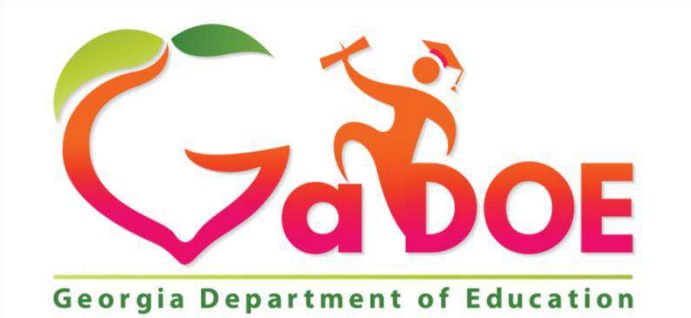

Richard Woods, Georgia's School Superintendent
"Educating Georgia's Future"

DRAFT

SCIENCE

Georgia Standards of Excellence (GSE)

Kindergarten – Grade 12

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Kindergarten Standards

The Science Georgia Standards of Excellence are designed to provide foundational knowledge and skills for all students to develop proficiency in science. The Project 2061's *Benchmarks for Science Literacy* and the follow up work, *A Framework for K-12 Science Education* were used as the core of the standards to determine appropriate content and process skills for students. The Science Georgia Standards of Excellence focus on a limited number of core disciplinary ideas and crosscutting concepts which build from Kindergarten to high school. The standards are written with the core knowledge to be mastered integrated with the science and engineering practices needed to engage in scientific inquiry and engineering design.

The Science Georgia Standards of Excellence drive instruction. Hands-on, student-centered, and inquiry-based approaches should be the emphasis of instruction. The standards are a required minimum set of expectations that show proficiency in science. However, instruction can extend beyond these minimum expectations to meet student needs. At the same time, these standards set a maximum expectation on what will be assessed by the Georgia Milestones Assessment System.

Science consists of a way of thinking and investigating, as well a growing body of knowledge about the natural world. To become literate in science, students need to possess sufficient understanding of fundamental science content knowledge, the ability to engage in the science and engineering practices, and to use scientific and technological information correctly. Technology should be infused into the curriculum and the safety of the student should always be foremost in instruction.

The Kindergarten Georgia Standards of Excellence for science engage students in raising questions about the world around them. Though not developmentally ready for in-depth explanations, kindergarten students wonder why things move and note the various patterns in their movement (e.g., the sun and the moon appear and disappear in the sky). Students learn to use whole numbers to describe scientific data and how to identify parts of things (i.e. tools and toys). Kindergarteners use their senses (sight, smell, taste, touch, and sound) to group objects and to make observations about the physical world by describing, comparing, and sorting items according to physical attributes (i.e. number, shape, texture, size, weight, color, and motion). They learn to follow rules to stay safe.

Kindergarten Standards

Earth Science

SKE1. Obtain, evaluate, and communicate observations about time patterns (day to night and night to day) and objects (sun, moon, stars) in the day and night sky.

a. Ask questions to classify objects according to those seen in the day sky, the night sky, and both.

b. Develop a model to communicate the changes that occur in the sky during the day, as day turns into night, during the night, and as night turns into day using pictures and words.
(*Clarification statement:* Students are not expected to understand tilt of the Earth, rotation, or revolution.)

SKE2. Obtain, evaluate, and communicate information to describe the physical attributes of earth materials (soil, rocks, water, and air).

a. Ask questions to identify and describe earth materials—soil, rocks, water, and air.

b. Construct an argument supported by evidence for how rocks can be grouped by physical attributes (size, weight, texture, color).

c. Use tools to observe and record physical attributes of soil such as texture and color.

Physical Science

SKP1. Obtain, evaluate, and communicate information to describe objects in terms of the materials they are made of and their physical attributes.

a. Ask questions to compare and sort objects made of different materials. (Common materials include clay, cloth, plastic, wood, paper, and metal.)

b. Use senses and science tools to classify common objects, such as buttons or swatches of cloth, according to their physical attributes (color, size, shape, weight, and texture).

c. Plan and carry out an investigation to predict and observe whether objects, based on their physical attributes, will sink or float.

SKP2. Obtain, evaluate, and communicate information to compare and describe different types of motion.

a. Plan and carry out an investigation to determine the relationship between an object's physical attributes and its resulting motion (straight, circular, back and forth, fast and slow, and motionless) when a force is applied. (Examples could include toss, drop, push, and pull.)

b. Construct an argument as to the best way to move an object based on its physical attributes.

Life Science

SKL1. Obtain, evaluate, and communicate information about how organisms (alive and not alive) and non-living objects are grouped.

a. Construct an explanation based on observations to recognize the differences between organisms and nonliving objects.
b. Develop a model to represent how a set of organisms and nonliving objects are sorted into groups based on their attributes.

SKL2. Obtain, evaluate, and communicate information to compare the similarities and differences in groups of organisms.

a. Construct an argument supported by evidence for how animals can be grouped according to their features.
b. Construct an argument supported by evidence for how plants can be grouped according to their features.
c. Ask questions and make observations to identify the similarities and differences of offspring to their parents and to other members of the same species.

First Grade Standards

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The First Grade Georgia Standards of Excellence for science engage students in raising questions about the world around them and seeking answers by making observations. First graders use whole numbers to analyze scientific data. They identify how magnets pull on all things made of iron and either attract or repel other magnets. First graders create drawings that correctly depict something being described. The students are asked to plan and carry out simple investigations to understand patterns (shadows, sound, weather, and daily needs of plants and animals) observed in the world around them and make predictions based on these investigations. They follow safety rules.

First Grade Standards

Earth Science

S1E1. Obtain, evaluate, and communicate weather data to identify weather patterns.

a. Represent data in tables and/or graphs to identify and describe different types of weather and the characteristics of each type.
b. Ask questions to identify forms of precipitation such as rain, snow, sleet, and hailstones as either solid (ice) or liquid (water).
c. Plan and carry out investigations on current weather conditions by observing, measuring with simple weather instruments (thermometer, wind vane, rain gauge), and recording weather data (temperature, precipitation, sky conditions, and weather events) in a periodic journal, on a calendar seasonally, and graphically.
d. Analyze data to identify seasonal patterns of change. (*Clarification statement:* Examples could include temperature, rainfall/snowfall, and changes to the environment.)

Physical Science

S1P1. Obtain, evaluate, and communicate information to investigate light and sound.

a. Use observations to construct an explanation of how light is required to make objects visible.
b. Ask questions to identify and compare sources of light.
c. Plan and carry out an investigation of shadows by placing objects at various points from a source of light.
d. Construct an explanation to observe and provide evidence that vibrating materials can make sound and that sound can make materials vibrate.
e. Design a signal that can serve as an emergency alert using light and/or sound to communicate over a distance.

S1P2. Obtain, evaluate, and communicate information to demonstrate the effects of magnets on other magnets and other objects.

a. Construct an explanation of how magnets are used in everyday life. (*Clarification statement:* Everyday life uses could include refrigerator magnets, toys, magnetic latches, and name tags.)
b. Plan and carry out an investigation to demonstrate how magnets attract and repel each other and the effect of magnets on common objects.

Life Science

S1L1. Obtain, evaluate, and communicate information about the basic needs of plants and animals.

a. Ask questions to identify the parts of a plant—root, stem, leaf, and flower.
b. Ask questions to compare and contrast the basic needs of plants (air, water, light, and nutrients) and animals (air, water, food, and shelter).
c. Design a solution to ensure that a plant or animal has all of its needs met.

Second Grade Standards

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The Second Grade Georgia Standards of Excellence for science engage students in raising questions about the world around them and seeking answers by making observations and exploring. At the appropriate times, students will ask, "How do you know?" and will attempt to answer the question. They will use whole numbers as well as basic fractions (such as one-half and one-fourth) to identify and analyze scientific data. Second graders will find sums and differences of single digit numbers and then justify the answer. They will give rough estimates to problems and estimate lengths, weights, and time intervals. They will explain to others how to solve numerical problems related to a science activity.

Second grade students push, pull, and manipulate things to see what will happen. They study the changing patterns of the moon and the sun and its effects on Earth. Second graders conduct simple investigations to understand that no matter how parts of an object are assembled their overall weight is the same as the total weight of the parts. They understand that heating and cooling cause changes in the properties of the materials. They observe changes caused by weather, plants, animals, and humans to the environment and study the life cycle of different organisms.

Second Grade Standards

Earth Science

S2E1. Obtain, evaluate, and communicate information about stars having different sizes and brightness.

a. Ask questions to describe the physical attributes (size and brightness) of stars.
b. Construct an argument to support the claim that although the sun appears to be the brightest and largest star, it is actually medium in size and brightness.

S2E2. Obtain, evaluate, and communicate information to develop an understanding of the patterns of the Sun and the moon and the sun's effect on Earth.

a. Plan and carry out an investigation to determine the effect of the position of the sun in relation to a fixed object on Earth at various times of the day.
b. Design and build a structure that demonstrates how shadows change throughout the day.
c. Represent data in tables and/or graphs of the length of the day and night to recognize the change in seasons.
d. Use data from personal observations to describe, illustrate, and predict how the appearance of the moon changes over time in a pattern.
(*Clarification statement:* Students are not required to know the names of the phases of the moon or understand the tilt of the Earth.)

S2E3. Obtain, evaluate, and communicate information about how weather, plants, animals, and humans cause changes to the environment.

a. Ask questions and obtain information about major changes to the environment in your community.
b. Construct an explanation of the causes of a change to the environment in your community.

Physical Science

S2P1. Obtain, evaluate, and communicate information about the properties of matter and changes that occur in objects.

a. Ask questions to describe and classify different objects according to their physical properties.
(*Clarification statement:* Examples of physical properties could include color, mass, length, texture, hardness, strength, absorbency, and flexibility.)
b. Construct an explanation for how structures made from small pieces (linking cubes, building blocks) can be disassembled and then rearranged to make new and different structures.

c. Provide evidence from observations to construct an explanation that some changes in matter caused by heating or cooling can be reversed and some changes are irreversible.
(*Clarification statement:* Changes in matter could include heating or freezing of water, baking a cake, boiling an egg.)

S2P2. Obtain, evaluate, and communicate information to demonstrate changes in speed and direction using a force (a push or a pull).

a. Plan and carry out an investigation to demonstrate how pushing and pulling on an object affects the motion of the object.
b. Design a device to change the speed or direction of an object.
c. Record and analyze data to decide if a design solution works as intended to change the speed or direction of an object with a force (a push or a pull).

Life Science

S2L1. Obtain, evaluate, and communicate information about the life cycles of different living organisms.

a. Ask questions to determine the sequence of the life cycle of common animals in your area: a mammal such as a cat, dog or classroom pet, a bird such as a chicken, an amphibian such as a frog, and an insect such as a butterfly.
b. Plan and carry out an investigation of the life cycle of a plant by growing a plant from a seed and by recording changes over a period of time.
c. Develop a simple model that depicts an animal's role in dispersing seeds or in the pollination of plants.
d. Develop models to illustrate the unique and diverse life cycles of organisms other than humans.

Third Grade Standards

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The Third Grade Georgia Standards of Excellence for science engage students in making observations and using information they obtained to answer questions. Their communication skills allow them to record findings, analyze data, and recognize the importance of keeping records of observations without making alterations. Third graders add and subtract whole numbers mentally, on paper, and with a calculator. They observe, construct, and measure objects using ordinary hand tools. They observe things with many parts and describe the ways in which the parts influence or interact with one another. They represent objects in the real world with geometric figures, number sequences, graphs, diagrams, maps, and stories. The students will use this information to explain physical attributes of rocks and soils, understand how fossils provide evidence of organisms that lived long ago, describe ways in which heat energy is transferred and measured, identify features of plants and animals within the geographical regions of Georgia, and the recognize the effects of pollution on the environment.

Third Grade Standards

Earth Science

S3E1. Obtain, evaluate, and communicate information about the physical attributes of rocks and soils.

a. Ask questions and analyze data to classify rocks by their physical attributes (shape, color, texture, luster, and hardness) using simple tests.
(*Clarification statement*: Mohs scale should be studied at this level. Cleavage and streak as well as classification of rocks into sedimentary, igneous, and metamorphic are not addressed at this level.)

b. Plan and carry out investigations to describe properties (color, texture, capacity to retain water, and ability to support growth of plants) of soils and soil types (sand, clay, loam).

c. Make observations of the local environment to construct an explanation of how water and/or wind have made changes to soil and/or rocks over time.
(*Clarification statement:* Examples could include ripples in dirt on a playground and a hole formed under gutters.)

S3E2. Obtain, evaluate, and communicate information on how fossils provide evidence of past organisms.

a. Construct an argument from observations of fossils (authentic or reproductions) to communicate how they serve as evidence of past organisms and the environments in which they lived.

b. Develop a model to describe the sequence and conditions required for an organism to become fossilized.
(*Clarification statement:* Types of fossils (cast, mold, trace, and true) are not addressed in this standard.)

Physical Science

S3P1. Obtain, evaluate, and communicate information about the ways heat energy is transferred and measured.

a. Ask questions to identify sources of heat energy.
(*Clarification statement:* Examples could include sunlight, friction, and burning.)

b. Plan and carry out an investigation to gather data using thermometers to produce tables and charts that illustrate the effect of sunlight on various objects.
(*Clarification statement:* The use of both Fahrenheit and Celsius temperature scales is expected.)

c. Use tools and every day materials to design and construct a device/structure that will increase/decrease the warming effects of sunlight on various materials.
(*Clarification statement:* Conduction, convection, and radiation are taught in upper grades, and should not be taught at this grade level.)

Life Science

S3L1. Obtain, evaluate, and communicate information about the similarities and differences between plants, animals, and habitats found within geographic regions (Blue Ridge Mountains, Piedmont, Coastal Plains, Valley and Ridge, and Appalachian Plateau) of Georgia.

a. Ask questions to differentiate between plants, animals, and habitats found within Georgia's geographic regions.
b. Identify external features and adaptations (camouflage, use of hibernation, protection, migration, mimicry) of animals to construct an explanation of how these features/adaptations allow them to survive in their habitat.
c. Use evidence to construct an explanation of why some organisms can thrive in one habitat and not in another.

S3L2. Obtain, evaluate, and communicate information about the effects of pollution (air, land, and water) and humans on the environment.

a. Ask questions to collect information and create records of sources and effects of pollution on the plants and animals of Georgia.
b. Explore, research, and communicate solutions, such as conservation of resources and recycling materials, to protect plants and animals of Georgia.

Fourth Grade Standards

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The Fourth Grade Georgia Standards of Excellence for science engage students in constructing meaningful models that allow them to gain understanding of the natural world. They speculate about observations they make. They add, subtract, multiply and divide whole numbers on paper, mentally, and with calculators. They list common materials for making simple mechanical constructions and for repairing things. Fourth graders gather and interpret data and use records, tables, or graphs to identify patterns of change. They write instructions and make sketches that allow others to carry out a scientific investigation. They determine whether or not a comparison is fair if conditions are different for each thing being compared. They question claims or statements made by people outside their field of expertise. The students will use this information to compare and contrast the physical attributes of stars and planets, model the effects of the relative motion of the Earth and moon around the sun, use weather charts/maps to predict weather events, conduct investigations about the water cycle and understand their relationship with heat energy, communicate information about the nature of light and sound, study the effects of balanced and unbalanced forces on an object, and describe the flow of energy in an ecosystem and the roles organisms play in a community.

Fourth Grade Standards

Earth Science

S4E1. Obtain, evaluate, and communicate information to compare and contrast the physical attributes of stars, and planets.

a. Ask questions to compare and contrast technological advances that have changed the amount and type of information on distant objects in the sky.

b. Construct an argument on why some stars (including the Earth's sun) appear to be larger or brighter than other stars.
(*Clarification statement:* Differences are limited to distance and size, not age or stage.)

c. Construct an explanation of the differences between stars and planets in the sky.

d. Evaluate strengths and limitations of models of our solar system in describing relative size, order, appearance, and composition of planets and the sun.
(*Clarification statement:* Composition of planets is limited to rocky vs. gaseous.)

S4E2. Obtain, evaluate, and communicate information to model the effects of the position and motion of the Earth and the moon in relation to the sun as observed from the Earth.

a. Develop a model to support an explanation of why the length of day and night change throughout the year.

b. Develop a model based on observations to describe the repeating pattern of the phases of the moon (new, crescent, quarter, gibbous, and full).

c. Construct an explanation of how the Earth's orbit, with its consistent tilt, affects seasonal changes.

S4E3. Obtain, evaluate, and communicate information to demonstrate the water cycle.

a. Plan and carry out investigations to observe the flow of energy in water as it changes states from solid (ice) to liquid (water) to gas (water vapor) and changes from gas to liquid to solid.

b. Develop models to illustrate multiple pathways water may take during the water cycle (evaporation, condensation, and precipitation).
(*Clarification statement:* Students should understand that the water cycle does not follow a single pathway.)

S4E4. Obtain, evaluate, and communicate information using weather charts/maps and collect weather data to predict weather events and infer weather patterns.

a. Ask questions to explain how weather instruments (thermometer, rain gauge, barometer, wind vane, and anemometer) are used in gathering weather data and making forecasts.

b. Interpret data from weather maps to identify fronts (warm, cold, and stationary), temperature, and precipitation to make an informed prediction about tomorrow's weather.
c. Ask questions and use observations of cloud types (cirrus, stratus, and cumulus) and data of weather conditions to predict weather events and patterns throughout the year.
d. Construct an explanation based on research to communicate the difference between weather and climate.

Physical Science

S4P1. Obtain, evaluate, and communicate information about the nature of light and how light interacts with objects.

a. Plan and carry out investigations to observe and record how light interacts with various materials to classify them as opaque, transparent, or translucent.
b. Plan and carry out investigations on the path light travels from a light source to a mirror and how it is reflected by the mirror using different angles.
c. Plan and carry out an investigation utilizing everyday materials to explore examples of when light is refracted.
(*Clarification statement:* Everyday materials could include prisms, eyeglasses, and a glass of water.)

S4P2. Obtain, evaluate, and communicate information about how sound is produced and changed and how sound and/or light can be used to communicate.

a. Plan and carry out an investigation utilizing everyday objects to produce sound and predict the effects of changing the strength or speed of vibrations.
b. Design and construct a device to communicate across a distance using light and/or sound.

S4P3. Obtain, evaluate, and communicate information about the relationship between balanced and unbalanced forces.

a. Plan and carry out an investigation on the effects of balanced and unbalanced forces on an object and communicate the results.
b. Construct an argument to support the claim that gravitational force affects the motion of an object.
c. Ask questions to identify and explain the uses of simple machines (lever, pulley, wedge, inclined plane, wheel and axle, and screw) and how forces are changed when simple machines are used to complete tasks.
(*Clarification statement:* The use of mathematical formulas is not expected.)

Life Science

S4L1. Obtain, evaluate, and communicate information about the roles of organisms and the flow of energy within an ecosystem.

a. Develop a model to describe the roles of producers, consumers, and decomposers in a community.
(*Clarification statement:* Students are not expected to identify the different types of consumers – herbivores, carnivores, omnivores, and scavengers.)

b. Develop simple models to illustrate the flow of energy through a food web/food chain beginning with sunlight and including producers, consumers, and decomposers.

c. Communicate a scenario to demonstrate the effect of a change on an ecosystem. (*Clarification statement:* Include living and non-living factors in the scenario.)

d. Use printed and digital data to develop a model illustrating and describing changes to the flow of energy in an ecosystem when plants or animals become scarce, extinct, or over-abundant.

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The Fifth Grade Georgia Standards of Excellence for science engage students in investigations of scientific concepts. Students are active learners and use hand on activities to discover and explain phenomena. They understand that science is a process for gaining knowledge about the natural world and are able to conduct experiments and report their findings in the form of written reports, charts, and various other presentations including multi-media projects. Their scientific explanations emphasize evidence and begin to use scientific principles, models, and theories.

Fifth graders keep records of investigations and observations and understand why they should not alter records. They use numerical data to describe and compare objects, convert the fractions to decimals in scientific calculations, and identify the largest and smallest possible value of something. They use reference books, back issues of magazines or newspapers, and computer databases to locate scientific information.

Students at this grade level are able to identify the causes of some of Earth's surface features, explain the difference between a physical and a chemical change, investigate electricity and magnetism and the relationship between them, use scientific procedures to classify organisms, understand the difference between behaviors and traits, contrast the parts of animal and plant cells, and argue from evidence on how microorganisms can be beneficial or harmful to other organisms.

Fifth Grade Standards

Earth Science

S5E1. Obtain, evaluate, and communicate information to identify surface features on the Earth caused by constructive and/or destructive processes.

a. Construct an argument supported by scientific evidence to identify surface features (examples could include deltas, sand dunes, mountains, volcanoes) as being caused by constructive and/or destructive processes (examples could include deposition, weathering, erosion, and impact of organisms).

b. Develop simple interactive models to collect data that illustrate how changes in surface features are/were caused by constructive and/or destructive processes.

c. Ask questions to obtain information on how technology is used to limit and/or predict the impact of constructive and destructive processes.
(*Clarification statement:* Examples could include seismological studies, flood forecasting (GIS maps), engineering/construction methods and materials, and infrared/satellite imagery.)

Physical Science

S5P1. Obtain, evaluate, and communicate information to explain the differences between a physical change and a chemical change.

a. Plan and carry out investigations by manipulating, separating, and mixing dry and liquid materials and communicate collected data to demonstrate examples of physical change.

b. Construct an argument based on observations that the physical changes in the state of water are due to temperature differences, which cause small particles that cannot be seen to move differently.

c. Plan and carry out an investigation to determine if a chemical change occurred based on observable evidence (color, gas, temperature change, odor, new substance produced).

S5P2. Obtain, evaluate, and communicate information to investigate electricity.

a. Obtain and combine information from multiple sources to explain the difference between naturally occurring electricity (static) and human-harnessed electricity.

b. Design a complete, simple electric circuit, and explain all necessary components.

c. Investigate and test common materials to determine if they are insulators or conductors of electricity.

S5P3. Obtain, evaluate, and communicate information about magnetism and its relationship to electricity.

a. Construct an argument based on experimental evidence to communicate the differences in function and purpose of an electromagnet and magnet.

(*Clarification statement:* Function is limited to understanding temporary and permanent magnetism.)

b. Plan and carry out an investigation to observe the interaction between a magnet and a magnetic object on opposite sides of various materials such as wood, paper, glass, metal, and rocks.

Life Science

S5L1. Obtain, evaluate, and communicate information to group organisms using scientific classification procedures.

a. Develop a model that illustrates how animals are sorted into groups (vertebrate and invertebrate) and how vertebrates are sorted into groups (fish, amphibians, reptiles, bird, and mammal) using data from multiple sources.
b. Develop a model that illustrates how plants are sorted into groups (seed producers, non-seed producers) using data from multiple sources.

S5L2. Obtain, evaluate, and communicate information showing that some characteristics of organisms are inherited and other characteristics are acquired.

a. Ask questions to compare and contrast the characteristics of instincts and learned behaviors.
b. Ask questions to compare and contrast inherited and acquired physical traits. (*Clarification statement:* Punnett squares and genetics are taught in future grades.)

S5L3. Obtain, evaluate, and communicate information to compare and contrast the parts of plant and animal cells.

a. Gather evidence by utilizing technology tools to construct an explanation that plants and animals are comprised of cells too small to be seen without magnification.
b. Develop a model to identify and label parts of a plant cell (membrane, wall, cytoplasm, nucleus, chloroplasts) and of an animal cell (membrane, cytoplasm, and nucleus).
c. Construct an explanation that differentiates between the structure of plant and animal cells.

S5L4. Obtain, evaluate, and communicate information about how microorganisms benefit or harm larger organisms.

(*Clarification statement:* Possible microorganisms could include Tardigrades, Lactobacillus, Probiotics, Rotifers, Salmonella, Clostridium botulinum (Botox), E-coli, Algae, etc. Students are not expected to know these specific organisms. The list is provided to give teachers examples.)

a. Construct an argument using scientific evidence to support a claim that microorganisms are beneficial.

b. Construct an argument using scientific evidence to support a claim that microorganisms are harmful.

Sixth Grade – Earth Science Standards

The Science Georgia Standards of Excellence are designed to provide foundational knowledge and skills for all students to develop proficiency in science. The Project 2061's *Benchmarks for Science Literacy* and the follow up work, *A Framework for K-12 Science Education* were used as the core of the standards to determine appropriate content and process skills for students. The Science Georgia Standards of Excellence focus on a limited number of core disciplinary ideas and crosscutting concepts which build from Kindergarten to high school. The standards are written with the core knowledge to be mastered integrated with the science and engineering practices needed to engage in scientific inquiry and engineering design.

The Science Georgia Standards of Excellence drive instruction. Hands-on, student-centered, and inquiry-based approaches should be the emphasis of instruction. The standards are a required minimum set of expectations that show proficiency in science. However, instruction can extend beyond these minimum expectations to meet student needs. At the same time, these standards set a maximum expectation on what will be assessed by the Georgia Milestones Assessment System.

Science consists of a way of thinking and investigating, as well a growing body of knowledge about the natural world. To become literate in science, students need to possess sufficient understanding of fundamental science content knowledge, the ability to engage in the science and engineering practices, and to use scientific and technological information correctly. Technology should be infused into the curriculum and the safety of the student should always be foremost in instruction.

The Sixth Grade Georgia Standards of Excellence for science are designed to give all students an overview of common strands in earth science including, but not limited to, meteorology, geology, astronomy, oceanography, resources, and human impact on the Earth.

Students use records they keep and analyze the data they collect. They observe and explain how an aspect of weather can affect a weather system and construct explanations based on evidence of the role of water in Earth processes. The students recognize how the presence of land and water in combination with the energy from the sun affect the climate and weather of a region. They use different models to represent systems such as the solar system and the sun/moon/Earth system. They study uses and conservation of Earth's natural resources. They use what they observe about the Earth's materials to infer the processes and timelines that formed them. Sixth graders write instructions, describe observations, and show information in graphical form. When analyzing the data they collect, sixth graders can recognize relationships in simple charts and graphs and find more than one way to interpret their findings. They replicate investigations and compare results to find similarities and differences.

Sixth Grade Standards

S6E1. Obtain, evaluate, and communicate information about current scientific views of the universe and how those views evolved.

a. Ask questions to determine changes in models of Earth's position in the solar system, and origins of the universe as evidence that scientific theories change with the addition of new information.
(*Clarification statement:* Students should consider Earth's position in geocentric and heliocentric models and the Big Bang as it describes the formation of the universe.)

b. Develop a model to represent the position of the solar system in the Milky Way galaxy and in the known universe.

c. Analyze and interpret data to compare the planets in terms of:
- size relative to Earth,
- surface and atmospheric features,
- relative distance from the sun, and
- ability to support life.

d. Develop and use a model to explain the interaction of gravity and inertia that governs the motion of objects in the solar system.

e. Ask questions to compare and contrast the characteristics, composition, and location of comets, asteroids, and meteoroids.

S6E2. Obtain, evaluate, and communicate information about the effects of the relative positions of the sun, Earth, and moon.

a. Develop and use a model to demonstrate the phases of the moon by showing the relative positions of the sun, Earth, and moon.

b. Construct an explanation of the alignment of the sun, Earth, and moon during solar and lunar eclipses.

c. Analyze and interpret data to relate the tilt of the Earth to the distribution of sunlight throughout the year and its effect on seasons.

S6E3. Obtain, evaluate, and communicate information to recognize the significant role of water in Earth processes.

a. Ask questions to determine where water is located on Earth's surface (oceans, rivers, lakes, groundwater, aquifers, and ice), and communicate the relative proportion of water at each location using a circle/pie graph.

b. Plan and carry out an investigation to illustrate the role of the sun's energy in atmospheric conditions that lead to the cycling of water.
(*Clarification statement:* The water cycle should include evaporation, condensation, precipitation, transpiration, infiltration, groundwater, and runoff.)

c. Ask questions to identify and communicate using graphs and maps the composition, location, and subsurface topography of the world's oceans.
d. Analyze and interpret data to create graphic representations of the causes and effects of waves, currents, and tides in Earth's systems.

S6E4. Obtain, evaluate, and communicate information about how the sun, land, and water affect climate and weather.

a. Analyze and interpret data to compare and contrast the of Earth's atmospheric layers (including the ozone layer) and greenhouse gases.
(*Clarification statement:* Earth's atmospheric layers include the troposphere, stratosphere, mesosphere, and thermosphere.)
b. Plan and carry out an investigation to demonstrate how energy from the sun transfers heat to air, land and water at different rates.
(*Clarification statement:* Heat transfer should include the processes of conduction, convection and radiation.)
c. Develop a model demonstrating the interaction between unequal heating and the rotation of the Earth that causes local and global wind systems.
d. Construct an explanation of the relationship between air pressure, fronts, and air masses and meteorological events such as tornados and thunderstorms.
e. Analyze and interpret weather data to explain the effects of moisture evaporating from the ocean on weather patterns and weather events such as hurricanes.

S6E5. Obtain, evaluate, and communicate information to show how Earth's surface is formed.

a. Ask questions to compare and contrast the Earth's crust, mantle, inner and outer core, including temperature, density, thickness, and composition.
b. Plan and carry out an investigation of the characteristics of minerals and how minerals contribute to rock composition.
c. Construct an explanation of how to classify rocks by their formation and how rocks change through geologic processes in the rock cycle.
d. Ask questions to identify types of weathering, agents of erosion and transportation, and environments of deposition.
(*Clarification statement:* Environments of deposition include deltas, barrier islands, beaches, marshes, and rivers.)
e. Develop a model to demonstrate how natural processes (weathering, erosion, and deposition) and human activity change rocks and the surface of the Earth.
f. Construct an explanation of how the movement of lithospheric plates (convergent boundary, divergent boundary, transform boundary), called plate tectonics, is due to convection currents below the lithosphere, and can cause major geologic events such as earthquakes and volcanic eruptions.

g. Construct an argument using maps and data collected to support a claim of how fossils show evidence of the changing surface and climate of the Earth.
h. Plan and carry out an investigation to provide evidence that soil is composed of layers of weathered rocks and decomposed organic material.

S6E6. Obtain, evaluate, and communicate information about the uses and conservation of various natural resources and how they impact the Earth.

a. Ask questions to determine the differences between renewable/sustainable energy resources (i.e., hydro, solar, wind, geothermal, tidal, and biomass) and nonrenewable energy resources (i.e., nuclear: uranium, and fossil fuels: oil, coal, and natural gas), and how they are used in our everyday lives.
b. Design and evaluate solutions for sustaining the quality and supply of natural resources such as water, soil, and air.
c. Construct an argument evaluating contributions to a rise in global temperatures over the past century.
(*Clarification statement:* Tables, graphs, and maps of global and regional temperatures, and atmospheric levels of greenhouse gases such as carbon dioxide and methane, should be used as sources of evidence.)

Seventh Grade – Life Science Standards

The Science Georgia Standards of Excellence are designed to provide foundational knowledge and skills for all students to develop proficiency in science. The Project 2061's *Benchmarks for Science Literacy* and the follow up work, *A Framework for K-12 Science Education* were used as the core of the standards to determine appropriate content and process skills for students. The Science Georgia Standards of Excellence focus on a limited number of core disciplinary ideas and crosscutting concepts which build from Kindergarten to high school. The standards are written with the core knowledge to be mastered integrated with the science and engineering practices needed to engage in scientific inquiry and engineering design.

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The Seventh Grade Georgia Standards of Excellence for science are designed to give all students the necessary skills for a smooth transition from elementary life science standards to high school biology standards. The purpose is to give all students an overview of common strands in life science including, but not limited to, diversity of living organisms, structure and function of cells, heredity, ecosystems, and biological evolution.

Seventh grade students keep records of their observations and use those records to analyze the data they collect. They make and use observations to explain diversity of living organisms and how the organisms are classified, how they reproduce and how genetic information is passed from parents to their offspring. They use different models to represent systems such as cells, tissues, and organs. They use what they know about ecosystems to explain the cycling of matter and energy. They use the concepts of natural selection and fossil evidence in explanations. Seventh graders write instructions, describe observations, and show information in graphical form. When analyzing the data they collect, seventh graders can recognize relationships in simple charts and graphs and find more than one way to interpret their findings. The students replicate investigations and compare results to find similarities and differences.

Seventh Grade Standards

S7L1. Obtain, evaluate, and communicate information to investigate the diversity of living organisms and how they can be compared scientifically.

a. Develop and defend a model that categorizes organisms based on common characteristics.

b. Evaluate historical models of how organisms were classified based on physical characteristics and how that led to the six kingdom system (currently archaea, bacteria, protists, fungi, plants, and animals).
(*Clarification statement:* This includes common examples and characteristics such as, but not limited to, prokaryotic, eukaryotic, unicellular, multicellular, asexual reproduction, sexual reproduction, autotroph, heterotroph, and unique cell structures. Modern classification will be addressed in high school.)

S7L2. Obtain, evaluate, and communicate information to construct scientific explanations to describe how cell structures, cells, tissues, organs, and organ systems interact to maintain the basic needs of organisms.

a. Develop a model and construct an explanation of how cell structures (specifically the nucleus, cytoplasm, cell membrane, cell wall, chloroplasts, lysosome, and mitochondria) contribute to the function of the cell as a system in obtaining nutrients in order to grow, reproduce, make needed materials, and process waste.
(*Clarification statement:* The intent is for students to demonstrate how the component structures of the cell interact and work together to allow the cell as a whole to carry out various processes. Additional structures, beyond those listed, will be addressed in high school Biology.)

b. Develop and use a conceptual model of how cells are organized into tissues, tissues into organs, organs into systems, and systems into organisms.

c. Construct an argument that systems of the body (Cardiovascular, Excretory, Digestive, Respiratory, Muscular, Nervous, and Immune) interact with one another to carry out life processes.
(*Clarification statement:* The emphasis is not on learning individual structures and functions associated with each system, but on how systems interact to support life processes.)

S7L3. Obtain, evaluate, and communicate information to explain how organisms reproduce either sexually or asexually and transfer genetic information to determine the traits of their offspring.

a. Construct an explanation supported with scientific evidence of the role of genes and chromosomes in the process of inheriting a specific trait.

b. Develop and use a model to describe how asexual reproduction can result in offspring with identical genetic information while sexual reproduction results in genetic variation.
(*Clarification statement:* Models could include, but are not limited to, the use of monohybrid Punnett squares to demonstrate the heritability of genes and the resulting genetic variation, identification of heterozygous and homozygous, and comparison of genotype vs. phenotype.)
c. Ask questions to gather and synthesize information about the ways humans influence the inheritance of desired traits in organisms through selective breeding.
(*Clarification statement:* The element specifically refers to artificial selection and the ways in which it is fundamentally different than natural selection.)

S7L4. Obtain, evaluate, and communicate information to examine the interdependence of organisms with one another and their environments.

a. Construct an explanation to describe the patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of the ecosystem.
(*Clarification statement:* The interactions include, but are not limited to, predator-prey relationships, competition, mutualism, parasitism, and commensalism.)
b. Develop a model to describe the cycling of matter and the flow of energy among biotic and abiotic components of an ecosystem.
(*Clarification statement:* Emphasis is on tracing movement of matter and flow of energy, not on the biochemical mechanisms of photosynthesis and cellular respiration.)
c. Analyze and interpret data to provide evidence for how resource availability, disease, climate, and human activity affect individual organisms, populations, communities, and ecosystems.
d. Ask questions to gather and synthesize information from multiple sources to differentiate between Earth's major terrestrial biomes (i.e., tropical rain forest, savanna, temperate forest, desert, grassland, taiga, and tundra) and aquatic ecosystems (i.e., freshwater, estuaries, and marine).
(Clarification statement: Emphasis is on the factors that influence patterns across biomes such as the climate, availability of food and water, and location.)

S7L5. Obtain, evaluate, and communicate information from multiple sources to explain the theory of evolution of living organisms through inherited characteristics.

a. Use mathematical representations to evaluate explanations of how natural selection leads to changes in specific traits of populations over successive generations.
(*Clarification statement:* Referencing data should be obtained from multiple sources including, but not limited to, existing research and simulations. Students

should be able to calculate means, represent this data in a table or graph, and reference it when explaining the principles of natural selection.)

b. Construct an explanation based on evidence that describes how genetic variation and environmental factors influence the probability of survival and reproduction of a species.
c. Analyze and interpret data for patterns in the fossil record that document the existence, diversity, and extinction of organisms and their relationships to modern organisms.
(*Clarification statement:* Evidence of evolution found in comparisons of current/modern organisms such as homologous structures, DNA, and fetal development will be addressed in high school.)

Eighth Grade – Physical Science Standards

The Science Georgia Standards of Excellence are designed to provide foundational knowledge and skills for all students to develop proficiency in science. The Project 2061's *Benchmarks for Science Literacy* and the follow up work, *A Framework for K-12 Science Education* were used as the core of the standards to determine appropriate content and process skills for students. The Science Georgia Standards of Excellence focus on a limited number of core disciplinary ideas and crosscutting concepts which build from Kindergarten to high school. The standards are written with the core knowledge to be mastered integrated with the science and engineering practices needed to engage in scientific inquiry and engineering design.

The Science Georgia Standards of Excellence drive instruction. Hands-on, student-centered, and inquiry-based approaches should be the emphasis of instruction. The standards are a required minimum set of expectations that show proficiency in science. However, instruction can extend beyond these minimum expectations to meet student needs. At the same time, these standards set a maximum expectation on what will be assessed by the Georgia Milestones Assessment System.

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The Eighth Grade Georgia Standards of Excellence for science are designed to give all students the necessary skills for a smooth transition from elementary physical science standards to high school physical science standards. The purpose is to give all students an overview of common strands in physical science including, but not limited to, the nature of matter, laws of energy, matter, motion and forces, and energy transformation. These standards are not intended in any way to take the place of the high school physical science standards.

Eighth grade students record their observations clearly and accurately. They keep records and analyze the data they collect. They work conceptually on the laws of physical science (conservation of matter, conservation of energy, motion and forces, and energy transformation). They use what they observe to explain the difference between physical and chemical changes and cause and effect relationships between force, mass, and the motion of objects. Students in eighth grade construct explanations based on evidence on the difference and similarities between electromagnetic and mechanical waves. Eighth graders write instructions, describe observations, and show information in graphical form. When analyzing the data they collect, eighth graders can recognize relationships in simple charts and graphs and find more than one way to interpret their findings.

Eighth Grade Standards

S8P1. Obtain, evaluate, and communicate information about the structure and properties of matter.

a. Develop and use a model to compare and contrast pure substances (elements and compounds) and mixtures.
(*Clarification statement:* Include heterogeneous and homogeneous mixtures. Types of bonds and compounds will be addressed in high school physical science.)

b. Develop and use models to describe the movement of particles in solids, liquids, gases, and plasma states when thermal energy is added or removed.

c. Plan and carry out investigations to compare and contrast chemical (i.e., reactivity, combustibility) and physical properties of matter (i.e., density, melting point, boiling point).

d. Construct an argument to support the claim that when a change occurs it is either chemical or physical.
(*Clarification statement:* Evidence could include ability to separate mixtures, development of a gas, formation of a precipitate, change in energy, color, and/or form.)

e. Develop models (e.g., atomic-level models, including drawings, and computer representations) by analyzing patterns within the periodic table that illustrate the structure, composition, and characteristics of atoms (including protons, neutrons, and electrons) and simple molecules.

f. Construct an explanation based on evidence to describe conservation of matter and mass in a chemical reaction including the resulting differences between products and reactants.
(*Clarification statement:* Evidence could include models with balanced chemical equations.)

S8P2. Obtain, evaluate, and communicate information about the law of conservation of energy to develop arguments that energy can transform from one form to another within a system.

a. Analyze and interpret data to create graphical displays that illustrate the relationships of kinetic energy to mass and speed and potential energy to mass and height of an object.

b. Plan and carry out an investigation to explain the transformation between kinetic and potential energy within a system (e.g., roller coasters, pendulums, rubber bands).

c. Construct an explanation about energy transformations within a system [e.g., lighting a match (light to heat), turning on a light (electrical to light)].

d. Plan and carry out investigations on the effects of heat transfer on molecular motion as it relates to the collision of atoms (conduction), through space (radiation), or in currents in a liquid or a gas (convection).

S8P3. Obtain, evaluate, and communicate information about cause and effect relationships between force, mass, and the motion of objects.

a. Analyze and interpret data to identify patterns in the relationships between speed and distance, and velocity and acceleration.
(*Clarification statement:* Students should be able to analyze motion graphs, but students should not be expected to calculate velocity or acceleration.)
b. Construct an explanation using Newton's Laws of Motion to describe the effects of balanced and unbalanced forces on the motion of an object.
c. Construct an argument from evidence to support the claim that heavier objects require a greater force to accelerate (inertia).

S8P4. Obtain, evaluate, and communicate information to support the claim that electromagnetic (light) waves behave differently than mechanical (sound) waves.

a. Ask questions to develop explanations about the similarities and differences between electromagnetic and mechanical waves.
(*Clarification statement:* Include transverse and longitudinal waves and wave parts such as crest, trough, compressions, and rarefactions.)
b. Construct an explanation using data to illustrate the relationship between the electromagnetic spectrum and energy.
c. Obtain, evaluate, and communicate information to explain practical applications of the electromagnetic spectrum (e.g., communication, medical, military).
d. Develop and use a model to compare and contrast how light and sound waves are reflected, refracted, absorbed, diffracted, or transmitted through various materials.
(*Clarification statement:* Include echo and how color is seen but not interference and scattering.)
e. Analyze and interpret data to predict patterns in the relationship between density of media and wave behavior (i.e., speed).
f. Develop and use a model (e.g., simulations, graphs, illustrations) to predict and describe the relationships between wave properties (e.g., frequency, amplitude, and wavelength) and energy.
g. Develop and use models to demonstrate the effects and functions of lenses.

S8P5. Obtain, evaluate, and communicate information about the phenomena of gravity, electricity, and magnetism as major forces acting in nature.

a. Construct an argument using evidence to support the claim that fields (i.e., magnetic fields, gravitational fields, and electric fields) exist between objects exerting forces on each other even when the objects are not in contact.

b. Plan and carry out investigations to demonstrate the distribution of charge in conductors and insulators.
(*Clarification statement:* Include conduction, induction, and friction.)

c. Plan and carry out investigations to identify factors (e.g., distance between objects, magnetic force produced by an electromagnet with varying number of wire turns, varying number or size of dry cells, and varying size of iron core) that affect the strength of electric and magnetic forces.
(*Clarification statement:* The investigations included, but are not limited to, generators or motors.)

Biology Standards

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The Biology Georgia Standards of Excellence are designed to continue the student investigations of the life sciences that began in grades K-8 and provide students the necessary skills to be proficient in biology by focusing on the identification of patterns, processes, and relationships of living organisms. These standards include more abstract concepts such as the interdependence of organisms, the relationship of matter, energy, and organization in living systems, the behavior of organisms, and biological evolution. Students investigate biological concepts through experiences in laboratories and field work using the process of inquiry.

Biology students start by developing an understanding of the cellular structure and the role these structures play in living cells. The students then analyze how genetic information is passed to their offspring and how these mechanisms lead to variability and hence diversity of species. They use cladograms and phylogenetic trees to determine relationships among major groups of organisms. Biology students are able to recognize the central role the theory of evolution plays in explaining how the diversity observed within species has led to the diversity of life across species through a process of descent with adaptive modification.

Biology Standards

SB1. Obtain, evaluate, and communicate information to analyze the nature of the relationships between structures and functions in living cells.

a. Construct an explanation of how cell structures and organelles (including nucleus, cytoplasm, cell membrane, cell wall, chloroplasts, lysosome, Golgi, endoplasmic reticulum, vacuoles, ribosomes, and mitochondria) interact as a system to maintain homeostasis.

b. Develop and use models to explain the role of cellular reproduction (including binary fission, mitosis, and meiosis) in maintaining genetic continuity.

c. Construct arguments supported by evidence to relate the structure of macromolecules (carbohydrates, proteins, lipids, and nucleic acids) to their interactions in carrying out cellular processes.
(*Clarification statement:* The function of proteins as enzymes is limited to a conceptual understanding.)

d. Plan and carry out investigations to determine the role of cellular transport (e.g., active transport, passive transport, diffusion, and osmosis) in maintaining homeostasis.

e. Ask questions to investigate and provide explanations about the roles of photosynthesis and respiration in the cycling of matter and energy within the cell (e.g., single-celled alga).
(*Clarification statement:* Instruction should focus on understanding the inputs, outputs, and functions of photosynthesis and respiration and the functions of the major sub-processes of each, including glycolysis, Krebs cycle, electron transport chain, light reactions, and Calvin cycle.)

SB2. Obtain, evaluate, and communicate information to analyze how genetic information is expressed in cells.

a. Construct an explanation of how the structures of DNA and RNA lead to the expression of information within the cell via the processes of replication, transcription, and translation.

b. Construct an argument based on evidence to support the claim that inheritable genetic variations may result from:
- new genetic combinations through meiosis (crossing over, nondisjunction);
- non-lethal errors occurring during replication (insertions, deletions, substitutions); and/or
- heritable mutations caused by environmental factors (radiation, chemicals, and viruses).

c. Ask questions to gather and communicate information about the use and ethical considerations of biotechnology in forensics, medicine, and agriculture.

(*Clarification statement:* The element is intended to include advancements in technology relating to economics and society. Such advancements may include Genetically Modified Organisms.)

SB3. Obtain, evaluate, and communicate information to analyze how biological traits are passed on to successive generations.

a. Use Mendel's laws (segregation and independent assortment) to ask questions and define problems that explain the role of meiosis in reproductive variability.
b. Use mathematical models to predict and explain patterns of inheritance. (*Clarification statement:* Students should be able to use Punnett squares (monohybrid and dihybrid crosses) and/or rules of probability to analyze the following inheritance patterns: dominance, codominance, incomplete dominance.)
c. Construct an argument to support a claim about the relative advantages and disadvantages of sexual and asexual reproduction.

SB4. Obtain, evaluate, and communicate information to illustrate the organization of interacting systems within single-celled and multi-celled organisms.

a. Construct an argument supported by scientific information to explain patterns in structures and function among clades of organisms, including the origin of eukaryotes by endosymbiosis. Clades should include:
   - archaea
   - bacteria
   - eukaryotes
     - fungi
     - plants
     - animals

   (*Clarification statement:* This is reflective of 21st century classification schemes and nested hierarchy of clades and is intended to develop a foundation for comparing major groups of organisms. The term 'protist' is useful in describing those eukaryotes that are not within the animal, fungal or plant clades but the term does not describe a well-defined clade or a natural taxonomic group.)
b. Analyze and interpret data to develop models (i.e., cladograms and phylogenetic trees) based on patterns of common ancestry and the theory of evolution to determine relationships among major groups of organisms.
c. Construct an argument supported by empirical evidence to compare and contrast the characteristics of viruses and organisms.

SB5. Obtain, evaluate, and communicate information to assess the interdependence of all organisms on one another and their environment.

a. Plan and carry out investigations and analyze data to support explanations about factors affecting biodiversity and populations in ecosystems.

(*Clarification statement:* Factors include size, carrying capacity, response to limiting factors, and keystone species.)

b. Develop and use models to analyze the cycling of matter and flow of energy within ecosystems through the processes of photosynthesis and respiration by
   - Arranging components of a food web according to energy flow.
   - Comparing the quantity of energy in the steps of an energy pyramid.
   - Explaining the need for cycling of major biochemical elements (C, O, N, P, and H).

c. Construct an argument to predict the impact of environmental change on the stability of an ecosystem.

d. Design a solution to reduce the impact of a human activity on the environment. (*Clarification statement:* Human activities may include chemical use, natural resources consumption, and introduction of non-native species, and greenhouse gas production.)

e. Construct explanations that predict an organism's ability to survive within changing environmental limits (e.g., temperature, pH, drought, fire).

SB6. Obtain, evaluate, and communicate information related to the theory of evolution.

a. Construct an explanation of how new understandings of Earth's history, the emergence of new species from pre-existing species, and our understanding of genetics have influenced our understanding of biology.

b. Analyze and interpret data to explain patterns in biodiversity that result from speciation.

c. Construct an argument using valid and reliable sources to support the claim that evidence from comparative morphology (analogous vs. homologous structures), embryology, biochemistry (protein sequence) and genetics support the theory that all living organisms are related by way of common descent.

d. Develop and use mathematical models to support explanations of how undirected genetic changes in natural selection and genetic drift have led to changes in populations of organisms.
(*Clarification statement:* This element is intended to focus on basic statistical and graphic analysis. Hardy Weinberg would be an optional application to address this element.)

e. Develop a model to explain the role natural selection plays in causing biological resistance (e.g., pesticides, antibiotic resistance, and influenza vaccines).

Chemistry Standards

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The Chemistry Georgia Standards of Excellence are designed to continue student investigations of the physical sciences that began in grades K-8 and provide students the necessary skills to be proficient in chemistry. These standards include more abstract concepts such as the structure of atoms, structure and properties of matter, the conservation and interaction of energy and matter, and the use of Kinetic Molecular Theory to model atomic and molecular motion in chemical and physical processes. Students investigate chemistry concepts through experiences in laboratories and field work using the process of inquiry.

Chemistry students use the periodic table to help with the identification of elements with particular properties, recognize patterns that lead to explain chemical reactivity and bond formation. They use the IUPAC nomenclature in order to predict chemical names for ionic (binary and ternary), acidic, and inorganic covalent compounds, and conduct experiments to manipulate factors that affect chemical reactions.

Chemistry Standards

SC1. Obtain, evaluate, and communicate information about the use of the modern atomic theory and periodic law to explain the characteristics of atoms and elements.

a. Evaluate the merits and limitations of different models of the atom in relation to relative size, charge, and position of protons, neutrons, and electrons in the atom.
b. Construct an argument to support the claim that the proton (and not the neutron or electron) defines the element's identity.
c. Construct an explanation, based on scientific evidence, of the production of elements heavier than hydrogen by nuclear fusion.
d. Construct an explanation that relates the relative abundance of isotopes of a particular element to the atomic mass of the element.
e. Construct an explanation of light emission and the movement of electrons to identify elements.
f. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms (including atomic radii, ionization energy, and electronegativity of various elements).
g. Develop and use models including electron configuration of atoms and ions to predict an element's chemical properties.

SC2. Obtain, evaluate, and communicate information about the chemical and physical properties of matter resulting from the ability of atoms to form bonds.

a. Plan and carry out an investigation to gather evidence to compare the physical and chemical properties at the macroscopic scale to infer the strength of intermolecular and intramolecular forces.
b. Construct an argument by applying principles of inter- and intra- molecular forces to identify substances based on chemical and physical properties.
c. Construct an explanation about the importance of molecular-level structure in the functioning of designed materials.
(*Clarification statement:* Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.)
d. Develop and use models to evaluate bonding configurations from nonpolar covalent to ionic bonding.
(*Clarification statement:* VSEPR theory is not addressed in this element.)
e. Ask questions about chemical names to identify patterns in IUPAC nomenclature in order to predict chemical names for ionic (binary and ternary), acidic, and inorganic covalent compounds.

f. Develop and use bonding models to predict chemical formulas including ionic (binary and ternary), acidic, and inorganic covalent compounds.
g. Develop a model to illustrate the release or absorption of energy (endothermic or exothermic) from a chemical reaction system depends upon the changes in total bond energy.

SC3. Obtain, evaluate, and communicate information about how the Law of Conservation of Matter is used to determine chemical composition in compounds and chemical reactions.

a. Use mathematics and computational thinking to balance chemical reactions (i.e., synthesis, decomposition, single replacement, double replacement, and combustion) and construct an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
b. Plan and carry out investigations to determine that a new chemical has formed by identifying indicators of a chemical reaction (specifically precipitate formation, gas evolution, color change, water production, and changes in energy to the system should be investigated).
c. Use mathematics and computational thinking to apply concepts of the mole and Avogadro's number to conceptualize and calculate:
   - percent composition
   - empirical/molecular formulas
   - mass, moles, and molecules relationships
   - molar volumes of gases
d. Use mathematics and computational thinking to identify and solve different types of reaction stoichiometry problems (i.e., mass to moles, mass to mass, moles to moles, and percent yield) using significant figures.
   (*Clarification statement for elements c and d:* Emphasis is on use of mole ratios to compare quantities of reactants or products and on assessing students' use of mathematical thinking and is not on memorization and rote application of problem-solving techniques.)
e. Plan and carry out an investigation to demonstrate the conceptual principle of limiting reactants.

SC4. Obtain, evaluate, and communicate information about how to refine the design of a chemical system by applying engineering principles to manipulate the factors that affect a chemical reaction.

a. Plan and carry out an investigation to provide evidence of the effects of changing concentration, temperature, and pressure on chemical reactions.
   (*Clarification statement:* Pressure should not be tested experimentally.)

b. Construct an argument using collision theory and transition state theory to explain the role of activation energy in chemical reactions.
(*Clarification statement:* Reaction coordinate diagrams could be used to visualize graphically changes in energy (direction flow and quantity) during the progress of a chemical reaction.)
c. Construct an explanation of the effects of a catalyst on chemical reactions and apply it to everyday examples.
d. Refine the design of a chemical system by altering the conditions that would change forward and reverse rates and the amount of products at equilibrium.
(*Clarification statement:* Emphasis is on the application of LeChatelier's principle.)

SC5. Obtain, evaluate, and communicate information about the Kinetic Molecular Theory to model atomic and molecular motion in chemical and physical processes.

a. Plan and carry out an investigation to calculate the amount of heat absorbed or released by chemical or physical processes.
(*Clarification statement:* Calculation of the enthalpy, heat change, and Hess's Law are addressed in this element.)
b. Construct an explanation using a heating curve as evidence of the effects of energy and intermolecular forces on phase changes.
c. Develop and use models to quantitatively, conceptually, and graphically represent the relationships between pressure, volume, temperature, and number of moles of a gas.

SC6. Obtain, evaluate, and communicate information about the properties that describe solutions and the nature of acids and bases.

a. Develop a model to illustrate the process of dissolving in terms of solvation versus dissociation.
b. Plan and carry out an investigation to evaluate the factors that affect the rate at which a solute dissolves in a specific solvent.
c. Use mathematics and computational thinking to evaluate commercial products in terms of their concentrations (i.e., molarity and percent by mass).
d. Communicate scientific and technical information on how to prepare and properly label solutions of specified molar concentration.
e. Develop and use a model to explain the effects of a solute on boiling point and freezing point.
f. Use mathematics and computational thinking to compare, contrast, and evaluate the nature of acids and bases in terms of percent dissociation, hydronium ion concentration, and pH.
(*Clarification statement:* Understanding of the mathematical relationship between negative logarithm of the hydrogen concentration and pH is not expected in this

element. Only a conceptual understanding of pH as related to acid/basic conditions is needed.)

g. Ask questions to evaluate merits and limitations of the Arrhenius and Bronsted-Lowry models of acid and bases.
h. Plan and carry out an investigation to explore acid-base neutralization.

Earth Systems Standards

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The Science Georgia Standards of Excellence drive instruction. Hands-on, student-centered, and inquiry-based approaches should be the emphasis of instruction. The standards are a required minimum set of expectations that show proficiency in science. However, instruction can extend beyond these minimum expectations to meet student needs. At the same time, these standards set a maximum expectation on what will be assessed by the Georgia Milestones Assessment System.

Science consists of a way of thinking and investigating, as well a growing body of knowledge about the natural world. To become literate in science, students need to possess sufficient understanding of fundamental science content knowledge, the ability to engage in the science and engineering practices, and to use scientific and technological information correctly. Technology should be infused into the curriculum and the safety of the student should always be foremost in instruction.

The Earth Systems Georgia Standards of Excellence are designed to continue student investigations that began in K-8 Earth Science and Life Science curricula on the connections among Earth's systems through Earth history. These systems – the atmosphere, hydrosphere, geosphere, and biosphere – interact through time to produce the Earth's landscapes, ecology, and resources. These standards develop the explanations of phenomena fundamental to the sciences of geology and physical geography, including the early history of the Earth, plate tectonics, landform evolution, the Earth's geologic record, weather and climate, and the history of life on Earth. Instruction should focus on inquiry and the development of scientific explanations, rather than mere descriptions of phenomena. Case studies, laboratory exercises, maps, and data analysis should be integrated into units. Special attention should be paid to topics of current interest (e.g., recent earthquakes, tsunamis, global warming, price of resources) and to potential careers in the geosciences.

Earth Systems Standards

SES1. Obtain, evaluate, and communicate information to investigate the composition and formation of Earth systems, including the Earth's place in the solar system.

a. Construct an explanation of the origins of the solar system from scientific evidence including the composition, distribution and motion of solar system objects.
(*Clarification statement:* Include the nebular hypothesis in this element.)

b. Ask questions to evaluate evidence for the development and composition of Earth's early systems, including the geosphere (crust, mantle, and core), hydrosphere, and atmosphere.
(*Clarification statement:* Include differentiation by density of Earth into crust, mantle, and core in this element.)

c. Develop a model of the physical composition of Earth's layers using multiple types of evidence (e.g., Earth's magnetic field, composition of meteorites and seismic waves).
(*Clarification statement:* Earth's layers include crust, mantle, inner core and outer core.)

SES2. Obtain, evaluate, and communicate information to understand how plate tectonics creates certain geologic features, landforms, Earth materials, and geologic hazards.

a. Construct an explanation that describes radioactive decay as the source of energy that drives plate tectonics through the process of convection.

b. Develop and use models for the different types of plate tectonic settings (convergent, divergent, and transform boundaries).
(*Clarification statement:* Include subduction zones, continental collisions, rift zones, and ocean basins.)

c. Construct an explanation that communicates the relationship of geologic features, landforms, Earth materials, and geologic hazards to each plate tectonic setting.

d. Ask questions to compare and contrast the relationship between transformation processes of all rock types (sedimentary, igneous, and metamorphic) and specific plate tectonic settings.
(*Clarification statement:* The plate tectonic settings to be considered here are continental collision, subduction zone, mid-ocean ridge, transformation fault, hot spot, and passive zone.)

e. Construct an argument using multiple forms of evidence that supports the theory of plate tectonics (e.g., fossils, paleomagnetism, and seafloor age).

SES3. Obtain, evaluate, and communicate information to explore the actions of water, wind, ice, and gravity as they relate to landscape change.

a. Plan and carry out an investigation that demonstrates how surface water and groundwater act as the major agents of physical and chemical weathering.
b. Develop a model of the processes and geologic hazards that result from both sudden and gradual mass wasting.
c. Construct an explanation that relates the past and present actions of ice, wind, and water to landform distribution and landscape change.
d. Construct an argument based on evidence that relates the characteristics of the sedimentary materials to the energy by which they were transported and deposited.

SES4. Obtain, evaluate, and communicate information to understand how rock relationships and fossils are used to reconstruct the Earth's past.

a. Use mathematics and computational thinking to calculate the absolute age of rocks using a variety of methods (e.g., radiometric dating, rates of erosion, rates of deposition, and varve count).
b. Construct an argument applying principles of relative age (superposition, original horizontality, cross-cutting relations, and original lateral continuity) to interpret a geologic cross-section and describe how unconformities form.
c. Analyze and interpret data from rock and fossil succession in a rock sequence to interpret major events in Earth's history such as mass extinction, major climatic change, and tectonic events.
d. Construct an explanation applying the principle of uniformitarianism to show the relationship between sedimentary rocks and their fossils to the environments in which they were formed.
e. Construct an argument using spatial representations of Earth data that interprets major transitions in Earth's history from the fossil and rock record of geologically defined areas.
(*Clarification statement:* Students should use maps and cross-sections with a focus on Georgia.)

SES5. Obtain, evaluate and communicate information to investigate the interaction of solar energy and Earth's systems to produce weather and climate.

a. Develop and use models to explain how latitudinal variations in solar heating create differences in air pressure, global wind patterns, and ocean currents that redistribute heat globally.
b. Analyze and interpret data (e.g., maps, meteograms, and weather apps) that demonstrate how the interaction and movement of air masses creates weather.
c. Construct an argument that predicts weather patterns based on interactions among ocean currents, air masses, and topography.
d. Analyze and interpret data to show how temperature and precipitation produce the pattern of climate regions (zones) on Earth.

e. Construct an explanation that describes the conditions that generate extreme weather events (e.g., hurricanes, tornadoes, and thunderstorms) and the hazards associated with these events.
f. Construct an argument relating changes in global climate to variation to Earth/sun relationships and atmospheric composition.

SES6. Obtain, evaluate, and communicate information about how life on Earth responds to and shapes Earth's systems.

a. Construct an argument from evidence that describes how life has responded to major events in Earth's history (e.g., major climatic change, tectonic events) through extinction, migration, and/or adaptation.
b. Construct an explanation that describes how biological processes have caused major changes in Earth's systems through geologic time (e.g., nutrient cycling, atmospheric composition, and soil formation).
c. Ask questions to investigate and communicate how humans depend on Earth's land and water resources, which are distributed unevenly around the planet as a result of past geological and environmental processes.
d. Analyze and interpret data that relates changes in global climate to natural and anthropogenic modification of Earth's atmosphere and oceans.

Environmental Science Standards

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The Environmental Science Georgia Standards of Excellence are designed to continue student investigations that began in grades K-8. These standards integrate the study of many components of our environment, including the human impact on our planet. Students investigate the flow of energy and cycling of matter within ecosystems, and evaluate types, availability, allocation, and sustainability of energy resources. Instruction should focus on student data collection and analysis from field and laboratory experiences. Some concepts are global; in those cases, interpretation of global data sets from scientific sources is strongly recommended. Chemistry, physics, mathematical, and technological concepts should be integrated throughout the course. Whenever possible, careers related to environmental science should be emphasized.

Environmental Science Standards

SEV1. Obtain, evaluate, and communicate information to investigate the flow of energy and cycling of matter within an ecosystem.

a. Develop and use a model to compare and analyze the levels of biological organization including organisms, populations, communities, ecosystems, and biosphere.
b. Develop and use a model based on the Laws of Thermodynamics to predict energy transfers throughout an ecosystem (food chains, food webs, and trophic levels). (*Clarification statement:* The first and second law of thermodynamics should be used to support the model.)
c. Analyze and interpret data to construct an argument of the necessity of biogeochemical cycles (hydrologic, nitrogen, phosphorus, oxygen, and carbon) to support a sustainable ecosystem.
d. Evaluate claims, evidence, and reasoning of the relationship between the physical factors (e.g., insolation, proximity to coastline, topography) and organismal adaptations within terrestrial biomes.
e. Plan and carry out an investigation of how chemical and physical properties impact aquatic biomes in Georgia.
(*Clarification statement:* Consider the diverse aquatic ecosystems across the state such as streams, ponds, coastline, estuaries, and lakes.)

SEV2. Obtain, evaluate, and communicate information to construct explanations of stability and change in Earth's ecosystems.

a. Analyze and interpret data related to short-term and long-term natural cyclic fluctuations associated with climate change.
(*Clarification statement:* Short-term examples include but are not limited to El Niño and volcanism. Long-term examples include but are not limited to variations in Earth's orbit such as Milankovitch cycles.)
b. Analyze and interpret data to determine how changes in atmospheric chemistry (CO_2 and methane) impact the greenhouse effect.
c. Construct an argument to predict changes in biomass, biodiversity, and complexity within ecosystems, in terms of ecological succession.
d. Construct an argument to support a claim about the value of biodiversity in ecosystem resilience including keystone, invasive, native, endemic, indicator, and endangered species.

SEV3. Obtain, evaluate, and communicate information to evaluate types, availability, allocation, and sustainability of energy resources.

a. Analyze and interpret data to communicate information on the origin and consumption of renewable forms of energy (wind, solar, geothermal, biofuel, and tidal) and non-renewable energy sources (fossil fuels and nuclear energy).
b. Construct an argument based on data about the risks and benefits of renewable and nonrenewable energy sources.
(*Clarification statement:* This may include, but is not limited to, the environmental, social, and economic risks and benefits.)
c. Obtain, evaluate, and communicate data to predict the sustainability potential of renewable and non-renewable energy resources.
d. Design and defend a sustainable energy plan based on scientific principles for a specific location.

SEV4. Obtain, evaluate, and communicate information to analyze human impact on natural resources.

a. Construct and revise a claim based on evidence on the effects of human activities on natural resources.

Human Activities	Natural Resources
Agriculture Forestry Ranching Mining Urbanization Fishing Water use Pollution Desalination Waste water treatment	Land Water Air Organisms

b. Design, evaluate, and refine solutions to reduce human impact on the environment including, but not limited to, smog, ozone depletion, urbanization, and ocean acidification.
c. Construct an argument to evaluate how human population growth affects food demand and food supply (GMOs, monocultures, desertification, Green Revolution).

SEV5. Obtain, evaluate, and communicate information about the effects of human population growth on global ecosystems.

a. Construct explanations about the relationship between the quality of life and human impact on the environment in terms of population growth, education, and gross national product.

b. Analyze and interpret data on global patterns of population growth (fertility and mortality rates) and demographic transitions in developing and developed countries.
c. Construct an argument from evidence regarding the ecological effects of human innovations (Agricultural, Industrial, Medical, and Technological Revolutions) on global ecosystems.
d. Design and defend a sustainability plan to reduce individual contributions to environmental impacts, taking into account how market forces and societal demands (including political, legal, social, and economic) influence personal choices.

Physical Science Standards

The Science Georgia Standards of Excellence are designed to provide foundational knowledge and skills for all students to develop proficiency in science. The Project 2061's *Benchmarks for Science Literacy* and the follow up work, *A Framework for K-12 Science Education* were used as the core of the standards to determine appropriate content and process skills for students. The Science Georgia Standards of Excellence focus on a limited number of core disciplinary ideas and crosscutting concepts which build from Kindergarten to high school. The standards are written with the core knowledge to be mastered integrated with the science and engineering practices needed to engage in scientific inquiry and engineering design.

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The Physical Science Georgia Standards of Excellence are designed to continue student investigations of the physical sciences that began in grades K-8, and provide students the necessary skills to have a richer knowledge base in physical science. The standards in this course are designed as a survey of the core ideas in the physical sciences. Those core ideas will be studied in more depth during in the chemistry and physics courses. The physical science standards include abstract concepts such as the conceptualization of the structure of atoms and the role they play in determining the properties of materials, motion and forces, the conservation of energy and matter, wave behavior, electricity, and the relationship between electricity and magnetism. The idea of radioactive decay is limited to the understanding of whole half-lives and how a constant proportional rate of decay is consistent with declining measures that only gradually approach to zero. Students investigate physical science concepts through experiences in laboratories and field work.

Physical Science Standards

SPS1. Obtain, evaluate, and communicate information from the Periodic Table to explain the relative properties of elements based on patterns of atomic structure.

a. Develop and use models to compare and contrast the structure of atoms, ions and isotopes.
(*Clarification statement:* Properties include atomic number, atomic mass and the location and charge of subatomic particles.)

b. Analyze and interpret data to determine trends of the following:
- number of valence electrons
- types of ions formed by main group elements
- location and properties of metals, nonmetals, and metalloids
- phases at room temperature

c. Use the Periodic Table as a model to predict the above properties of main group elements.

SPS2. Obtain, evaluate, and communicate information to explain how atoms bond to form stable compounds.

a. Analyze and interpret data to predict properties of ionic and covalent compounds. (*Clarification statement*: Properties are limited to types of bonds formed, elemental composition, melting point, boiling point, and conductivity.)

b. Develop and use models to predict formulas for stable, binary ionic compounds based on balance of charges.

c. Use the International Union of Pure and Applied Chemistry (IUPAC) nomenclature for translating between chemical names and chemical formulas.
(*Clarification statement:* Limited to binary covalent and binary ionic, containing main group elements, compounds but excludes polyatomic ions.)

SPS3. Obtain, evaluate, and communicate information to support the Law of Conservation of Matter.

a. Plan and carry out investigations to generate evidence supporting the claim that mass is conserved during a chemical reaction.
(*Clarification statement:* Limited to synthesis, decomposition, simple replacement, and double replacement reactions.)

b. Develop and use a model of a chemical equation to illustrate how the total number of atoms is conserved during a chemical reaction.
(*Clarification statement:* Limited to chemical equations that include binary ionic and covalent compounds and will not include equations containing polyatomic ions.)

SPS4. Obtain, evaluate, and communicate information to explain the changes in nuclear structure as a result of fission, fusion and radioactive decay.

a. Develop a model that illustrates how the nucleus changes as a result of fission and fusion.
b. Use mathematics and computational thinking to explain the process of half-life as it relates to radioactive decay.
(*Clarification statement:* Limited to calculations that include whole half-lives.)
c. Construct arguments based on evidence about the applications, benefits, and problems of nuclear energy as an alternative energy source.

SPS5. Obtain, evaluate, and communicate information to compare and contrast the phases of matter as they relate to atomic and molecular motion.

a. Ask questions to compare and contrast models depicting the particle arrangement and motion in solids, liquids, gases, and plasmas.
b. Plan and carry out investigations to identify the relationships among temperature, pressure, volume, and density of gases in closed systems.
(*Clarification statement:* Using specific Gas laws to perform calculations is beyond the scope of this standard; emphasis should focus on the conceptual understanding of the behavior of gases rather than calculations.)

SPS6. Obtain, evaluate, and communicate information to explain the properties of solutions.

a. Develop and use models to explain the properties (solute/solvent, conductivity, and concentration) of solutions.
b. Plan and carry out investigations to determine how temperature, surface area, and agitation affect the rate a solute dissolves in a specific solvent.
c. Analyze and interpret data from a solubility curve to determine the effect of temperature on solubility.
d. Obtain and communicate information to explain the relationship between the structure and properties (e.g., pH and color change in the presence of an indicator) of acids and bases.
(*Clarification statement:* Limited to only the structure of simple acids and bases (e.g., HCl and NaOH) that demonstrates the presence of an H^+ or OH^-.
e. Plan and carry out investigations to detect patterns in order to classify common household substances as acidic, basic, or neutral.

SPS7. Obtain, evaluate, and communicate information to explain transformations and flow of energy within a system.

a. Construct explanations for energy transformations within a system.
(*Clarification statement:* Types of energy to be addressed include chemical, mechanical, electromagnetic, light, sound, thermal, electrical, and nuclear.)

b. Plan and carry out investigations to describe how molecular motion relates to thermal energy changes in terms of conduction, convection, and radiation.
c. Analyze and interpret specific heat data to justify the selection of a material for a practical application (e.g., insulators and cooking vessels).
d. Analyze and interpret data to explain the flow of energy during phase changes using heating/cooling curves.

SPS8. Obtain, evaluate, and communicate information to explain the relationships among force, mass, and motion.

a. Plan and carry out an investigation and analyze the motion of an object using mathematical and graphical models.
(*Clarification statement:* Mathematical and graphical models could include distance, displacement, speed, velocity, time, and acceleration.)
b. Construct an explanation based on experimental evidence to support the claims presented in Newton's three laws of motion.
(*Clarification statement:* Evidence could demonstrate relationships among force, mass, velocity, and acceleration.)
c. Analyze and interpret data to identify the relationship between mass and gravitational force for falling objects.
d. Use mathematics and computational thinking to identify the relationships between work, mechanical advantage, and simple machines.

SPS9. Obtain, evaluate, and communicate information to explain the properties of waves.

a. Analyze and interpret data to identify the relationships among wavelength, frequency, and energy in electromagnetic waves and amplitude and energy in mechanical waves.
b. Ask questions to compare and contrast the characteristics of electromagnetic and mechanical waves.
c. Develop models based on experimental evidence that illustrate the phenomena of reflection, refraction, interference, and diffraction.
d. Analyze and interpret data to explain how different media affect the speed of sound and light waves.
e. Develop and use models to explain the changes in sound waves associated with the Doppler Effect.

SPS10. Obtain, evaluate, and communicate information to explain the properties of and relationships between electricity and magnetism.

a. Use mathematical and computational thinking to support a claim regarding relationships among voltage, current, and resistance.

b. Develop and use models to illustrate and explain the conventional flow (direct and alternating) of current and the flow of electrons in simple series and parallel circuits.
(*Clarification statement:* Include advantages and disadvantages of series and parallel circuits.)

c. Plan and carry out investigations to determine the relationship between magnetism and the movement of electrical charge.
(*Clarification statement:* Investigations could include electromagnets, simple motors, and generators.)

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The Physics Georgia Standards of Excellence are designed to continue student investigations of the physical sciences that began in grades K-8, and provide students the necessary skills to be proficient in physics. These standards include more abstract concepts such as nuclear decay processes, interactions of matter and energy, velocity, acceleration, force, energy, momentum, properties and interactions of matter, electromagnetic and mechanical waves, and electricity, magnetism and their interactions. Students investigate physics concepts through experiences in laboratories and field work using the process of inquiry.

Physics Standards

SP1. Obtain, evaluate, and communicate information about the relationship between distance, displacement, speed, velocity, and acceleration as functions of time.

a. Plan and carry out an investigation of one-dimensional motion to calculate average and instantaneous speed and velocity.
   - Analyze one-dimensional problems involving changes of direction, using algebraic signs to represent vector direction.
   - Apply one-dimensional kinematic equations to situations with no acceleration, and positive or negative constant acceleration.

b. Analyze and interpret data using created or obtained motion graphs to illustrate the relationships among position, velocity, and acceleration, as functions of time.

c. Ask questions to compare and contrast scalar and vector quantities.

d. Analyze and interpret data of two-dimensional motion with constant acceleration.
   - Resolve position, velocity, or acceleration vectors into components (x and y, horizontal and vertical).
   - Add vectors graphically and mathematically by adding components.
   - Interpret problems to show that objects moving in two dimensions have independent motions along each coordinate axis.
   - Design an experiment to investigate the projectile motion of an object by collecting and analyzing data using kinematic equations.
   - Predict and describe how changes to initial conditions affect the resulting motion.
   - Calculate range and time in the air for a horizontally launched projectile.

SP2. Obtain, evaluate, and communicate information about how forces affect the motion of objects.

a. Construct an explanation based on evidence using Newton's Laws of how forces affect the acceleration of a body.
   - Explain and predict the motion of a body in absence of a force and when forces are applied using Newton's 1st Law (principle of inertia).
   - Calculate the acceleration for an object using Newton's 2nd Law, including situations where multiple forces act together.
   - Identify the pair of equal and opposite forces between two interacting bodies and relate their magnitudes and directions using Newton's 3rd Law.

b. Develop and use a model of a Free Body Diagram to represent the forces acting on an object (both equilibrium and non-equilibrium).

c. Use mathematical representations to calculate magnitudes and vector components for typical forces including gravitational force, normal force, friction forces, tension forces, and spring forces.

d. Plan and carry out an investigation to gather evidence to identify the force or force component responsible for causing an object to move along a circular path.

- Calculate the magnitude of a centripetal acceleration.

e. Develop and use a model to describe the mathematical relationship between mass, distance, and force as expressed by Newton's Universal Law of Gravitation.

SP3. Obtain, evaluate, and communicate information about the importance of conservation laws for mechanical energy and linear momentum in predicting the behavior of physical systems.

a. Ask questions to compare and contrast open and closed systems.
b. Use mathematics and computational thinking to analyze, evaluate, and apply the principle of conservation of energy and the Work-Kinetic Energy Theorem.
   - Calculate the kinetic energy of an object.
   - Calculate the amount of work performed by a force on an object.
c. Plan and carry out an investigation demonstrating conservation and rate of transfer of energy (power) to solve problems involving closed systems.
d. Construct an argument supported by evidence of the use of the principle of conservation of momentum to:
   - explain how the brief application of a force creates an impulse,
   - describe and perform calculations involving one dimensional momentum,
   - connect the concepts of Newton's 3rd law and impulse, and
   - experimentally compare and contrast inelastic and elastic collisions.

SP4. Obtain, evaluate, and communicate information about the properties and applications of waves.

a. Develop and use mathematical models to explain mechanical and electromagnetic waves as a propagating disturbance that transfers energy.
   (*Clarification statement:* Mathematically describe how the velocity, frequency, and wavelength of a propagating wave are related.)
b. Develop and use models to describe and calculate characteristics related to the interference and diffraction of waves (single and double slits).
c. Construct an argument that analyzes the production and characteristics of sound waves.
   (*Clarification statement:* Includes, but is not limited to, Doppler Effect, standing waves, wavelength, the relationship between amplitude and the energy of the wave, and the relationship between frequency and pitch.)
d. Plan and carry out investigations to characterize the properties and behavior of electromagnetic waves.
   (*Clarification statement:* Properties of waves include, but are not limited to, amplitude, frequency, wavelength, and the relationship between frequency or wavelength and the energy of the wave.)
e. Plan and carry out investigations to describe common features of light in terms of color, polarization, spectral composition, and wave speed in transparent media.

- Analyze experimentally and mathematically aspects of reflection and refraction of light waves and describe the results using optical ray diagrams.
- Perform calculations related to reflections from plane surfaces and focusing using thin lenses.

f. Plan and carry out investigations to identify the behavior of light using lenses. (*Clarification statement:* Investigations concerning Snell's Law, optical ray diagrams, and thin lens equation should be conducted.)

g. Plan and carry out investigations to describe changes in diffraction patterns associated with geometry and wavelength for mechanical and electromagnetic waves.

SP5. Obtain, evaluate, and communicate information about electrical and magnetic force interactions.

a. Develop and use mathematical models and generate diagrams to compare and contrast the electric and gravitational forces between two charged objects. (*Clarification statement:* Coulomb's and Universal Gravitation Law should be addressed.)

b. Plan and carry out investigations to demonstrate and qualitatively explain charge transfer by conduction, friction, and induction.

c. Construct an explanation based on evidence of the behavior of charges in terms of electric potential energy.

d. Plan and carry out an investigation of voltage, current, and power for direct current circuits.
(*Clarification statement:* Application of Ohm's Law to different circuit configurations, not limited to parallel and series, and calculations of equivalent resistance are expected.)

e. Plan and carry out investigations to clarify the relationship between electric currents and magnetic fields.
(*Clarification statement:* This includes coils and their importance in the design of motors and generators.)

SP6. Obtain, evaluate, and communicate information about nuclear changes of matter and related technological applications.

a. Develop and use models to explain, compare, and contrast nuclear processes including radioactive decay, fission, and fusion.

b. Construct an argument to compare and contrast mechanisms and characteristics of radioactive decay.
(*Clarification statement:* Include alpha, beta, and gamma decays and their effects.)

c. Develop and use mathematical models and representations to calculate the amount of substance present after a given amount of time based on its half-life and relate this to the law of conservation of mass and energy.