Appendix B – 1

Pennsylvania Integrated Standards for Science, Environment, Ecology, Technology and Engineering (Grades K–5) [1][2]

Kindergarten

Earth and Space Sciences

Earth and Human Activity

1. Use a model to represent the relationship between the needs of different plants or animals (including humans) and the places they live.
2. Ask questions to obtain information about the purpose of weather forecasting to prepare for, and respond to, severe weather.
3. Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.

Earth's Systems

1. Use observations of local weather conditions to describe patterns over time.
2. Construct an argument supported by evidence for how plants and animals (including humans) can change the environment to meet their needs.

[1] Across grades K-5, all of the core ideas in Table 1 are covered, but not every discipline or core idea is reflected at every grade.
[2] The language of the standards is adapted, informed by or taken from the: National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. North American Association for Environmental Education (2019) *K–12 environmental education: Guidelines for excellence;* International Society for Technology in Education Standards. (2019). *ISTE standards for students; International Technology and Engineering Educators Association (ITEEA) (2020); NGSS Lead States. (2013). Next generation science standards: For states, by states; Standards for technological and engineering literacy: The role of technology and engineering in STEM education. National Council for Agricultural Education. (2015); International Society for Technology in Education. (2019). ISTE Standards for students. Agriculture, food and natural resources (AFNR) career cluster content standards; Pennsylvania State Board of Education. (2002). Academic standards for science and technology; Pennsylvania Department of Education. (2002). Safety guidelines for elementary and technology education teachers; Pennsylvania Department of Education. (n.d.). Pennsylvania career ready skills continuum; Standards for Technological and Engineering Literacy. (2020); Pennsylvania Association for Environmental Educators. (September 2015). Pennsylvania environmental literacy plan Pennsylvania State Board of Education. (2002). Academic standards for environment and ecology. North American Association for Environmental Education. (2014). State environmental literacy plans: 2014 status report.*

Life Science

From Molecules to Organisms: Structures and Processes

1. Use observations to describe patterns of what plants and animals (including humans) need to survive.

Physical Science

Motion and Stability: Forces and Interactions

1. Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.
2. Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.

Energy

1. Make observations to determine the effect of sunlight on Earth's surface.
2. Use tools and materials to design and build a structure that will reduce the warming effect of sunlight on an area.

Grade 1

Earth and Space Sciences

Earth's Place in the Universe

1. Use observations of the sun, moon, and stars to describe patterns that can be predicted.
2. Make observations at different times of year to relate the amount of daylight to the time of year.

Life Science

From Molecules to Organisms: Structures and Processes

1. Use materials to design a solution to a human problem by mimicking how plants and/or animals use their external parts to help them survive, grow, and meet their needs.
2. Read texts and use media to determine patterns in behavior of parents and offspring that help offspring survive.

Heredity: Inheritance and Variation of Traits

1. Make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents.

Physical Science

Waves and Their Applications in Technologies for Information Transfer

1. Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.
2. Make observations to construct an evidence-based account that objects can be seen only when illuminated.
3. Plan and conduct an investigation to determine the effect of placing objects made with different materials in the path of a beam of light.
4. Use tools and materials to design and build a device that uses light or sound to solve the problem of communicating over a distance.

Grade 2

Earth and Space Sciences

Earth's Place in the Universe

1. Use information from several sources to provide evidence that Earth events can occur quickly or slowly.

Earth's Systems

1. Compare multiple solutions designed to slow or prevent wind or water from changing the shape of the land.
2. Develop a model to represent the shapes and kinds of land and bodies of water in an area.
3. Obtain information to identify where water is found on Earth and that it can be solid or liquid.

Life Science

Ecosystems: Interactions, Energy, and Dynamics

1. Plan and conduct an investigation to determine if plants need sunlight and water to grow.
2. Develop a simple model that mimics the function of an animal in dispersing seeds or pollinating plants.

Biological Evolution: Unity and Diversity

1. Make observations of plants and animals to compare the diversity of life in different habitats.

Matter and its Interactions

1. Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.

2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.
3. Make observations to construct an evidence-based account of how an object made of a small set of pieces can be disassembled and made into a new object.
4. Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.

Grade 3

Earth and Space Sciences

Earth's Systems

1. Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.
2. Obtain and combine information to describe climates in different regions of the world.

Earth and Human Activity

1. Make a claim supported by evidence about the merit of a design solution that reduces the impacts of a weather-related hazard.

Life Science

From Molecules to Organisms: Structures and Processes

1. Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction, and death.

Ecosystems: Interactions, Energy, and Dynamics

1. Construct an argument that some animals have physical and behavioral adaptations that help members survive.

Heredity: Inheritance and Variation of Traits

1. Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.
2. Use evidence to support the explanation that traits can be influenced by the environment.

Biological Evolution: Unity and Diversity

1. Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago.

2. Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.
3. Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.
4. Make a claim supported by evidence about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.

Physical Science

Motion and Stability: Forces and Interactions

1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.
2. Make and communicate observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.
3. Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.
4. Define a simple design problem that can be solved by applying scientific ideas about magnets.

Grade 4

Earth and Space Sciences

Earth's Place in the Universe

1. Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time.

Earth's Systems

1. Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.
2. Analyze and interpret data from maps to describe patterns of Earth's features.

Earth and Human Activity

1. Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.
2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

Life Science

From Molecules to Organisms: Structures and Processes

1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.
2. Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.

Physical Science

Waves and Their Applications in Technologies for Information Transfer

1. Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.
2. Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.
3. Generate and compare multiple solutions that use patterns to transfer information.

Energy

1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.
2. Make and communicate observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.
4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

Grade 5

Earth and Space Sciences

Earth's Place in the Universe

1. Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from Earth.
2. Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.

Earth's Systems

1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.
2. Describe and graph the amounts and percentages of water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.

Earth and Human Activity

1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.
2. Generate and design possible solutions to a current environmental issue, threat, or concern.

Life Science

From Molecules to Organisms: Structures and Processes

1. Support an argument that plants get the materials they need for growth chiefly from air and water.

Ecosystems: Interactions, Energy, and Dynamics

1. Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

Physical Science

Matter and Its Interactions

1. Develop a model to describe that matter is made of particles too small to be seen.
2. Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.
3. Make and communicate observations and measurements to identify materials based on their properties.
4. Conduct an investigation to determine whether the mixing of two or more substances results in new substances.
5. Interpret and analyze data and observations to make decisions about how to utilize materials based on their properties.

Motion and Stability: Forces and Interactions

1. Support an argument that the gravitational force exerted by Earth on objects is directed down.

Energy

1. Use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain body warmth) was once energy from the sun.

Standards by Grade Band

Grades K–2: Environment and Ecology

Decision-Making and Action Skills

1. Examine and express their own views on environmental issues.
2. Determine whether action is needed on selected environmental issues and whether they should be involved. They describe their reasoning.
3. Develop an action strategy or design solution for a specific local environmental issue of their choosing.
4. Identify environmental and social consequences of design solutions and civic actions, including their own actions.

Personal and Civic Responsibility

1. Describe their basic rights and responsibilities as members of a community and the importance of these rights and responsibilities in promoting environmental quality and community well-being.
2. Describe how they can realistically and meaningfully contribute to their community and environmental quality.
3. Identify ways in which they are responsible for the environmental and social effects of their actions.

Earth's Physical and Living Systems

1. Describe characteristics of Earth's physical systems, including air, water, and land. They explain how these systems interact with one another and identify changes in the physical environment over time. They provide examples of how physical systems affect living organisms, including humans.
2. Identify basic similarities and differences among a wide variety of living organisms. They explain ways that living organisms, including humans, affect the environment in which they live, and how their environment affects them.

Human Systems

1. Generate examples of how people act, as individuals, as members of a group, and as members of society, toward the environment. They articulate their own beliefs and the

beliefs of family and community members about the environment and environmental issues.

2. Identify ways that people express different cultural backgrounds and how these can influence environmental perceptions and activities.

Environment and Society

1. Identify ways that people depend on, change, and are affected by the environment.
2. Describe ways people harvest, re-distribute, and use natural resources.
3. Identify ways that places differ in their physical and human characteristics.
4. Recognize that change is a normal part of individual and societal life.

Skills for Analyzing and Investigating Environmental Issues

1. Identify and investigate issues in their local environment and community.
2. Use their knowledge of how ecological and human systems are interconnected to describe the environmental and social consequences of local environmental issues.
3. Develop plans, including possible design solutions, for addressing selected local environmental issues.
4. Demonstrate openness and receptivity while listening to and working with others who have perspectives about the environment that are different from their own.

Grades K–2: Technology and Engineering

Applying, Maintaining, and Assessing Technological Products and Systems

1. Analyze how things work.
2. Identify and use everyday symbols.
3. Describe qualities of everyday products.

Core Concepts of Technology and Engineering

1. Illustrate how systems have parts or components that work together to accomplish a goal.
2. Safely use tools to complete tasks.
3. Explain that materials are selected for use because they possess desirable properties and characteristics.
4. Develop a plan in order to complete a task.
5. Collaborate effectively as a member of a team.

Design in Technology and Engineering Education

1. Apply design concepts, principles, and processes through play and exploration.
2. Demonstrate that designs have requirements.
3. Explain that design is a response to wants and needs.
4. Discuss that all designs have different characteristics that can be described.
5. Illustrate that there are different solutions to a design and that none are perfect.
6. Demonstrate essential skills of the engineering design process.
7. Apply skills necessary for making in design**.**

History of Technology

1. Discuss how the way people live and work has changed throughout history because of technology.

Impacts of Technology

1. Explain ways that technology helps with everyday tasks.
2. Illustrate helpful and harmful effects of technology.
3. Compare simple technologies to evaluate their impacts.
4. Select ways to reduce, reuse, and recycle resources in daily life.
5. Design new technologies that could improve their daily lives.

Influence of Society on Technological Development

1. Explain the needs and wants of individuals and societies.
2. Explore how technologies are developed to meet individual and societal needs and wants.
3. Investigate the use of technologies in the home and community.

Integration of Knowledge, Technologies, and Practices

1. Apply concepts and skills from technology and engineering activities that reinforce concepts and skills across multiple content areas.
2. Draw connections between technology and human experiences.

Nature and Characteristics of Technology and Engineering

1. Compare the natural world and human-made world.
2. Explain the tools and techniques that people use to help them do things.
3. Demonstrate that creating can be done by anyone.

4. Discuss the roles of scientists, engineers, technologists and others who work with technology.

Grades 3–5: Environment and Ecology

Decision-Making and Action Skills

1. Identify, justify, and clarify their views on environmental issues and alternative ways to address them.
2. Evaluate whether action is needed in specific situations, using environmental, cultural/social, and economic criteria. They decide whether they should be involved in that action.
3. Use their research results to develop action strategies and design solutions at levels consistent with their maturity and preparation. As appropriate, they implement their plans.
4. Analyze the effects of design solutions, their own civic actions, and actions taken by other individuals and groups. They describe the short- and long-term effects of these actions and design solutions in terms of environmental, social, and economic consequences.

Personal and Civic Responsibility

1. Explain the rights and responsibilities of community membership and their role in addressing environmental quality and sustainability.
2. Possess a realistic self-confidence in their effectiveness as community members to make changes in their community that address environmental quality and sustainability.
3. Describe the broad environmental, social, and economic consequences of their personal and group actions and as appropriate, accept responsibility for their actions.

Earth's Physical and Living Systems

1. Describe the physical processes that shape Earth, including weather, climate, plate tectonics, and the hydrologic cycle. They explain how matter cycles and energy flows among the abiotic and biotic components of the environment. They describe how humans affect and are affected by Earth’s physical systems.
2. Describe how living things, including humans, are dependent on their environment and are adapted to live in particular ecosystems under particular environmental conditions. They describe major interactions among organisms and populations of organisms and explain the importance of biodiversity to ecosystem health. They describe how humans affect and are affected by the biosphere.

Human Systems

1. Explain ways that individual traits and group membership or affiliation influence perceptions of and actions toward the environment. They describe how their environmental beliefs and values are shaped by their community and the larger society. They compare their beliefs and values to those held by others in their community.

2. Describe examples of the interconnection between cultural perspectives and the environment.
3. Describe how political systems at varying scales account for, manage, and affect natural resources and environmental quality.
4. Describe how economic systems and economic decision-making influence natural resource use and management as well as environmental and human well-being.

Environment and Society

1. Describe human-caused changes that affect the immediate environment as well as other places, other people, and future times.
2. Explain that uneven geographic distribution of natural resources influences their use and perceived value.
3. Describe the meaning of "place" both close to home and around the world.
4. Explain that human social systems are dynamic and that conflicts sometimes arise over differing and changing viewpoints about the environment and natural resource use and management.

Skills for Analyzing and Investigating Environmental Issues

1. Use primary and secondary sources of information and apply research and analytical skills to investigate environmental issues, beginning in their own community and region.
2. Apply their knowledge of ecological and human processes and systems to describe the short- and long- term consequences of selected environmental issues on sustainability.
3. Identify and develop action strategies, including design solutions, appropriate for addressing a range of environmental issues at community and regional levels. They describe how their action strategies and design solutions might impact environmental quality and other people now and in the future.
4. Demonstrate active listening, tolerance, adaptability, and openness as they work with others to gather a range of perspectives and information.

Grades 3–5: Technology and Engineering

Applying, Maintaining, and Assessing Technological Products and Systems

1. Follow directions to complete a technological task.

2. Use appropriate symbols, numbers and words to communicate key ideas about technological products and systems.
3. Identify why a product or system is not working properly.
4. Examine information to assess the trade-offs of using a product or system.

Core Concepts of Technology and Engineering

1. Describe how a subsystem is a system that operates as a part of another larger system.
2. Illustrate how, when parts of a system are missing, it may not work as planned.
3. Identify the resources needed to get a technical job done, such as people, materials, capital, tools, machines, knowledge, energy, and time.
4. Describe the properties of different materials.
5. Demonstrate how tools and machines extend human capabilities, such as holding, lifting, carrying, fastening, separating, and computing.
6. Describe requirements of designing or making a product or system.
7. Create a new product that improves someone's life.

Design in Technology and Engineering Education

1. Illustrate that there are multiple approaches to design.
2. Demonstrate essential skills of the engineering design process.
3. Evaluate designs based on criteria, constraints, and standards.
4. Interpret how good design improves the human condition.
5. Apply universal principles and elements of design.
6. Evaluate the strengths and weaknesses of existing design solutions, including their own solutions.
7. Practice successful design skills.
8. Apply tools, techniques, and materials in a safe manner as part of the design process.

History of Technology

1. Create representations of the tools people made, how they cultivated to provide food, made clothing, and built shelters to protect themselves.

Impacts of Technology

1. Describe the helpful and harmful effects of technology.
2. Judge technologies to determine the best one to use to complete a given task or meet a need.
3. Classify resources used to create technologies as either renewable or nonrenewable.

4. Explain why responsible use of technology requires sustainable management of resources.
5. Predict how certain aspects of their daily lives would be different without given technologies.

Influence of Society on Technological Development

1. Determine factors that influence changes in a society's technological systems or infrastructure.
2. Explain how technologies are developed or adapted when individual or societal needs and wants change.

Integration of Knowledge, Technologies, and Practices

1. Demonstrate how simple technologies are often combined to form more complex systems.
2. Explain how various relationships can exist between technology and engineering and other content areas.

Nature and Characteristics of Technology and Engineering

1. Compare how things found in nature differ from things that are human-made, noting differences and similarities in how they are produced and used.
2. Describe the unique relationship between science and technology, and how the natural world can contribute to the human-made world to foster innovation.
3. Differentiate between the role of scientists, engineers, technologists, and others in creating and maintaining technological systems.
4. Design solutions by safely using tools, materials, and skills.
5. Explain how solutions to problems are shaped by economic, political, and cultural forces.

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.

[4] The language of the standards is adapted, informed by or taken from the: National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. North American Association for Environmental Education (2019) *K–12 environmental education: Guidelines for excellence;* International Society for Technology in Education Standards. (2019). *ISTE standards for students; International Technology and Engineering Educators Association (ITEEA) (2020); NGSS Lead States. (2013). Next generation science standards: For states, by states; Standards for technological and engineering literacy: The role of technology and engineering in STEM education. National Council for Agricultural Education. (2015); International Society for Technology in Education. (2019). ISTE Standards for students. Agriculture, food and natural resources (AFNR) career cluster content standards; Pennsylvania State Board of Education. (2002). Academic standards for science and technology; Pennsylvania Department of Education. (2002). Safety guidelines for elementary and technology education teachers; Pennsylvania Department of Education. (n.d.). Pennsylvania career ready skills continuum; Standards for Technological and Engineering Literacy. (2020); Pennsylvania Association for Environmental Educators. (September 2015). Pennsylvania environmental literacy plan Pennsylvania State Board of Education. (2002). Academic standards for environment and ecology. North American Association for Environmental Education. (2014). State environmental literacy plans: 2014 status report.*

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.
1. 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.
2. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*
3. 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.
4. 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 embryological development 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.

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

[6] The language of the standards is adapted, informed by or taken from the: National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. North American Association for Environmental Education (2019) *K–12 environmental education: Guidelines for excellence;* International Society for Technology in Education Standards. (2019). *ISTE standards for students; International Technology and Engineering Educators Association (ITEEA) (2020); NGSS Lead States. (2013). Next generation science standards: For states, by states; Standards for technological and engineering literacy: The role of technology and engineering in STEM education. National Council for Agricultural Education. (2015); International Society for Technology in Education. (2019). ISTE Standards for students. Agriculture, food and natural resources (AFNR) career cluster content standards; Pennsylvania State Board of Education. (2002). Academic standards for science and technology; Pennsylvania Department of Education. (2002). Safety guidelines for elementary and technology education teachers; Pennsylvania Department of Education. (n.d.). Pennsylvania career ready skills continuum; Standards for Technological and Engineering Literacy. (2020); Pennsylvania Association for Environmental Educators. (September 2015). Pennsylvania environmental literacy plan Pennsylvania State Board of Education. (2002). Academic standards for environment and ecology. North American Association for Environmental Education. (2014). State environmental literacy plans: 2014 status report.*

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.

Technology and Engineering Academic Standards[7]

Grades 6–8

Nature and Characteristics of Technology and Engineering

1. Consider historical factors that have contributed to the development of technologies and human progress.
2. Engage in a research and development process to simulate how inventions and innovations have evolved through systematic tests and refinements.
3. Differentiate between inputs, processes, outputs, and feedback in technological systems.
4. Demonstrate how systems thinking involves considering relationships between every part, as well as how the systems interact with the environment in which it is used.
5. Create an open-loop system that has no feedback path and requires human intervention.
6. Create a closed-loop system that has a feedback path and requires no human intervention.
7. Predict outcomes of a future product or system at the beginning of the design process.
8. Apply informed problem-solving strategies to the improvement of existing devices or processes or the development of new approaches.
9. Explain how technology and engineering are closely linked to creativity, which can result in both intended and unintended innovations.
10. Compare how different technologies involve different sets of processes.

Integration of Knowledge, Technologies, and Practices

1. Compare, contrast, and identify overlap between the contributions of science, technology, engineering, and mathematics in the development of technological systems.
2. Analyze how different technological systems often interact with economic, environmental, and social systems.
3. Adapt and apply an existing product, system, or process to solve a problem in a different setting.
4. Demonstrate how knowledge gained from other content areas affects the development of technological products and systems.

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[7] The language of the standards is adapted, informed or from the: *International Technology and Engineering Educators Association (ITEEA). (2020). Standards for technological and engineering literacy: The role of technology and engineering in STEM education. Pennsylvania State Board of Education. (2002). Academic standards for science and technology; Pennsylvania Department of Education. (2002). Safety guidelines for elementary and technology education teachers; Pennsylvania Department of Education. (n.d.). Pennsylvania career ready skills continuum.*

Applying, Maintaining, Assessing and Evaluating Technological Products and Systems

1. Examine the ways that technology can have both positive and negative effects at the same time.
2. Analyze how the creation and use of technologies consumes renewable, non-renewable, and inexhaustible resources; creates waste; and may contribute to environmental challenges.
3. Consider the impacts of a proposed or existing technology and devise strategies for reducing, reusing, and recycling waste caused by its creation.
4. Analyze examples of technologies that have changed the way people think, interact, live, and communicate.
5. Hypothesize what alternative outcomes (individual, cultural, and/or environmental) might have resulted had a different technological solution been selected.
6. Analyze how an invention or innovation was influenced by the context and circumstances in which it is developed.
7. Evaluate trade-offs based on various perspectives as part of a decision process that recognizes the need for careful compromises among competing factors.
8. Research information from various sources to use and maintain technological products or systems.
9. Use tools, materials, and machines to safely diagnose, adjust, and repair systems.
10. Use devices to control technological systems.
11. Design methods to gather data about technological systems.
12. Interpret the accuracy of information collected.
13. Use instruments to gather data on the performance of everyday products.

Design Thinking in Technology and Engineering Education

1. Apply a technology and engineering design thinking process.
2. Develop innovative products and systems that solve problems and extend capabilities based on individual or collective needs and wants.
3. Illustrate the benefits and opportunities associated with different approaches to design.
4. Create solutions to problems by identifying and applying human factors in design.
5. Evaluate and assess the strengths and weaknesses of various design solutions given established principles and elements of design.
6. Refine design solutions to address criteria and constraints.
7. Defend decisions related to a design problem.

Grades 9–12

Nature and Characteristics of Technology & Engineering

1. Evaluate how technology and engineering have been powerful forces in reshaping the social, cultural, political, and economic landscapes throughout history.
2. Relate how technological and engineering developments have been evolutionary, often the result of a series of refinements to basic inventions or technological knowledge.
3. Identify and explain how the evolution of civilization has been directly affected by, and has in turn affected, the development and use of tools, materials, and processes.
4. Analyze how the Industrial Revolution resulted in the development of mass production, sophisticated transportation and communication systems, advanced construction practices, and improved education and leisure time.
5. Investigate the widespread changes that have resulted from the Information Age, which has placed emphasis on the processing and exchange of information.
6. Analyze the rate of technological and engineering development and predict future diffusion and adoption of new innovations and technologies.
7. Demonstrate the use of conceptual, graphical, virtual, mathematical, and physical modeling to identify conflicting considerations before the entire system is developed and to aid in design decision making.
8. Analyze the stability of a technological system and how it is influenced by all of the components in the system, especially those in the feedback loop.
9. Troubleshoot and improve a flawed system embedded within a larger technological, social, or environmental system.
10. Use project management tools, strategies, and processes in planning, organizing, and controlling work.
11. Implement quality control as a planned process to ensure that a product, service, or system meets established criteria.

Integration of Knowledge, Technologies, and Practices

1. Assess how similarities and differences among scientific, technological, engineering, and mathematical knowledge and skills contributed to the design of a product or system.
2. Develop a plan that incorporates knowledge from science, mathematics, and other disciplines to design or improve a technological product or system.
3. Analyze how technology transfer occurs when a user applies an existing innovation developed for one function for a different purpose.
4. Evaluate how technology enhances opportunities for new products and services through globalization.

5. Connect technological and engineering progress to the advancement of other areas of knowledge and vice versa.

Applying, Maintaining, Assessing, and Evaluating Technological Products and Systems

1. Develop a solution to a technological problem that has the least negative environmental and social impact.
2. Develop a device or system for the marketplace.
3. Evaluate ways that technology and engineering can impact individuals, society, and the environment.
4. Critique whether existing or proposed technologies use resources sustainably.
5. Critically assess and evaluate a technology that minimizes resource use and resulting waste to achieve a goal.
6. Evaluate a technological innovation that arose from a specific society's unique need or want.
7. Evaluate how technology and engineering advancements alter human health and capabilities.
8. Evaluate a technological innovation that was met with societal resistance impacting its development.
9. Use various approaches to communicate processes and procedures for using, maintaining, and assessing technological products and systems.
10. Synthesize data and analyze trends to make decisions about technological products, systems, or processes.
11. Interpret laws, regulations, policies, and other factors that impact the development and use of technology.

Design Thinking in Technology and Engineering Education

1. Apply a broad range of design skills to a design thinking process.
2. Implement and critique principles, elements, and factors of design.
3. Evaluate and define the purpose of a design.
4. Conduct research to inform intentional inventions and innovations that address specific needs and wants.
5. Analyze and use relevant and appropriate design thinking processes to solve technological and engineering problems.
6. Implement the best possible solution to a design using an explicit process.
7. Apply principles of human-centered design.
8. Optimize a design by addressing desired qualities within criteria and constraints while considering trade-offs.

9. Use a design thinking process to design an appropriate technology for use in a different culture.
10. Apply appropriate design thinking processes to diagnose, adjust, and repair systems to ensure precise, safe, and proper functionality.
11. Recognize and explain how their community and the world around them informs technological development and engineering design.
12. Safely apply an appropriate range of making skills to a design thinking process.