Pennsylvania Integrated Standards for Science, Environment and Ecology (Grades 6–12)

Standards for Grades 6–8[3][4]

Physical Science

Structure and Properties of Matter

1. Develop models to describe the atomic composition of simple molecules and extended structures
2. Gather and make sense of information to describe how synthetic materials come from natural resources and impact society.
3. Develop a model that predicts and describes changes in the particle motion, temperature and state of a pure substance when thermal energy is added or removed.

Chemical Reactions

1. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
2. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.
3. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*

Forces and Interactions

1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*

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[3] The asterisk (*) indicates that the Performance Expectation is integrating Engineering Design.

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2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.
4. Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.
5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

Energy

1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass and speed of an object.
2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*
4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.
5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

Waves and Electromagnetic Radiation

1. Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.
2. Develop and use a model to describe how waves are reflected, absorbed, or transmitted through various materials.
3. Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.

Life Science

Structure, Function, and Information Processing

1. Conduct an investigation to provide evidence that living things are made of cells, either one cell or many different numbers and types of cells.
2. Develop and use a model to describe the function of a cell as a whole and the ways that parts of cells contribute to the function.

3. Use arguments supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.
4. Gather and synthesize information about how sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

Matter and Energy in Organisms and Ecosystems

1. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.
2. Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.
3. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
4. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
5. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Interdependent Relationships in Ecosystems

1. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
2. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.*

Growth, Development, and Reproduction of Organisms

1. Use arguments based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants, respectively.
2. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
3. Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.
4. Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.
5. Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.

Natural Selection and Adaptations

1. Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.
2. Apply scientific ideas to construct an explanation for anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.
3. Analyze displays of pictorial data to compare patterns of similarities in anatomical structures across multiple species to identify relationships not evident in the fully formed anatomy.
4. Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.
5. Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

Earth and Space Science

Space Systems

1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.
2. Develop and use a model to describe the role of gravity in the motion within galaxies and the solar system.
3. Analyze and interpret data to determine scale properties of objects in the solar system.

History of Earth

1. Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.
2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.
3. Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of past plate motions.

Earth's Systems

1. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.
2. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.
3. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.

Weather and Climate

1. Collect data to provide evidence for how the motion and complex interactions of air masses result in changes in weather conditions.
2. Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
3. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

Human Impacts

1. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.
2. Apply scientific principles to design a method for monitoring and minimizing human impact on the environment.*
3. Construct an argument supported by evidence for how increases in human population and per capita consumption of natural resources impact Earth's systems.

Engineering, Technology, and Applications of Science

Engineering Design (Define Problems, Develop Solutions and Improve Designs)

1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Environmental Literacy and Sustainability

Agricultural and Environmental Systems and Resources

Agricultural Systems

1. Develop a model to describe how agricultural and food systems function, including the sustainable use of natural resources and the production, processing, and management of food, fiber, and energy.

Environment & Society

1. Analyze and interpret data about how different societies (economic and social systems) and cultures use and manage natural resources differently.

Watersheds and Wetlands

1. Develop a model to describe how watersheds and wetlands function as systems, including the roles and functions they serve.

Environmental Literacy Skills

Investigating Environmental Issues

1. Gather, read, and synthesize information from multiple sources to investigate how Pennsylvania environmental issues affect Pennsylvania's human and natural systems.

Environmental Experiences

1. Collect, analyze, and interpret environmental data to describe a local environment.

Evaluating Solutions

1. Obtain and communicate information on how integrated pest management could improve indoor and outdoor environments.

Sustainability and Stewardship

Environmental Sustainability

1. Obtain and communicate information to describe how best management practices and environmental laws are designed to achieve environmental sustainability.

Environmental Stewardship

1. Design a solution to an environmental issue in which individuals and societies can engage as stewards of the environment.

Environmental Justice

1. Construct an explanation that describes regional environmental conditions and their implications on environmental justice and social equity.

Standards for Grades 9–12[5] [6]

Physical Science

Structure and Properties of Matter

1. 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.
2. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
3. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
4. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*

Chemical Reactions

1. Construct and revise 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.
2. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
3. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
4. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*

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5. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Forces and Interactions

1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.
3. Apply scientific and engineering ideas to design, evaluate and refine a device that minimizes the force on a macroscopic object during a collision.*
4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
5. Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

Energy

1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).
3. Design, build and refine a device that works within given constraints to convert one form of energy into another form of energy.*
4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

Waves and Electromagnetic Radiation

1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
2. Evaluate questions about the advantages of using digital transmission and storage of information.

3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model and that for some situations one model is more useful than the other.
4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*

Life Science

Structure and Function

1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

Matter and Energy in Organisms and Ecosystems

1. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
2. Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.
3. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.
4. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.
5. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.
6. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

Interdependent Relationships in Ecosystems

1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
3. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
4. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.*
5. Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.
6. Create or revise a simulation to test a solution to mitigate the adverse impacts of human activity on biodiversity.*

Inheritance and Variation of Traits

1. Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.
2. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
3. Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
4. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

Natural Selection and Evolution

1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
2. Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
3. Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.
4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.
5. Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

Earth and Space Science

Space Systems

1. Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation.
2. Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, the motion of distant galaxies, and the composition of matter in the universe.
3. Communicate scientific ideas about the way stars, over their life cycle, produce elements.
4. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.

History of Earth

1. Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.
2. Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.
3. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.

Earth's Systems

1. Analyze geoscience data to make the claim that one change to Earth's surface can create feedback that causes changes to other Earth systems.
2. Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.
3. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.
4. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
5. Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.

Weather and Climate

1. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
2. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

Human Sustainability

1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*
3. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
4. Evaluate or refine a technological solution that reduces the impact of human activities on natural systems.*
5. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity

Engineering, Technology, and Applications of Science

Engineering Design (Define Problems, Develop Solutions and Improve Designs)

1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Environmental Literacy and Sustainability

Agricultural and Environmental Systems and Resources

Agricultural Systems

1. Analyze and interpret how issues, trends, technologies, and policies impact agricultural, food, and environmental systems and resources.

Environment and Society

1. Apply research and analytical skills to evaluate the conditions and motivations that lead to conflict, cooperation, and change among individuals, groups, and nations.

Watersheds and Wetlands

1. Analyze and interpret how issues, trends, technologies, and policies impact watersheds and water resources.

Environmental Literacy Skills

Investigating Environmental Issues

1. Apply research and analytical skills to systematically investigate environmental issues ranging from local issues to those that are regional or global in scope.

Environmental Experiences

1. Plan and conduct an investigation utilizing environmental data about a local environmental issue.

Evaluating Solutions

1. Evaluate and communicate the effect of integrated pest management practices on indoor and outdoor environments.

Sustainability and Stewardship

Environmental Sustainability

1. Analyze and evaluate how best management practices and environmental laws achieve sustainability of natural resources.

Environmental Stewardship

1. Design and evaluate solutions in which individuals and societies can promote stewardship in environmental quality and community well-being.

Environmental Justice

1. Analyze and interpret data on a regional environmental condition and its implications on environmental justice and social equity.