiences, observations or measurements.*

2.ETS1.4	Compare and contrast solutions to a design problem by using evidence to point out strengths and weaknesses of the design. **COMPONENT IDEA:** *C. Optimizing the Solution Design*	**EXPLANATION:** A design problem will have multiple solutions. Selecting from a group of solutions is deliberate and requires compromises. Students should evaluate multiple solutions to a process by carrying out tests of the solutions and gather evidence used in a discussion of strengths and weaknesses of particular solutions.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students identify cause and effect relationships through observable patterns, utilizing simple tests to provide evidence that supports or refutes their ideas.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Using mathematics and computational thinking** *Students compare two different solutions to a problem from collected data.*

2.ETS2: Links Among Engineering, Technology, Science, and Society			
2.ETS2.1	Use appropriate tools to make observations, record data, and refine design ideas. **Component idea:** *A. Interdependence of Science, Technology, Engineering, and Math*	**Explanation:** In both kindergarten and first grade students are introduced to a small number of simple tools that can be used to make quantitative observations. This second grade standard calls for further application of the usages of these tools to include in the refinement of design ideas. Examples might include design/building challenges where students can capture and record data to be used in the refinement of a design.	**Crosscutting Concept:** **Scale, Proportion, and Quantity** *Students make comparisons using relative scales. (e.g. bigger or smaller, closer or further, sooner or later)* **Science and Engineering Principle:** **Analyzing and interpreting data.** *Students analyze observations and measurements for a device to ensure it satisfies specifications.*
2.ETS2.2	Predict and explain how human life and the natural world would be different without current technologies. **Component idea:** *B. Influence of Engineering, Technology, and Science on Society and the Natural World*	**Explanation:** In order for humans to design, produce, and use objects in our daily lives, we rely on knowledge acquired from interacting with the natural world. Such knowledge may be about the properties of different materials which informs in the process of design of a device or the knowledge might inspire a solution to a design problem based on observations in the natural world. The materials used in the construction of various technologies throughout history have depended on materials acquired from the natural world.	**Crosscutting Concept:** **Systems and System Models** *Students investigate how the roles of specific components of a system affect the functioning of the larger system.* **Science and Engineering Principle:** **Engaging in argument from evidence** *Students can make and support claims about a proposed device or solution.*

Third Grade:

3.PS1: Matter and Its Interactions			
3.PS1.1	Describe the properties of solids, liquids, and gases and identify that matter is made up of particles too small to be seen. **Component idea:** *A. Structure and Properties of Matter*	**Explanation:** Students should focus on two different aspects of matter in a variety of materials in order to lead into discussions of intermolecular forces in later grades. Properties of materials which might be observed include: hardness, visibility, flexibility, and the ability to stand up independently. Additionally students should understand that all phases are constructed of invisible particles. Though gases are seldom seen, students are prepared to consider the idea that the sense of smell requires that particles of a substance must touch our olfactory nerves in order to be detected. Other phenomena such as leaves blowing in the wind, the formation of "sweat" on the side of a glass provide evidence for the existence of invisible particles. Their existence can be further inferred by actions such as blowing up a balloon, or even by tracking the weight of objects that seem to disappear. *(Students are not responsible for explaining the interactions between molecules which govern the processes of evaporation and condensation.)*	**Crosscutting Concept:** **Pattern** *Students use patterns as evidence in an argument or to make predictions, construct explanations, and engage in arguments.* **Science and Engineering Principle:** **Developing and using models** *Student models begin to become abstract and metaphorical, incorporating relationships between events and predictive aspects for recurring events.*
3.PS1.2	Differentiate between changes caused by heating or cooling that can be reversed and that cannot. **Component idea:** *B. Chemical Processes*	**Explanation:** The purpose of this standard is to prepare students to justify when chemical reactions have or have not occurred in later grades. Examples of reversible changes may include ice and butter in an ice cube tray melting outside and then refreezing back in the tray to original shape. Examples of irreversible changes may include taking a raw egg, cooking or hard boiling it, and trying to refreeze it to go back to raw, or taking a piece of paper and burning it. (Students should be limited to observations they can make directly with their senses.)	**Crosscutting Concept:** **Cause and Effect** *Students routinely search for cause and effect relationships in systems they study.* **Science and Engineering Principle:** **Engaging in argument from evidence** *Students can create evidence based explanations for relationships seen in the natural world as well as identify evidence that supports other explanations.*

3.PS1.3	Describe and compare the physical properties of matter including color, texture, shape, length, mass, temperature, volume, state, hardness, and flexibility. **<u>COMPONENT IDEA:</u>** *A. Structure and Properties of Matter*	**EXPLANATION:** In addition to familiarizing students with base units of measure, this standard helps prepare students to justify when chemical reactions have or have not occurred, in later grades. Scientists use changes in certain physical properties of a material, such as color, as evidence of chemical reactions. In addition to properties explicitly mentioned in the standard, students may also consider: reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility. (Quantitative comparisons should involve only base measurements and not derived quantities such as density.)	**<u>Crosscutting Concept:</u>** **Scale, Proportion, and Quantity** *Students make measurements of physical properties of objects using base units.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Planning and carrying out controlled investigations** *Students carry out investigations in groups, where conditions and variables are controlled, utilize appropriate instruments, and deliberately plan multiple trials.*

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3.PS2: Motion and Stability: Forces and Interactions			
3.PS2.1	Explain the cause and effect relationship of magnets. **COMPONENT IDEA:** *B. Types of Interactions*	**EXPLANATION:** A major focus of the investigations of magnets should be on the idea that there are forces that can be exerted without objects actually coming into contact. This idea will develop as students explore electrical interactions and gravity in later grades. Student investigations can include the interactions of two permanent magnets or electromagnets and magnetic materials such as paperclips. Students may vary investigations by considering the effects of distance on the strength of the attraction, the effects of multiple magnets, the orientations of the magnets, or the number of loops or material used to make an electromagnet. The force between an electromagnet and steel paperclips, and the force exerted by one magnet verses the force exerted by two magnets. Students can record their observations using arrows to represent forces. The relative sizes of arrows can be used to represent forces of differing strengths, and the direction of the forces can be designated using the arrowheads. (Only qualitative data should be collected for the sizes of forces.)	**Crosscutting Concept:** **Cause and Effect** *Students use patterns as evidence in an argument or to make predictions, construct explanations, and engage in arguments.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students carry out investigations in groups, where conditions and variables are controlled, utilize appropriate instruments, and deliberately plan multiple trials.*
3.PS2.2	Solve a problem by applying the use of the interactions between two magnets. **COMPONENT IDEA:** *B. Types of Interactions*	**EXPLANATION:** Possible problems may include creating a latch mechanism, utilizing two magnets to keep surfaces from touching, separating a mixture of different materials, or sorting metals for recycling based on magnetic properties.	**Crosscutting Concept:** **Structure and Function** *Students begin to attribute the shapes of sub-components to the function of the part.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students can design a device utilizing scientific ideas as well as compare competing solutions based on constraints and criteria for success.*

3.PS3: Energy			
3.PS3.1	Recognize that energy is present when objects move; describe the effects of energy transfer from one object to another. **COMPONENT IDEA:** *B. Conservation of Energy and Energy Transfer*	**EXPLANATION:** When objects are in motion, they possess energy and the faster they are traveling, the more energy it possesses. Changes in motion mean that the amount of energy changes as well. To understand collisions, students must also understand that energy is present whenever sound, light, or heat is present. However, these three phenomena should not be considered types of energy. Energy can be transferred by waves (such as sound, mechanical, electromagnetic radiation) or electric currents. During a collision between a moving object and an object at rest, the energy of the moving object will decrease as the collision results in the transfer of that energy to the previously stationary object. Collisions generally produce some heat and sound, which is energy lost from the system during the transfer. Simple bar graphs of a system before and after a collision are an effective way to keep track of energy exchanges. *(Students are only responsible for recognizing qualitative changes in energy.)*	**Crosscutting Concept:** **Energy and Matter** *Students begin to recognize types of energy present in a system and the ability to transfer this energy between obejcts.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Student models begin to become abstract and metaphorical, incorporating relationships between events and predictive aspects for recurring events.*
3.PS3.2	Apply scientific ideas to design, test, and refine a device that converts electrical energy to another form of energy, using open or closed simple circuits. **COMPONENT IDEA:** *B. Conservation of Energy and Energy Transfer*	**EXPLANATION:** Building on the idea that moving objects possess energy and that this energy can be transferred during a collision, students are to construct a device which turns stored electrical energy into another form. These forms could include: motion, sound, light, or heat. Electric circuits can be viewed as a way to move energy from the stored energy to some sort of output (motor, speaker, bulb, heating element). It should also be noted that the energy of motion is able to produce electrical energy in devices such as generators or turbines in hydroelectric applications.	**Crosscutting Concept:** **Energy and Matter** *Students begin to recognize types of energy present in a system and the ability to transfer this energy between objects.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students can design a device utilizing scientific ideas as well as compare competing solutions based on constraints and criteria for success.*

3.PS3.3	Evaluate how magnets cause changes in the motion and position of objects, even when the objects are not touching the magnet. **<u>COMPONENT IDEA:</u>** *C. Relationship Between Energy and Forces and Fields*	**EXPLANATION:** Forces can be exerted when objects touch or through fields. Students should be given the opportunity to observe that motion of an object can change without being touched because the object interacts with a magnetic field. The object which is set into motion gains energy of motion. This energy was formerly stored by the magnetic field based on changes in the relative positions of the object in the field and the object creating the field. Therefore the transfer process can be viewed as transferring energy from the magnetic field to the object now in motion. Students should try using magnets to slow down an object as well as speed up the object.	**<u>Crosscutting Concept:</u>** **Cause and Effect** *Students routinely search for cause and effect relationships in systems they study.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Analyzing and interpreting data.** *Students should be able to organize experimental data to reveal patterns and utilize data using simple graph to form explanations.*

<table>
<tr><th colspan="4">3.LS1: From Molecules to Organisms: Structures and Processes</th></tr>
<tr><td rowspan="2">3.LS1.1</td><td rowspan="2">Analyze the internal and external structures that aquatic and land animals and plants have to support survival, growth, behavior, and reproduction.

<u>Component idea:</u>
A. Structure and Function</td><td rowspan="2">Explanation: In earlier grades, students have examined external structures of plants (first grade) and animals (second grade). The functions of the external structures were generalized to processes such as reproduction, protection, or sensing. Mirroring discussions in the physical science discipline, students should consider internal structures that may not be visible. External animal structures may include legs, wings, feathers, trunks, claws, fins, horns, and antennae. Animal organs might include eyes, ears, nose, heart, stomach, lungs, brain, and skin. Plant structures might include seeds, leaves, roots, stems, bark, and flowers. (Instruction should not include any microscopic processes, such as exchanges of gas within the lungs, merely the macroscopic function of breathing.)</td><td><u>Crosscutting Concept:</u>
Structure and Function
Students begin to recognize that obejcts have smaller substructures which determine the property of a material or system.</td></tr>
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Students can create evidence based explanations for relationships seen in the natural world as well as identify evidence that supports other explanations.</td></tr>
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3.LS2: Ecosystems: Interactions, Energy, and Dynamics			
3.LS2.1	Construct an argument to explain why some animals benefit from forming groups. **<u>Component idea:</u>** *D. Social Interaction and Group Behavior*	**Explanation:** In later grades, students will look within an organism to investigate how groups of cells work collectively as tissues and organs to increase efficiency in tasks such as collecting, transporting, and removing materials throughout a larger system. Third grade lessons investigate a larger scale, examining the effects of organisms working collectively and how grouping benefits both individuals and the group. Forming groups provides a way for an individual to cope with change. Discussions of groups should also include general structures within a group (e.g., equality amongst all individuals, hierarchy, family groups, gender groups, age groups). Examples of animals benefiting from forming groups may include dolphins surrounding a school of fish and then taking turns darting into the center to eat the fish trapped in the middle or animals living in groups for protection, such as baboons. One single baboon might not be able to fight off a leopard, but a troop of baboons often would be able to do so. Additional benefits may include movement as a group creating confusion for the predator.	**<u>Crosscutting Concept:</u>** **Systems and System Models** *Students group and describe interactions of the components that define a larger system.* **<u>Science and Engineering Principle:</u>** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider whether an argument is supported by evidence or relies on opinions or incomplete representations of relevant evidence.*

<table>
<tr><th colspan="4">3.LS4: Biological Change: Unity and Diversity</th></tr>
<tr><td rowspan="2">3.LS4.1</td><td rowspan="2">Explain the cause and effect relationship between a naturally changing environment and an organism's ability to survive.

<u>Component idea:</u>
C. Adaptation</td><td rowspan="2">Explanation: Changes to an environment can happen suddenly or occur gradually. At times these changes can be harmful to living organism. Detrimental changes can cause organisms to struggle to find food, water, or clean air and may cause some to die. Examples should include needs of a specific organism, characteristics of a particular environment, and how the two support each other. Examples may include alligators now thriving after all these years in their habitat; polar bears losing their sea ice habitat, causing their population to be threatened; and the dodo bird which is now extinct partly due to predators introduced by humans.</td><td><u>Crosscutting Concept:</u>
Cause and Effect
Students routinely search for cause and effect relationships in systems they study.</td></tr>
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Students create and identify evidence-based arguments and consider whether an argument is supported by evidence or relies on opinions or incomplete representations of relevant evidence.</td></tr>
</table>

3.LS4.2	Infer that plant and animal adaptations help them survive in land and aquatic biomes. **COMPONENT IDEA:** *C. Adaptation*	**EXPLANATION:** The idea of this standard as compared to 3.LS1.1 is that when variations of a trait occur, some of these variations help an organism to survive as compared to others within their species. Some adaptations could include; blubber, dense feathers, and thick fur for warmth; ability to burrow underground, nocturnal, and drought tolerant to escape heat, spines or thorns to avoid being eaten, large beaks or appendages that can grab fruit from tree tops, shallow roots to absorb water quickly, waxy leaves to protect water, and gills for taking in oxygen.	**Crosscutting Concept:** **Systems and System Models** *Students begin to recognize that obejcts have smaller substructures which determine the property of a material or system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students can create evidence-based explanations for relationships seen in the natural world as well as identify evidence that supports other explanations.*
3.LS4.3	Explain how changes to an environment's biodiversity influence human resources. **COMPONENT IDEA:** *D. Biodiversity and Humans*	**EXPLANATION:** Changes to biodiversity can be brought on by habitat destruction, pollution, introduction to invasive species, or overuse of shared resources. Healthy ecosystems provide humans with natural resources and perform various ecosystem services. Examples of how an environment's biodiversity can influence human resources may include food, medicines, and functions (such as scrubbing carbon dioxide from the atmosphere). When a species is threatened due to overexploitation is can lead to a decrease in a human resource. An example of this is the overexploitation of fish leaving a shrinking population of food.	**Crosscutting Concept:** **Systems and System Models** *Students group and describe interactions of the components that define a larger system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Student models begin to become abstract and metaphorical, incorporating relationships between events and predictive aspects for recurring events.*

3.ESS1: Earth's Place in the Universe			
3.ESS1.1	Use data to categorize the planets in the solar system as inner or outer planets according to their physical properties. **COMPONENT IDEA:** *B. Earth and the Solar System*	**EXPLANATION:** The orbital path a planet follows around the sun is dictated by a combination of the mass of the planet and how fast it travels through space. Students should be led to make comparisons about these factors (e.g., Planets closer to the sun must either be very small, orbit very quickly, or a combination of the two.). On a particular planet, the duration of its day is determined by how quickly it spins on its axis. Additionally, students should collect data which can be used to create a classification system for planets.	**Crosscutting Concept:** **Scale, Proportion, and Quantity** *Students become familiar with sizes immensely large or small or durations extremely short or long.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Choose a SEP** *(Optain/Evaluate) Students can read and summarize text and embedded, non-text elements from multiple sources synthesizing an understanding on a scientific idea. Students can communicate scientific information in writing utilizing embedded elements.*

3.ESS2: Earth's Systems			
3.ESS2.1	Explain the cycle of water on Earth. **COMPONENT IDEA:** *A. Earth Materials and Systems*	**EXPLANATION:** In second grade, students examined reservoirs for Earth's surface waters and interactions between Earth's systems. In third grade, students are introduced to the particulate nature of matter and to transformations of energy. These new concepts provide necessary understandings to explore water in its gaseous phase and its transformations throughout the hydrosphere. Students should address changes in state and energy throughout the water cycle as well as water's transport of materials as it succumbs to gravity. Consideration should be given to relative abundances of water and fresh water and its distribution between the various stores. Students should begin to explore the interactions between the hydrosphere and other earth systems such as the biosphere and geosphere.	**Crosscutting Concept:** **Systems and System Models** *Students group and describe interactions of the components that define a larger system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Student models begin to become abstract and metaphorical, incorporating relationships between events and predictive aspects for recurring events.*
3.ESS2.2	Associate major cloud types (nimbus, cumulus, cirrus, and stratus) with weather conditions. **COMPONENT IDEA:** *A. Earth Materials and Systems*	**EXPLANATION:** As air masses are transported by winds, clouds interact with landforms giving rise to weather patterns. Students should collect observations of cloud types and subsequent weather to build a predictive model for weather.	**Crosscutting Concept:** **Pattern** *Students recognize, classify, and record patterns involving rates of change.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students organize data (observations and measurements) in a manner which faciltates further analysis and comparisons.*

3.ESS2.3	Use tables, graphs, and tools to describe precipitation, temperature, and wind (direction and speed) to determine local weather and climate. **COMPONENT IDEA:** *D. Weather and Climate*	**EXPLANATION:** Clarification may be needed to differentiate between the terms weather and climate. Weather scientists record data at different times of the day/year and also in different areas. By analyzing pattern sin their data, it is possible for scientists to make weather predictions. Students should become familiar with the tools and techniques used to monitor weather. These measurements should be gathered and organized to permit classification of their climate as well as making short term predictions such as probable weather that accompanies wind from a particular direction.	**Crosscutting Concept:** **Pattern** *Students recognize, classify, and record patterns involving rates of change.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students organize data (observations and measurements) in a manner which faciltates further analysis and comparisons.*
3.ESS2.4	Incorporate weather data to describe major climates (polar, temperate, and tropical) in different regions of the world. **COMPONENT IDEA:** *D. Weather and Climate*	**EXPLANATION:** Classification of different climates should be based on weather differences. Students should be explicit in the differences between timeframe and geographic scale of weather compared to climate. As part of these differences in scale there should be recognition that changes in climate may not be apparent during the span of their lives.	**Crosscutting Concept:** **Scale, Proportion, and Quantity** *Students become familiar with sizes immensely large or small or durations extremely short or long.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *(Optain/Evaluate) Students can read and summarize text and embedded, non-text elements from multiple sources synthesizing an understanding on a scientific idea. Students can communicate scientific information in writing utilizing embedded elements.*

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3.ESS3: Earth and Human Activity			
3.ESS3.1	Explain how natural hazards (fires, landslides, earthquakes, volcanic eruptions, floods) impact humans and the environment. **COMPONENT IDEA:** *B. Natural Hazards*	**EXPLANATION:** The focus of this standard should be on the idea that natural hazards will occur, and will have effects on humans. Each of these hazards originates from natural processes. The goal of studying natural hazards is to decrease their negative impacts. Understanding specific effects on humans and the environments provides information needed to define engineering problems and consider appropriate constraints.	**Crosscutting Concept:** **Cause and Effect** *Students routinely search for cause and effect relationships in systems they study.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *(O/E) Students can read and summarize text and embedded, non-text elements from multiple sources synthesizing an understanding on a scientific idea. (C) Students can communicate scientific information in writing utilizing embedded elements.*
3.ESS3.2	Design solutions to reduce the impact of natural hazards (fires, landslides, earthquakes, volcanic eruptions, floods) on the environment. **COMPONENT IDEA:** *B. Natural Hazards*	**EXPLANATION:** Examples of designs may include using a model of a sediment tray to illustrate the effects of a landslide, flood, or lost vegetation by running water and creating a solution to slow the impact of these hazards on the environment.	**Crosscutting Concept:** **Systems and System Models** *Students group and describe interactions of the components that define a larger system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students can design a device utilizing scientific ideas as well as compare competing solutions based on constraints and criteria for success.*

3.ETS1: Engineering Design			
3ETS1.1	Design a solution to a real-world problem that includes specified criteria for constraints. **COMPONENT IDEA:** *A. Defining and Deliminating and Engineering Problems*	**EXPLANATION:** In K-2 students developed the ability to define engineering problems that incorporated observations about the environment or conditions associated with the problem. These observations are incorporated in both determining the criteria for a successful design as well as constraints that limit design possibilities. Constraints might include limited availability of either materials or resources. Students also learned to communicate their initial ideas using drawings. Understanding these constraints, students can now undertake the task of evaluating proposals for design solutions and then consider how well the proposals meet criteria for success and work within the constraints.	**Crosscutting Concept:** **Systems and System Models** *Students group and describe interactions of the components that define a larger system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students can design a device utilizing scientific ideas as well as compare competing solutions based on constraints and criteria for success.*
3ETS1.2	Apply evidence or research to support a design solution. **COMPONENT IDEA:** *A. Defining and Deliminating and Engineering Problems*	**EXPLANATION:** Supporting a design solution is dependent on gathering evidence or conducting research. The focus in these efforts should be to compare the solution to the criteria and constraints that were established when the problem was initially defined.	**Crosscutting Concept:** **Systems and System Models** *Students group and describe interactions of the components that define a larger system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *(O/E) Students can read and summarize text and embedded, non-text elements from multiple sources synthesizing an understanding on a scientific idea. (C) Students can communicate scientific information in writing utilizing embedded elements.*

3.ETS2: Links Among Engineering, Technology, Science, and Society			
3ETS2.1	Identify and demonstrate how technology can be used for different purposes. **COMPONENT IDEA:** *A. Interdependence of Science, Technology, Engineering, and Math*	**EXPLANATION:** As scientific understanding of the natural world increases, these understandings can lead to improvements in engineered objects. In turn, improvements the tools produced by engineers can enable further discovery by scientists. Scientists utilize devices produced by engineers in innovative ways that may have never been considered initially. Examples of this concept might include using a cell phone as an interactive map of the night sky or apps such as eBird (Cornell University) which can be used to track and catalog sightings of birds using the user's GPS location.	**Crosscutting Concept:** **Pattern** *Students use patterns as evidence in an argument or to make predictions, construct explanations, and engage in arguments.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Using mathematics and computational thinking** *Students can make measurements for the purpose of testing and comparing competing design solutions or understanding the effects of modifications to an existing device.*

Fourth Grade:

4.PS3: Energy			
4.PS3.1	Use evidence to explain the cause and effect relationship between the speed of an object and the energy of an object. **COMPONENT IDEA:** *A. Definitions of Energy*	**EXPLANATION:** The energy of a moving object is properly referred to as kinetic energy. This knowledge is imperative to teaching 4.PS3.2. As an object's speed increases, so too does its kinetic energy. To illustrate this concept, consider dropping balls of play dough from different heights. Slow motion videos can confirm the increase in speeds when dropped from varying heights. Relating back to 2.PS3.1, students can recognize that larger changes in shape are associated with greater amounts of energy.	**Crosscutting Concept:** **Cause and Effect** *Students routinely search for cause and effect relationships in systems they study.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students can create evidence-based explanations for relationships seen in the natural world as well as identify evidence that supports other explanations.*
4.PS3.2	Observe and explain the relationship between potential energy and kinetic energy. **COMPONENT IDEA:** *D. Energy in Chemical Processes and Everyday Life*	**EXPLANATION:** The idea that humans produce energy from nothingness is a misconception that students might possess. Energy exists in various stored forms know as potential energies. This potential energy can then be converted or released. For instance, water at high at elevation contains (gravitational) potential energy that can be harnessed by hydroelectric dams to produce electricity by spinning turbines. Food is a stored energy form that is released during digestion. Examples which build on these ideas might include using a hoop spring or elastic band to propel a toy car forward (elastic potential energy). Recognizing that deforming the spring to greater amounts increases the potential energy of the spring. Additionally, students can use electric toy cars with different numbers of batteries and observe the speeds of these cars. (electric potential energy) To "remove" batteries, but allow the car to function, the ends of the batteries can first be taped over with masking tape to prevent them from releasing energy into the circuit. The battery can then be wrapped neatly in aluminum foil and inserted into the toy as normal. The foil allows electricity to flow through the circuit.	**Crosscutting Concept:** **Energy and Matter** *Students begin to recognize types of energy present in a system and the ability to transfer this energy between obejcts.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students carry out investigations in groups, where conditions and variables are controlled, utilize appropriate instruments, and deliberately plan multiple trials.*

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4.SP3.3	Describe how stored energy can be converted into another form for practical use. **<u>COMPONENT IDEA:</u>** *D. Energy in Chemical Processes and Everyday Life*	**EXPLANATION:** There are various mechanisms to store or concentrate energy to be used at a later time. Plants store up the suns energy and store this energy. When the plants are consumed, the energy can be unleased. For processes such as these to work, energy must be stored so that it can be released. A dam stores water on its uphill side, plants store energy from sunlight as they produce food, and batteries store electricity.	**<u>Crosscutting Concept:</u>** **Energy and Matter** *Students begin to recognize types of energy present in a system and the ability to transfer this energy between obejcts.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Constructing explanations and designing solutions** *Students can create evidence based explanations for relationships seen in the natural world as well as identify evidence that supports other explanations.*

4.PS4: Waves and Their Applications in Technologies for Information Transfer			
4.PS4.1	Use a model of a simple wave to explain regular patterns of amplitude, wavelength, and direction. **COMPONENT IDEA:** *A. Wave Properties: Mechanical and Electromagnetic*	**EXPLANATION:** Student models should explore the patterns in the shapes of both longitudinal and transverse waves as well as patterns occurring when two waves interact. Students should be able to both identify amplitude within a model for a wave, as well as identify patterns for how amplitude changes when waves interact. Students should note the effects on the direction a wave travels when it intersects another wave while traveling through a medium. Waves can be observed traveling through an elongated spring that is quickly jerked sideways and returned to center on a tile floor. Floor tiles can be used as reference points where a wave might have an amplitude of one floor tile. (Students are not responsible for boundary behaviors of waves such as reflection at a fixed end.)	**Crosscutting Concept:** **Pattern** *Students recognize, classify, and record patterns involving rates of change.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Student models begin to become abstract and metaphorical, incorporating relationships between events and predictive aspects for recurring events.*
4.PS4.2	Describe how the colors of available light sources and the bending of light waves determine what we see. **COMPONENT IDEA:** *B. Electromagnetic Radiation*	**EXPLANATION:** In first grade, students discussed the idea that objects are visible because they either reflect or emit their own light. Light was treated as a beam of light and color was not addressed in first grade. This standard provides students the opportunity to see that white light is composed of a combination of red, green, and blue light. Students can examine and record how the appearances of objects (solid-color and multi-color) change depending on the light source. Prisms can be used to bend light so that it is separated into component colors. Lenses and combinations of lenses can bend light to magnify or focus light for objects that cannot be seen with the naked eye. (Students are not responsible for explaining the properties of materials that cause them to absorb/reflect certain colors.)	**Crosscutting Concept:** **Cause and Effect** *Students routinely search for cause and effect relationships in systems they study.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students should be able to organize experimental data to reveal patterns and utilize data using simple graph-to-form explanations.*

4.SP4.3	Investigate how lenses and digital devices like computers or cell phones use waves to enhance human senses. **COMPONENT IDEA:** *C. Information Technologies and Instrumentation*	**EXPLANATION:** In 4.PS4.2, students are exposed to the bending of light as it crosses over the boundary between two materials. Students could investigate or construct varying arrangements of lenses to determine how they are utilized in devices such as eyeglasses, microscopes, or telescopes. Digital devices are devices/components of devices that are either on or off. An LCD (computer/smartphone) screen is a series of tiny lightbulbs (pixels) that can be turned on or off individually to create a picture. A model of this process might be crowds at a stadium holding pieces of colored paper above their heads to create a mosaic when viewed from above. Computers store information about which pixels are turned on an off to display an image. This stored digital information can be transmitted using waves to share pictures remotely.	**Crosscutting Concept:** **Structure and Function** *Students begin to attribute the shapes of sub-components to the function of the part.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *(O/E) Students can read and summarize text and embedded, non-text elements from multiple sources synthesizing an understanding on a scientific idea. (C) Students can communicate scientific information in writing utilizing embedded elements.*

4.LS2: Ecosystems: Interactions, Energy, and Dynamics			
4.LS2.1	Support an argument with evidence that plants get the materials they need for growth and reproduction chiefly through a process in which they use carbon dioxide from the air, water, and energy from the sun to produce sugars, plant materials, and waste (oxygen); and that this process is called photosynthesis. **COMPONENT IDEA:** *A. Interdependent Relationships in Ecosystems*	**EXPLANATION:** In second grade, students were introduced to the idea that organisms depend on their environment to meet general survival needs. In third grade, students were introduced to gaseous matter in their physical sciences studies. Building on that information, students are now prepared to examine the invisible needs of plants for survival. Plants fulfill the role of "producer" which implies that nearly all types of food originated as a plant. Students can examine elodea plants in water to observe their production of gas (oxygen) under varying conditions. Bromothymol blue can be used as an indicator to show the conversion of carbon dioxide (blow bubbles into water) into oxygen by the elodea. In preparation for later grades, it should be emphasized that plant matter comes from carbon dioxide, not the soil or water. In addition to forms of matter involved with photosynthesis, discussions should include the role of plants in capturing energy from the sun and bringing this energy into the biosphere. (Instruction should be limited to the requirements for photosynthesis/plant growth and not the processes.)	**Crosscutting Concept:** **Energy and Matter** *Students begin to recognize types of energy present in a system and the ability to transfer this energy between objects* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider whether an argument is supported by evidence or relies on opinions or incomplete representations of relevant evidence.*

4.LS2.2	Develop models of terrestrial and aquatic food chains to describe the movement of energy among producers, herbivores, carnivores, omnivores, and decomposers. **COMPONENT IDEA:** *A. Interdependent Relationships in Ecosystems*	**EXPLANATION:** In fourth grade, students should become cognizant that living systems require energy (a term in limited use in earlier grades) in addition to matter. All ecosystems require an organism that is able to convert energy from some form into chemical energy that can be passed along a food chain. For most ecosystems on Earth, the Sun's energy is captured by photosynthetic organisms (producers) creating the foundation for energy transfer up the food chain. Consumers are organisms that eat other organisms. Based on their specific diet, consumers can be classified as either herbivores, carnivores, or omnivores. Decomposers fulfill a unique role by returning certain nutrients to the soil so that they can be reincorporated into the food chain at the producer level. There are far less substantial means of energy production, such as sulfur-reducing bacteria, that allow certain producers to obtain energy from abiotic sources. Within the biosphere, organisms have certain dietary habits that allow them to organize in a manner that tracks the flow of energy in an ecosystem. (Instruction should focus on photosynthesis as the primary means of bringing energy into the biosphere.)	**Crosscutting Concept:** **Energy and Matter** *Students begin to recognize types of energy present in a system and the ability to transfer this energy between obejcts.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Student models begin to become abstract and metaphorical, incorporating relationships between events and predictive aspects for recurring events.*

4.LS2.3	Using information about the roles of organisms (producers, consumers, decomposers), evaluate how those roles in food chains are interconnected in a food web, and communicate how the organisms are continuously able to meet their needs in a stable food web **<u>COMPONENT IDEA:</u>** *A. Interdependent Relationships in Ecosystems*	**EXPLANATION:** The focus of this standard is on the relationships in an ecosystem. Ecosystems contain organisms that act in different ways to meet their needs. Food chains and food webs create feeding relationships. Food chains effectively organize a hierarchy or relationships based on patterns in consumption for organisms. By contrast, food webs present more realistic visualizations for the transfer of energy and matter within an ecosystem. An example of how roles of organisms are interconnected in a food web might include grass (producer) in a forest clearing, which produces its own food through photosynthesis. A rabbit (consumer-herbivore) eats the grass. A fox (consumer-carnivore) eats the rabbit. When the fox dies, decomposers such as worms and mushrooms break down its body, returning the matter and energy stored in the fox to the soil where it provides nutrients for plants like grass. *(This standard does not include discussion of various forms of symbiosis.)*	**<u>Crosscutting Concept:</u>** **Structure and Function** *Students begin to recognize that obejcts have smaller substructures which determine the property of a material or system.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Developing and using models** *Student models begin to become abstract and metaphorical, incorporating relationships between events and predictive aspects for recurring events.*

4.LS2.4	Develop and use models to determine the effects of introducing a species to, or removing a species from an ecosystem and how either one can damage the balance of an ecosystem. **COMPONENT IDEA:** *A. Interdependent Relationships in Ecosystems*	**EXPLANATION:** It is important that discussions of this standard extend beyond simply investigating invasive species. Instruction should have an equal focus on using the number of different species present in an ecosystem as an indication of the overall health of that ecosystem. Ecosystems can be threatened by invasive species which can outcompete native species for shared energy and resources. As a result of the inability to compete, the variety of native species decreases, reducing biodiversity. The reduced biodiversity presents the opportunity for more significant consequences from external factors, which are no longer damped by the ecosystem. When an ecosystem changes, some organisms survive while others do not, with less diversity, threats to single species prove more substantial. Models such as food webs can serve predictive functions. An example of introducing a species may include the introduction of tilapia and snakehead fish to countless streams, lakes, and rivers throughout the Indonesian Islands and other locations around the world, where these predatory fish almost always eat any native fish species to extinction. An example of removing a species might include prairie dogs, which are beneficial and contribute to the existence of the ecosystem in which they live. Without their existence, their ecosystem would be dramatically different or cease to exist altogether.	**Crosscutting Concept:** **Stability and Change** *Students begin to describe changes in terms of time over which they occur; their rate.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider whether an argument is supported by evidence or relies on opinions or incomplete representations of relevant evidence.*

4.LS2.5	Analyze and interpret data about changes (land characteristics, water distribution, temperature, food, and other organisms) in the environment and describe what mechanisms organisms can use to affect their ability to survive and reproduce. **COMPONENT IDEA:** *C. Ecosystem Dynamics, Functioning, and Resilience*	**EXPLANATION:** The foundation for this standard began in first grade when students first examined the reliance of organisms on their surroundings to meet needs. Before reaching this standard, students have also examined the consequences of changes in the environment on the organisms. This standard begins to unify the core ecology ideas with those of natural selection. Environmental changes can threaten some species, while proving advantageous to others. When the ecosystem changes, some organisms will survive and reproduce while others will not. Those organisms who struggle in an environment after a change has occurred will either die off or may move to a new location. Changes to the environment may also provide opportunities for new organisms to establish themselves. The organisms that are most likely to survive may have lifestyles and structures that provide them advantages. In the instruction of this standard, it is important to introduce students to a variety of changes in the environment and make connections between these changes and the ability of the ecosystems to meet the needs of organisms. Examples of specific adaptations should be secondary discussions as those discussions appear as part of standards under life sciences disciplinary core idea 4.	**Crosscutting Concept:** **Cause and Effect** *Students routinely search for cause and effect relationships in systems they study.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students should be able to organize experimental data to reveal patterns and utilize data using simple graph to form explanations.*

4.LS4: Biological Change: Unity and Diversity			
4.LS4.1	Obtain information about what a fossil is and ways a fossil can provide information about the past. **Component idea:** *A. Evidence of Common Ancestry*	**Explanation:** In 3.LS4.1, students were introduced to the idea that variations within a species may favor the survival of some organisms over. By extension, it is likely that this discussion also included the idea that some types of organisms that were once found on Earth have become extinct Through the use of fossil timelines we can observe changes in organisms over long periods of time. For example: We see fish without jawbones 500 million years ago, yet fossils from 400 million years ago show the emergence of jawbones. The appearance of new animal types can also be observed (amphibians 350mya, reptiles 300mya, mammals 230mya, and birds 120mya). Younger rocks contain embedded fossils that are younger and look more like the animals we see today. Examples of information could include type, size, and distribution of fossil organisms. Fossils used for examination can include both visible and microscopic.	**Crosscutting Concept:** **Scale, Proportion, and Quantity** *Students become familiar with sizes immensely large or small or durations extremely short or long.* **Science and Engineering Principle:** **Constructing explanations and designing solutions** *Students can create evidence based explanations for relationships seen in the natural world as well as identify evidence that supports other explanations.*

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4.ESS1: Earth's Place in the Universe			
4.ESS1.1	Generate and support a claim with evidence that over long periods of time, erosion (weathering and transportation) and deposition have changed landscapes and created new landforms. **COMPONENT IDEA:** *C. The History of Planet Earth*	**EXPLANATION:** Students should separate the processes of weathering and erosion and their roles in changing the surface of Earth. Weathering processes are more explicitly addressed in 4.ESS2.1 and pertain to the breaking down of materials. Erosive processes transport these broken down materials. The focus of this standard is on the idea that these processes occur over very long periods of time. Throughout history, there have been events such as earthquakes and volcanoes that create sudden dramatic changes to the landscape. However, gradual processes occurring continuously have also played a significant role in creating Earth's current landscape. Landforms which should be explored include local, regional, and global. Students can model the effects of weathering and erosion to create small scale landforms to understand how particular structures and formations may arise from weathering and erosion processes.	**Crosscutting Concept:** **Stability and Change** *Students recognize that even apparently stable systems may be undergoing imperceptible changes.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Student models begin to become abstract and metaphorical, incorporating relationships between events and predictive aspects for recurring events.*
4.ESS1.2	Use a model to explain how the orbit of the Earth and sun cause observable patterns: a. day and night; b. changes in length and direction of shadows over a day. **COMPONENT IDEA:** *B. Earth and the Solar System*	**EXPLANATION:** In 5.PS2.3, students begin to explore gravity and at that point can develop an understanding of the role of gravity and inertia in maintaining Earth's orbit. This standard sets a foundation for those discussions by leading students to make connections between the shadows that they see changing over a day and the events occurring at a planetary scale underlying those changes. These changes in the length and direction of shadows become key evidence in connecting the tilt of the Earth's axis to the formation of seasons in fifth grade. Opportunities to explore this standard might include recording the length of their shadows at preset times during the day over an extended period of time, using a spotlight/floodlight/flashlight to model this process within a classroom, and/or creating a scale model using spheres and a flashlight.	**Crosscutting Concept:** **Scale, Proportion, and Quantity** *Students become familiar with sizes immensely large or small or durations extremely short or long.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students should be able to organize experimental data to reveal patterns and utilize data using simple graph-to-form explanations.*

4.ESS2: Earth's Systems			
4.ESS2.1	Collect and analyze data from observations to provide evidence that rocks, soils, and sediments are broken into smaller pieces through mechanical weathering (frost wedging, abrasion, tree root wedging) and are transported by water, ice, wind, gravity, and vegetation. **COMPONENT IDEA:** *A. Earth Materials and Systems*	**EXPLANATION:** This standard focuses on the actual processes and mechanisms that break down rocks to form soils and sediments and transport these sediments. Mechanical weathering includes wearing of rock by water, ice, wind, living organisms, and gravity. Once broken down, the materials can be moved by a number of different mechanisms. Students can recreate the process of frost wedging by freezing a sealed water bottle and observing the effects. Early introductions to the idea of experimental design can be achieved by freezing an empty water bottle at the same time. (4.ESS2.1 focuses on processes whereas 4.ESS1.1 focuses on the landforms affected/created by these processes.)	**Crosscutting Concept:** **Cause and Effect** *Students identify conditions required for specific cause and effect interactions to occur through investigation.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students can create evidence based explanations for relationships seen in the natural world as well as identify evidence that supports other explanations.*

4.ESS2.2	Interpret maps to determine that the location of mountain ranges, deep ocean trenches, volcanoes, and earthquakes occur in patterns. **COMPONENT IDEA:** *B. Plate Tectonics and Large-Scale Systems Interactions*	**EXPLANATION:** 2.ESS2.3 introduced students to reading maps and identifying features on very simple maps. There are two developments to this standard. The first added complexity is that students must now be able to read more complicated maps. The maps that are examined should include the location and distribution of features that students may not have experienced firsthand, whereas second grade map features were familiar, natural resources. In addition, students are now examining the maps with the goal of observing patterns in the locations of features. As cartographers produced increasingly more detailed maps, including sonar-generated maps of the ocean floor, patterns which appeared became incorporated into the origin of tectonic theory. Major trends include that mountain chains form at the inside or edge of continents, and the presence of major bands of earthquakes and volcanoes occur where mountains meet oceans. Evidence for previous volcanic activity can include the presence of igneous rocks.	**Crosscutting Concept:** **Pattern** *Students use patterns as evidence in an argument or to make predictions, construct explanations, and engage in arguments.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students should organize data (observations and measurements) in a manner which faciltates further analysis and comparisons.*

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4.ESS2.3	Provide examples to support the claim that organisms affect the physical characteristics of their regions. **<u>COMPONENT IDEA:</u>** *E. Biogeology*	**EXPLANATION:** These effects that organisms have on their regions can include both short-and-long term effects. Living organisms depend on the Earth to meet basic needs. Long-term effects include restructuring the surface of the land to suit human needs (e.g. building of roads, dams, fuels, agriculture) or other organisms creating habitats and shelters. Much earlier in Earth's history, it was the dramatic increases of living organisms in certain areas and that created deposits of fossil fuels for the remains of these organisms.	**<u>Crosscutting Concept:</u>** **Systems and System Models** *Students group and describe interactions of the components that define a larger system.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Obtaining, evaluating, and communicating information** *(Observe/Evaluate) Students can read and summarize text and embedded, non-text elements from multiple sources synthesizing an understanding on a scientific idea. Students can communicate scientific information in writing utilizing embedded elements.*

4.ESS2.4	Analyze and interpret data on the four layers of Earth, including thickness, composition, and physical states of these layers. **<u>Component idea:</u>** *A. Earth Materials and Systems*	**Explanation:** Earth's systems include the atmosphere, hydrosphere, biosphere, and geosphere. This standard elaborates on the internal structure of the geosphere to include: the crust, mantle, outer core, and inner core. Students should develop an understanding of the relative positions, thicknesses, and compositions of these layers. Knowing the characteristics of each layer prepares students to understand processes such as convection within the mantle or radioactive decay within Earth's core.	**<u>Crosscutting Concept:</u>** **Systems and System Models** *Students group and describe interactions of the components that define a larger system.* **<u>Science and Engineering Principle:</u>** **Analyzing and interpreting data.** *Students organize data (observations and measurements) in a manner which faciltates further analysis and comparisons.*

4.ESS3: Earth and Human Activity			
4.ESS3.1	Obtain and combine information to describe that energy and fuels are derived from natural resources and that some energy and fuel sources are renewable (sunlight, wind, water) and some are not (fossil fuels, minerals). **COMPONENT IDEA:** *A. Natural Resources*	**EXPLANATION:** All material resources and energy used by humans are taken from the environment. This idea is originally presented in kindergarten when students begin to consider the ways that humans utilize the land (e.g. wood can be burnt for heating). In kindergarten, the examples given did not involve processing of the materials. Discussions of 4.ESS3.1 should also include basic discussions of how the materials are extracted or obtained to support 4.ESS3.2. These discussions do not need to involve detailed descriptions of the processes, but should focus on the general consequences of obtaining the different types of energy. (e.g., fossil fuels are extracted from deposits below Earth's surface.) The extraction processes used to obtain resources from the earth have effects on the earth. Students should develop an understanding of what differentiates the listed renewable and non-renewable resources. A full discussion relating the time to renew resources to human lifetimes will occur in 6.ESS3.1.	**Crosscutting Concept:** **Energy and Matter** *Students begin to recognize types of energy present in a system and the ability to transfer this energy between obejcts.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students can create evidence based explanations for relationships seen in the natural world as well as identify evidence that supports other explanations.*
4.ESS3.2	Create an argument, using evidence from research, that human activity (farming, mining, building) can affect the land and ocean in positive and/or negative ways. **COMPONENT IDEA:** *C. Human Impacts on Earth Systems*	**EXPLANATION:** As addressed in 4.ESS3.2 the processes used to obtain materials from the environment have consequences. Students should examine the activities that humans undertake and their effects. Discussions can include, but are not limited to farming, mining, and building. For example, human development frequently involves paving of roads affecting runoff in areas. Development can be carried out to include measures which deliberately minimize its effects. Examples include treatment of sewage, recycling of resources, and monitoring the byproducts of agricultural activities.	**Crosscutting Concept:** **Cause and Effect** *Students routinely search for cause and effect relationships in systems they study.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider whether an argument is supported by evidence or relies on opinions or incomplete representations of relevant evidence.*

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4.ETS1: Engineering Design			
4.ETS1.1	Categorize the effectiveness of design solutions by comparing them to specified criteria for constraints **<u>Component idea</u>**: *C. Optimizing the Solution Design*	**Explanation:** While the human imagination is boundless, the success of engineering solutions is dictated by real-world constraints. In grades K-2 student involvement in designing engineering problems focused on identifying opportunities for technology and engineering to fulfill a need or desire and recognizing the importance of a full understanding of the potential problem. In 3.ETS1, students were introduced to the principle of constraints. With this standard, students are asked to evaluate the effectiveness of various solutions, placing emphasis on incorporating the constraints into the critique of solutions that meet the proposed criteria for success. Students might examine proposed design solutions meant to minimize the human impact on the land and ocean, or means of obtaining natural resources.	**<u>Crosscutting Concept:</u>** **Systems and System Models** *Students group and describe interactions of the components that define a larger system.* **<u>Science and Engineering Principle:</u>** **Analyzing and interpreting data.** *Students should interpret simple graphs to compare a set of solutions to a problem.*

4.ETS2: Links Among Engineering, Technology, Science, and Society			
4.ETS2.1	Use appropriate tools and measurements to build a model. **<u>Component idea:</u>** *A. Interdependence of Science, Technology, Engineering, and Math*	**Explanation:** Progress in science and engineering are intertwined. As scientific understanding increases, it can provide information for the development of new processes and materials that will improve technology. These improvements permit the creation of better tools for scientific investigation. Through the use of tools, students can replicate the processes of engineers in design. As tools used in manufacturing and design progress, the production and design processes become more efficient. A recent example might include the ability to create prototypes utilizing 3D printing which produces scale models with tighter tolerances than traditional hand crafted models. To appreciate these developments, students should experience simple methods of constructing models to support their science content. Examples of appropriate tools and measurements may include rulers, scissors, glass lenses or mirrors to develop a pin-hole camera, a periscope, or kaleidoscope to explain the phenomena of visible light must bounce off an object and enter the eye for an object to be seen.	**<u>Crosscutting Concept:</u>** **Scale, Proportion, and Quantity** *Students make measurements of physical properties of objects using base units.* **<u>Science and Engineering Principle:</u>** **Planning and carrying out controlled investigations** *Students can make measurements for the purpose of testing and comparing competing design solutions or understanding the effects of modifications to an existing device.*
4.ETS2.2	Determine the effectiveness of multiple solutions to a design problem given the criteria and the constraints. **<u>Component idea:</u>** *C. Optimizing the Solution Design*	**Explanation:** While the human imagination is boundless, the success of engineering solutions is dictated by real-world constraints. In grades K-2 student involvement in designing engineering problems focused on identifying opportunities for technology and engineering to fulfill a need or desire and recognizing the importance of a full understanding of the potential problem. In 3.ETS1, students are introduced to the principle of constraints. With this standard, students are asked to evaluate the effectiveness of various solutions, placing emphasis on incorporating the constraints into the critique of solutions that meet the proposed criteria for success. Students might examine proposed design solutions meant to minimize the human impact on the land and ocean, or means of obtaining natural resources.	**<u>Crosscutting Concept:</u>** **Systems and System Models** *Students group and describe interactions of the components that define a larger system.* **<u>Science and Engineering Principle:</u>** **Analyzing and interpreting data.** *Students can interpret simple graphs to compare a set of solutions to a problem.*

4.ETS2.3	Explain how engineers have improved existing technologies to increase their benefits, to decrease known risks, and to meet societal demands. (artificial limbs, seatbelts, cell phones). **COMPONENT IDEA:** *B. Influence of Engineering, Technology, and Science on Society and the Natural World*	**EXPLANATION:** Examples can extend beyond those suggested, in the standard. The rationale behind these three was to address the three facets of the standard: 1)Improvements in artificial limbs improve the benefits of an already extant technology, 2) Seatbelts decrease the risks of injuries in car accidents, and 3) Cell phones meet the societal demand for greater connectedness and convenience. As technology changes, it creates new demands from society as previously inconceivable technologies are realized.	**Crosscutting Concept:** **Cause and Effect** *Students routinely search for cause and effect relationships in systems they study.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider whether an argument is supported by evidence or relies on opinions or incomplete representations of relevant evidence.*

Fifth Grade:

5.PS1: Matter and Its Interactions			
5.PS1.1	Analyze and interpret data from observations and measurements of the physical properties of matter to explain phase changes between a solid, liquid, or gas. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** The purpose of this standard is not to emphasize phases of matter. That topic is covered extensively in third grade. Instead, the focus should be on phase changes for materials and the associate physical properties of boiling point and melting point to prepare students to address intermolecular attractions in later grades. Students should make observations and collect data that the temperature of ice water will remain (near) zero degrees Celsius until all of the ice has melted. Water will have a characteristic boiling point of one hundred degrees Celsius. Building understanding of these physical properties will allow students to use them as criteria in 5.PS1.4. (Phase change diagrams such a heating and cooling curves are beyond the scope of this standard.)	**Crosscutting Concept:** **Structure and Function** *Students begin to recognize that objects have smaller substructures which determine the property of a material or system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students should organize data (observations and measurements) in a manner which faciltates further analysis and comparisons.*
5.PS1.2	Analyze and interpret data to show that the amount of matter is conserved even when it changes form, including transitions where matter seems to vanish. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** Instances where matter appears to vanish might include dissolving salt or sugar into water or dropping antacid tablets into a glass of water, producing gas. Students can make measure the masses of these systems before and after combining to provide evidence for the law of conservation of mass even when particles seem to vanish.	**Crosscutting Concept:** **Energy and Matter** *Students track transformations of matter to demonstrate the law of conservation of mass.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students organize data (observations and measurements) in a manner which faciltates further analysis and comparisons.*

5.PS1.3	Design a process to measure how different variables (temperature, particle size, stirring) affect the rate of dissolving solids into liquids. **<u>COMPONENT IDEA:</u>** *B. Chemical Processes*	**EXPLANATION:** Students can create experiments to investigate the relationships between these variables. Care should be taken to ensure that subsequent trails are comparable by using controls. For example, if studying the effect of varying temperature on dissolving a solid, equal amounts of solid should be utilized. This standard can be connected to 5.PS1.2 since the process of dissolving the solids might appear to cause matter to vanish.	**<u>Crosscutting Concept:</u>** **Stability and Change** *Students begin to describe changes in terms of time over which they occur; their rate.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Planning and carrying out controlled investigations** *Students carry out investigations in groups, where conditions and variables are controlled, utilize appropriate instruments, and deliberately plan multiple trials.*
5.PS1.4	Evaluate the results of an experiment to determine whether the mixing of two or more substances result in a change of properties **<u>COMPONENT IDEA:</u>** *B. Chemical Processes*	**EXPLANATION:** In standard 3.PS1.3 and 5.PS1.1, students build familiarity with physical properties of substances that make each substance unique. When two materials are mixed, the result can be either a "mixture" or a new compound. Students should use their knowledge of physical properties to provide support for the argument that the mixing of substances created a new substance or resulted in a mixture that consists of the original substance.	**<u>Crosscutting Concept:</u>** **Cause and Effect** *Students routinely search for cause and effect relationships in systems they study.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider whether an argument is supported by evidence or relies on opinions or incomplete representations of relevant evidence.*

5.PS2: Motion and Stability: Forces and Interactions			
5.PS2.1	Test the effects of balanced and unbalanced forces on the speed and direction of motion of objects. **COMPONENT IDEA:** *A. Forces, Fields, and Motion*	**EXPLANATION:** Students have investigated forces acting on objects and the effects of multiple forces in second grade. This standard begins to introduce students to the idea of net force, the total of all forces that act on an object. In eighth grade, students will combine this understanding of net force with an understanding of inertia (mass) to fully develop Newton's Second Law. At this point, it is important that students are able to recognize that it is common to have multiple forces acting on any object simultaneously. For instance: While standing still, the force of gravity pushes down on a person, while the surface of the Earth must push them upwards to keep the person from sinking down into the Earth's crust. Note: It is likely that scenarios may arise in which a force acts diagonally on an object (as opposed to sideways/or up and down). Such forces should be considered to act: partially in a direction parallel to the way that an object can possibly move, and partially in the direction perpendicular. Students should consider the effects of both balanced forces which will not change the motion of an object, and unbalanced forces which do change the motion of an object. (Students are not responsible for forces that act diagonally with respect to the direction an object will move or is moving. All forces will act in only one dimension, either parallel or perpendicular.)	**Crosscutting Concept:** **Stability and Change** *Students begin to describe changes in terms of time over which they occur; their rate.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students carry out investigations in groups, where conditions and variables are controlled, utilize appropriate instruments, and deliberately plan multiple trials.*
5.PS2.2	Make observations and measurements of an object's motion to provide evidence that pattern can be used to predict future motion. **COMPONENT IDEA:** *C. Stability and Instability in Physical Systems*	**EXPLANATION:** The focus of this standard is to provide students with the opportunity to observe motion that occurs in cycles and use an understanding of these cycles to make future predictions. This type of motion is called simple harmonic motion. Examples might include any variety of pendulum, a see-saw or objects traveling circular paths such as a carousel. (Instruction should focus on the forces required to create periodic motion and how these forces change, but not emphasize technical terms such as period.)	**Crosscutting Concept:** **Pattern** *Students recognize, classify, and record patterns involving rates of change.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Student models begin to become abstract and metaphorical, incorporating relationships between events and predictive aspects for recurring events.*

5.PS2.3	Use evidence to support that the gravitational force exerted by Earth on objects is directed toward the Earth's center. **COMPONENT IDEA:** *A. Forces, Fields, and Motion*	**EXPLANATION:** Evidence may include personal experience. It is not likely that a student has been to a wide variety of places on Earth, so further discussions may be required. To compensate for this, students might consider that a ball dropped anywhere on Earth will fall towards Earth's surface. A model could be constructed based on such discussions, wherein all objects are falling towards Earth's center.	**Crosscutting Concept:** **Cause and Effect** *Students use patterns as evidence in an argument or to make predictions, construct explanations, and engage in arguments.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Student models begin to become abstract and metaphorical, incorporating relationships between events and predictive aspects for recurring events.*
5.PS2.4	Explain the cause and effect relationship between two factors (mass and distance) that affect gravity. **COMPONENT IDEA:** *B. Types of Interactions*	**EXPLANATION:** An understanding of this concept should provide students a way to reconcile that all objects fall downwards the same rate. In second grade, students observed that larger (more massive) objects are harder to move. Building on this observation, it follows that gravity must exert a larger force if large objects, which are harder to move, fall at the same rate as smaller objects which are easier to move. Examples of the effect of distance on gravity might include that astronauts eventually experience weightlessness as they get further from the surface of the earth. (Care should be taken when addressing gravity on the moon vs Earth as an example, because there are differences in both mass and distance (radius), so identifying a single cause for the changes to gravity cannot be attributed exclusively to mass or distance.)	**Crosscutting Concept:** **Cause and Effect** *Students use patterns as evidence in an argument or to make predictions, construct explanations, and engage in arguments.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider whether an argument is supported by evidence or relies on opinions or incomplete representations of relevant evidence.*

5.PS2.5	Explain how forces can create patterns within a system (moving in one direction, shifting back and forth, or moving in cycles), and describe conditions that affect how fast or slowly these patterns occur. **<u>COMPONENT IDEA:</u>** *C. Stabilitiy and Instability in Physical Systems*	**EXPLANATION:** This standard provides elaboration on 5.PS2.2. Once patterns are observed in the motion of an object, students should begin to explore the underlying causes for this motion. Examples of moving in one direction might include objects in freefall, accelerated by gravity. Objects moving back and forth could include a mass bobbing up and down at the end of a stretched spring. Objects moving in cycles could include a yo-yo while performing the "around the world" trick. Planets orbiting the sun are also examples of moving in cycles, but students understanding the invisible force of gravity may not be possible. The tension force exerted by a yo-yo string is more tangible than gravity.	**<u>Crosscutting Concept:</u>** **Pattern** *Elaboration on CCC* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider whether an argument is supported by evidence or relies on opinions or incomplete representations of relevant evidence.*

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5.LS1: From Molecules to Organisms: Structures and Processes			
5.LS1.1	Compare and contrast animal responses that are instinctual versus those that are gathered through senses, processed, and stored as memories to guide their actions. **<u>Component idea:</u>** *D. Information Processing*	**Explanation:** This standard builds on a concept that was introduced in kindergarten: the idea that animals and humans have senses (sight, sound, touch) that allow them to gather information about their surroundings. Now, students should begin to consider that organisms have various types of sense receptors that gather information by directly interacting with their surroundings. Examples of these sense receptors include photoreceptors, auditory receptors, touch receptors, and taste receptors. In animals, information that is gathered may elicit instinctual responses or stored as memories that guide future actions. Instinctual responses might include migrations in response to temperature changes. (Cell types are beyond the scope of this standard and grade level; instead the generic term "sense receptors" is used to describe a group of these cells.)	**<u>Crosscutting Concept:</u>** **Pattern** *Students use patterns as evidence in an argument or to make predictions, construct explanations, and engage in arguments.* **<u>Science and Engineering Principle:</u>** **Developing and using models** *Student models begin to become abstract and metaphorical, incorporating relationships between events and predictive aspects for recurring events.*

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5.LS3: Heredity			
5.LS3.1	Distinguish between inherited characteristics and those characteristics that result from a direct interaction with the environment. **Component idea:** *A. Inheritance of Traits*	**Explanation:** A foundation is being built to explain that organisms look alike because of genetic controls. In 2.LS3.1, students observed that parents and offspring look similar and there can be groups (species) of organisms that also resemble each other. The goal of this standard is to extend the concept of heredity to explain that some reasons that organisms may look dissimilar are consequences of their environment. The interactions of an organism with its environment can extend from diet to learning Examples of this could be the stunted growth of plants with insufficient water, the lack of green color in plants grown without light, a lizard that has lost its tail due to a predator, a dog being overfed or under-exercised becoming overweight. The overall appearance and characteristics of an organism are due to a blend of inheritance and interaction.	**Crosscutting Concept:** **Choose a CCC** *Students routinely search for cause and effect relationships in systems they study.* **Science and Engineering Principle:** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider whether an argument is supported by evidence or relies on opinions or incomplete representations of relevant evidence.*
5.LS3.2	Provide evidence and analyze data that plants and animals have traits inherited from parents and that variations of these traits exist in a group of similar organisms. **Component idea:** *B. Variation of Traits*	**Explanation:** This standard focuses on a group of related organisms and the traits within those organisms. When looking at a particular trait, students should be drawn to observe that there are multiple variations of a particular trait present. There are two levels of discussion appropriate to this standard. The first level of discussion is at a species level, observing that within a particular species multiple variations of a trait are observable. At a higher level, further variation of the traits are also possible. It is appropriate to point out that organisms will look like their parents which should permit the inference that information causing the similar appearance is inherited from parents. *(Discussions of genetic mechanisms for inheritance and prediction of traits are beyond the scope of this standard.)*	**Crosscutting Concept:** **Pattern** *Students use patterns as evidence in an argument or to make predictions, construct explanations, and engage in arguments.* **Science and Engineering Principle:** **Analyzing and interpreting data.** *Students should organize data (observations and measurements) in a manner which faciltates further analysis and comparisons.*

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5.LS4: Biological Change: Unity and Diversity			
5.LS4.1	Analyze and interpret data from fossils to describe types of organisms and their environments that existed long ago. Compare similarities and differences of those to living organisms and their environments. Recognize that most kinds of animals (and plants) that once lived on Earth are now extinct. **COMPONENT IDEA:** *A. Evidence of Common Ancestry*	**EXPLANATION:** Fossils provide evidence for the types of organisms that were found on Earth long ago. Students are introduced to fossils and the information that they contain about the appearance/structure of organisms that existed long ago in 4.LS4.1. This standard builds on that background by asking students to make inferences about the environment where the fossils lived. Since both plant and animal materials can become fossilized, information found in fossils can provide evidence about the environment at the time that organism lived. Inferences can be drawn from sets of fossils found geographically and chronologically near to each other, or by comparing the structure of fossils from extinct organisms to similar organisms still living. Such inferences can include descriptions of both habits and habitats of now extinct organisms. An example could include the bottom-dwelling trilobite living mostly in water that was able to curl up much like today's pill bugs. Examples of fossils and their environments could include marine fossils that are now found on land, tropical plant fossils found in the Arctic, and fossils of extinct organisms.	**Crosscutting Concept:** **Structure and Function** *Students begin to attribute the shapes of sub-components to the function of the part.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students create and identify evidence-based arguments and consider whether an argument is supported by evidence or relies on opinions or incomplete representations of relevant evidence.*

5.LS4.2	Use evidence to construct an explanation for how variations in characteristics among individuals within the same species may provide advantages to those individuals in their survival and reproduction. **<u>COMPONENT IDEA:</u>** *B. Natural Selection*	**EXPLANATION:** 5.LS3 focuses on the idea that inheritance provides a mechanism for both similarity and variation in the appearances of living organisms. These changes may provide advantages to certain individuals and species, providing a mechanism for large-scale changes over time. Though these effects are ongoing, they can be punctuated at times due to catastrophic events. This process which favors certain traits within a population, contributing to the increase in the prevalence of those traits and suppression of others, is known as natural selection. Examples might include rose bushes with longer thorns being less likely to be eaten by herbivores or color variations within a species being favored in certain environments due to benefits such a camouflage.	**<u>Crosscutting Concept:</u>** **Stability and Change** *Students begin to describe changes in terms of time over which they occur; their rate.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Obtaining, evaluating, and communicating information** *(O/E) Students can read and summarize text and embedded, non-text elements from multiple sources synthesizing an understanding on a scientific idea. (C) Students can communicate scientific information in writing utilizing embedded elements.*

5.ESS1: Earth's Place in the Universe			
5.ESS1.1	Explain that differences in apparent brightness of the sun compared to other stars are due to their relative distances from the Earth. **COMPONENT IDEA:** *A. The Universe and Its Stars*	**EXPLANATION:** Our Sun is an example of a star, just like the stars that we see in the night sky. The Sun is close enough to illuminate our planet, creating the phenomenon of daytime. Other stars would have similar effects were it not for the immense distance between Earth and these other stars. The difference in distance makes the sun appear much larger than these other stars. To appreciate the actual size of the sun relative to these other stars, students should be familiar with the types and classifications the sun and other stars and basic stellar life cycles. A general understanding of star types should include: main sequence, giants, super giants, and white dwarfs. Students can model the effects of distance on the apparent size of objects by taking playground balls out onto the playground/gym/cafeteria/hallway and noting the difference in apparent sizes. Understanding the different star types sets a foundation for explaining the formation of elements in later grades. (Knowledge of mass and temperature and their effects on stellar life cycle are beyond the scope of this standard, as is a Hertzsprung-Russel Diagram.)	**Crosscutting Concept:** **Scale, Proportion, and Quantity** *Students become familiar with sizes immensely large or small or durations extremely short or long.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Student models begin to become abstract and metaphorical, incorporating relationships between events and predictive aspects for recurring events.*
5.ESS1.2	Research and explain the position of the Earth and the solar system within the Milky Way galaxy, and compare the size and shape of the Milky Way to other galaxies in the universe. **COMPONENT IDEA:** *A. The Universe and Its Stars*	**EXPLANATION:** Views looking down onto the Milky Way galaxy show several arms radiating outward from the center of the galaxy as well as spurs and bridges connecting these central arms. Each of these features is notable for their dense populations of stars. The Milky Way galaxy is located on the Orion Arm (sometimes called spur). Many of the perceived stars visible to the naked eye are actually entire galaxies of stars. The Milky Way galaxy is just one type of galaxy in space. The arrangement of stars in other galaxies can result in different shapes for these galaxies. These shapes include: spiral, elliptical, lenticular, and irregular.	**Crosscutting Concept:** **Systems and System Models** *Students recognize that large objects are made up of collections of particles.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *(Observe/Evaluate) Students can read and summarize text and embedded, non-text elements from multiple sources synthesizing an understanding on a scientific idea. Students can communicate scientific information in writing utilizing embedded elements.*

5.ESS1.3	Use data to categorize different bodies in our solar system including moons, asteroids, comets, and meteoroids according to their physical properties and motion. **COMPONENT IDEA:** *B. Earth and the Solar System*	**EXPLANATION:** This standard continues the development of the scale of the bodies found in space. Physical properties of the planets can include their general composition (solid/gas) as well as sizes. Properties of the motion includes their relative positions. Clarifications should be made regarding the criteria for classification as a planet. These criteria include that the body must: orbit the sun, have a nearly round shape, and have significant mass to have cleared its orbital path.	**Crosscutting Concept:** **Systems and System Models** *Students group and describe interactions of the components that define a larger system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students should be able to organize experimental data to reveal patterns and utilize data using simple graph-to-form explanations.*
5.ESS1.4	Explain the cause and effect relationship between the positions of the sun, earth, and moon and resulting eclipses, position of constellations, and appearance of the moon. **COMPONENT IDEA:** *B. Earth and the Solar System*	**EXPLANATION:** In addition to daily and seasonal patterns, recording phenomena such as the shape of the moon, the location of constellations in the night sky, and the appearance of the moon reveal patterns as well. It is possible to record the changes to the shape of the moon to compare with a smaller model, and with significant advanced planning, an ongoing record could be kept but would take ~28 days for a full cycle to complete. Student models should permit explanations for the appearance of the moon as well as eclipse patterns.	**Crosscutting Concept:** **Cause and Effect** *Students routinely search for cause and effect relationships in systems they study.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Student models begin to become abstract and metaphorical, incorporating relationships between events and predictive aspects for recurring events.*

5.ESS1.5	Relate the tilt of the Earth's axis, as it revolves around the sun, to the varying intensities of sunlight at different latitudes. Evaluate how this causes changes in day-length and seasons. **COMPONENT IDEA:** *B. Earth and the Solar System*	**EXPLANATION:** In 4.ESS1.2, students were first introduced to the phenomenon of day and night as patterns that they experience daily, having origins in the motion of the earth. The cause of the seasons is rooted in the tilt of the earth's axis combined with the effects of variations in the sun's intensity based on the angle that the sun's rays strike the earth. Due to the tilt of the Earth's axis, the duration of daylight hours and intensity of sunlight changes over the course of the year. Rotating a sphere about a tilted axis in front of a fixed light source can begin to demonstrate the effect of the tilt on daylight hours. If this demonstration is carried out at four different positions (90-degree progressions through a circle relative to the first position), it is possible to track and record the differences in the amount of time that a position on the earth receives sunlight based on the location of the sphere relative to the light source. This same activity can be carried out as an investigation where students record the percentage of the ball that would be illuminated at varying positions throughout a "year" on the model.	**Crosscutting Concept:** **Systems and System Models** *Students group and describe interactions of the components that define a larger system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students carry out investigations in groups, where conditions and variables are controlled, utilize appropriate instruments, and deliberately plan multiple trials.*
5.ESS1.6	Use tools and describe how stars and constellations appear to move from the Earth's perspective throughout the seasons. **COMPONENT IDEA:** *B. Earth and the Solar System*	**EXPLANATION:** Constellations are arrangements of stars in the sky. Planets are also visible in the evening sky and can be differentiated from stars based on their appearance to the naked eye. Positions of constellations and planets vary throughout the year as the relative position of the sun, earth, and distant stars change in the night sky. Tools such as star charts can be used to track and predict the location of constellations at various times during the year. Throughout history, the location of some constellations and stars have been used in navigation. Telescopes	**Crosscutting Concept:** **Pattern** *Students recognize, classify, and record patterns involving rates of change.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Asking questions (for science) and defining problems (for engineering)** *Questions generated by students are still based on experience, and begin to incorporate relationships between two things.*

5.ESS1.7	Use evidence from the presence and location of fossils to determine the order in which rock strata were formed. **<u>Component idea:</u>** *C. The History of Planet Earth*	**Explanation:** This particular standard concludes and provides evidence for ideas that were developed in fourth grade. The processes that result in the production of either fossils or sedimentary rock are very slow processes, requiring incredibly large periods of time to complete. Since these processes are well understood after fourth grade, revisiting this discussion along with discussions of space and the solar system allow for inferences that the Earth's formation must have occurred long ago. In 8.PS2.4, this topic will be revisited as students gather evidence supporting tectonic theory. (It may be appropriate to link instruction of this standard to instruction of 5LS4.)	**<u>Crosscutting Concept:</u>** **Scale, Proportion, and Quantity** *Students become familiar with sizes immensely large or small or durations extremely short or long.* **<u>Science and Engineering Principle:</u>** **Analyzing and interpreting data.** *Students should organize data (observations and measurements) in a manner which faciltates further analysis and comparisons.*

5.ETS1: Engineering Design			
5.ETS1.1	Research, test, re-test, and communicate a design to solve a problem. **COMPONENT IDEA:** *B. Developing Possible Solutions*	**EXPLANATION:** In order to effectively design a solution for a given problem, it is imperative that engineers become experts in the relevant fields. Students can use a deliberately crafted problem as a focal point for the design of a solution to the problem. Research driven by the need to solve a problem may provide a way for students to explore new concepts/phenomena. Communication may involve brainstorming possible solutions as well as presenting the results of the designed tests. Examples may include using a real-world problem, such as the effects of Hurricane Katrina or Harvey, and having students design solutions using constraints such as time, materials, and space. Other examples may include solutions to areas in a flood zone: dams holding water back, reservoirs storing flood water, levees and embankments preventing overflow, and channel straightening increasing speed of flow.	**Crosscutting Concept:** **Pattern** *Students use patterns as evidence in an argument or to make predictions, construct explanations, and engage in arguments.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *Students can communicate technical information about proposed design solutions using tables, graphs, and diagrams.*
5.ETS1.2	Plan and carry out tests on one or more elements of a prototype in which variables are controlled and failure points are considered to identify which elements need to be improved. Apply the results of tests to redesign the prototype. **COMPONENT IDEA:** *B. Developing Possible Solutions*	**EXPLANATION:** Engineered objects are methodically tested before production. Tests are designed to stress certain components to determine the extremes to which a given component will remain functional. Student-developed tests should move beyond simply making a device and "trying it out" and should have tests designed to cause failure into a specified component a biomedical engineering example may include creating a prosthetic hand piece using materials such as tape, spoon, paperclips, and foam pieces. Then, test the prototype, evaluate, make modifications, and retest.	**Crosscutting Concept:** **Cause and Effect** *Students identify conditions required for specific cause and effect interactions to occur through investigation.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can identify specific limitations of their models.*

5.ETS1.3	Describe how failure provides valuable information toward finding a solution. **COMPONENT IDEA:** *B. Developing Possible Solutions*	**EXPLANATION:** Failure is essential to both science and engineering. Without failure it is not possible to understand the limitations or shortcomings of a device or explanation. Students should be encouraged to embrace productive failure as part of the design process to encourage persistent exploration. Scientific discussions might include now revised theories such as vis viva.	**Crosscutting Concept:** **Pattern** *Students use patterns as evidence in an argument or to make predictions, construct explanations, and engage in arguments.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students make and support claims about a proposed device or solution.*

5.ETS2: Links Among Engineering, Technology, Science, and Society			
5.ETS2.1	Use appropriate measuring tools, simple hand tools, and fasteners to construct a prototype of a new or improved technology. **COMPONENT IDEA:** *A. Interdependence of Science, Technology, Engineering, and Math*	**EXPLANATION:** Using tools allows students to acquire two important engineering skills. Students can gain an understanding of how tools have enabled humans to build. Students acquire the ability to produce actual prototypes as part of the engineering process. This skill allows for development of more involved tests of components of a design.	**Crosscutting Concept:** **Structure and Function** *Students begin to attribute the shapes of sub-components to the function of the part.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can create a design plan or prototype of a tool or object which incorporates cause and effect behaviors within the device.*
5.ETS2.2	Describe how human beings have made tools and machines (X-ray cameras, microscopes, satellites, computers) to observe and do things that they could not otherwise sense or do at all, or as quickly or efficiently. **COMPONENT IDEA:** *A. Interdependence of Science, Technology, Engineering, and Math*	**EXPLANATION:** Scientific understanding develops as scientists are able to observe and explain things in the natural world. Technology has enabled scientists to extend their senses through the use of tools. These tools allow data storage, complex mathematical models, and increased capacity to see smaller and smaller details.	**Crosscutting Concept:** **Scale, Proportion, and Quantity** *Students become familiar with sizes immensely large or small or durations extremely short or long.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students can create evidence based explanations for relationships seen in the natural world as well as identify evidence that supports other explanations.*

5.ETS2.3	Identify how scientific discoveries lead to new and improved technologies. **<u>Component idea:</u>** *B. Influence of Engineering, Technology, and Science on Society and the Natural World*	**Explanation:** The processes of scientific discovery and technological evolution are symbiotic. Scientific understanding allows engineers to design systems differently and utilize materials to their fullest extent. This perpetuates the creation of new devices that are more efficient or powerful than previous versions. The new devices open new research opportunities and permit further scientific understanding. This cycle is perpetual. Examples may include taking a current piece of technology, viewing how the invention has developed through the years, and making predictions on how that technology might improve: (e.g., telegraph, telephone, and cell phone).	**<u>Crosscutting Concept:</u>** **Pattern** *Students use patterns as evidence in an argument or to make predictions, construct explanations, and engage in arguments.* **<u>Science and Engineering Principle:</u>** **Engaging in argument from evidence** *Students make and support claims about a proposed device or solution.*

Sixth Grade:

6.PS3: Energy			
6.PS3.1	Analyze the properties and compare the sources of kinetic, elastic potential, gravitational potential, electric potential, chemical, and thermal energy. **<u>Component idea:</u>** *A. Definitions of Energy*	**Explanation:** Students should develop an understanding of energy which has two components: energy storage (6.PS3.1) and transformation (6.ps3.2). Energy can be possessed by an object or stored in fields. Objects can possess energy as kinetic (motion of objects), thermal (motion of particles), or chemical energy (energy stored in chemical bonds). Fields can possess energy based on the position of an object within the field. Gravitational fields store/release gravitational potential energy when an object changes position within the gravitational field. Electric fields store/release electric potential energy as charges change position within an electric field. Finally, forces which distort the shapes of objects store energy in the elastic/distorted object (elastic potential). For example, the elastic bands of a sling shot store energy when they are pulled back. Upon release, the elastic bands then do work on the object in the slingshot transferring energy away from the bands and giving kinetic energy to the projectile.	**<u>Crosscutting Concept:</u>** **Energy and Matter** *Students give general descriptions of different forms and mechanisms for energy storage within a system.* **<u>Science and Engineering Principle:</u>** **Developing and using models** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*

6.PS3.2	Construct a scientific explanation of the transformation between potential and kinetic energy. **<u>Component idea:</u>** *A. Definitions of Energy*	**Explanation:** Students are first exposed to potential energy in fourth grade, but at that time students were not expected to classify types of energy. Students should develop an understanding of energy which has two components: energy storage (6.ps3.1) and transformation (6.ps3.2). Transfer of energy can move the energy from one energy type to a different energy type. (Types of energy are included in 6.ps3.1) The methods of energy transfer include work, heat, and radiation. For example: If fired upwards, a projectile slows down as it ascends, doing work on Earth's gravitational field and storing gravitational potential energy in the field. Ultimately it stops at a maximum height. For this moment of rest, the object possesses no energy. Earth's gravitational field can then do work on the object speeding it up as it then descends and returning energy to the projectile as kinetic energy while the object returns to the ground. *(A focus should be placed on examples in which work is the means of energy transfer.)*	**<u>Crosscutting Concept:</u>** **Energy and Matter** *Students track energy changes through transformations in a system.* **<u>Science and Engineering Principle:</u>** **Constructing explanations and designing solutions** *Students form explanations using source (including student developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and can support or cause revisions of a particular conclusion.*

6.PS3.3	Analyze and interpret data to show the relationship between kinetic energy and the mass of an object and its speed. **COMPONENT IDEA:** *A. Definitions of Energy*	**EXPLANATION:** Students should analyze data to see that kinetic energy is directly proportional to mass and to the square of velocity. Students can be provided data to carry out this analysis. Alternately, heavy objects can be dropped into beds of flour or soft material and comparisons of the indentions can be made. Doubling the mass and dropping from the same height will produce an indention with a volume twice as great. Dropping an object from a height twice as great leaves and indention with four times the volume. *(Instruction of this standard can be limited to recognizing that as the speed of an object increases, the kinetic energy increases at a greater rate and describing qualitative changes to kinetic energy. Creating proportionalities, graphing linear/quadratic relationships and exponents all exceed sixth grade Tennessee math standards, but can be used for enrichment in with advanced students.)*	**CROSSCUTTING CONCEPT:** **Scale, Proportion, and Quantity** *Students create proportional and algebraic relationships from graphical representations* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students should create and analyze graphical presenations of data to identify linear and non-linear relationships, consider statistical features within data and evaluate multiple data sets for a single phenomenon.*

6PS34.4	Conduct an investigation to demonstrate the way that heat (thermal energy) moves among objects through radiation, conduction, or convection. **COMPONENT IDEA:** *A. Definitions of Energy*	**EXPLANATION:** In everyday language, "heat" is used to refer to thermal energy. Students should emphasize the difference between these two terms. Heating is a method by which energy can be transferred from one object to another. Thermal energy is the energy stored by the movement of particles and is measured using a thermometer. There are three specific means of heating: conduction, convection, and radiation. Radiation (light) can be seen as a form of heating, but is unique from conduction and convection, because it can transfer energy across empty space. Students can observe changes in thermal energy (by recording temperature) using any of the above methods of heating.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students begin to connect their explanations for cause and effect relationships to specific scientific theory.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students begin to investigate independently, select appropriate independent variables to explore a dependent variable and recognize the value of failure and revision in the experimental process.*

6.LS2: Ecosystems: Interactions, Energy, and Dynamics			
6.LS2.1	Evaluate and communicate the impact of environmental variables on population size. **Component idea:** *A. Interdependent Relationships in Ecosystems*	**Explanation:** Students have developed a basic understanding that organisms are sustained by their environments (2.LS2.1) and the roles within an ecosystem (producers and consumers) (4.LS2). Populations are sustained by producers capturing and converting energy from the sun. An ecosystem will increase in size until it reaches its carrying capacity. (Organisms within a resource) have needs for similar resources: food, water, and habitat. Increasing population sizes result in increased competition for these resources. Examples may include a population of antelope decreasing because of a drought and then the lion population decreasing also as a result. Another example could include the relationship between deer and wolf populations: When the deer population increases, the wolf population will increase until it causes the deer population to decrease, which in turn causes the wolf population to decrease, and the cycle continues. Each of these variables dictates the niche of the organism, for example, the wolf is the carnivore and tertiary consumer in its ecosystem.	**Crosscutting Concept:** **Stability and Change** *Students explain that systems in motion or dynamic equilibruim can be stable.* **Science and Engineering Principle:** **Analyzing and interpreting data.** *Students should create and analyze graphical presenations of data to identify linear and non-linear relationships, consider statistical features within data and evaluate multiple data sets for a single phenomenon.*
6.LS2.2	Determine the impact of competitive, symbiotic, and predatory interactions in an ecosystem. **Component idea:** *A. Interdependent Relationships in Ecosystems*	**Explanation:** Population sizes are influenced by the interactions of organisms within the ecosystem. Predators can decrease population sizes, while mutualistic relationships creates a sort of interdependence where the two populations within a community move in tandem. It should be noted that changes in one population result in changes to different populations. Students should be familiar with the basic parasitic, mutualistic, and commensalistic relationships that exist between species. *(The focus should be on relationships within a food web of an ecosystem and the recognition of types of symbiosis, not on specific examples.)*	**Crosscutting Concept:** **Cause and Effect** *Students infer and identify cause and effect relationships from patterns.* **Science and Engineering Principle:** **Engaging in argument from evidence** *Students critique and consider the degree to which competing arguments are supported by evidence.*

6.LS2.3	Draw conclusions about the transfer of energy through a food web and energy pyramid in an ecosystem. **COMPONENT IDEA:** *B. Cycles of Matter and Energy Transfer in Ecosystems*	**EXPLANATION:** Students should be able to consider the transfer of energy between three groups: producers, consumers, and decomposers. Transfer of energy into an ecosystem by consumers is accompanied by transfer of matter; energy radiated by the sun is captured by plants as chemical energy is stored as food. Consumers combine the food with oxygen, permitting the use of the stored energy. Throughout its lifetime, an organism will use, on average, 90 percent of the energy it consumes. Ultimately, this 90% of energy is released back into the environment as heat. The remaining 10% can be passed along to further consumers or decomposers. *(Emphasis should be placed on the 10% rule and how energy is transferred to the environment as heat and approximately 10% of potential energy is passed to the next trophic level.)*	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students track energy changes through transformations in a system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*

6.LS2.4	Using evidence from climate data, draw conclusions about the patterns of abiotic and biotic factors indifferent biomes, specifically the tundra, tiaga, deciduous forest, desert, grasslands, rainforest, marine, and freshwater ecosystems. **COMPONENT IDEA:** *C. Ecosystem Dynamics, Functioning, and Resilience*	**EXPLANATION:** Ecosystems can be seen as "organisms" with specific needs for energy in the same way that a single organism has energy demands that must be met. Just as organisms have identifiable characteristics, so too do ecosystems. This standard allows students to look at various regions on Earth and observe that similar combinations of biotic and abiotic factors persist and that these allow the classification of ecosystems into certain types. Emphasis is on the relationship between temperature and pattern of global ocean and wind currents, the temperature of the air that is blown onto land, and then the causation of climate to dictate the type of abiotic factors. For example, the tundra has a lot of ice and permafrost because it is in the northern Hemisphere, does not receive direct sunlight so the water currents and resulting wind currents are cold, which causes a cold climate. Only biotic factors adapted to those abiotic factors can survive in that biome.	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record patterns in data, graphs, and charts.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students form explanations using source (including student developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and can support or cause revisions of a particular conclusion.*

6.LS2.5	Analyze existing evidence about the effect of a specific invasive species on native populations in Tennessee and design a solution to mitigate its impact. **COMPONENT IDEA:** *C. Ecosystem Dynamics, Functioning, and Resilience*	**EXPLANATION:** In 6.LS4.1, students discuss biodiversity. Invasive species that take hold in an ecosystem often outcompete native species in an ecosystem. In doing so, this single species may fill the niche of a variety of organisms, thereby decreasing the overall biodiversity of an ecosystem and reducing the availability of natural resources to native species. Tennessee-specific examples may include kudzu, Tree of Heaven, fire ants, Africanized bees, and zebra mussels. Solution may impact both native and invasive species. Firewood transport ban for various counties is a good example.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use cause and effect relationships to make predictions.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *(Observe) Students can evaluate text, media, and visual displays of information with the intent of clarifying claims and reconciling explanations. Students can communicate scientific information in writing utilizing embedded tables, charts, figures, graphs*

6.LS2.6	Research the ways in which an ecosystem has changed over time in response to changes in physical conditions, population balances, human interactions, and natural catastrophes. **COMPONENT IDEA:** *C. Ecosystem Dynamics, Functioning, and Resilience*	**EXPLANATION:** This standard should focus on the way that abiotic factors or external biotic factors can apply pressures and create disturbances in ecosystems. Healthy ecosystems (high biodiversity) are able to absorb these pressure. External agents will cause changes (even in healthy ecosystems), but a resilient ecosystem will stabilize. Examples may include the change in the world's oceans, changes in climate over time or an increase in human populations. Students can plan and carry out an investigation to model this process.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students develop models to investigate scales that are beyond normal experiences.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*
6.LS2.7	Compare and contrast auditory and visual methods of communication among organisms in relation to survival strategies of a population. **COMPONENT IDEA:** *D. Social Interaction and Group Behavior*	**EXPLANATION:** Prior to this standard, discussions of group dynamics have included the structures of groups and variety of groups. Students should draw conclusions about the advantages and disadvantages of group sociality in animal populations. Additionally, a group will cease to exist if that group no longer provides a benefit to its individuals. Patterns established between and among taxa could be recognized. Students may begin to draw conclusions about survival and reproduction based on observed communications. Examples include communication in social animals such as meerkats in the presence of different predators and how that can impact individual survival. Other examples include the predatory communication of group hunters such as the spotted hyena, African Hunting Dogs, and Orcas. Plant communication may include pheromones.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students infer and identify cause and effect relationships from patterns.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students present an argument based on empirical evidence, models, and invoke scientific reasoning.*

6.LS2: Ecosystems: Interactions, Energy, and Dynamics			
6.LS4.1	Explain how changes in biodiversity would impact ecosystem stability and natural resources. **COMPONENT IDEA:** *D. Biodiversity and Humans*	**EXPLANATION:** Healthy ecosystems exist in a state of dynamic equilibrium. In this state, ecosystems are able to recover from disturbances. The level of biodiversity in an ecosystem is an indicator of the health of an ecosystem. Low levels of biodiversity amplify the effects of disturbances, as the effect on a single species may spread across several niches. Biodiversity also includes the observation of a variety of characteristics within a single population or species to promote the survival of that species. To model the effects of biodiversity in an ecosystem, consider two food webs of varying biodiversity, and consider the effects of the removal of one of the species within this food web. Examples may include the loss of potentially medicinal plants in the rainforest, a shortage of potable water, ecosystems with population extinctions, and overfishing causing a decrease in the ability for human consumption of ocean species.	**CROSSCUTTING CONCEPT:** **Stability and Change** *Students explain that systems in motion or dynamic equilibruim can be stable.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students present an argument based on empirical evidence, models, and invoke scientific reasoning.*
6.LS4.2	Design a possible solution for maintaining biodiversity of ecosystems while still providing necessary human resources without disrupting environmental equilibrium. **COMPONENT IDEA:** *D. Biodiversity and Humans*	**EXPLANATION:** The living world provides humans with many materials they need, and humans can dramatically reshape the land and interactions between living systems to meet those needs. Without thoughtful consideration, humans can dramatically impact ecosystems through avenues such as habitat destruction and depletion of resources. The subsequent loss of biodiversity can then have negative impacts for humans. Natural resources that can be threatened by disturbing environmental equilibrium include food, energy, and medicines as well as the loss of services provided by ecosystems including water purification and recycling of nutrients by decomposers.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students develop models for systems which include both visible and invisible inputs and outputs for that system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *Students can communicate technical information about proposed design solutions usings tables, graphs, and diagrams.*

6.ESS2: Earth's Systems			
6.ESS2.1	Gather evidence to justify that oceanic convection currents are caused by the sun's transfer of heat energy and differences in salt concentration leading to global water movement. **COMPONENT IDEA:** *C. The Roles of Water in Earth's Surface Processes*	**EXPLANATION:** Understanding of ocean convection currents requires that students are familiar with: unequal heating of the earth's surface (built from 5.ess1.5), the density-related rise of heated fluids, and the density-related descent of cooler fluids. From third grade, students will have developed understandings of mass and volume; however, the topic of density will need to be explored to fully support 6.ESS2.1 and 6.ESS2.2. Demonstrations of the temperature-based behavior can be performed by heating one side of a water-filled baking dish and cooling the opposite side. If the water is initially allowed to settle, drops of food coloring will trace out the convection patterns which develop. Pipets can be used to insert the food coloring into the lower currents. Models for the effect of salt on creating a sinking mass of water can be accomplished by partially filling a large container with water then covering the surface of the water with plastic wrap and pouring an additional volume of salt-containing, colored water onto the wrap. With the gentle removal of the plastic wrap, the mixing will be visible. Reversing the order that the waters are added will provide alternate effects, and finally using two samples with coloring but no salt can provide a control. (Calculations of density are beyond the scope of this standard.)	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use cause and effect relationships to make predictions.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations using source (including student developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and can support or cause revisions of a particular conclusion.*

6.ESS2.2	Diagram convection patterns that flow due to uneven heating of the earth. **COMPONENT IDEA:** *D. Weather and Climate*	**EXPLANATION:** The process of convection is explored both in the ocean (6.ESS2.1) and in the atmosphere (6.ESS2.2). Models for oceanic convection based on temperature differences are appropriate for use to explain atmospheric convection processes. Atmospheric movements lead to the transport of water from stores and to certain areas of Earth's surface. A model for heating of the Earth shows more direct heating of the earth's equator relative to the poles creating two large convection cycles which move upward at the equator and descend at the poles. When the rotation of the earth is factored in, the two convection cycles are broken into a total of six cycles. This effect (Coriolis effect) can be modeled by a pair of students using a marker and a large sphere. If the sphere is stationary, a student can use a marker to draw a straight line from the equator to the poles. If the ball is rotated while drawing this same straight line, the resulting line drawn on the sphere will curve. Rate of rotation determines the severity of the curvature, Earth's angular velocity results in three cells, with deserts focused at latitudes near 30 degrees and 60 degrees north and south, and predictable surface winds. (Memorization of global wind patterns and layers of the atmosphere are beyond the scope of this standard.)	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students give general descriptions of different forms and mechanisms for energy storage within a system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*
6.ESS2.3	Construct explanation for how atmospheric flow, geographic features, and ocean currents affect the climate of a region through heat transfer. **COMPONENT IDEA:** *D. Weather and Climate*	**EXPLANATION:** Weather describes the immediate atmospheric conditions in a particular location, whereas climate describes long term patterns in a region's weather. It is possible for the climate in a region to vary from the climate seen at similar latitudes due to the presence of geographic features such as mountains or lakes. Coastal air rising over mountains will be depleted of its moisture and create deserts on the back side of the mountain. Likewise, large bodies of water can influence the temperature and humidity of a region due to the ability of water to store large amounts of thermal energy.	**CROSSCUTTING CONCEPT:** **Stability and Change** *Students explain that systems in motion or dynamic equilibruim can be stable.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students critique and consider the degree to which competing arguments are supported by evidence.*

6.ESS2.4	Apply scientific principles to design a method to analyze and interpret the impact of humans and other organisms on the hydrologic cycle. **COMPONENT IDEA:** *E. Biogeology*	**EXPLANATION:** Biogeological discussions in 4.ESS2.3 were general, whereas 6.ESS2.4 focuses specifically on the hydrologic cycle. Some organisms such as plants have very defined and ongoing involvement through transpiration. Other impacts have occurred over time including changes to water tables, and the effects of rates of weathering and erosion to land surfaces on watersheds and wetlands.	**CROSSCUTTING CONCEPT:** **SYSTEMS AND SYSTEM MODELS** *Students include relevant and exclude irrelevant factors when defining a system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION** *(Observe) Students can evaluate text, media, and visual displays of information with the intent of clarifying claims and reconciling explanations. Students can communicate scientific information in writing utilizing embedded tables, charts, figures, graphs*
6.ESS2.5	Analyze and interpret data from weather conditions, weather maps, satellites, and radar to predict probable local weather patterns and conditions. **COMPONENT IDEA:** *D. Weather and Climate*	**EXPLANATION:** The ability to recognize global patterns in climate distributions, describe deviations such as deserts created by the rain shadow effect is dependent, or to make predictions for future weather is dependent on collecting and interpreting weather related data. Examples of data from weather conditions include wind speed, wind direction, air temperature, humidity, and air pressure. In 3.ESS2.3, students were introduced to the use of tools to read temperature, precipitation, wind speed, and wind direction. By making a barometer, students are able to gain a better understanding of the intangible idea of air pressure. A vacuum demonstration is a good method to experience the phenomenon of air pressure. At this grade level, understanding should move beyond making readings and include a focus on using data to make predictions. *(Emphasis should be how high and low pressures are related to current weather conditions. Differentiation of cloud types was addressed in 3.ESS2.2.)*	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use cause and effect relationships to make predictions.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students should create and analyze graphical presenations of data to identify linear and non-linear relationships, consider statistical features within data and evaluate multiple data sets for a single phenomenon.*

6.ESS2.6	Explain how relationships between the movement and interactions of air masses, high and low pressure systems, and frontal boundaries result in weather conditions and severe storms. **<u>COMPONENT IDEA:</u>** *D. Weather and Climate*	**EXPLANATION:** The underlying principle is that high-pressure areas will push into or fill low-pressure areas. Low-pressure areas are columns of the atmosphere with a lower-pressure than surrounding air. As the surrounding higher pressure air pushes in to fill this area, the air in this low pressure column is displaced upward where condensation and precipitation occur as the elevation of this air increases. This air mass spins due again to Earth's rotation (Coriolis Effect). The opposite phenomenon occurs for high pressure areas, with a resulting spin in the opposite direction. The convergence of opposing pressure fronts creates severe weather phenomena due to the inverse nature of the air masses. This standard includes both occluded and stationary fronts, but not the memorization of specific air masses (e.g., continental polar or maritime tropical).	**<u>CROSSCUTTING CONCEPT:</u>** **Systems and System Models** *Students develop models for systems which include both visible and invisible inputs and outputs for that system.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Developing and using models** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*

6.ESS3: Earth and Human Activity			
6.ESS3.1	Differentiate between renewable and nonrenewable resources by asking questions about their availability and sustainability. **COMPONENT IDEA:** *A. Natural Resources*	**EXPLANATION:** In fourth grade, students were introduced to several specific examples of renewable and nonrenewable resources. Discussions included general descriptions of where resources were located on earth, how they are obtained, and the effects these processes have on the earth. Students should now develop a full, working distinction between these sets of resources. Renewable resources can be replenished during a human lifetime. However, non-renewable resources can be exhausted or, in the case of a living species, complete eliminated. Geologic processes which create some natural resources result in isolated pockets with large accumulations of a specific resource (e.g., oil deposits in the middle east, coal deposits in the western United States, gold deposits in California, the use of Tennessee waterways for hydroelectric power generation.)	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students evaluate the sub-systems that may make up a larger system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *(Observe) Students can evaluate text, media, and visual displays of information with the intent of clarifying claims and reconciling explanations. Students can communicate scientific information in writing utilizing embedded tables, charts, figures, graphs*
6.ESS3.2	Investigate and compare existing and developing technologies that will utilize renewable and alternate energy sources. **COMPONENT IDEA:** *A. Natural Resources*	**EXPLANATION:** Utilization of natural resources involves weighing environmental, economic, and oftentimes political conversations. Environmental discussions should include models which help to predict effects and gains of using a natural resource on the environment. Economic considerations include the amount of energy which can be harvested for the cost. For example, the economy of installing residential photovoltaic systems depends on the availability of sunlight in a person's location or on their property. Political conversations are impacted by considering global distributions of energy sources. As technologies progress, energy harvesting becomes less expensive and more efficient such that conversations regarding the utilization of renewable and alternate energy sources may shift over time.	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students track energy changes through transformations in a system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students critique and consider the degree to which competing arguments are supported by evidence.*

6.ESS3.3	Assess the impacts of human activities on the biosphere including conservation, habitat management, species endangerment, and extinction. **<u>COMPONENT IDEA:</u>** *C. Human Impacts on Earth Systems*	**EXPLANATION:** Human activities have greatly altered rates of change to Earth's surface. As humans develop land and build roads, large amounts of natural habitat are lost, affecting the species indigenous to that habitat. Students can obtain and evaluate evidence that increases in human populations or increases in the amount of energy consumed per person also increase negative effects, but engineered solutions can mitigate some of these negative effects. For example, development of low energy consumption lightbulbs (such as LED) can reduce the amount of energy used in a home. The processes listed specifically address measures offset the effects of human changes to the Earth's surface. Assessments of human activities should include models which can assist in making predictions for the efficacy of conservation efforts with competing interests.	**<u>CROSSCUTTING CONCEPT:</u>** **Cause and Effect** *Students use cause and effect relationships to make predictions.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **DEVELOPING AND USING MODELS** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*

6.ETS1: Engineering Design			
6.ETS1.1	Evaluate design constraints on solutions for maintaining ecosystems and biodiversity. **COMPONENT IDEA:** *A. Defining and Deliminating and Engineering Problems*	**EXPLANATION:** The wording and specificity of an engineering problem is a major factor in the quality of the solutions that may be created for a particular problem. Effective problems should have clear design constraints that incorporate scientific understanding. For example attempting to eliminate an invasive species may only result in replacing one invasive species with a new invasive species or knowledge of local climate might influence plantings. Examples include comparing recycling programs (deposits, curbside pickup, drop-off centers) and the cost/benefit analysis of recycling solutions. Address engineering design issues centered on water treatment (filtration, chemical treatment, reverse osmosis). Design solutions to minimize soil erosion (forestry practices, farming techniques, construction, and recreation). Examples of design solutions could include scientific, economic, or social considerations.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students develop models for systems which include both visible and invisible inputs and outputs for that system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Asking questions (for science) and defining problems (for engineering)** *Students define design problems, invoking scientific background knowledge to define multiple criteria and constraints for solutions.*
6.ETS1.2	Design and test different solutions that impact energy transfer. **COMPONENT IDEA:** *C. Optimizing the Solution Design*	**EXPLANATION:** Even design solutions that meet criteria and constraints for a successful design may fail in production. The tests should be designed to expose failure in specific components of a device. The results of these tests can then be used to create a comprehensive solution. Design tasks might relate to selecting materials to minimize or maximize energy transfer into or out of a system by minimizing heat loss, or sound production or by maintaining initial kinetic energies.	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students track energy changes through transformations in a system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students can design tests which determine the effectiveness of a device under varying conditions.*

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Seventh Grade:

7.PS1: Matter and Its Interactions			
7.PS1.1	Develop and use models to illustrate the structure of atoms, including the subatomic particles with their relative positions and charges **Component idea:** *A. Structure and Properties of Matter*	**Explanation:** Ultimately, understanding of the sub-structure of atoms will allow Chemistry I students to understand causes for intermolecular attractions as well as bonding and the implications of these phenomena. In fifth grade, students observed some of these phenomena including dissolving solids and phase changes. This seventh grade standard acts as the intermediate point between what students have already seen, and the explanations that can occur when this foundation is set in place. Relevant historical models include Thomson's plum pudding model to explain the behavior of electrons and ion formation and the work of Rutherford and Bohr to explain nuclear developments and structures descriptions of isotopes. Observations of static charge attractions between invisible tape, paper, and foil present an opportunity for students to employ Thomson's model. (Electron configurations are beyond the scope of this standard and grade level.)	**Crosscutting Concept:** **Structure and Function** *Students begin to attribute atomic structure and interactions between particles to the properties of a material.* **Science and Engineering Principle:** **Developing and using models** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*
7.PS1.2	Compare and contrast elemental molecules and compound molecules. **Component idea:** *A. Structure and Properties of Matter*	**Explanation:** This standard may be the first instance where students begin to investigate chemical formulae and supports 7.PS1.3 and 7.PS1.4. Emphasis should include definitions of both monoatomic elements existing as atoms as well as diatomic elements which form true molecules. Students should also be able to differentiate between molecules of a diatomic element and compound molecules.	**Crosscutting Concept:** **Scale, Proportion, and Quantity** *Students develop models to investigate scales that are beyond normal experiences.* **Science and Engineering Principle:** **Analyzing and interpreting data.** *Students form explanations using sources (including student-developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and can support or cause revisions of a particular conclusion.*

7.PS1.3	Classify matter as pure substances or mixtures based on composition. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** Pure substances include both elements and compounds. Mixtures include both mixtures of elements and compounds. This standard indirectly builds on the idea that chemicals have specific properties. When elements/compounds exist in a mixture, each of the parts retains its unique physical properties. In the event of a reaction within this mixture, a pure substance can result (assuming perfect ratios of constituent parts). This new pure substance will have a new set of physical properties (e.g., boiling point, state of matter at room temperature, conductivity).	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record patterns for macroscopic phenomena based on microscopic structure.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students present an argument based on empirical evidence, models, and invoke scientific reasoning.*
7.PS1.4	Analyze and interpret chemical reactions to determine if the total number of atoms in the reactants and products support the Law of Conservation of Mass. **COMPONENT IDEA:** *B. Chemical Reactions*	**EXPLANATION:** Students are expected to be able to interpret chemical formulae to determine the number and identity of different atoms taking part in a chemical reaction. Treatment of reactions should include the handling of polyatomic ions when these ions are present in both the reactants and products. A grade level definition of polyatomic ions is a literal interpretation of the name that these are a set of atoms that function as a single atom. It is important to note that the coefficients proceeding a substance in a reaction represent the number of atoms/molecules/formula units or moles in a balanced reaction. In high school, these coefficients will be used to determine mole ratios, so beginning to use the term mole is helpful. Since the word mole literally translates, to “lump” there is no need to define an actual amount in a mole. *(Discussion of molar mass and Avogadro’s Number are beyond the scope of this standard. Quantitative evaluation is limited to determining the number of each type of element or polyatomic ions in a reaction.)*	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students demonstrate conservation of mass in physical and chemical changes.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data** *Students should create and analyze graphical presenations of data to identify linear and non-linear relationships, consider statistical features within data and evaluate multiple data sets for a single phenomenon.*

7.PS1.5	Use the periodic table as a model to analyze and interpret evidence relating to physical and chemical properties to identify a sample of matter. **COMPONENT IDEA:** *B. Chemical Reactions*	**EXPLANATION:** The properties of a pure substance under specific conditions can be used to identify that substance. Examples of such properties might include, melting point, boiling point, ability to conduct an electrical current, flammability, odor, pH, or interacting with magnets. This standard is intricately connected with 7.PS1.3 as changes from a mixture into a pure substance result in a change to these physical properties. For instance, the mixture of two liquids with differing pHs can create a new substance with a unique pH. Discussions should include both pure elemental substances and pure compounds. Use of the periodic table should also include similarities in physical and chemical properties of compounds formed from a metal and a non-metal (ionic compounds), compared with compounds formed from a pair of non-metals (molecular compounds).	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record patterns for macroscopic phenomena based on microscopic structure.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students should create and analyze graphical presenations of data to identify linear and non-linear relationships, and consider statistical features within data and evaluate multiple data sets for a single phenomenon.*
7.PS1.6	Create and interpret models of substances whose atoms represent the states of matter with respect to temperature and pressure. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** The state of matter of a substance is dependent on three factors: the intermolecular attractions between the atoms/molecules of the substance, the external pressure on the substance, and the temperature of the substance. Some substances such as hydrogen and helium atoms exist primarily as gasses due to very weak intermolecular attractions. This contrasts with substances such as ionic compounds which have extremely strong intermolecular attractions keeping atoms in a very organized crystal lattice pattern even at high temperatures. Pressure can be seen as an external force from surrounding matter pushing the particles closer together. It is logical to incorporate triple point diagrams into discussions of this standard. *(Students are not expected to differentiate between the types of intermolecular attractions, merely to recognize their role in substances moving between states of matter.)*	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students infer and identify cause and effect relationships from patterns.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*

7.LS1: From Molecules to Organisms: Structures and Processes			
7.LS1.1	Develop and construct models that identify and explain the structure and function of major cell organelles as they contribute to the life activities of the cell and organism. **<u>Component idea:</u>** *A. Structure and Function*	**Explanation:** The focus of this standard is to understand that cellular organelles work in coordination with one another to form a working system. Just as large multicellular organisms must obtain food and water, as well as remove waste, single cells (including those within multicellular organisms) must carry out these same functions. Organelles provide a way to distribute these particular responsibilities, thus increasing efficiency. Cells and cell organelles are microscopic in scale and therefore must be demonstrated in the form of models that demonstrate their structural, functional, proportional relationships. Examples of models could be drawn or represented by types of candy or dried beans that bear similarities to the cell parts specified in appearance as well as function. Students can compare the main parts of the cell to the parts of a factory or school in function. Students could construct a model depicting the structure and function of the cell membrane and its role in maintaining homeostasis in the organism. Microscopes are a great way to examine their own cheek cells. (The emphasis is on the function in addition to identification of organelles (nucleus, chloroplast, mitochondria, cell membrane, cell wall, vacuole, and cytoplasm). Focus should be on cause and effect of organelles functions both independently and in coordination with other organelles/environment as a working system.)	**<u>Crosscutting Concept:</u>** **Systems and System Models** *Students develop models for systems which include both visible and invisible inputs and outputs for that system.* **<u>Science and Engineering Principle:</u>** **Developing and using models** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*

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7.LS1.2	Conduct an investigation to demonstrate how the cell membrane maintains homeostasis through the process of passive transport. **<u>Component idea:</u>** *A. Structure and Function*	**Explanation:** The function of this standard is to build an understanding for the processes of passive transport within the cell membrane. It is not necessary to elaborate on the variety of structures embedded in the cell membrane. Materials move into the cell based on the concentrations of materials inside vs. outside of the cell. When accompanied by particle diagrams, the classic diffusion into and out of an egg demonstration is a suitable investigation. Asking for a variety of models to show understanding of simple diffusion can push students to uncover flaws in or more fully develop their own mental models.	**<u>Crosscutting Concept:</u>** **Stability and Change** *Students make explanations of stability and change discussing molecular components of a system.* **<u>Science and Engineering Principle:</u>** **Planning and carrying out controlled investigations** *Students begin to investigate independently, select appropriate independent variables to explore a dependent variable and recognize the value of failure and revision in the experimental process.*

7.LS1.3	Evaluate evidence that cells have structural similarities and differences across kingdoms. **COMPONENT IDEA:** *A. Structure and Function*	**EXPLANATION:** Taxonomic classification has developed as human capacity to organize and observe patterns within life has increased. Carl Linnaeus developed his original classification system consisting of two biologically significant families: plants and animals. (Linnaeus also included a now defunct system for classification of minerals.) Understanding of life cycles and the fields of microscopy have led to further expansion of these kingdoms to the six current, widely-accepted, kingdoms: Archaea, Bacteria, Protista, Fungi, Plantae, and Animalia. Current revisions to these kingdoms brought on by advances in gene sequencing have raised questions as to the validity of Kingdom Protista due to the lack of similarity between organisms within this kingdom. Activities may include comparing real plant and animal cells for presence of a nucleus, cell wall, structural orientation of cells, and presence of chloroplasts using a compound light microscope. Students can use examples of prokaryotic and eukaryotic organisms and point out the presence of the nucleus distinguishes the eukaryotes from the prokaryotes. Students should be able to differentiate and classify organisms into the six current kingdoms. Students should understand basic physical characteristics of each kingdom, i.e. being unicellular or multicellular, how food is obtained. (Focus is on structural and functional differences at a cellular level between domains and kingdoms as well as the introduction of increasingly more complex cell structure from prokaryotic to eukaryotic organisms.)	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record patterns in data, graphs, and charts.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students present an argument based on empirical evidence, models, and invoke scientific reasoning.*

7.LS1.4	Diagram the hierarchical organization of multicellular organisms from cells to organism. **<u>Component idea:</u>** *A. Structure and Function*	**Explanation:** Prior to 7.LS1, students have not been introduced to Cell Theory. 7.LS1.3 introduces students to the various kingdoms of life. This standard examines deeper levels of organization within various types of multicellular organisms. Cell types are differentiated as a result of their varying function. This standard may be demonstrated by having students create representations of the hierarchical organization of multicellular organisms building from cells to organs to organ systems up through entire organisms. Consider the following example: cardiac muscle cell in groups form tissues of the heart, arteries and veins, and the circulatory/cardiovascular system. Effectively covering this standard sets a foundation for success in high school biology where students make connections between the prevalence of certain organelles in different cell types based on the function of those cells.	**<u>Crosscutting Concept:</u>** **Systems and System Models** *Students evaluate the sub-systems that may make up a larger system.* **<u>Science and Engineering Principle:</u>** **Developing and using models** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*
7.LS1.5	Explain that the body is a system comprised or subsystems that maintain equilibrium and support life through digestion, respiration, excretion, circulation, sensation (nervous and integumentary) and locomotion (musculoskeletal). **<u>Component idea:</u>** *A. Structure and Function*	**Explanation:** Students have already studied both internal and external structures and how these structures support essential life functions. It is very important to see this standard as a continuation of discussions of structure. It may be helpful by addressing the body system as an analog to an ecosystem: The body consists of a number of individual pieces with interconnected functions. Systems of organs increase the efficiency of these functions. Interdependence between the systems might be addressed by considering effects of exercise on the various body systems. Energy demands are heightened, requiring increased inputs from the respiratory and circulatory systems to support that activity of the musculoskeletal system. (Lymphatic, endocrine, immune, and reproductive systems are great for enrichment, but beyond the scope of this standard.)	**<u>Crosscutting Concept:</u>** **Systems and System Models** *Students evaluate the sub-systems that may make up a larger system.* **<u>Science and Engineering Principle:</u>** **Constructing explanations and designing solutions** *Students form explanations using source (including student-developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and can support or cause revisions of a particular conclusion.*

7.LS1.6	Develop an argument based on empirical evidence and scientific reasoning to explain how behavioral and structural adaptations in animals and plants affect the probability of survival and reproductive success. **<u>Component idea:</u>** *B. Growth and Development of Organisms*	**Explanation:** As a general concept, 3.LS1.1 asks students to consider internal and external structures that can contribute to reproductive success and survival. This standard conveys the same idea but with greater complexity. Third grade represented a student's first encounter with the idea that organisms have any invisible internal structure, therefore examples were very simple and isolated. While the structures addressed in prior standards played a role in meeting the general needs of living organisms, this standard focuses specifically on adaptations connected to reproductive successes. Examples of reproductive adaptations in plants might include: bright flowers, nectar, hard shells, and pollen or seeds. Animal behaviors associated with reproductive success should also be discussed. These behaviors may include nest building, herding, and vocalization. Some plants are reliant on animals as part of their reproductive strategy through interactions such as seed scarification. (Students should not be led to memorize as many examples as possible. In contrast, students should be provided opportunities to utilize deductive reasoning to create their explanations.)	**<u>Crosscutting Concept:</u>** **Cause and Effect** *Students infer and identify cause and effect relationships from patterns.* **<u>Science and Engineering Principle:</u>** **Engaging in argument from evidence** *Students present an argument based on empirical evidence, models, and invoke scientific reasoning.*

7.LS1.7	Evaluate and communicate evidence that compares and contrasts the advantages and disadvantages of sexual and asexual reproduction. **Component idea:** *B. Growth and Development of Organisms*	**Explanation:** Discussions of this standard should focus on the increase to biodiversity and variation within a species that occurs as a result of sexual reproduction. However, asexual reproduction occurs at a more rapid rate and does not require a mate. Students should examine the benefits and challenges associated with each reproductive strategy. Regardless of strategy it is important to note that both processes transfer genetic information to offspring, which serves to explain patterns in the appearance of offspring and parents or within a species as explored in earlier grades.	**Crosscutting Concept:** **Cause and Effect** *Students infer and identify cause and effect relationships from patterns.* **Science and Engineering Principle:** **Obtaining, evaluating, and communicating information** *(Observe) Students can evaluate text, media, and visual displays of information with the intent of clarifying claims and reconciling explanations. Students can communicate scientific information in writing utilizing embedded tables, charts, figures, graphs*

7.LS1.8	Construct an explanation demonstrating that the function of mitosis for multicellular organisms is for growth and repair through the production of genetically identical daughter cells. **COMPONENT IDEA:** *B. Growth and Development of Organisms*	**EXPLANATION:** In order to grow or heal, both multicellular organisms use the process of mitosis. The result of mitosis is a set of cells identical to the parent cell. In later grades, students will explore how interactions with these cells with their surroundings result in variation amongst these otherwise identical cells. The mass/matter that accounts for the growth of plants is obtained from the air during the process of photosynthesis. Animals obtain this matter by eating either plants or other animals. (As part of this particular component idea, the focus of this standard should be on the process of cell growth, and not on the inheritance of DNA as covered in LS3.)	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students demonstrate conservation of mass in physical and chemical changes.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations using source (including student-developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and can support or cause revisions of a particular conclusion.*

7.LS1.9	Construct a scientific explanation based on compiled evidence for the processes of photosynthesis of cellular respiration, and anaerobic respiration in the cycling of matter and flow of energy into and out of organisms. **COMPONENT IDEA:** *C. Organization for Matter and Energy Flow in Organisms*	**EXPLANATION:** Students should carry out investigations to generate evidence for the requirements of pathways utilized to obtain energy and matter. Evidence can be obtained by observing stomata on the underside of plant leaves, observing changes to water pH (due to dissolved gases) as a result of photosynthesis in plants such as Elodea, observing byproducts of respiration. The focus should be on the interconnectedness of plants and animals in the cycling of matter. Processes inside of organisms rearrange atoms of the food materials and release stored chemical energy. (This standard should not focus on memorizing the equation for photosynthesis.)	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students develop models for systems which include both visible and invisible inputs and outputs for that system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students begin to investigate independently, select appropriate independent variables to explore a dependent variable, and recognize the value of failure and revision in the experimental process.*

7.LS2: Ecosystems: Interactions, Energy, and Dynamics			
7.LS2.1	Develop a model to depict the cycling of matter, including carbon and oxygen, including the flow of energy among biotic and abiotic parts of an ecosystem. **<u>COMPONENT IDEA:</u>** *B. Cycles of Matter and Energy Transfer in Ecosystems*	**EXPLANATION:** Standard 7.LS1.9 provides an opportunity to gather evidence for the cycling of matter between living organisms. While 7.LS2.1 certainly draws on this same evidence, discussions should be expanded to include abiotic factors as well. This might include decomposition or combustion releasing matter from non-living systems, such as waterways, and permitting its reincorporation into living systems. Decomposers can break down fecal material from living organisms, making those materials available once again. The same atoms are used over and over again by living systems; new atoms are not created.	**<u>CROSSCUTTING CONCEPT:</u>** **Energy and Matter** *Students demonstrate conservation of mass in physical and chemical changes.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Developing and using models** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*

7.LS3: Heredity			
7.LS3.1	Hypothesize that the impact of structural changes to genes (i.e., mutations) located on chromosomes may result in harmful, beneficial, or neutral effects to the structure and function of the organism. **COMPONENT IDEA:** *B. Variation of Traits*	**EXPLANATION:** To fully develop this standard, students must be informed of the role of DNA in the production of proteins and the role of these proteins in determining a phenotype. Students can examine or research a particular chromosome or gene on that chromosome to show that it makes a protein to exhibit a trait. This is often best accomplished using a monogenetic trait. For example tyrosinase and can be explored with respect to its role in the production of melanin where a mutation to that protein can result in the albinism condition. An example might also show a human karyotype with genes displayed as sections of a chromosome. (The processes of transcription and translation are above this standard.)	**CROSSCUTTING CONCEPT:** **Structure and Function** *Students begin to attribute atomic structure and interactions between particles to the properties of a material.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *(Observe) Students can evaluate text, media, and visual displays of information with the intent of clarifying claims and reconciling explanations. Students can communicate scientific information in writing utilizing embedded tables, charts, figures, graphs*
7.LS3.2	Distinguish between mitosis and mitosis and meiosis and compare the resulting daughter cells. **COMPONENT IDEA:** *B. Variation of Traits*	**EXPLANATION:** The process of sexual reproduction produces one set of genetic information for an offspring (with two copies of most genes) where each parent has contributed half of the genetic information (one copy of each gene). The focus of this standard is not on the memorization of the specific names of phases of cell reproduction, but on developing an understanding of how daughter cells compare between each process. The stages of either process may be used in support during instruction. For example, students could trace a single chromosome through the process, noticing that each of the new sex cells produced are genetically different from the parent cell based on two divisions and half the DNA. *(This standard does not anticipate that students will memorize the names of the phases of mitosis/meiosis.)*	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students infer and identify cause and effect relationships from patterns.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*

7.LS3.3	Predict the probability of individual dominant and recessive alleles to be transmitted from each parent to offspring during sexual reproduction and represent the genotypic and phenotypic patterns using ratios. **<u>COMPONENT IDEA:</u>** *B. Variation of Traits*	**EXPLANATION:** It is imperative that this standard is not merely an exercise of probability, but confirms 7.LS3.1 and 7.LS3.2. An allele may be considered dominant if a single copy of that allele (from one parent) produces sufficient amounts of a given protein to produce the related phenotype. For example, a single copy of the tyrosinase gene can produce enough of the tyrosinase enzyme to result in the production of melanin by melanocytes. Other possible examples might include pea plant flower color, seed shape, seed size, or visibly acquired traits. *(This standard does not include the idea of codominance, incomplete dominance, polygenic inheritance, or genetic linkage.)*	**<u>CROSSCUTTING CONCEPT:</u>** **Pattern** *Students recognize, classify, and record patterns for macroscopic phenomena based on microscopic structure.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Analyzing and interpreting data.** *Students should create and analyze graphical presenations of data to identify linear and non-linear relationships, consider statistical features within data and evaluate multiple data sets for a single phenomenon.*

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<table>
<tr><th colspan="4">7.ESS3: Earth and Human Activity</th></tr>
<tr><td rowspan="2">7.ESS3.1</td><td rowspan="2">Graphically represent the composition of the atmosphere as a mixture of gases and discuss the potential for atmospheric change.

COMPONENT IDEA:
D. Global Climate Change</td><td rowspan="2">EXPLANATION: The atmosphere is ~78% nitrogen, ~21% oxygen, ~1% argon, water vapor, carbon dioxide, and other trace gases. Students should examine both the major and trace gases making up Earth's atmosphere. Discussions regarding the potential for atmospheric change should center on how natural biogeochemical cycles and human impacts determine its composition. Discussion of atmospheric change should include identification of greenhouse gases and the mechanism by which these gases affect climate change. (Emphasis is not based on memorization of atmospheric composition.)</td><td>CROSSCUTTING CONCEPT:
Stability and Change
Students make explanations of stability and change discussing molecular components of a system.</td></tr>
<tr><td>SCIENCE AND ENGINEERING PRINCIPLE:
Analyzing and interpreting data.
Students should create and analyze graphical presenations of data to identify linear and non-linear relationships, consider statistical features within data and evaluate multiple data sets for a single phenomenon.</td></tr>
<tr><td rowspan="2">7.ESS3.2</td><td rowspan="2">Engage in a scientific argument through graphing and translating data regarding human activity and climate.

COMPONENT IDEA:
D. Global Climate Change</td><td rowspan="2">EXPLANATION: The ability to comprehend human impacts on the atmosphere and climate depends on both translating both historical and present-day data as well as interpreting data generated through models. Data sets can include levels of carbon dioxide in the atmosphere, the temperature of the earth, levels of energy use, efficiency of energy use, glacial land areas, ocean water levels, areas of polar ice, and areas of forested land. Human activities include the release of greenhouse gases. Extension of this discussion should address the use of scientific understanding and engineering to drive future decision making.</td><td>CROSSCUTTING CONCEPT:
Pattern
Students recognize, classify, and record patterns in data, graphs, and charts.</td></tr>
<tr><td>SCIENCE AND ENGINEERING PRINCIPLE:
Engaging in argument from evidence
Students present an argument based on empirical evidence, models, and invoke scientific reasoning.</td></tr>
</table>

7.ETS2: Links Among Engineering, Technology, Science, and Society			
7.ETS2.1	Examine a problem from the medical field pertaining to biomaterials and design a solution taking into consideration the criteria, constraints, and relevant scientific principles of the problem that may limit possible solutions. **<u>Component idea:</u>** *A. Interdependence of Science, Technology, Engineering, and Math*	**Explanation:** Fields such as material sciences depend heavily on the advancement of scientific understanding. The on-going advancement of these fields is pushed by progress in science. The development of new biomaterials also requires consideration for the long term effects of medical materials that may be used internally, such as heart valves. Finding solutions for material use in the body is difficult. Bioengineers must consider strength, flexibility, durability, and chemical inactivity depending on its role. Students should think about chemical and physical properties of materials and chemical reactivity while engineering design solutions that can be employed to help people with human genetic disorders or mutations.	**<u>Crosscutting Concept:</u>** **Scale, Proportion, and Quantity** *Students recognize that phenomena are not necessarily observable at all scales.* **<u>Science and Engineering Principle:</u>** **Constructing explanations and designing solutions** *Students can design as well as test devices meant to meet specific design criteria, with the objective of increasing the effectiveness of multiple solutions.*

Eighth Grade:

<table>
<tr><th colspan="4">8.PS2: Motion and Stability: Forces and Interactions</th></tr>
<tr><td rowspan="2">8.PS2.1</td><td rowspan="2">Design and conduct investigations depicting the relationship between magnetism and electricity in electromagnets, generators, and electrical motors, emphasizing the factors that increase or diminish the electric current and the magnetic field strength.

<u>COMPONENT IDEA:</u>
B. Types of Interactions</td><td rowspan="2">EXPLANATION: Students should develop a basic understanding that electric currents produce magnetic fields as well as understanding a conductor moved through a magnetic field will develop an electric current. The phenomena of induced currents can be observed using a galvanometer attached to the two ends of an unplugged extension cord if the cord is moved in a jump-rope type manner. The reciprocal phenomena of magnetic fields produced by electric currents can be observed with a compass placed around a current carrying wire. Once the reciprocal nature of electric and magnetic fields have been investigated, students can apply their knowledge through investigations into motors, generators and solenoids and the design factors that influence the functioning of these devices.</td><td><u>CROSSCUTTING CONCEPT:</u>
Structure and Function
Students design systems, selecting materials for their relevant properties.</td></tr>
<tr><td><u>SCIENCE AND ENGINEERING PRINCIPLE:</u>
Planning and carrying out controlled investigations
Students begin to investigate independently, select appropriate independent variables to explore a dependent variable and recognize the value of failure and revision in the experimental process.</td></tr>
</table>

8.PS2.2	Conduct an investigation to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. **COMPONENT IDEA:** *B. Types of Interactions*	**EXPLANATION:** Students have already been exposed to the idea of gravity in fifth grade and have discussed the mechanisms for storing potential energy in magnetic, gravitational, and electric fields. However, this is the first time where students explore that forces can act on without the objects making contact. These non-contact forces should be incorporated in discussions of Newton's Laws in other standards. Once a student is competent in diagramming motion maps, and grounded in Newton's Second Law, a foundation exists to infer that non-contact forces must exist in order for objects in freefall to accelerate.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students develop models for systems which include both visible and invisible inputs and outputs for that system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations using source (including student developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and can support or cause revisions of a particular conclusion.*
8.PS2.3	Create a demonstration of an object in motion that describe the position, force, and direction of the object. **COMPONENT IDEA:** *A. Forces, Fields, and Motion*	**EXPLANATION:** Position, velocity (motion), acceleration (motion) and force are all examples of vector quantities. Vectors must include both a size/quantity and a direction (e.g. forward, backward, up, down). This standard introduces students to different conventions for representing these vector quantities. Representations of position and motion can be carried out using motion maps or simple graphs of position vs time and velocity vs time. Students should be able to perform qualitative comparisons from multiple representations. Forces can be represented using free-body diagrams. (See 8.PS2.3) (Performing calculations from graphs, such as determining velocity from a position time graph, is beyond the scope of this standard.)	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students make and evaluate derived/proportional measurements.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students should create and analyze graphical presenations of data to identify linear and non-linear relationships, consider statistical features within data and evaluate multiple data sets for a single phenomenon.*

8.PS2.4	Plan and conduct an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. **COMPONENT IDEA:** *A. Forces, Fields, and Motion*	**EXPLANATION:** This standard is an introduction to Newton's Second Law. Correctly stated, this law explains that acceleration is proportional to the sum of the forces acting an object and inversely proportional to the mass of an object. More simply stated, it is harder to change the motion of more massive objects. Free-body diagrams are an excellent tool for students to use to quantitatively represent multiple forces acting on an object. Students can use the free body diagrams to determine total amounts of force acting parallel or perpendicular to the direction of motion of an object. Students should be able to calculate acceleration given a set of forces and the mass of an object. (Objects on inclined planes are beyond the scope of this standard. Forces should act in either the parallel or perpendicular direction, and not at intermediate angles. Forces should cancel such that net forces are either parallel or perpendicular and not at intermediate angles.)	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use cause and effect relationships to make predictions.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Asking questions (for science) and defining problems (for engineering)** *Questions originate based on experience as well as need to clarify and test other explanations, or determine explicit relationships between variables.*
8.PS2.5	Evaluate and interpret that for every force exerted on an object there is an equal force exerted in the opposite direction. **COMPONENT IDEA:** *A. Forces, Fields, and Motion*	**EXPLANATION:** This standard provides students with exposure to Newton's Third Law. This standard provides a complement to 8.PS2.4. When diagramming forces using free-body diagrams, it should be noted that a pair of third law forces will not be found on the same diagram. It will always require two diagrams to show a third law pair. For example, when a person stands of a bathroom scale, they exert a normal force acting downward on the scale which results in an equal, yet opposite normal force being exerted upwards by the scale. One force is exerted by the person, the other by the scale. Even when a force results in motion for only one object, there is an equal and opposite force resulting from the first force. Jumping is accomplished because a person pushes down on the ground, and the ground pushes back up with an equal and opposite force accelerating the person upwards.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students begin to connect their explanations for cause and effect relationships to specific scientific theory.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations using source (including student developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and can support or cause revisions of a particular conclusion.*

8.PS4: Waves and Their Applications in Technologies for Information Transfer			
8.PS4.1	Develop and use models to represent the basic properties of waves including frequency, amplitude, wavelength and speed. **<u>Component idea:</u>** *A. Wave Properties: Mechanical and Electromagnetic*	**Explanation:** The speed of a wave is dependent on properties of the medium that the wave travels through. In a given medium, a specific type of wave will have a set speed. (E.g. the speed of sound is approximately 340m/s) Given that the speed of the wave is set, waves of differing frequencies will have different wavelengths, as these two factors describe the propagation of a wave. The amplitude of a wave is dependent on the amount of energy being transported by the wave. Students have diagrammed waves and labeled parts for both longitudinal and transverse waves in fourth grade while exploring interference patterns when two waves intersect. Students should now be performing quantitative analysis of wave behaviors.	**<u>Crosscutting Concept:</u>** **Scale, Proportion, and Quantity** *Students develop models to investigate scales that are beyond normal experiences.* **<u>Science and Engineering Principle:</u>** **Developing and using models** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*

8.PS4.2	Compare and contrast mechanical waves and electromagnetic waves based on refraction, reflection, transmission and absorption and their behavior through a vacuum and/or various media. **Component idea:** *A. Wave Properties: Mechanical and Electromagnetic*	**Explanation:** Wave speed is dependent on the properties of the medium. Phenomena such as refraction occur when a wave travels out of one medium and into a different medium, resulting in a change to the wave speed. Regardless of type, waves are a means of transferring energy from one location to another. It is electromagnetic waves that carry energy from the sun to our planet. While sound waves travel through a medium, ultimately transferring energy to ear drums creating the sensation of hearing. The principal difference between wave types is the ability to propagate without a medium in the case of electromagnetic waves. However, even mechanical waves leave the medium undisturbed after passing through. (Students should be exposed to the varying frequencies for EM waves, but memorization of specific frequencies/wavelengths is not expected.)	**Crosscutting Concept:** **Energy and Matter** *Students track energy changes through transformations in a system.* **Science and Engineering Principle:** **Constructing explanations and designing solutions** *Students form explanations using source (including student developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and can support or cause revisions of a particular conclusion.*

8.PS4.3	Evaluate the role that waves play in different communication systems. **<u>Component idea:</u>** *C. Information Technologies and Instrumentation*	**Explanation:** Digitizing is the process of converting information into a series of binary ones and zeroes. Once digitized, information can be transmitted as wave pulses and stored reliably so that the information can be recreated at a later time. This process can be demonstrated for students by connecting a solar cell to a small amplified speaker. A laser pointer flashed on and off striking the surface of the solar cell will make an audible popping noise. For a more profound demonstration, the laser pointer can then be connected to the headphone jack of an audio player and music can be played across open spaces. Interrupting the beam will stop the sound. Students should explore similar applications of information transfer in the functioning of radios, televisions, cellphones, and wireless computer networks.	**<u>Crosscutting Concept:</u>** **Structure and Function** *Students design systems, selecting materials for their relevant properties.* **<u>Science and Engineering Principle:</u>** **Obtaining, evaluating, and communicating information** *(Observe) Students can evaluate text, media, and visual displays of information with the intent of clarifying claims and reconciling explanations. Students can communicate scientific information in writing utilizing embedded tables, charts, figures, graphs* *Students can communicate technical information about proposed design solutions using tables, graphs, and diagrams.*

8.LS4: Biological Change: Unity and Diversity			
8.LS4.1	Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change in life forms throughout Earth's history. **<u>Component idea:</u>** *A. Evidence of Common Ancestry*	**Explanation:** Whether or not an organism becomes fossilized is dictated by factors such as the nature of its body tissues and structures, the behavior and habitat of the organisms, and the manner of the organism's death and burial. Fossils might also include preserved evidence from organisms interacting with their environment and leaving traces such as footprints. Some organisms (e.g. hard-shelled, sediment-dwelling organisms) are more likely to be found as fossils. A chronological history of life on Earth can be reconstructed using sedimentary evidence and radioactive dating. Students may compare structural similarities and differences of organic evidence in geological cross sections to determine evidence presence and changes in taxa on a geologic time scale. Analyze and interpret data from index fossils and the structure and ordering of rock layers to infer the relative age of rocks and fossils. Construct and analyze scientific arguments to support claims that different types of fossils provide evidence of (1) the progressive diversity of life that has existed in the past, and (2) relationships between past and existing life forms in relation to environmental changes that have occurred during Earth's history.	**<u>Crosscutting Concept:</u>** **Scale, Proportion, and Quantity** *Students develop models to investigate scales that are beyond normal experiences.* **<u>Science and Engineering Principle:</u>** **Analyzing and interpreting data.** *Students form explanations using source (including student developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and can support or cause revisions of a particular conclusion.*

8.LS4.2	Construct an explanation addressing the similarities and differences of the anatomical structures and genetic information between extinct and extant organisms using evidence of common ancestry and patterns between taxa. **<u>COMPONENT IDEA:</u>** *A. Evidence of Common Ancestry*	**EXPLANATION:** It can be observed that living organisms all share common features, such a genetic information that is passed from parent to offspring. Student explanations should also reconcile that despite this unity, living organisms contain immense biodiversity. Students may compare and contrast examples of the skeletal structure of birds, reptiles and dinosaurs or embryonic forms of mammals compared to other kingdoms. Students may examine cladograms to infer relatedness. Students should recognize patterns seen in anatomical structures and embryonic development between time and taxa. Cladogram dissection as well as construction should be enforced for understanding of hierarchal relationships between the organisms.	**<u>CROSSCUTTING CONCEPT:</u>** **Pattern** *Students recognize, classify, and record patterns in data, graphs, and charts.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Constructing explanations and designing solutions** *Students form explanations using source (including student developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and can support or cause revisions of a particular conclusion.*

8.LS4.3	Analyze evidence from geology, paleontology, and comparative anatomy to support that specific phenotypes within a population can increase the probability of survival of that species and lead to adaptation. **<u>COMPONENT IDEA:</u>** *B. Natural Selection*	**EXPLANATION:** Students should recognize patterns seen in anatomical structures and embryonic development between time and taxa. Cladogram dissection as well as construction should be enforced for understanding of hierarchal relationships between the organisms. Examples may include the anatomical similarities and differences in finches and unique species of the Galapagos Islands.	**<u>CROSSCUTTING CONCEPT:</u>** **Cause and Effect** *Students begin to connect their explanations for cause and effect relationships to specific scientific theory.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Analyzing and interpreting data.** *Students form explanations using source (including student developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and can support or cause revisions of a particular conclusion.*

8.LS4.4	Develop a scientific explanation of how natural selection plays a role in determining the survival of a species in a changing environment. **COMPONENT IDEA:** *B. Natural Selection*	**EXPLANATION:** In 7.LS3, students develop an understanding of alleles and their relationship to the phenotype of an organism through the expression of a gene (production of a protein). Additionally, students relate changes to chromosomes to their phenotypic manifestations. Natural selection explains that certain of these structural changes may increase the survival and reproduction of the affected individual. These traits will be more likely to exist in the gene pool of a species, and over long periods of time their frequency will increase if reproductive successes continue. Sudden changes to the environment can punctuate this process by creating conditions which strongly favor the survival of some species. Organismal models may include peppered moths in England that existed in two phenotypes and different phenotypes persisted before and after the Industrial Revolution, as well as ornamental design of male birds of paradise and their reproductive success. *(Hardy-Weinberg and allele frequency are beyond the scope of this standard.)*	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students begin to connect their explanations for cause and effect relationships to specific scientific theory.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students critique and consider the degree to which competing arguments are supported by evidence.*
8.LS4.5	Obtain, evaluate, and communicate information about the technologies that have changed the way humans use artificial selection to influence the inheritance of desired traits in other organisms. **COMPONENT IDEA:** *B. Natural Selection*	**EXPLANATION:** Early implementations of artificial selection involved selective breeding where certain organisms were selected for breeding based on characteristics that were favorable. Examples of these processes in agriculture include artificially bred producers such as fruit, vegetables and grains to resist strains of disease and pesticides. Animal examples may include dog breeds selected for hypoallergenic characteristics or cattle and livestock. The focus of these discussions should focus on the use of artificial selection to develop organisms with traits that are advantageous or desired.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students infer and identify cause and effect relationships from patterns.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations using source (including student developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and can support or cause revisions of a particular conclusion.*

8.ESS1: Earth's Place in the Universe			
8.ESS1.1	Research, analyze, and communicate that the universe began with a period of rapid expansion using evidence from the motion of galaxies and composition of stars. **COMPONENT IDEA:** *A. The Universe and Its Stars*	**EXPLANATION:** In 5.ESS1.1 students learned that there are different types of stars, while 7.PS1 addresses both atomic structure and the variety of elements found in the universe. This standard unifies these separate discussions. Many students struggle to grasp the idea that the mass of the universe could have emanated from a single point. This misconception illuminates a failure to grasp that all mass was once energy, and energy does not occupy space. Stars are regions in space where immense gravitation facilitates the conversion of mass back into energy via nuclear fusion. The energy released in these processes increases the thermal energy of the gaseous atoms making up the star or radiates out into space. This radiant energy (some of which is visible light) can be detected. The exact color of a star depends on its composition since each element releases only specific colors of light. Thus, a star's composition can be determined by evaluating the color of light that it radiates. Building on grade level discussions of wave properties, student should explore Doppler shift as evidence for the expansion of the universe. A model used to demonstrate Doppler shift can be created by placing a buzzer into a tennis ball and twirling the tennis ball in a circular motion above one's head. The person twirling the ball will not hear a variation in the tone as the ball is a fixed distance from their head, but observers will experience the Doppler shift in the sound.	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students track energy changes through transformations in a system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Asking questions (for science) and defining problems (for engineering)** *Questions originate based on experience as well as need to clarify and test other explanations, or determine explicit relationships between variables.*

8.ESS1.2	Explain the role of gravity in the formation of our sun and planets. Extend this explanation to address gravity's effect on the motion of celestial objects in our solar system and Earth's ocean tides. **<u>COMPONENT IDEA:</u>** *B. Earth and the Solar System*	**EXPLANATION:** 8.ESS1.1 addresses gravity as the force contributing to the coalescence of gases which eventually forms a star. These same attractive forces explain both the orbit of planets around the sun and the formation of planets. In the collapse of a nebula, dust and gas are drawn together by mutual gravitational attraction. As each particle has some initial velocity, the centrally directed force of gravity causes the particles to begin to swirl, accumulate, and compress into a large flask disk like a spinning disk of pizza dough. Planets accumulate within these spinning protoplanetary disks. This process occurred in our solar system long, long ago. By observing patterns in other distant nebula we are able to reconstruct the history of our own solar system. We can see the long range effects of gravitation by observing our own tides. Students should be able to address the changing distribution of water in tidal patterns for spring and neap tides.	**<u>CROSSCUTTING CONCEPT:</u>** **Scale, Proportion, and Quantity** *Students develop models to investigate scales that are beyond normal experiences.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Obtaining, evaluating, and communicating information** *Students can evaluate text, media, and visual displays of information with the intent of clarifying claims and reconciling explanations. Students can communicate scientific information in writing utilizing embedded tables, charts, figures, and graphs*

8.ESS2: Earth's Systems			
8.ESS2.1	Analyze and interpret data to support the assertion that rapid or gradual geographic changes lead to drastic population changes and extinction events. **COMPONENT IDEA:** *E. Biogeology*	**EXPLANATION:** Grade level discussion of biological change will include examinations of common ancestry and natural selection. 8.ESS2.1 facilitates a connection between geologic events and biological change. The principles of uniformitarianism, gradualism, and catastrophism should be explored. Rapid geographic changes such as meteor impacts have resulted in mass extinctions. Disturbances both sudden and gradual have resulted in the formation of a variety of ecological niches contributing to diversity seen on Earth. Data may be drawn from rock strata, formation and erosion of Hawaiian islands, glacial retreat, historic sea levels and elsewhere. Catastrophic events include meteor impacts, massive volcanic eruptions, tsunamis, and/or earthquakes. Gradual changes may include ice ages, warming periods, and or tectonic movements.	**CROSSCUTTING CONCEPT:** **Scale, Proportion, and Quantity** *Students recognize that phenomena are not necessarily observable at all scales.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students critique and consider the degree to which competing arguments are supported by evidence.*
8.ESS2.2	Evaluate data collected from seismographs to create a model of Earth's structure. **COMPONENT IDEA:** *B. Plate Tectonics and Large-Scale Systems Interactions*	**EXPLANATION:** 8.PS4.2 addresses the medium dependent properties of waves. Seismic waves obey these same properties. For example, seismic waves traveling through the Earth's mantle will be refracted as the density of the material changes due to heating from Earth's core. Additionally, earthquakes produce two different waves visible on seismographs: pressure waves (P-waves) and shear waves (S-waves). These two waves travel at different speeds, so will be separated by increasing distance at points of increasing distance from the epicenter of an earthquake. Likewise, only P-waves travel efficiently through solids, so a S-wave shadow at seismograph stations on the opposite side of the earth is evidence for Earth's solid core. A four layer structure for Earth is developed in fourth grade. To support 8.ESS2.4, further detail is required at this grade level.	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record patterns in data, graphs, and charts.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*

8.ESS2.3	Describe the relationship between the processes and forces that create igneous, sedimentary, and metamorphic rocks. **COMPONENT IDEA:** *B. Plate Tectonics and Large-Scale Systems Interactions*	**EXPLANATION:** The forces and processes and forces influencing the rock cycle are respectively enormous and gradual. This is an excellent opportunity to elaborate on this crosscutting concept. Tectonic movements and convection within the earth's interior act as the engine for change.	**CROSSCUTTING CONCEPT:** **Scale, Proportion, and Quantity** *Students recognize that phenomena are not necessarily observable at all scales.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Asking questions (for science) and defining problems (for engineering)** *Questions originate based on experience as well as need to clarify and test other explanations, or determine explicit relationships between variables.*

8.ESS2.4	Gather and evaluate evidence that energy form the earth's interior drives convection cycles within the asthenosphere which create changes within the lithosphere including plate movements, plate boundaries, and sea-floor spreading. **<u>COMPONENT IDEA:</u>** *A. Earth Materials and Systems*	**EXPLANATION:** Earth is heated by the sun at the surface, but also from its own interior. Having investigated cycles of convection, students should be prepared to understand the way that heat is released from the core would drive convection cycles. Students have been exposed to the structure of atoms in seventh grade, so the concept of neutrons and isotopes will be familiar. The decay of these isotopes within the earth's solid core is the source of heat.	**<u>CROSSCUTTING CONCEPT:</u>** **Cause and Effect** *Students begin to connect their explanations for cause and effect relationships to specific scientific theory.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Developing and using models** *Students create models which are responsive and incorporate features that are not visible in the natural world, but have implications on the behavior of the modeled systems and can identify limitations of their models.*

8.ESS2.5	Construct a scientific explanation using data that explains that the gradual processes of plate tectonics accounting for A) the distribution of fossils on different continents, B) the occurrence of earthquakes, and C) continental and ocean floor features (including mountains, volcanoes, faults, and trenches). **COMPONENT IDEA:** *B. Plate Tectonics and Large-Scale Systems Interactions*	**EXPLANATION:** As early as second grade, students were beginning to make observations about features on the earth's surface. Prior to eighth grade, the focus of studies regarding geologic history has been on collecting observations which begged for explanation. Students are now prepared to describe a cause for this collection of observations. As this is one of the first scientific theories students will be exposed to by name, it is important properly introduce theories as explanations of observations/patterns in nature. In this case, students tectonic theory explains the three components of the standard. Though not part of the standard, it might be interesting to discuss prior explanations for these same observations.	**CROSSCUTTING CONCEPT:** **Scale, Proportion, and Quantity** *Students recognize that phenomena are not necessarily observable at all scales.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations using source (including student developed investigations) which show comprehension of parsimony, utilize quantitative and qualitative models to make predictions, and can support or cause revisions of a particular conclusion.*

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8.ESS3: Earth and Human Activity			
8.ESS3.1	Interpret data to explain that Earth's mineral, fossil fuel, and groundwater resources are unevenly distributed as a result of tectonic processes. **Component idea:** *A. Natural Resources*	**Explanation:** Discussions of natural resources have been developed in kindergarten, fourth, and sixth grade. These discussions have progressed from consideration of the use of nature to meet human needs, to extraction and its effects and onto global distributions of earth's natural resources. The function of this standard is to finally utilize tectonic theory as an explanation for the apparently random distribution of natural resources. Students can collect data on the locations of minerals, fossil fuel, and groundwater resources. These locations can then be compared to geologic activities to reveal patterns. Examples include the location of groundwater sources related to the presence of permeable in impermeable rock layers and amounts of precipitation or the creation of fossil fuels where geologic heat and pressure acted on biomass covered by sediment. *(Rock and mineral identification is useful as enrichment, but beyond the scope of this standard.)*	**Crosscutting Concept:** **Cause and Effect** *Students infer and identify cause and effect relationships from patterns.* **Science and Engineering Principle:** **Obtaining, evaluating, and communicating information** *Students can evaluate text, media, and visual displays of information with the intent of clarifying claims and reconciling explanations. Students can communicate scientific information in writing utilizing embedded tables, charts, figures, and graphs*
8.ESS3.2	Collect data, map, and describe patterns in the locations of volcanoes and earthquakes related to tectonic plate boundaries, interactions, and hotspots. **Component idea:** *B. Natural Hazards*	**Explanation:** Such maps have been addressed extensively in 4.ESS2.2 as well as 8.ESS2.5. The focus of this standard is to consider the utilization of such maps and data in decision making processes. For example, structural decisions in building must weigh out cost factors against the likelihood of natural hazards. Unlike forecastable natural disasters, earthquakes and volcanoes are unpredictable with respect to their timing, but predictable with respect to patterns in their locations.	**Crosscutting Concept:** **Pattern** *Students recognize, classify, and record patterns in data, graphs, and charts.* **Science and Engineering Principle:** **Analyzing and interpreting data.** *Students should create and analyze graphical presenations of data to identify linear and non-linear relationships, consider statistical features within data and evaluate multiple data sets for a single phenomenon.*

8.ETS1: Engineering Design			
8.ETS1.1	Develop a model to generate data for ongoing testing and modification of an electromagnet, a generator, and a motor such that optimal design can be achieved. **COMPONENT IDEA:** *C. Optimizing the Solution Design*	**EXPLANATION:** Design plans and specifications may permit evaluation of a solution, but these early plans cannot be subjected to physical tests. Prototypes are models that are developed and that can be subjected to actual testing. Well-designed tests allow for a systematic evaluation of competing solutions. The testing of multiple competing solutions may reveal certain ideas in each different prototype that lead to a completely new prototype that incorporates the strengths of each prior design. Examples of models may include creating, testing, and modifying simple electromagnets, using a coil of wire and a magnet to produce electricity, and creating a simple electric motor with magnets, a battery and paper clips. This can be expanded to include engineering design feats such as junkyard electromagnets or motor strengths for the job required under certain design constraints.	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record patterns in data, graphs, and charts.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can design tests which determine the effectiveness of a device under varying conditions.*

8.ETS1.2	Research and communicate information to describe how data from technologies (telescopes, spectroscopes, satellites, and space probes) provide information about objects in the solar system and universe. **<u>Component idea:</u>** *A. Interdependence of Science, Technology, Engineering, and Math*	**Explanation:** The increases in scientific knowledge facilitating technological advances have enabled dynamic views of our universe. Early astronomers were limited to observing patterns in the motion of the cosmos to make measurements using principles of geometry. More sophisticated tools such as spectroscopes allow us to determine the types of elements in distant stars as well as make observations about the relative motion of heavenly bodies. Examples may include the types of data/information that come from each of the various listed technologies and their uses. For example, how the Hubble Space telescope allows for imaging at greater distances than terrestrial-based telescopes. Emphasis is on tool selection and its alignment with function as it embeds with the content standard. Students should discuss the development of each technology and be able to rudimentarily explain how each gathers information.	**<u>Crosscutting Concept:</u>** **Structure and Function** *Students begin to attribute atomic structure and interactions between particles to the properties of a material.* **<u>Science and Engineering Principle:</u>** **Obtaining, evaluating, and communicating information** *Students can evaluate text, media, and visual displays of information with the intent of clarifying claims and reconciling explanations. Students can communicate scientific information in writing utilizing embedded tables, charts, figures, and graphs*

Biology:

BIO1.LS1: From Molecules to Organisms: Structures and Processes			
BIO1.LS1.1	Compare and contrast existing models, identify patterns, and use structural and functional evidence to analyze the characteristics of life. Engage in argument about the designation of viruses as non-living based on these characteristics. **Component idea:** *B. Growth and Development of Organisms*	**Explanation:** Students begin to develop patterns of living and non-living organisms in kindergarten and build on detailed characteristics of different classifications of living organisms throughout elementary and middle school. Biology 1 discussions introduce viral particles and viral cycles, building on student understanding of living organisms to engage in an argument regarding the classification of a viral particle as either living or non-living.	**Crosscutting Concept:** **Pattern** *Students recognize, classify, and record patterns in quantitative data from empirical research and mathematical representations.* **Science and Engineering Principle:** **Engaging in argument from evidence** *Students critically evaluate evidence supporting an argument and create written or oral arguments that invoke empirical evidence, scientific reasoning and scientific explanations.*

BIO1.LS1.2	Evaluate comparative models of various cell types with a focus on organic molecules that make up cellular structures. **COMPONENT IDEA:** *A. Structure and Function*	**EXPLANATION:** Students explicitly discuss the structure and function of major cellular organelles in seventh grade. Building on this understanding, Biology I students should shift their focus to the different types of cells found in organisms and how the role of each cell type relates to its composition and the prevalence of different organelles within that cell. An example might include the absence (or enucleation) of the nucleus in red blood cells in mammals providing for increased levels of oxygen transport in organisms or the lack of centrioles in most neurons. Varying cell types can include both prokaryotic and eukaryotic cell types	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students create and manipulate a variety of different models: physical, mathematical, computational.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can test the predictive abilities of their models in a real-world setting and make comparisons of two models of the same process or system.*
BIO1.LS1.3	Integrate evidence to develop a structural model of a DNA molecule. Using the model, develop and communicate an explanation for how DNA serves as a template for self-replication and encodes biological information. **COMPONENT IDEA:** *A. Structure and Function*	**EXPLANATION:** Discussions of DNA in earlier grades have been limited to discussions of genes and the role of genes in the appearance and activities of organism. Biology 1 represents a student's introduction to a molecular model of DNA as well as the organization of DNA into genes and genes subsequently into chromosomes. Students should address interactions between genes in proteins which regulate both the shape and reproduction of DNA molecules. It is important to note that not all segments of DNA are transcribed for proteins. Portions of DNA are involved in regulating the expression of genes or affect the structure of the chromosomes (replication origin, centromeres, and telomeres).	**CROSSCUTTING CONCEPT:** **Structure and Function** *Students apply patterns in structure and function to unfamiliar phenomena.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can test the predictive abilities of their models in a real-world setting and make comparisons of two models of the same process or system.*

BIO1.LS1.4	Demonstrate how DNA sequence information is decoded through transcriptional and translational processes within the cell in order to synthesize proteins. Examine the relationship of structure and function of various types of RNA and the importance of this relationship in these processes. **COMPONENT IDEA:** *A. Structure and Function*	**EXPLANATION:** In seventh grade, students discuss the passage of alleles from parent to offspring during sexual reproduction. Biology 1 should build on this understanding of genotypic and phenotypic relationships by establishing a connection between genotypes and the phenotypes resulting from expression of the genes. Specific examples such as pathways for melanin or lactase production can be used to relate monogentic inheritance to phenotypes. In such pathways, students can demonstrate the role of various RNA types in the production of a protein through the processes of transcription and translation.	**CROSSCUTTING CONCEPT:** **Structure and Function** *Students apply patterns in structure and function to unfamiliar phenomena.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can test the predictive abilities of their models in a real-world setting and make comparisons of two models of the same process or system.*

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BIO1.LS1.5	Research examples that demonstrate the functional variety of proteins and construct an argument based on evidence for the importance of the molecular structure to its function. Plan and carry out a controlled investigation to test prediction about factors which should cause an effect on the structure and function of a protein. **COMPONENT IDEA:** *A. Structure and Function*	**EXPLANATION:** Focus of this standard is on the activities of proteins and the role of the structure of proteins in carrying out these activities. Students can be reminded of the concept of reversible and irreversible changes addressed in earlier physical science standards. Investigations might include the effect of amylase activity on a starch substrate as a function of varying temperature or another independent variable. Roles of proteins include cellular regulation, cell signaling, enzymatic function, and structural components	**CROSSCUTTING CONCEPT:** **Structure and Function** *Students infer the function of a component of a system based on its shape and interactions with other components.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students plan and perform investigations to aid in the development of a predictive model for interacting variables, considering the quantity of data with respect to experimental uncertainty, and select methods for collection and analysis of data.*

BIO1.LS1.6	Create a model for the major events of the eukaryotic cell cycle, including mitosis. Compare and contrast the rates of cell division in various eukaryotic cell types in multicellular organisms. **<u>COMPONENT IDEA:</u>** *B. Growth and Development of Organisms*	**EXPLANATION:** Students first discuss mitosis in seventh grade, specifically focusing on the role of mitosis in creating genetically identical daughter cells. Biology 1 discussions should connect a student's understanding of gene expression and protein function with the process of mitosis to explore the differentiation of cell types from otherwise identical daughter cells. Discussions should also include varying rates of mitotic division and the relationship between these rates of division and the function of specific cell types within eukaryotic organisms. Examples may include the extremely limited use of mitosis by neurons due to their interconnectedness within neural networks or the rapid rates of mitosis with growing root tips.	**<u>CROSSCUTTING CONCEPT:</u>** **Pattern** *Students recognize, classify, and record patterns in quantitative data from empirical research and mathematical representations.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Developing and using models** *Students can test the predictive abilities of their models in a real-world setting and make comparisons of two models of the same process or system.*

BIO1.LS1.7	Utilize a model of a cell plasma membrane to compare the various types of cellular transport and test predictions about the movement of molecules into or out of a cell based on the homeostasis of energy and matter in cells. **COMPONENT IDEA:** *A. Structure and Function*	**EXPLANATION:** Students are first introduced to the structure of the plasma membrane and an initial discussion of passive transport to maintain homeostasis in the seventh grade. Biology I discussion of passive transport is still relevant, but discussions of transport should extend to include additional types of cellular transport and how they are accomplished by proteins embedded in the plasma membranes.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students make predictions from models taking into account assumptions and approximations.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*

BIO1.LS1.8	Create a model of photosynthesis demonstrating the net flow of matter and energy into a cell. Use the model to explain energy transfer from light energy into stored chemical energy in the product. **COMPONENT IDEA:** *C. Organization for Matter and Energy Flow in Organisms*	**EXPLANATION:** Students should address the processes used during photosynthesis to convert light energy (solar radiation) into stored chemical energy. Additionally, consider the role of photosynthesis in capturing carbon, hydrogen, and oxygen needed to produce other cellular macromolecules such as proteins and DNA necessary for growth and reproduction. The chemical reactions needed for constant reorganization of these elements to form new compounds provides a way to transfer energy between systems across all levels of organization.	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students explain the conservation of energy by discussing the transfer mechanisms between objects or fields as well as into or out of a system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students plan and perform investigations to aid in the development of a predictive model for interacting variables, considering the quantity of data with respect to experimental uncertainty, and select methods for collection and analysis of data.*

BIO1.LS1.9	Create a model of aerobic respiration demonstrating flow of matter and energy out of a cell. Use the model to explain energy transfer mechanisms. Compare aerobic respiration to alternative processes of glucose metabolism. **COMPONENT IDEA:** *C. Organization for Matter and Energy Flow in Organisms*	**EXPLANATION:** In addition to models that explore the major reactions of cellular respiration, students should be led to consider the way that the chemical reactions of respiration provide a way for energy and matter captured using photosynthesis to be transferred and reorganized by consumers. Cellular respiration is a set of reactions that allow for sugars to re-organized to form other macromolecules. Students should consider differences in the efficiencies of different processes of glucose metabolism. Some of the energy released by respiration is used to maintain a constant body temperature despite constant loss of thermal energy to the surroundings. Both matter and energy are conserved throughout transformations.	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students explain the conservation of energy by discussing the transfer mechanisms between objects or fields as well as into or out of a system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students plan and perform investigations to aid in the development of a predictive model for interacting variables, considering the quantity of data with respect to experimental uncertainty, and select methods for collection and analysis of data.*

BIO1.LS2: Ecosystems: Interactions, Energy, and Dynamics			
BIO1.LS2.1	Analyze mathematical and /or computational representations of population data that support explanations of factors that affect population size and carrying capacities of populations within an ecosystem. Examine a representative ecosystem and based on interdependent relationships present, predict population size effects due to a given disturbance. **<u>Component idea:</u>** *A. Interdependent Relationships in Ecosystems*	**Explanation:** An ecosystem should be appreciated as a dynamic set of relationships among living and nonliving resources. Population size should be recognized as a balance between reproductive rates, death rates, immigration rates, and emigration rates. Biotic factors should be distinguished as a producer, consumer, or decomposer, and the necessity for each of these components to the survival of the other should be appreciated. A population's survival and growth is dependent on the resources obtained through relationships, and thus there is a continuous struggle for balance between competing factors within an ever changing ecosystem.The existence of even a single organism changes the environment in which it exits through resource consumption and waste production. Population data can be collected (logistic or exponential growth) from simulations that model ecosystem interactions and/or graphs that plot a population size versus affecting factors, such as predation, resource availability, competition, etc. Using the information collected and an understanding of population-affecting factors, students can predict the impact of a variety of disturbances such as new species introduction, population crash due to disease, abiotic resource depletion, etc.	**<u>Crosscutting Concept:</u>** **Systems and System Models** *Students make predictions from models taking into account assumptions and approximations.* **<u>Science and Engineering Principle:</u>** **Using mathematics and computational thinking** *Students can create computational or mathematical models for interactions in the natural world using unit equivalencies.*

BIO1.LS2.2	Create a model tracking carbon atoms between inorganic and organic molecules in an ecosystem. Explain human impacts on climate based on this model. **COMPONENT IDEA:** *B. Cycles of Matter and Energy Transfer in Ecosystems*	**EXPLANATION:** Students created models demonstrating carbon and oxygen between biotic and abiotic components in 7.LS2.1. Deeper understanding should include pools or stores for carbon, with models that account for the effects of changes in one pool on another. Complex models for the carbon cycle should include both carbon pools (stores) where carbon stockpiles as well as carbon fluxes, or movements between the various pools. General changes to the sizes of stores can include both sinks and sources. When a store acts as a sink, it is able to absorb more carbon than it releases. Growth of a new forest is an example of a sink. By contrast, a source releases more carbon to the surroundings than it absorbs, which can contribute to greenhouse gases. Using the model, students can construct arguments predicting the effects on one carbon pool in response to an alteration of another. For example, if fossil fuels are converted into atmospheric carbon dioxide, if photosynthesizing organisms are decreased through deforestation, etc.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students design or define systems in order to evaluate a specific phenomenon or problem.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Student models are functioning prototypes and are able to generate data useful for both computation and problem solving.*
BIO1.LS2.3	Analyze through research the cycling of matter in our biosphere and explain how biogeochemical cycles are critical for ecosystem function. **COMPONENT IDEA:** *B. Cycles of Matter and Energy Transfer in Ecosystems*	**EXPLANATION:** Biogeochemical cycles include the movement of matter through both living and non-living systems and the transformation of elements between usable and unusable forms. Living organisms must incorporate matter from their surroundings in order to grow. Some organisms are able to fix elements directly from the atmosphere such as plants through photosynthesis, or bacteria through nitrogen fixation. Focus should be on understanding that fixation permits the production of usable forms of the elements needed to support life. Understanding of these processes is vital to successful agricultural processes which can otherwise contaminate waterways with excess nitrogen in the form of nitrates. *(Memorization of diagrams of cycles misses the intent of this standard. Instead, students should focus on understanding the roles of the various parts of each cycle.)*	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students demonstrate and explain conservation of mass and energy in systems including systems with inputs and outputs.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can create models for interactions of two separate systems.*

BIO1.LS2.4	Analyze data demonstrating the decrease in biomass observed in each successive trophic levels. Construct an explanation considering the laws of conservation of energy and matter and represent this phenomenon in a mathematical model to describe the transfer of energy and matter between trophic levels. **<u>COMPONENT IDEA:</u>** *B. Cycles of Matter and Energy Transfer in Ecosystems*	**EXPLANATION:** It should be appreciated that matter and energy are not destroyed/lost as they transfer between trophic levels. The laws of conservation are supported as organic matter and its chemical energy is transferred into inorganic matter and heat energy through respiration and decomposition. In addition, it should be recognized that energy transfer is inefficient with loss of approximately 90% at each trophic level transfer. Any set(s) of population data from an ecosystem that clearly shows the mass of all organisms represented at primary, secondary, tertiary, etc. trophic levels can be utilized to examine the phenomenon and ask probing questions of why and how. Considering the laws of conservation of energy and matter, an explanation should strive to explain how and where energy and matter transfer from the organic pools in each trophic level. A model should illustrate the "10% rule" of energy transfer and can be displayed in a pyramid model and/or simulation activity.	**<u>CROSSCUTTING CONCEPT:</u>** **Energy and Matter** *Students explain the conservation of energy by discussing the transfer mechanisms between objects or fields as well as into or out of a system.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Obtaining, evaluating, and communicating information** *(Observe/Evaluate) Students can critically read scientific literature, integrating, extracting, and accurately simplifying main ideas from multiple sources while maintaining accuracy and validating data whenever possible. Students can provide written and oral explanations for phenomena and multi-part systems using models, graphs, data tables, and diagrams.*

BIO1.LS2.5	Analyze examples of ecological succession, identifying and explaining the order of events responsible for the formation of a new ecosystem in response to extreme fluctuations in environmental conditions or catastrophic events. **COMPONENT IDEA:** *C. Ecosystem Dynamics, Functioning, and Resilience*	**EXPLANATION:** Since first grade, discussions about ecosystem have involved relatively stable ecosystems, limiting disturbances to the impact of introduced species on these stable ecosystems. Under stable conditions, ecosystems remain in a condition of dynamic equilibrium. Catastrophic events can destroy entire ecosystems. This destruction can include the loss of soils in the creation of new habitat. Students can research primary succession examples such as a glacial retreat in Alaska, volcanism in Hawaii, or wetland development in Florida everglades, and secondary succession examples such as the conversion of natural areas to agricultural land before subsequent abandonment, forest fire devastation, or other natural disaster events. The order of events might include movement from pioneer species through several communities to the climax community.	**CROSSCUTTING CONCEPT:** **Stability and Change** *Students provide examples and explanations for sudden and gradual changes.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*

BIO1.LS3: Heredity			
BIO1.LS3.1	Model chromosome progression through meiosis and fertilization in order to argue how the process of sexual reproduction leads to both genetic similarities and variation in diploid organisms. Compare and contrast the processes of sexual and asexual reproduction, identifying the advantages and disadvantages of each. **COMPONENT IDEA:** *B. Variation of Traits*	**EXPLANATION:** In 7.LS2.8, students develop an understanding that organisms grow from a single cell to a potentially complex multicellular organism through mitosis. It is critical to note that meiosis is introduced in 7.LS3.2 with the sole purpose to focus on the resulting daughter cells. Meiosis related content is categorized under LS3. While meiosis can be viewed as a unique form of cell division that provides a mechanism that results in offspring with a genotype unique unto itself. It should be recognized that mutations are the primary source of variation created through asexual reproduction by mitosis or binary fission and that mutations are passed to sexually reproduced offspring only when they are present in gametes. Attention should be drawn to the idea that population diversity must be advantageous considering the disadvantages of sexual reproduction (partner requirement and increased energy requirement). Meiosis and fertilization can be modeled with diagrams, 3D models, animations, etc. An emphasis should be placed on events that lead to genetic differences (mutations, crossing over, and random segregation) as well as events that generate similarities in parent and offspring (DNA replication and transmission). Similarities and differences in sexual and asexual reproductive strategies can be compiled and analyzed by students through the use of comparative models previously used (BIO1.LS1.5) and/or other resources (text, video, etc). These models may further be used to demonstrate how chromosomal-based diseases such as Trisomy 21 (Down syndrome) occur and/or how sterile hybrids, such as mules or seedless watermelons, cannot effectively complete meiosis due to non-homologous chromosomes from different parent species.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can test the predictive abilities of their models in a real-world setting and make comparisons of two models of the same process or system.*

BIO1.LS3.2	Explain how protein formation results in phenotypic variation and discuss how changes in DNA can lead to somatic or germline mutations. **<u>Component idea:</u>** *A. Inheritance of Traits*	**Explanation:** The general idea that genes create proteins and that these proteins determine the function and appearance of cells and organisms has been established in 7.LS3. In BIO1.LS1.4 the mechanism by which proteins are produced from genes is explored. This standard is designed to complete the connection between genotypes, protein synthesis, and resulting phenotypes by examining concrete examples. It should become clear that recessive traits occur when neither diploid copy of a gene produces a functional protein. Students could research the cause of specific and relatively simple examples of monogenic traits using a variety of level-appropriate resources (text, video, lecture, etc.) in order to elucidate the gene-protein-phenotype link. Classic examples could include but are not limited to: brown/blue base eye color due to melanin protein; PTC tasting due to a taste receptor on tongue cells; sickle cell anemia due to hemoglobin protein; PKU due to the enzyme that breaks down the amino acid phenylalanine; Hemophilia due to a clotting factor protein; ABO blood type due to an enzyme that attaches carbohydrates A, B, or nothing to the red blood cell. Students should recognize that phenotypic variation arises not only from genotypic variation, but also from gene expression variation, the latter of which can often be the result of environmental influences. For example: temperature regulates sex organ development in some fish species or fur color expression in some rabbit species; light regulates butterfly wing development; exercise increases muscle protein expression, isolation rearing in social animals alters brain gene expression; etc.	**<u>Crosscutting Concept:</u>** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **<u>Science and Engineering Principle:</u>** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*

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BIO1.LS3.3	Through pedigree analysis, identify patterns of trait inheritance to predict family member genotypes. Use mathematical thinking to predict the likelihood of various types of trait transmission. **COMPONENT IDEA:** *B. Variation of Traits*	**EXPLANATION:** In 7.LS3, students utilized Punnet squares to make predictions about allele combinations passed to offspring. Their predictions were limited to monohybrid crosses. While gene sequencing has permitted examination of the actual genetic information underlying a particular trait, that is a new process. Early models of investigating inheritance were dependent on pedigrees and the analysis of the appearance of phenotypes across generations. Modes of inheritance should include autosomal and sex-linked genes that are dominant/recessive, codominant, or incompletely dominant. Students can practice deductive reasoning using a basic set of criteria (including successive generation transmission and male/female ratio) in order to predict a mode of inheritance for a trait, define alleles for the trait, and assign genotypes to the family members of a given pedigree. Students can also practice using probability-based mathematics to predict offspring genotypes and phenotypes based on a given parental set.	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record patterns in quantitative data from empirical research and mathematical representations.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*

<table>
<tr><th colspan="4">BIO1.LS4: Biological Change: Unity and Diversity</th></tr>
<tr><td rowspan="2">BIO1.LS4.1</td><td rowspan="2">Evaluate scientific data collected from analysis of molecular sequences, fossil records, biogeography, and embryology. Identify chronological patterns of change and communicate that biological evolution is supported by multiple lines of empirical evidence that identify similarities inherited from a common ancestor.

<u>COMPONENT IDEA:</u>
A. Evidence of Common Ancestry</td><td rowspan="2">EXPLANATION: In earlier grades, students have discussed the origin of fossils, the fossil record, and comparative anatomy. BIO1.LS3 delves into the molecular basis for the phenotype of an organism. That new understanding provides a foundation for discussions about the significance of similarities between the genomes of extinct and extant organisms. Similarities in genomes provide a rationale for common amino acid sequences. Well-documented examples for data analysis could include but are not limited to the following: Molecular data demonstrating that all life shares the same genetic code; comparative DNA and protein sequence data demonstrating conservation of ubiquitous genes/proteins such as ribosomal protein, cytochrome c, etc.; fossil records demonstrating that major life forms currently on earth were not present in the past and major past life forms are not currently present; transitional fossil records that demonstrate anatomical changes over time showing radiation from fish to tetrapods, reptile (dinosaur) to birds, synapsids to mammals, land mammals to aquatic mammals, horse lineage, etc; biogeographical data demonstrating that species in close geographical proximity (regardless of habitat differences) resemble more than species in more similar habitats of distant proximity such as the Galapagos island species that most closely resemble their nearest neighbors in South America; embryological data demonstrating shared anatomical structures among the embryos of organism groups such as gill slits and tail display in all vertebrate embryos.</td><td><u>CROSSCUTTING CONCEPT:</u>
Stability and Change
Students provide examples and explanations for sudden and gradual changes.</td></tr>
<tr><td><u>SCIENCE AND ENGINEERING PRINCIPLE:</u>
Engaging in argument from evidence
Students critically evaluate evidence supporting an argument and create written or oral arguments that invoke empirical evidence, scientific reasoning and scientific explanations.</td></tr>
</table>

BIO1.LS4.2	Using a model that demonstrates the change in allele frequencies resulting in evolution of a population over many generations, identify causative agents of change. **<u>COMPONENT IDEA:</u>** *A. Evidence of Common Ancestry*	**EXPLANATION:** Requirements for natural selection (variation, inheritance and competition) should be recognized that with each generation there are random modifications, only some of which may enhance reproductive success within the given environment, allowing for persistence into the next generation. Repetition of this process over many generations leads to the non-random accumulation of adaptive traits in a given environmental setting. Students should investigate the mechanism by which isolation (reproductive isolation, geographical isolation, temporal isolation) can lead to evolutionary change. Other agents of change may include genetic drift (population bottlenecks, founder effect and sampling error). Predict observations that would be observed in accordance with this phenomenon. A simulation could be used that exhibits random variation introductions through mutations or gene flow and genetically-based trait transmission through generations in order to investigate causative agents of change such as a natural disaster or isolation that results in random modification of the population (genetic drift) or altered climate, resources, competitors, etc. that result in nonrandom accumulation of adaptive traits (natural selection). Students can analyze a variety of common examples of adaptations such as bird beak adaptations, insect mimicry, antibacterial-resistant strains of bacteria, etc. and explain the factors that led to an accumulation of a particular trait in a population. This explanation can be extended to also explain how natural selection mechanisms can result in the observation of non-beneficial traits such as species overspecialization (i.e. the cheetah, panda bear, koala) that increases probability of going extinct, suboptimal traits (i.e. vertebrate eye structure that causes blind spots) ,or vestigial traits (i.e. eye structures in cave fish). (Hardy-Weinberg equation may be used for enrichment, but is beyond the scope of BIO1.)	**<u>CROSSCUTTING CONCEPT:</u>** **Cause and Effect** *Students use and evaluate empirical evidence to classify causation vs. correlation.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Developing and using models** *Students plan and perform investigations to aid in the development of a predictive model for interacting variables, considering the quantity of data with respect to experimental uncertainty, and select methods for collection and analysis of data.*

BIO1.LS4.3	Identify ecosystem services and assess the role of biodiversity in support of these services. Analyze the role human activities have on disruption of these services. **COMPONENT IDEA:** *D. Biodiversity and Humans*	**EXPLANATION:** Biodiversity is first mentioned in 6.LS4.1. The relationship between levels of biodiversity and the fitness of an ecosystem are explicitly discussed as well. Discussing human activities draws this conversation to a larger scale. The loss of biodiversity or species has the same impact globally as it would at ecosystem levels. Natural selection is expedited by significant changes to ecosystems. Without deliberate efforts, human development causing habitat loss can be the significant change wiping out ecosystems. Students should appreciate that biodiversity increases with preservation of evolutionary lineages (decreased extinction rates) and in a feed-forward mechanism, biodiversity promotes ecosystem stability, which decreases extinction rates and enhances biodiversity. Students can investigate the various levels of biodiversity (genetic, species, ecosystem) required to provide services such as food, medicine, water purification, pollination, etc. and maintain ecosystem stability through climate stabilization, waste decomposition, maintenance of interdependent relationships, etc. Analysis of human activities may include habitat fragmentation, introduction of non-native or invasive species, overharvesting, pollution, eutrophication, and climate change.	**CROSSCUTTING CONCEPT:** **Scale, Proportion, and Quantity** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Asking questions (for science) and defining problems (for engineering)** *Questions about arguments and interpretations should elicit further elaboration or investigation.*

BIO1.ETS2: Links Among Engineering, Technology, Science, and Society			
BIO1.ETS2.1	Obtain, evaluate, and communicate information on how molecular biotechnology may be used in a variety of fields. **<u>Component idea:</u>** *A. Interdependence of Science, Technology, Engineering, and Math*	**Explanation:** The goal is to help students appreciate that the basic science knowledge being studied can be manipulated and used to design useful tools for further scientific investigations, medical treatments, agricultural yields, etc. A detailed understanding of any technical procedures is not expected, but rather a "big picture" view of concepts the technology utilizes and the applications the technology is being used for. These technologies may be best investigated along with the standards from LS1 From Molecules to Organisms: Structure and Functions, as the students are learning about DNA and protein. Comparative DNA and protein sequence analysis is also a large part of current phylogenic research and could accompany LS4 Biological Change: Unity and Diversity. Students may also consider the pros and cons of biotechnical applications. Investigation of techniques utilized could come from field trips to witness the use of these techniques in practice, lab exercises, virtual labs, simulation activities, interviews with professionals, etc. Molecular techniques could include: PCR, electrophoresis, restriction enzyme digestion of DNA, DNA sequencing, plasmid-based transformation, transfection, etc. These techniques are used in fields of medicine, agriculture, biomedical engineering, forensic science, etc.	**<u>Crosscutting Concept:</u>** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **<u>Science and Engineering Principle:</u>** **Obtaining, evaluating, and communicating information** *(Observe/Evaluate) Students can critically read scientific literature, integrating, extracting, and accurately simplifying main ideas from multiple sources while maintaining accuracy and validating data whenever possible. Students can provide written and oral explanations for phenomena and multi-part systems using models, graphs, data tables, and diagrams.*
BIO1.ETS2.2	Investigate means by which karyotypes are utilized in diagnostic medicine. **<u>Component idea:</u>** *B. Influence of Engineering, Technology, and Science on Society and the Natural World*	**Explanation:** Engineers incorporate growing scientific knowledge in order to increase benefits to humans and decrease cost and risks. Karyotyping technology and its use in medical diagnosis can complement the standards from LS3: Hereditary: Inheritance, and Variation of Traits, as the students are learning about chromosomal organization of genomic information that determines one's phenotype. Analyze a large set of karyotypes to identify common patterns. Identify variations from the most commonly observed patterns and correlate them with patient phenotypes to propose a cause and effect relationship, discussing limitations of correlative data interpretation.	**<u>Crosscutting Concept:</u>** **Pattern** *Students recognize, classify, and record patterns in quantitative data from empirical research and mathematical representations.* **<u>Science and Engineering Principle:</u>** **Developing and using models** *Students can test the predictive abilities of their models in a real-world setting and make comparisons of two models of the same process or system.*

BIO1.ETS2.3	Analyze scientific and ethical arguments to support the pros and cons of applications of a specific biotechnology technique such as stem cell usage, in vitro fertilization, or genetically modified organisms. **COMPONENT IDEA:** *B. Influence of Engineering, Technology, and Science on Society and the Natural World*	**EXPLANATION:** The utilization of new technologies in any field of science is dependent on both economic and social factors. In addition to evaluating these factors, scientists must also consider long-term consequences that may not be initially apparent. The emphasis should be on the construction of a rationale argument that supports a position on the use of an application with ethical and social impact. Students should begin to appreciate the differences in ethical values that exist, and recognize that discussion of these values is imperative as knowledge and technology continue to advance, even when resolutions of differences can be rare. After investigation of a specific biotechnology application, students can write a position paper and/or participate in a classroom debate.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use and evaluate empirical evidence to classify causation vs. correlation.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students critically evaluate evidence supporting an argument and create written or oral arguments that invoke empirical evidence, scientific reasoning and scientific explanations.*

Chemistry:

CHEM1.PS1: Matter and Its Interactions			
CHEM1.PS1.1	Understand and be prepared to use values specific to chemical processes: the mole, molar mass, molarity, and percent composition. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** During the early and mid-1800s, a tremendous amount of early research poured into building an understanding of the way that atoms combine. This work required analysis of the percent composition of different substances. Joseph Proust's work with tin oxides led him to publish his law of definite proportions noting that a given pure substance will have a constant ratio for the combination of elements making up the substance. Building on Proust's work, John Dalton published his law of multiple proportions and atomic theory noting that multiple patterns exist for the way that atoms combine, yet the combining atoms are invariable. Meanwhile Amedeo Avogadro hypothesizes that given equal pressures and temperatures, two equal volumes of gas will contain equal numbers of atoms. Acknowledging that the exact number of atoms was unknown in these gaseous volumes, the Latin word "mole" was used. "Mole" translates to "lump" recognizing the ambiguous quantity of gas. A number of attempts have been undertaken historically to quantify the mole. Robert Millikan's oil drop experiment revealed the change of a single electron, which could then be divided into Faraday's Constant for the charge of a mole of electrons. Dividing the charge of a mole of electrons by the charge of a single electron yields the number of electrons in a mole, 6.022x10^23. Students should be familiar with how to translate between the given quantities. Student's first use atomism/Dalton's atomic theory in third grade noting that matter is made up of particles too small to be seen. This the first time where students will undertake the process of counting these invisible particles. Electrolysis of water provides a tangible experience to demonstrate the constituent parts of water, though the definite proportions of water may not be easily seen due to the solubility of the gasses produced. The concept of relative mass can be explored by comparing small groups of like items. For example, relative masses of beans can be compared with pinto, white, and black beans. If bags are created with equal numbers of like beans, students can develop a concept of why the smallest bean will have a relative mass of 1, analogous to hydrogen.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*

CHEM1.PS1.2	Demonstrate that atoms, and therefore mass, are conserved during a chemical reaction by balancing chemical reactions. **<u>COMPONENT IDEA:</u>** *B. Chemical Processes*	**EXPLANATION:** Standard 7.PS1.4 explores the idea that chemical reactions are rearrangements of atoms, and students undertake the process of balancing chemical reactions with that standard in seventh grade. The introduction of molar masses in high school makes an explicit connection between the number of atoms, as previously investigated, and the actual masses of the atoms, permitting the collection of more concrete evidence for the conservation of mass in chemical reactions.	**<u>CROSSCUTTING CONCEPT:</u>** **Energy and Matter** *Students demonstrate and explain conservation of mass and energy in systems, including systems with inputs and outputs.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Engaging in argument from evidence** *Students critically evaluate evidence supporting an argument and create written or oral arguments that invoke empirical evidence, scientific reasoning and scientific explanations.*

CHEM1.PS1.3	Perform stoichiometric calculations involving the following relationships: mole-mole; mass-mass; mole-mass; mole-particle; and mass-particle. Show a qualitative understanding of the phenomenon of percent yield, limiting, and excess reagents in a chemical reaction through pictorial and conceptual examples. (states of matter liquid and solid; excluding volume of gasses) **COMPONENT IDEA:** *B. Chemical Processes*	**EXPLANATION:** This standard builds on the idea that balancing chemical reactions provides evidence for conservation of mass and that the behavior of atoms follows predictable patterns. Students now have the opportunity to utilize this understanding as they perform and evaluate chemical reactions. (The concepts of limiting reagent and percent yield are presented; however, students are not expected to determine these values algebraically. Use of molar volume in stoichiometric processes is beyond the scope of this standard.)	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students create and manipulate a variety of different models: physical, mathematical, computational.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can test the predictive abilities of their models in a real-world setting and make comparisons of two models of the same process or system.*

CHEM1.PS1.4	Use the reactants in a chemical reaction to predict the products and identify reaction classes (synthesis, decomposition, combustion, single replacement, double replacement). **COMPONENT IDEA:** *B. Chemical Processes*	**EXPLANATION:** Chemical reactions are rearrangements of atoms that follow predicable patterns. There are patterns both at the macroscopic level in the behavior of some of the reaction classes, as well as patterns in the rearrangements of the atoms underlying the reaction. Students should be able to predict the products of the reactions, which also requires the ability to recognize the general patterns for each type of reaction.	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize that different patterns for the same system may be present depending on the scale at which the system is analyzed.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*

CHEM1.PS1.5	Conduct investigations to explore and characterize the behavior of gasses (pressure, volume, and temperature), develop models to represent this behavior, and construct arguments to explain this behavior. Evaluate the relationship (qualitative and quantitatively) at STP between pressure and volume (Boyle's Law), temperature and volume (Charles' Law), temperature and pressure (Gay-Lussac Law) and moles and volume (Avogadro's Law), and evaluate and explain these relationships with respect to kinetic molecular theory. Be able to understand, establish, and predict the relationships between volume, temperature, and pressure using combined gas law both qualitatively and quantitatively. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** When exploring the behavior of gasses, it is important to consider experimental design. Experiments used to show the relationships between these sets of variables should include one independent and one dependent variable. Other variables should be held constant. Pressure should serve as the dependent variable because it cannot be manipulated directly. Avogadro's Law can be used to relate the amount of gas in two different containers in lieu of knowing actual number of gas particles in an individual container. Individual demonstrations can be performed to explore each of the different gas laws.	**CROSSCUTTING CONCEPT:** **Scale, Proportion, and Quantity** *Students use proportional relationships to predict how changing one property will affect another in a system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students should derive proportionalities and equalities for dependent variables that include multiple independent variables, considering uncertainty, and limitations of collected data.*

CHEM1.PS1.6	Use the ideal gas law, PV = nRT, to algebraically evaluate the relationship among the number of moles, volume, pressure, and temperature for ideal gases. **<u>Component idea:</u>** *A. Structure and Properties of Matter*	**Explanation:** If students have collected data during investigations for CHEM1.PS1.5, these data can then be used to linearize. With pressure assigned as the dependent variable and plotted against (moles)(temperature)/volume, the slope of the graph will be the gas constant, yielding the ideal gas law. After developing the mathematical model, this model can be used to make predictions for other systems.	**<u>Crosscutting Concept:</u>** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **<u>Science and Engineering Principle:</u>** **Developing and using models** *Students can test the predictive abilities of their models in a real-world setting and make comparisons of two models of the same process or system.*

CHEM1.PS1.7	Analyze solutions to identify solutes and solvents, quantitatively analyze concentrations (molarity, percent composition, and ppm), and perform separation methods such as evaporation, distillation, and/or chromatography and show conceptual understanding of distillation. Construct argument to justify the use of certain separation methods under different conditions. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** In seventh grade, students developed an understanding that chemical and physical properties of a sample of matter could be used to identify a substance. Building on this understanding, students now explore the use of these physical and chemical properties to separate mixtures. Analysis of the substances is performed to aid in further discussion and facilitate further quantitative analysis.	**CROSSCUTTING CONCEPT:** **Structure and Function** *Students apply patterns in structure and function to unfamiliar phenomena.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Asking questions (for science) and defining problems (for engineering)** *Questions should facilitate empirical investigation.*

CHEM1.PS1.8	Identify acids and bases as a special class of compounds with a specific set of properties. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** The concept of pH is first introduced in seventh grade as a chemical property of matter. Students should be introduced to multiple explanations of acid and base behavior to permit classification of common substances (e.g. baking soda, ammonia, carbon dioxide) as acids or bases. To further develop discussions of solubility, qualitative discussions of the differences between strong and weak acids are appropriate. *(Calculations of pH or ion concentrations are beyond the scope of this standard. Discussions of pOH are beyond the scope of this standard. Conjugate pairs are beyond the scope of this standard.)*	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students create and manipulate a variety of different models: physical, mathematical, computational.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students critically evaluate evidence supporting an argument and create written or oral arguments which invoke empirical evidence, scientific reasoning and scientific explanations.*
CHEM1.PS1.9	Draw models (qualitative models such as picture or diagrams to demonstrate understanding of radioactive stability and decay.) Understand and differentiate between fission and fusion reactions. Use models (graphs or tables) to explain the concept of half-life and its use in determining the age of materials (such as radiometric dating). **COMPONENT IDEA:** *C. Nuclear Processes*	**EXPLANATION:** To build an understanding of nuclear processes, students should attribute the existence of the nucleus and nuclear stability to neutrons and the strong nuclear force. The process of fusion is facilitated when two nuclei are forced near one another to the point where strong nuclear forces exceed repulsive electromagnetic forces. Due the random movements of nucleons, decay processes are also random but can be charted exhibiting consistent patterns. These patterns are useful in radiometric dating on varying scales.	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students reconcile conservation of mass in nuclear processes.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*

CHEM1.PS1.10	Compare alpha, beta, and gamma radiation in terms of mass, charge, and penetrating power. Identify examples of applications of different radiation types in everyday life (such as its applications in cancer treatment). **<u>Component idea:</u>** *C. Nuclear Processes*	**Explanation:** Nuclear decay processes occur due to random movements of nucleons resulting in variations in potential energy. At some point, the potential energy becomes great enough for a decay process to occur. Students should be familiar with the particles emitted during decay as well as changes to the composition of the nucleus. Forms of nuclear radiation include alpha decay, beta decay (electron and positron emission), and gamma radiation. (Discussions of the weak nuclear force are beyond the scope of this standard, but may be incorporated for enrichment.)	**<u>Crosscutting Concept:</u>** **Energy and Matter** *Students reconcile conservation of mass in nuclear processes.* **<u>Science and Engineering Principle:</u>** **Obtaining, evaluating, and communicating information** *(Observe/Evaluate) Students can critically read scientific literature, integrating, extracting, and accurately simplifying main ideas from multiple sources while maintaining accuracy and validating data whenever possible.* *Students can provide written and oral explanations for phenomena and multi-part systems using models, graphs, data tables, and diagrams.*

CHEM1.PS1.11	Develop and compare historical models of the atom (from Democritus to quantum model) and construct arguments to show how scientific knowledge evolves over time, based on experimental evidence, critique, and alternative interpretations. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** As students have developed an understanding of physical science concepts leading to chemistry, they have implemented a number of these models; however the names have not been made explicit. One approach which may be taken to this standard is to incorporate the ideas when appropriate to other standards. For example, Thomson's model is sufficient for bond classifications and nomenclature when differentiating between ionic and molecular compounds.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students create and manipulate a variety of different models: physical, mathematical, computational.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students critically evaluate evidence supporting an argument and create written or oral arguments which invoke empirical evidence, scientific reasoning and scientific explanations.*

CHEM1.PS1.12	Explain the organization of the periodic table. Predict chemical and physical properties of main group elements (reactivity, number of subatomic particles, ion, charge, ionization energy, atomic radius, and electronegativity) based on location on the periodic table. Construct an argument to describe how the quantum mechanical model of the atom (e.g. patterns of valence and inner electrons) defines periodic properties. Use the periodic table to draw Lewis dot structures and show understanding of orbital notations through drawing and interpreting graphical representations (i.e. arrows representing electrons in an orbital). **<u>COMPONENT IDEA:</u>** *A. Structure and Properties of Matter*	**EXPLANATION:** The concepts addressed in this standard appear as patterns leading to the arrangement of the periodic table or are patterns in the behavior of atom which can be explained by patterns within the periodic table. Students should engage in activities that provide opportunities to uncover these patterns. For example, an appropriate discussion of orbital notations would relate back to the organization of the periodic table, rather than merely following a chart simplifying the aufbau principle. Patterns for reactivity can be uncovered through investigation.	**<u>CROSSCUTTING CONCEPT:</u>** **Pattern** *Students recognize, classify, and record patterns in quantitative data from empirical research and mathematical representations.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*

CHEM1.PS1.13	Use the periodic table and electronegativity differences of elements to predict the types of bonds that are formed between atoms during chemical reactions and write the names of chemical compounds, including polyatomic ions using IUPAC criteria. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** It is recognized that the determination of exact bond classifications based on electronegativity can differ from one suggestion to the next. While specific values may change from one classroom to the next, attention should be paid to the underlying idea that all bonds represent some form of electromagnetic (electrostatic attraction). The differences between bond types can then be related back to cause for the electrostatic attraction, whether or not atoms are ionized when they interact.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*
CHEM1.PS1.14	Use Lewis dot structure and electronegativity differences to predict the polarities of simple molecules (linear, bent, trigonal planar, trigonal pyramidal, tetrahedral). Construct an argument to explain how electronegativity affects the polarity chemical molecules. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** The focus of this standard is on considering the polarity of molecules and the factors that influence that polarity. There are two separate strands of understanding associated with this concept. The first strand addresses the use of electronegativity in considering polarity. This level of understanding can be applied at a simple level to binary compounds, but may prove insufficient to explain the polarity of more complex compounds. The second strand of this standard also incorporates the shape of molecules to explain polarities. Student should be able to consider a given Lewis structure and determine the shape of the molecule as well as the polarity, taking the distribution of electron density into account when determining shape. *(Only molecules following the octet rule will be included, though molecules such as sulfur dioxide might be used during instruction to illustrate the effect of the unshared pair of electrons on the shape of the molecule, as compared to carbon dioxide which lacks this unshared pair. The additional repulsion of a lone pair to disrupt symmetry but not actual bond angles will be included.)*	**CROSSCUTTING CONCEPT:** **Structure and Function** *Students infer the function of a component of a system based on its shape and interactions with other components.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *Students can provide written and oral explanations for phenomena and multi-part systems using models, graphs, data tables, and diagrams.*

CHEM1.PS1.15	Investigate, describe, and mathematically determine the effect of solute concentration on vapor pressure using the solute's van't Hoff factor on freezing point depression and boiling point elevation. **<u>COMPONENT IDEA:</u>** *A. Structure and Properties of Matter*	**EXPLANATION:** Liquids undergo evaporation. The particles entering the air create vapor pressure above the liquid sample which pushes "up" against the "downward" pressure of the atmosphere. If a liquid sample is heated, more particles leave the sample and enter the air space above the liquid, increasing the vapor pressure pushing out of the liquid against the atmospheric pressure pushing back into the liquid. At the point where the vapor pressure of the liquid is equal to the atmospheric pressure, molecules within the liquid experience less pressure from the surrounding liquid and can form bubbles that rise to the surface due to low density. This phenomenon is described as boiling. When solute is added to a solvent, the surface of the liquid will contain less solvent particles, since solute particles now occupy some of the space. Therefore less solvent particles will enter the air above the liquid, lowering the vapor pressure. Now a greater temperature will be needed to supply enough solvent particles to create a vapor pressure equal to atmospheric pressure. Since the change in required temperature is due to the presence of solute particles at the solution's surface, only the number of solute particles created during the dissolving/dissociating processes is a factor. The number of particles (either molecules or ions) resulting from the addition of a solute is called the van 't Hoff factor. A heating curve for a solution brought to boiling will not plateau when it begins to boil since the concentration of the solution will rise as solvent particles are driven off.	**<u>CROSSCUTTING CONCEPT:</u>** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Planning and carrying out controlled investigations** *Students plan and perform investigations to aid in the development of a predictive model for interacting variables, considering the quantity of data with respect to experimental uncertainty, and select methods for collection and analysis of data.*

CHEM1.PS2: Motion and Stability: Forces and Interactions			
CHEM1.PS2.1	Draw, identify, and contrast graphical representations of chemical bonds (ionic, covalent, and metallic) based on chemical formulas. Construct and communicate explanations to show that atoms combine by transferring or sharing electrons. **<u>Component idea:</u>** *A. Structure and Properties of Matter*	**Explanation:** This standard resumes discussions of interactions between atoms from 7.PS1. In seventh grade, students observed patterns within the periodic table that related the physical and chemical properties of substances to the location of the constituent elements on the periodic table. Revisiting general trends is likely to be necessary however a focus should be placed on the transfer of electrons underlying differences in the differences in properties. It is beneficial to show that electrostatic interactions occur even between two non-conductors. Demonstrations can be carried out by using static charge to hold a balloon against a wall or showing that oppositely charged pieces of invisible tape are attracted not only to each other but also to a neutral conductors and non-conductors such as foil strips or paper.	**<u>Crosscutting Concept:</u>** **Structure and Function** *Students apply patterns in structure and function to unfamiliar phenomena.* **<u>Science and Engineering Principle:</u>** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*

CHEM1.PS2.2	Understand that intermolecular forces created by the unequal distribution of charges result in varying degrees of attraction between molecules. Compare and contrast the intermolecular forces (hydrogen bonding, dipole-dipole bonding and London dispersion forces) within different types of simple substances (only those following the octet rule) and predict and explain their effect on chemical and physical properties of those substances using models or graphical representations. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** This standard resumes where students left off in 7.PS1. Students' first exposure to all three phases of matter was in third grade, by fifth grade students were investigating phase changes in matter. These discussions have not included a mechanism to explain why states of matter are dependent on temperature and pressure. Students should consider this standard in conjunction with CHEM1.PS2.1 to explore differences in intermolecular attractions within molecular and ionic compounds and the behavior of electrons leading to these differences.	**CROSSCUTTING CONCEPT:** **Stability and Change** *Students provide examples and explanations for sudden and gradual changes.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can test the predictive abilities of their models in a real-world setting and make comparisons of two models of the same process or system.*

CHEM1.PS2.3	Construct a model to explain the process by which solutes dissolve in solutes, and develop an argument to describe how intermolecular forces affect the solubility of different chemical compounds. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** A similar task and standard exist in the fifth grade (5.PS1.3). At that time, students performed an investigation (which is again mentioned in CHEM1.PS2.4) into factors affecting solubility. However, student background knowledge was not sufficient to explore any explanation of their results. Explorations into intermolecular attractions in the previous standard (CHEM1.PS2.2) have introduced students to the existence of forces between molecules in a substance. Students can now apply these attractions to form explanations for how solute-solute, solute-solvent, and solvent-solvent attractions all interact as substances dissolve. *(Solubility constants and saturation of solutions are beyond the scope of this standard.)*	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students critically evaluate evidence supporting an argument and create written or oral arguments that invoke empirical evidence, scientific reasoning and scientific explanations.*
CHEM1.PS2.4	Conduct an investigation to determine how temperature, surface, and stirring affect the rate of solubility. Construct an argument to explain the relationship observed in experimental data using collision theory. **COMPONENT IDEA:** *A. Structure and Properties of Matter*	**EXPLANATION:** This standard is nearly identical to a fifth grade standard which explores factors affecting the solubility of a compound. Though collision theory is more closely related to rates of reaction, in this case the application of collision theory explores how the same factors underlying collision theory for how reactions also facilitate solvation processes.	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students design or define systems in order to evaluate a specific phenomenon or problem.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students plan and perform investigations to aid in the development of a predictive model for interacting variables, considering the quantity of data with respect to experimental uncertainty, and select methods for collection and analysis of data.*

CHEM1.PS3: Energy			
CHEM1.PS3.1	Contrast the concepts of temperature and heat flow in macroscopic and microscopic terms. Understand that thermal energy is a form of energy and temperature is a measure of average kinetic energy of a particle. **COMPONENT IDEA:** *A. Definitions of Energy*	**EXPLANATION:** Students have been exposed to the types of energy (potential, kinetic, thermal, and chemical) and energy transfer (working, heating, and radiating) in the sixth grade. At that time, students classified energy types in systems and transformations. The focus in Chemistry 1 should be on understanding that measuring the temperature of a system is a way to quantify the thermal energy (average kinetic energy) of the particles in that system. Heating is a mechanism that transfers energy to or from a system. Students should also explore absolute vs relative scales of temperature mechanisms. Students should recognize that energy will always flow from objects with greater thermal energy to areas with lesser thermal energy, but rates of energy flow are a property of the materials being heated. The degree to which the temperature changes as an object is also a physical property of a material. Activities may include collecting or analyzing pressure vs temperature data, then considering why a graph of collected data does not pass through the origin. (Heat capacity and conductivity will only be assessed qualitatively.)	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record patterns in quantitative data from empirical research and mathematical representations.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Using mathematics and computational thinking** *Students can create computational or mathematical models for interactions in the natural world using unit equivalencies.*

CHEM1.PS3.2	Draw and interpret heating and cooling curves and phase diagrams. Analyze the energy changes involved in calorimetry by using the law of conservation energy quantitatively (use of $q=mc\Delta T$) and qualitatively. **COMPONENT IDEA:** *B. Conservation of Energy and Energy Transfer*	**EXPLANATION:** This is one of two standards where students are to investigate changes in a specific types of energy: In this case, thermal energy and phase energy. Starting as early as kindergarten, students are introduced to solid and liquid phases of matter. By third grade, students are considering the particulate nature of matter to discuss physical properties of the different phases. In fifth grade, students discuss phase changes from the perspective of the arrangement of particles. Chemistry 1 is the first time that students make a connection between phase changes and energy changes. Students commonly struggle with the idea that substances can be heated, but that heating does not always result in a change in temperature. Models of phase energies associated with the arrangement of particles aid in dispelling these misconceptions. Comparisons should identify similarities in energies in solids and liquids as compared to vastly different energy in gases. Discussions of heat of fusion/vaporization and calculations to enrich these discussions are appropriate. Finally, students should be able to quantify relationships in which heating creates a change in the thermal energy of a sample. Activities may include determining energy released when an object is burned to change the temperature of a substance in a closed system. (Note that this standard is limited to calculations of energy associated with changes in thermal energy, and not energies associated with phase transformations.)	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Planning and carrying out controlled investigations** *Students plan and perform investigations to aid in the development of a predictive model for interacting variables, considering the quantity of data with respect to experimental uncertainty, and select methods for collection and analysis of data.*

CHEM1.PS3.3	Distinguish between endothermic and exothermic reaction by constructing potential energy diagrams and explain the differences between the two using chemical terms (e.g. activation energy). Recognize when energy is absorbed or given off depending on the bonds formed and bonds broken. **<u>Component idea:</u>** *B. Conservation of Energy and Energy Transfer*	**Explanation:** This is one of two standards where students are to investigate changes in a specific type of energy: In this case, chemical energy. Students should recognize that the formation of bonds releases energy, while the breaking of bonds is endothermic. Synthesis reactions to form metal oxides can provide observations if carried out taking proper precautions. Clear changes to masses and physical properties provide evidence of a reaction. (Specific discussions of enthalpy of formation are beyond the scope of this standard, but the topic may be useful for enrichment discussions about reactions where bonds are both broken and formed.)	**<u>Crosscutting Concept:</u>** **Systems and System Models** *Students design or define systems in order to evaluate a specific phenomenon or problem.* **<u>Science and Engineering Principle:</u>** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*

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CHEM1.PS3.4	Analyze energy changes to explain and defend the law of conservation of energy. **COMPONENT IDEA:** *B. Conservation of Energy and Energy Transfer*	**EXPLANATION:** Standards PS3.2 and PS3.3 identify the energy types most commonly associated with chemical reactions and build on sixth grade discussions of energy storage and transfer types. In Chemistry 1, students will synthesize an understanding of law of conservation of energy by being able to distinguish system from surroundings, and recognizing that tracking energy requires both the system and surrounding energies to be considered. Students can consider interactions such as a beverage warming/cooling, a refrigerator cooling food, the function of Freon in cooling systems, or a car's cooling system as examples where multiple systems interact.	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students explain the conservation of energy by discussing the transfer mechanisms between objects or fields as well as into or out of a system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can create models for interactions of two separate systems.*

CHEM1.PS4: Waves and Their Applications in Technologies for Information Transfer			
CHEM1.PS4.1	Using a model, explain why elements emit characteristic frequencies of light and how this information is used. **Component idea:** *B. Electromagnetic Radiation*	**Explanation:** An understanding of the behavior of light as has been developed first by investigating properties of waves in fourth grade and more recently in eighth grade when students differentiated between mechanical and electromagnetic waves. This is the first time that students investigate a mechanism for the emission of photons. Emphasis should be placed on the emission of characteristic colors of light emitted when electrons undergo specific movements and unique spectra of each element that result. Students should explore the implications of these ideas on astronomy. (Clarification may be needed to differentiate this particulate behavior of light from previous discussions of its wave properties; however, discussions of Quantum Theory in differentiating wave-particle duality are beyond the scope of this standard)	**Crosscutting Concept:** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **Science and Engineering Principle:** **Developing and using models** *Students can test the predictive abilities of their models in a real-world setting and make comparisons of two models of the same process or system.*

Physics:

PHYS.PS1: Matter and Its Interactions			
PHYS.PS1.1	Develop models to illustrate the changes in the composition of the nucleus of an atom and the energy released during the processes of fission, fusion, and radioactive decay. **COMPONENT IDEA:** *C. Nuclear Processes*	**EXPLANATION:** To build an understanding of nuclear processes, students should attribute the existence of the nucleus and nuclear stability to neutrons and the strong nuclear force. In any case, radioactive decay results in the formation of a nucleus with a lower energy. During the decay processes, particles, photons, or both can be emitted by a nucleus. A parallel can be drawn between the production of photons of light when an electron moves between energy level and the energetic photons released during nuclear decay. In nuclear decay however, the energy changes are much greater, and consequently the energy of the emitted particles (especially gamma particles) is much greater and well beyond the visible portion of the spectrum.	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students demonstrate and explain conservation of mass and energy in systems, including systems with inputs and outputs.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*
PHYS.PS1.2	Recognize and communicate examples from everyday life that use radioactive decay processes. **COMPONENT IDEA:** *C. Nuclear Processes*	**EXPLANATION:** The appropriateness of radioactive decay for an everyday process is largely due to the nature of the products of a decay process. More energetic particles are more likely to cause damage to living systems. Alpha particles are low energy particles and permit the utilization of alpha decay reactions in household devices such as smoke detectors. Beta decay is frequently utilized in medical diagnostics in the form of radiotracers. Large scale power generation utilizes nuclear fission to heat water and drive turbines, but must be carefully monitored due to the powerful gamma radiation released. Discussions of this standard should focus on the energy released during the decay and the potential consequences of this energy.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students design or define systems in order to evaluate a specific phenomenon or problem.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *Students can provide written and oral explanations for phenomena and multi-part systems using models, graphs, data tables, and diagrams.*

PHYS. PS1.3	Investigate and evaluate the expression for calculating the percentage a remaining atom (N(t) = N0e^-λt) using simulated models, calculations, and/or graphical representations. Define the half-life (t1/2) and decay constant (λ). Perform an investigation on probability and calculate half-life from acquired data. (Does not require use of actual radioactive samples.) **COMPONENT IDEA:** *C. Nuclear Processes*	**EXPLANATION:** As a general concept, half-life is the amount to time required for random processes to decay half the isotopes in a sample. Two common misconceptions for students are: 1) That the decayed isotopes are disappearing after decay and 2) That a sample is completely gone after two half-lives. The expression given relates the given size of a radioactive sample to the original sample size, Euler's number (e), the decay constant, and elapsed time. Euler's number is an irrational number with a value of ~2.718. The origin of this number is in exponential growth of systems. Graphically, Euler's number is multiplied by the original sample size (the value of the sample size (y) when time is zero (x)). In this case, the system is not a decay system so Euler's number is raised to a negative exponent. Lambda represents the decay constant for this particular isotope and t is the elapsed time for the sample to decay.	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students reconcile conservation of mass in nuclear processes.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Using mathematics and computational thinking** *Students can create computational or mathematical models for interactions in the natural world using unit equivalencies.*

PHYS.PS2: Motion and Stability: Forces and Interactions			
PHYS.PS2.1	Investigate and evaluate graphical and mathematical relationships of one-dimensional kinematic parameters (distance, displacement, speed, velocity, acceleration) with respect to an object's position, direction of motion, and time. **Component idea:** *A. Forces, Fields, and Motion*	**Explanation:** Discussions should lead students to differentiate between scalar and vector properties and appropriate uses for each. In eighth grade, standard 8.PS2.3 provides limited exposure to the different approaches to modeling the motion of an object. At that time, the focus was on creating the representations. It is not appropriate to use some of these representations to develop basic kinematic expressions. Students should not be able to explain and translate between models that include the motion of multiple objects on the same graph. It is also appropriate to introduce the concepts of derivatives (slopes of tangents) and integrals (areas under curves) to aid in the process transforming between representations.	**Crosscutting Concept:** **Systems and System Models** *Students create and manipulate a variety of different models: physical, mathematical, computational.* **Science and Engineering Principle:** **Planning and carrying out controlled investigations** *Students plan and perform investigations to aid in the development of a predictive model for interacting variables, considering the quantity of data with respect to experimental uncertainty, and select methods for collection and analysis of data.*
PHYS.PS2.2	Algebraically solve problems including constant velocity and constant acceleration in one-dimension. **Component idea:** *A. Forces, Fields, and Motion*	**Explanation:** Students can use the models they have developed in PHYS.PS2.1 to evaluate systems. For a system to undergo constant acceleration, the net force on the object must be constant throughout the problem. Algebraic problem solving should be extended to include proportional reasoning, beyond simple manipulation of variables.	**Crosscutting Concept:** **Scale, Proportion, and Quantity** *Students use proportional relationships to predict how changing one property will affect another in a system.* **Science and Engineering Principle:** **Using mathematics and computational thinking** *Students can create computational or mathematical models for interactions in the natural world using unit equivalencies.*

PHYS.PS2.3	Algebraically solve problems involving arc length, angular velocity, and angular acceleration. **COMPONENT IDEA:** *A. Forces, Fields, and Motion*	**EXPLANATION:** Though not explicitly stated, it is beneficial to develop this standard in the same manner which PHYS.PS2.1 is used to develop PHYS.PS2.2. In doing so, students can parallel rotational properties to translational properties, e.g., arc length can be seen as the rotational equivalent to displacement in the translational world. In doing so, radians becomes a logical unit of measure for rotational displacement. Since neither torque, nor moment of inertia are addressed in this course, discussions can be limited to considering only kinematics and not venturing into the realm of rotational dynamics.	**CROSSCUTTING CONCEPT:** **Scale, Proportion, and Quantity** *Students recognize that the presence of patterns can be dependent on the scale at which a system is observed.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Using mathematics and computational thinking** *Students can create computational or mathematical models for interactions in the natural world using unit equivalencies.*
PHYS.PS2.4	Use free-body diagrams to illustrate the contact and non-contact forces acting on an object. Use the diagrams in combination with graphic or component based analysis with Newton's first and second laws to predict position of the object on which the forces act in a constant net force scenario. **COMPONENT IDEA:** *A. Forces, Fields, and Motion*	**EXPLANATION:** The concept of net force and Newton's laws have been introduced in 8.PS2.3 and 8.PS2.4. At that time, free-body diagrams are introduced as a tool to represent the forces acting on an object. In further developing the use of free-body diagrams, it is now appropriate to include vectors that must be evaluated to parallel and perpendicular components. This includes objects on inclined planes as well as projectile motion as addressed in PHYS.PS2.13.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can test the predictive abilities of their models in a real-world setting and make comparisons of two models of the same process or system.*

PHYS.PS2.5	Gather evidence to defend the claim of Newton's first law of motion by explaining the effect that balanced forces have upon objects that are stationary or moving at a constant velocity. **<u>Component idea:</u>** *C. Stabilitiy and Instability in Physical Systems*	**Explanation:** Students should be able to discuss mass as a measurement of the amount of inertia in an object, with a unit of kg. Beginning as early as 5.PS2.3 students have been developing a understanding of gravity. Experiments determining the rate of acceleration of objects in freefall can be used to determine earth's gravitational field strength which can then be used to develop an object's gravitational mass. A discussion of Hook's Law and subsequent use of a spring with a known spring constant can be used to determine an object's inertial mass.	**<u>Crosscutting Concept:</u>** **Pattern** *Students recognize, classify, and record patterns in quantitative data from empirical research and mathematical representations.* **<u>Science and Engineering Principle:</u>** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*
PHYS.PS2.6	Using experimental evidence and investigations, determine that Newton's second law of motion defines force as a change in momentum, $F = \Delta p/\Delta t$. **<u>Component idea:</u>** *B. Types of Interactions*	**Explanation:** Previous examinations of Newton's second law have been limited to instances with constant forces. This standard expands that discussion to include instances where the objects interact with each other. To maximize the quality of experimental investigations, magnets might be used to create situations where objects "collide" in an elastic manner. Newton's second law can be expressed as $F = ma$. Viewing acceleration as a change in velocity over a period of time, one arrives at $F=m(\Delta v/\Delta t)$. Distributing mass into this equation yields $F = (mV-mV_o)/\Delta t$. A final recognition that momentum (p) is a property described by an object's mass and velocity allows for substitution to produce $F = \Delta p/\Delta t$.	**<u>Crosscutting Concept:</u>** **Energy and Matter** *Students explain the conservation of energy by discussing the transfer mechanisms between objects or fields as well as into or out of a system.* **<u>Science and Engineering Principle:</u>** **Planning and carrying out controlled investigations** *Students plan and perform investigations to aid in the development of a predictive model for interacting variables, considering the quantity of data with respect to experimental uncertainty, and select methods for collection and analysis of data.*

PHYS.PS2.7	Plan, conduct, and analyze the results of a controlled investigation of Newton's second law of motion in a system subject to a net unbalanced force, Fnet = ma or Fnet = Δp/Δt. **COMPONENT IDEA:** *A. Forces, Fields, and Motion*	**EXPLANATION:** A major challenge is often determining the magnitude of a force acting on an object in freefall. Students can first use spring scales to make a determination for Earth's gravitational field strength (g) in Newton's per kilogram. Ideally, this value can be obtained from the slope of a graph of newtons of force exerted on a hanging mass per kg of mass. With this piece of information it is possible to predict the magnitude of the net force acting on an object in freefall. Knowledge of this information permits experimental verification of the acceleration of an object in freefall based on this field strength.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students should derive proportionalities and equalities for dependent variables which include multiple independent variables, considering uncertainty, and limitations of collected data.*
PHYS.PS2.8	Use examples of forces between pairs of objects involving gravitation, electrostatic, friction, and normal forces to explain Newton's third law. **COMPONENT IDEA:** *A. Forces, Fields, and Motion*	**EXPLANATION:** Standard 8.PS2.5 introduces Newton's third law. With that standard, students are encouraged to use the newly acquired skill of drawing free-body diagrams to recognize that third law pairs must be present on different objects. Use of these free-body diagrams is again encouraged to explain atomic level interactions such as friction, electrostatic attractions, and normal forces, and the interconnections between these three. Understanding the microscopic interactions should facilitate macroscopic explanations for simple processes such as walking. Students should also explore systems where equal forces may not be apparent, such as collisions between objects of significantly different masses, e.g., a fly colliding with a windshield of a moving car.	**CROSSCUTTING CONCEPT:** **Scale, Proportion, and Quantity** *Students recognize that the presence of patterns can be dependent on the scale at which a system is observed.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Engaging in argument from evidence** *Students critically evaluate evidence supporting an argument and create written or oral arguments which invoke empirical evidence, scientific reasoning and scientific explanations.*

PHYS.PS2.9	Use Newton's law of universal gravitation to calculate the gravitational forces, mass or distance separating two objects with mass given the information about the other quantities. **COMPONENT IDEA:** *B. Types of Interactions*	**EXPLANATION:** While the focus of this standard is on determining the properties of objects interacting through gravitational fields, it may prove beneficial to relate this topic to a discussion of centrally directed net forces, or centripetal forces. Discussions of Newton's universal gravitation formula is frequently used to address satellite and planetary orbits both of which operate due to a centrally directed gravitational force.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students create and manipulate a variety of different models: physical, mathematical, computational.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *(O/E) Students can critically read scientific literature, integrating, extracting, and accurately simplifying main ideas form multiple sources while maintaining accuracy and validating data whenever possible.*
PHYS.PS2.10	Describe and mathematically determine the electrostatic interaction between electrically charged particles using Coulomb's law. Compare and contrast Coulomb's law and gravitational force, notably with respect to distance. **COMPONENT IDEA:** *B. Types of Interactions*	**EXPLANATION:** Comparisons should note that both of these forces decrease proportional to the square of the distance and both are field interactions. Due to the nature of electric charge, it is possible that coulombic forces can be either attractive or repulsive depending on the charges, while gravitational forces are attractive. Descriptions of electrostatic fields should also include field line diagrams representing both strength and direction of the field in space.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*

PHSY.PS2.11	Develop and apply the impulse-momentum theorem along with scientific and engineering ideas to evaluate and refine a device that minimizes the force on an object during a collision. **<u>Component idea:</u>** *B. Types of Interactions*	**Explanation:** This topic can be related to conservation of energy and work-energy theorem to explore that bringing an object to rest requires a set amount of energy to be dissipated. By increasing the stopping distance of the object during the time when the force is applied, the required force is decreased since the total work done on the stopping object remains constant. Students can design systems to maximize the stopping distance and in turn decrease the force required to stop the object. Working with constraints on their designs provides students an opportunity to make design decisions in applying their scientific knowledge.	**<u>Crosscutting Concept:</u>** **Scale, Proportion, and Quantity** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **<u>Science and Engineering Principle:</u>** **Constructing explanations and designing solutions** *Students can evaluate complex designed systems and select the optimal solution based on tests they design and conduct and take into account a prioritization of multiple constraints.*
PHYS.PS2.12	Use experimental evidence to demonstrate that air resistance is a velocity dependent drag force that leads to terminal velocity. **<u>Component idea:</u>** *A. Forces, Fields, and Motion*	**Explanation:** In performing such an experiment, students should treat air resistance as the dependent variable and must therefore be able to manipulate this variable. This can be done by considering a force diagram for an object falling at its terminal velocity. (PHYS.PS2.5) Doing so will reveal that the drag force is equal to the weight force. By varying the weight, the drag force is also varied. If an object with a significant air resistance is used, the terminal velocity can be determined when dropping the object from a significant height. *(Note: A common misconception is to treat drag force and weight force as a third law pair. This is incorrect.)*	**<u>Crosscutting Concept:</u>** **Cause and Effect** *Students use and evaluate empirical evidence to classify causation vs correlation.* **<u>Science and Engineering Principle:</u>** **Choose a SEP** *Students plan and perform investigations to aid in the development of a predictive model for interacting variables, considering the quantity of data with respect to experimental uncertainty, and select methods for collection and analysis of data.*

PHYS.PS2.13	Develop a model to predict the range of a two-dimensional projectile based upon its starting height, initial velocity, and angle at which it was launched. **<u>Component idea:</u>** *A. Forces, Fields, and Motion*	**Explanation:** Focus should center on the understanding that horizontal and vertical forces act independently of each other. Students may develop this idea using video capture tools (cell phones, tablets, web cams) which permit frame by frame analysis. Working with an object of known size as reference in frame, students can develop function for motion in the x and y separately. Use of free-body diagrams can be included to permit separate analysis of each component. Related predictions such as maximum height or situations where the launch height is at a different height than the landing/impact location should also be included. A scale model can be created for the motion of a projectile using strings of varying lengths to affix washers along a meter stick at equal intervals. With such a model, tradeoffs between height and distance can be observed as the initial launch angle is varied.	**<u>Crosscutting Concept:</u>** **Scale, Proportion, and Quantity** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **<u>Science and Engineering Principle:</u>** **Developing and using models** *Student models are functioning prototypes and are able to generate data useful for both computation and problem solving.*
PHYS.PS2.14	Plan and conduct an investigation to provide evidence that a constant force perpendicular to an object's motion is required for uniform circular motion (F = mV^2/r). **<u>Component idea:</u>** *A. Forces, Fields, and Motion*	**Explanation:** Circular motion requires a balance of two factors: a velocity which will carry an object forward and a force perpendicular to the object's velocity. This perpendicular force will cause the object's trajectory to curve inwards in the direction of the force, while continuing to travel forward. Building on a student's understanding of projectile motion, it should be made evident that the object's velocity will not change as there is no component to the force parallel to the object's motion. Investigations can be performed by selecting variables which students hypothesize will have an effect on the motion of an object moving in a circular pattern. If force sensors are available, this lab can be done by measuring the centrally directed force. Without force sensors, students can perform their investigation using a loose string passing through the center of a hollow tube. A measured hanging mass on the loose end of the string can be used to determine the tension force when the uniform circular motion is achieved. Discussions should also include circular paths that may not be complete circles, such as the apex of a hill or a curve in the road. (It is essential to clearly distinguish between uniform circular motion and rotational motion.)	**<u>Crosscutting Concept:</u>** **Scale, Proportion, and Quantity** *Students use proportional relationships to predict how changing one property will affect another in a system.* **<u>Science and Engineering Principle:</u>** **Planning and carrying out controlled investigations** *Students should derive proportionalities and equalities for dependent variables which include multiple independent variables, considering uncertainty, and limitations of collected data.*

PHYS.PS3: Energy			
PHYS.PS3.1	Identify and calculate different types of energy and their transformations (thermal, kinetic, potential, including magnetic and electrical potential energies) from one form to another in a system. **COMPONENT IDEA:** *A. Definitions of Energy*	**EXPLANATION:** In 6.PS3 students were introduced to the various types of energy and mechanisms for their transformations. Students should now be able to quantify the total energy of a system as well as quantify each different type of energy in a system. Energy is an abstract concept that does not have a physical form. It is a substance-like quantity that is recognized to be conserved as a system changes. Calculations present an opportunity to observe that potential energies are due to the positions of objects within a field, while kinetic energy is based on an object's mass and motion. Students can evaluate the total energy of a system by imagining that there are different types of energy storage accounts, just as money can be stored in different accounts. Energy can transferred into or out of any of these accounts. Three different processes can account for all energy changes: working, heating, and radiating. In energy storage due to field effects, such as gravitational or electrostatic fields, the field itself stores the potential energy and not the object in the field.	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students explain the conservation of energy by discussing the transfer mechanisms between objects or fields as well as into or out of a system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can create models for interactions of two separate systems.*
PHYS.PS3. 2	Investigate conduction, convection, and radiation as a mechanism for the transfer of thermal energy. **COMPONENT IDEA:** *B. Conservation of Energy and Energy Transfer*	**EXPLANATION:** Thermal energy is the energy of a system due to the motion of the particles in that system. One object can transfer its thermal energy to another object through the processes of heating or radiating. Convection and conduction are processes which require a physical medium to transfer the thermal energy. In the case of conduction, two objects are in direct contact, while convection transfers thermal energy through a liquid or gaseous medium. Radiation is a unique form of energy transfer which can transfer without a medium. One packet of this energy is called a photon. The energy of the photon determines the effect that it will have when it interacts with matter. Low energy photons such a microwaves add to the motion of matter and result in an increase of the thermal energy. Photons carry energy from the sun to Earth.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*

PHYS.PS3.3	Use the principle of energy conservation and mathematical representations to quantify the change in energy of one component of a system when the energy that flows in and out of the system and the change in energy of the other components is known. **COMPONENT IDEA:** *B. Conservation of Energy and Energy Transfer*	**EXPLANATION:** In PHYS.PS3.1 students quantify the various types of energy and consider methods for energy transfer. If a student is able to evaluate the total energy of a system, such evaluations before and after a change to a system provide a mechanism to show that energy of a system has been conserved. For example, students might use pie charts to show the distribution of the total energy. For an object about to freefall, the pie chart might be 100% gravitational potential energy. Mid-descent, the energy might be half gravitational potential energy and half kinetic energy. After colliding with the ground, the total energy may have decreased, which can be represented as heat energy lost from the pie chart.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students design or define systems in order to evaluate a specific phenomenon or problem.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Using mathematics and computational thinking** *Students can create computational or mathematical models for interactions in the natural world using unit equivalencies.*

PHYS.PS3.4	Assess the validity of the law of conservation of linear momentum (p=mV) by planning and constructing a controlled scientific investigation involving two objects moving in one dimension. **<u>COMPONENT IDEA:</u>** *B. Conservation of Energy and Energy Transfer*	**EXPLANATION:** Momentum is a useful tool when considering conservation of energy when two objects interact. Attempts to quantify all energy transformation in such a system often fail to account for energies lost due to the production of sound and heat. Collisions where energy is dissipated from the system are known as inelastic collisions. Though system energy may be lost to the surroundings, the conservation of momentum will still be observed. Thus the conservation of momentum can provide a tool to evaluate inelastic collisions.	**<u>CROSSCUTTING CONCEPT:</u>** **Stability and Change** *Students provide examples and explanations for sudden and gradual changes.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Planning and carrying out controlled investigations** *Students plan and perform investigations to aid in the development of a predictive model for interacting variables, considering the quantity of data with respect to experimental uncertainty, and select methods for collection and analysis of data.*

PHYS.PS3.5	Construct an argument based on qualitative and quantitative evidence that relates the change in temperature of a substance to its mass and heat energy added or removed from a system. **<u>COMPONENT IDEA:</u>** *B. Conservation of Energy and Energy Transfer*	**EXPLANATION:** Two different materials will undergo different degrees of temperature change even with the same amount of energy added to each. Heat capacity is a ratio (the slope of a temperature vs. heat added) that describes the change in temperature of a sample dependent on the amount of heating. Empirical determination of the heat capacity of a substance requires that both phase and mass of the substance are constants. Students can utilize proportional reasoning in the design of a second portion of this experiment to determine the effect of mass on temperature change.	**<u>CROSSCUTTING CONCEPT:</u>** **Scale, Proportion, and Quantity** *Students use proportional relationships to predict how changing one property will affect another in a system.* **<u>SCIENCE AND ENGINEERING PRINCIPLE:</u>** **Analyzing and interpreting data.** *Students should derive proportionalities and equalities for dependent variables which include multiple independent variables, considering uncertainty, and limitations of collected data.*

PHYS.PS3.6	Define power and solve problems involving the rate of energy production or consumption ($P=\Delta E/\Delta t$). Explain and predict changes in power consumption based on changes in energy demand or elapsed time. Investigate power consumption and power production systems in common use. **COMPONENT IDEA:** *D. Energy in Chemical Processes and Everyday Life*	**EXPLANATION:** This standard pairs well with PHYS.PS3.6. Students should understand that a given task will require a certain minimum amount of energy. In accordance with the work-energy theorem, this would be described as work done on the system. Power incorporates a rate element into this discussion. An object can be lifted to an identical height by two different mechanisms. The total energy input into the system (the object and Earth's gravitational field) will be the same in either case. However, if one mechanism for lifting the object does this in a smaller amount of time, it is said to be more powerful. Students may compare two different devices that accomplish the same task, but have different power ratings and explain the impact of the different power ratings on how the devices are used. For example, two microwaves might both pop a bag of popcorn, but a more powerful microwave might do it faster or be more likely to burn the popcorn at recommended time settings.	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students explain the conservation of energy by discussing the transfer mechanisms between objects or fields as well as into or out of a system.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students present evaluations of a device that incorporate scientific knowledge and results from student designed tests, as well as real-world factors. (e.g. societal, environmental)*

PHYS.PS3.7	Investigate and evaluate the laws of thermodynamics and use them to describe internal energy, heat, and work. **<u>Component idea:</u>** *B. Conservation of Energy and Energy Transfer*	**Explanation:** Internal energy of a system can be changed by either work or heat. For example: If a system is defined as Earth's gravitational field, then lifting a lump of clay upwards increases the energy/instability of this system as the field stores gravitational potential energy. It can be said that the person who lifted the clay higher and higher did work on the system. If the person is removed, the clay will fall. As the clay falls and strikes the ground, the internal energy of the gravitational field decreases by heating the surroundings (the clay and surface it falls onto). Systems move towards conditions of stability where their energy is at a minimum. According to the law of conservation of energy, the decrease in the energy of the system must mean that energy is transferred to the surroundings. Some of this energy can be utilized in designed systems to do productive work (e.g., lift something, turn something). In all cases, a portion of this energy will heat the surroundings by releasing photons of varying wavelengths. When a system loses energy and moves towards stability, the entropy of the universe increases. It may be helpful to consider entropy as a	**<u>Crosscutting Concept:</u>** **Stability and Change** *Students provide examples and explanations for sudden and gradual changes.* **<u>Science and Engineering Principle:</u>** **Developing and using models** *Students can create models for interactions of two separate systems.*

PHYS.PS3.8	Communicate scientific ideas to describe how forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space. Explain how energy is contained within the field and how energy changes when the objects generating and interacting with the field change their relative positions. **<u>Component idea:</u>** *C. Relationship Between Energy and Forces and Fields*	**Explanation:** In 6.PS3.1, students are introduced to the different types and mechanisms for storing energy. This standard should include quantification of the amount of energy stored as objects change positions within those fields. It is important that students can reconcile that objects do not store potential energy, rather that these potential energies are stored within the fields. Changing position within the field results in a change in potential energy as work is done either by the field (the potential energy decreases) or on the field (the potential energy increases).	**<u>Crosscutting Concept:</u>** **Energy and Matter** *Students explain the conservation of energy by discussing the transfer mechanisms between objects or fields as well as into or out of a system.* **<u>Science and Engineering Principle:</u>** **Using mathematics and computational thinking** *Students can create computational or mathematical models for interactions in the natural world using unit equivalencies.*

PHYS.PS3.9	Describe, compare, and diagrammatically represent both magnetic and electric fields. Qualitatively predict the motion of a charged particle in each type of field, but avoid situations where the two types of fields are combined in the same region of space. Restrict magnetic fields to those that are parallel or perpendicular to the path of a charged particle. **COMPONENT IDEA:** *C. Relationship Between Energy and Forces and Fields*	**EXPLANATION:** Students have explored the concept of non-contact forces in investigations of gravity, the effects of forces on the motion of an object, and have discussed the capacity of fields to store energy. This standard unites these principles by considering the impact of an object changing position within a field. As a charge moves through a field, the changes in position (depending on the direction of motion) can result in a change to the potential energy stored by the field. A decrease in the potential energy stored in the field, coupled with the law of conservation of energy, implies that work has been done by the field. If the work being done is applied to a moving charge, the applied force will result in a change to the trajectory of the moving charge. Students should be able to qualitatively describe the force applied to the charge using right hand rules. Such discussions may also be used to relate to the function of electrical generation or electric motors through induction. A demonstration of the electromotive force and the effect of the orientation can be observed using an electrical extension cord, unplugged with a galvanometer connecting the two ground prongs. If the cord is twirled through Earth's magnetic field, deflection will be observed.	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize that different patterns for the same system may be present depending on the scale at which the system is analyzed.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can create models for interactions of two separate systems.*

PHYS.PS3.10	Develop a model (sketch, CAD drawing, etc.) of a resistor circuit or capacitor circuit and use it to illustrate the behavior of electrons, electrical charge, and energy transfer. **COMPONENT IDEA:** *C. Relationship Between Energy and Forces and Fields*	**EXPLANATION:** Models can include the use of simulations. The focus of the models should be on the flow of charge and the utilization of energy within the circuit. It is important that students recognize that heat dissipated by resistors represents energy lost from the system that did not do effective work. (Extreme care should be taken if capacitors are used in the class.)	**CROSSCUTTING CONCEPT:** **Structure and Function** *Students infer the function of a component of a system based on its shape and interactions with other components.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Students can test the predictive abilities of their models in a real-world setting and make comparisons of two models of the same process or system.*

PHYS.PS3.11	Investigate Ohm's law (I=V/R) by conducting an experiment to determine the relationships between current and voltage, current and resistance, and voltage and resistance. **COMPONENT IDEA:** *C. Relationship Between Energy and Forces and Fields*	**EXPLANATION:** Ohm's law relates the current through a device or portion of a circuit to the voltage drop observed across that device. The voltage drop across a device will increase in a linear fashion as the current through that device is increased. The resistance of the device is given by the ratio of voltage drop to current across the device. In an ohmic device, this ratio will be constant. Simple, single-loop circuits may be analyzed by considering each resistor as part of the total (equivalent) resistance of the circuit. (It may be beneficial to describe non-ohmic devices, but such devices are beyond the scope of this standard.)	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record patterns in quantitative data from empirical research and mathematical representations.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students should derive proportionalities and equalities for dependent variables which include multiple independent variables, considering uncertainty, and limitations of collected data.*
PHYS.PS3.12	Apply the law of conservation of energy and charge to assess the validity of Kirchhoff's loop and junction rules when algebraically solving problems involving multi-loop circuits. **COMPONENT IDEA:** *B. Conservation of Energy and Energy Transfer*	**EXPLANATION:** Analysis of circuits using Ohm's Law is efficient for small, simple circuits. In more complex circuits, it is beneficial to evaluate the flow of charge and potential drops using Kirchhoff's Rules. These rules present an excellent opportunity to consider conservation laws. The junction rule reflects a conservation of charge, while the loop rule addresses conservation of energy for a unit of charge. This may be presented by considering the capacity of each charge to either do work or produce heat. In a complete loop, all of that capacity will have been eliminated.	**CROSSCUTTING CONCEPT:** **Energy and Matter** *Students demonstrate and explain conservation of mass and energy in systems including systems with inputs and outputs.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Using mathematics and computational thinking** *Students can apply and test computational models for the function of a device.*

PHYS.PS3.13	Predict the energy stored in a capacitor and how charge flows among capacitors connected in series or parallel. **<u>Component idea:</u>** *B. Conservation of Energy and Energy Transfer*	**Explanation:** Parallel plate capacitors provide a means to store an electric potential difference across the two plates. Charges can flow onto or off of the two plates when the poles are connected to a battery, until the potential difference across the plates is equal to the potential difference of the connected battery. When disconnected from the source, the potential difference remains in place across the capacitor. If the two ends are connected the two plates will return to their equipotential state. The flow of charge in capacitors should be explained by considering the point where charge ceases to flow due to the entire circuit having equal potential differences and justifying why current has stopped. A charged capacitor creates an electric field with the capacity to do work.	**<u>Crosscutting Concept:</u>** **Stability and Change** *Students provide examples and explanations for sudden and gradual changes.* **<u>Science and Engineering Principle:</u>** **Planning and carrying out controlled investigations** *Students plan and perform investigations to aid in the development of a predictive model for interacting variables, considering the quantity of data with respect to experimental uncertainty, and select methods for collection and analysis of data.*
PHYS.PS3.14	Recognize and communicate information about energy efficiency and/or inefficiency of machines used in everyday life. **<u>Component idea:</u>** *D. Energy in Chemical Processes and Everyday Life*	**Explanation:** An understanding of conservation of energy should lead to conversations about the efficiency of a device. A well designed device should utilize as much of the available energy as possible for the desired task. Other energy will be converted to forms, such as heat and noise, which may not be immediately useful based on the intended use for the device.	**<u>Crosscutting Concept:</u>** **Energy and Matter** *Students demonstrate and explain conservation of mass and energy in systems, including systems with inputs and outputs.* **<u>Science and Engineering Principle:</u>** **Engaging in argument from evidence** *Students present evaluations of a device that incorporate scientific knowledge and result from student designed tests, as well as real-world factors. (e.g. societal, environmental)*

PHYS.PS3.15	Compare and contrast the process, design, and performance of numerous next-generation energy sources (hydropower, wind power, solar power, geothermal power, biomass power etc.). **COMPONENT IDEA:** *D. Energy in Chemical Processes and Everyday Life*	**EXPLANATION:** The physics phenomena explored throughout this course are utilized engineers in designing energy capturing systems that are not reliant on non-renewable resources. Students can research these processes and relate them to both the scientific principles underlying the various processes, as well as implications of system design and efficiency behind improvements to these processes over time.	**CROSSCUTTING CONCEPT:** **Structure and Function** *Students apply patterns in structure and function to unfamiliar phenomena.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *(Observe/Evaluate) Students can critically read scientific literature, integrating, extracting, and accurately simplifying main ideas from multiple sources while maintaining accuracy and validating data whenever possible.*

PHYS.PS4: Waves and Their Applications in Technologies for Information Transfer			
PHYS.PS4.1	Know wave parameters (i.e. velocity, period, amplitude, frequency, angular frequency) as well as how these quantities are defined in the cases of longitudinal and transverse waves. **COMPONENT IDEA:** *A. Wave Properties: Mechanical and Electromagnetic*	**EXPLANATION:** Standard 4.PS4.1 is a student's introduction to waves. At this time, students address the properties of amplitude, wavelength and direction of a wave and principles of superposition of waves, but not by name. In 8.PS4.1, students revisit the topic adding frequency to their models and beginning to consider wave speed, but without mentioning factors affecting the speed of the waves. PHYS.PS2.3 includes discussion of rotational motion which can pair with discussions of simple harmonic motion to clarify angular velocity and angular speed. Discussions regarding the origin of waves can fully develop these ideas.	**CROSSCUTTING CONCEPT:** **Systems and System Models** *Students create and manipulate a variety of different models: physical, mathematical, computational.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*

PHYS.PS4. 2	Describe parameters of a medium that affect the propagation of a sound wave through it. **<u>Component idea:</u>** *A. Wave Properties: Mechanical and Electromagnetic*	**Explanation:** The focus of this discussion should be properties of the medium, specifically the density of the material. The density becomes a factor in optics and considering transmission of electromagnetic waves. Students can be led to make their descriptions by experimenting with coiled springs stretched to varying lengths. The topic of linear mass density can be used to explore analogous properties in the air.	**<u>Crosscutting Concept:</u>** **Structure and Function** *Students apply patterns in structure and function to unfamiliar phenomena.* **<u>Science and Engineering Principle:</u>** **Planning and carrying out controlled investigations** *Students plan and perform investigations to aid in the development of a predictive model for interacting variables, considering the quantity of data with respect to experimental uncertainty, and select methods for collection and analysis of data.*

PHYS.PS4. 3	Understand that the reflection, refraction, and transmission of waves at an interference between two media can be modeled on the basis of the characteristics of specific wave parameters and parameters of the medium. **COMPONENT IDEA:** *A. Wave Properties: Mechanical and Electromagnetic*	**EXPLANATION:** The focus of this standard is on developing an understanding for the behavior of waves at a boundary. To demonstrate these principles, it is suggested that students create waves on a coiled spring or string and send these waves towards either a free or fixed end or through a different weight of string. For instance, wave can be created in a section of a lighter string then transmitted towards a point where that string terminates into a heavier segment of string. In doing so, it is possible to observe the effects on wave amplitude and a discussion of energy differences. Students should extend their observations of these mechanical waves to wave behaviors at other scales.	**CROSSCUTTING CONCEPT:** **Cause and Effect** *Students use cause and effect models at one scale to make predictions about the behavior of systems at different scales.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students can differentiate between the appropriateness of quantitative and qualitative data.*

PHYS.PS4.4	Communicate scientific and technical information about how the principle of superposition explains the resonance and harmonic phenomena in air columns on strings and common sound devices. **COMPONENT IDEA:** *C. Information Technologies and Instrumentation*	**EXPLANATION:** In 4.PS4.1, students examine the effects of superposition of waves, but do not explore the behavior of waves at boundaries. Building on 4.PS4.3, the behavior of a wave at a free or fixed boundaries can create patterns where successive waves produced by a source interact with those reflected off a boundary. Discussions should include general development of the idea of harmonics. Once established, this topic can be extended to the specific function of stringed instruments such as guitars of simple open or closed tubes. The phenomena of resonance can be produced using a tuning fork held above a section of rigid tubing which is lowered or lifted into a pail of water. Resonance can be heard clearly at multiple points, providing an opportunity to model the source of resonance and relate the resonance points to the wavelength of the wave produced. The phenomenon of beats can be used to provide an introduction to this topic as it too is an audible phenomenon. Quick demonstrations of beats can be performed without tuning forks using multiple open windows in a browser simultaneously playing different frequencies.	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record patterns in quantitative data from empirical research and mathematical representations.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Obtaining, evaluating, and communicating information** *Students can provide written and oral explanations for phenomena and multi-part systems using models, graphs, data tables, and diagrams.*

PHYS.PS4.5	Evaluate the characteristics of the electromagnetic spectrum by communicating the similarities and differences among the different bands. Research and determine methods and devices used to measure these characteristics. **COMPONENT IDEA:** *B. Electromagnetic Radiation*	**EXPLANATION:** The visible portion of the electromagnetic spectrum will be familiar to students, as will the ideas of x-rays, microwaves, and radiowaves. However, students often struggle to see these phenomena as multiple manifestations of the same principles. It may be beneficial to relate these discussions to the physiology of the human eye, specifically the function of the rhodopsin photopigment. As a demonstration: the light bulbs on the front of remote controls emit light outside of the visible spectrum; however, inexpensive cell phone cameras lack IR filters (as well as some front facing cameras on more current cell phones). Rendering the IR light visible can help student to understand that many devices function by capturing the energy of electromagnetic waves. An additional option would be the creation of a crystal radio using a germanium diode.	**CROSSCUTTING CONCEPT:** **Pattern** *Students recognize, classify, and record patterns in quantitative data from empirical research and mathematical representations.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Analyzing and interpreting data.** *Students should use data to revise and optimize devices already in operation.*

PHYS.PS4. 6	Plan and conduct controlled scientific investigations to construct explanations of light's behavior (reflection, refraction, transmission, interference) including the use of ray diagrams. **COMPONENT IDEA:** *B. Electromagnetic Radiation*	**EXPLANATION:** In PHYS.PS4.3 students examine the behaviors of mechanical waves moving through a medium. Though the terminology in this standard is comparable, this standard focuses on optics of light. Students should work with lenses and mirrors to build an understanding of the behaviors of light as it interacts with surfaces (reflection, refraction, transmission). In 4.PS4.1 and PHYS.PS4.1, students investigated interference patterns with mechanical waves. Using a pair of speakers and an online tone/frequency generator, it is possible to demonstrate that sound waves, like mechanical waves, can interfere with each other. In such a demonstration, students are able to hear variations in the volume of the sound as they walk in a straight line across the field of sound created by the speakers.	**CROSSCUTTING CONCEPT:** **Structure and Function** *Students apply patterns in structure and function to unfamiliar phenomena.* **SCIENCE AND ENGINEERING PRINCIPLE:** **Developing and using models** *Student models are functioning prototypes and are able to generate data useful for both computation and problem solving.*

PHYS.PS4. 7	Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model. **Component idea:** *B. Electromagnetic Radiation*	**Explanation:** Most students willingly accept the particle behavior of light. As early as first grade, students have experimented with the behavior of light and observed that shadows can be created if some of the particles of light are blocked. Introductory explanations of the photoelectric effect can provide more advanced evidence for the particle behavior. Properties of wave behavior can be demonstrated by observing interference patterns in Young's double slit experiment. Simple models using strips of paper to represent waves can provide a more tangible experience to understand the interference phenomena.	**Crosscutting Concept:** **Pattern** *Students recognize, classify, and record patterns in quantitative data from empirical research and mathematical representations.* **Science and Engineering Principle:** **Obtaining, evaluating, and communicating information** *(Observe/Evaluate) Students can critically read scientific literature, integrating, extracting, and accurately simplifying main ideas from multiple sources while maintaining accuracy and validating data whenever possible.*
PHYS.PS4. 8	Obtain information to construct explanations on how waves are used to produce, transmit, and capture signals and store and interpret information. **Component idea:** *C. Information Technologies and Instrumentation*	**Explanation:** In 8.PS4.3 students are introduced to the use of waves in communication systems. Further development of these discussions might include a distinction between the differences between analog and digital signals and necessity for digital signals in communication. Additionally, waves can be used for detection in x-rays or ultrasound. Information that is digitized can be stored with very little loss to the quality of the data itself.	**Crosscutting Concept:** **Structure and Function** *Students infer the function of a component of a system based on its shape and interactions with other components.* **Science and Engineering Principle:** **Constructing explanations and designing solutions** *Students form explanations that incorporate sources (including models, peer reviewed publications, their own investigations), invoke scientific theories, and can evaluate the degree to which data and evidence support a given conclusion.*

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PHYS.PS4. 9	Investigate how information is carried in optical systems and use Snell's law to describe the properties of optical fibers. **<u>Component idea:</u>** *C. Information Technologies and Instrumentation*	**Explanation:** As light travels from one medium to another, the path of light is bent. Snell's law can be used to determine the critical angle for a medium. This angle represents the angle at which the light does not exit the medium but instead is reflected back into the medium. Fiber optic cables utilize this phenomena by transmitting light that reflects off of the internal walls of the cable rather than escaping the cable.	**<u>Crosscutting Concept:</u>** **Cause and Effect** *Students design a system to produce a desired outcome.* **<u>Science and Engineering Principle:</u>** **Asking questions (for science) and defining problems (for engineering)** *Questions should facilitate empirical investigation.*

Conclusions and Additional Resources:

The objective of the Science Standards Reference Guide is to provide information that supports the Tennessee Science Standards and three-dimensional science instruction. The reference guide should only be used as a tool to quickly support understandings or provide perspective on the progression of a student's science education, and not an insight into assessment.

Teachers are encouraged to dive deeply into A Framework for K-12 Science Education (https://www.nap.edu/read/13165/chapter/1).

In addition to this Science Standards Reference, a Tennessee Science Standards Implementation Guide has been written. The Implementation Guide can be used to lead groups of teachers in a study focused on three-dimensional instruction and how it shaped the Tennessee Science Standards. This document can be located at: https://www.tn.gov/education/article/science-standards.