

Callie Weitzel

caweitzel@bluevalleyk12.org

239-4268

Christie Purdon

cpurdon@bluevalleyk12.org

239-4375

<http://bluevalleyscience.weebly.com/>

<http://www.teachtci.com/>

<http://www.bozemanscience.com/next-generation-science-standards/>

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The Three Dimensions

Dimension 1: Science and Engineering Practices

What the students will do.

This dimension describes (a) the major practices that scientists employ as they investigate and build models and theories about the world and (b) a key set of engineering practices that engineers use as they design and build systems. We use the term “practices” instead of a term such as “skills” to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice. Similarly, because the term “inquiry,” extensively referred to in previous standards documents, has been interpreted over time in many different ways throughout the science education community, part of our intent in articulating the practices in Dimension 1 is to better specify what is meant by inquiry in science and the range of cognitive, social and physical practices that it requires. As in all inquiry-based approaches to science teaching, our expectation is that students will themselves engage in the practices and not merely learn about them secondhand. Students cannot comprehend scientific practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves.

Dimension 2: Crosscutting Concepts

How the students will organize and connect their knowledge.

The crosscutting concepts have application across all domains of science. As such, they provide one way of linking across the domains in Dimension 3. There is a need to consider not only content but also the ideas and practices that cut across the science disciplines.

Dimension 3: Disciplinary Core Ideas

What the students will understand.

The continuing expansion of scientific knowledge makes it impossible to teach all the ideas related to a given discipline in exhaustive detail during the K-12 years. But given the cornucopia of information available today virtually at a touch— people live, after all, in an information age—an important role of science education is not to teach “all the facts” but rather to prepare students with sufficient core knowledge so that they can later acquire additional information on their own. An education focused on a limited set of ideas and practices in science and engineering should enable students to evaluate and select reliable sources of scientific information and allow them to continue their development well beyond their K-12 school years as science learners, users of scientific knowledge, and perhaps also as producers of such knowledge.

EIGHT SCIENCE AND ENGINEERING PRACTICES

PRACTICE	SCIENCE	ENGINEERING
Asking Questions and Defining Problems	Science begins with a question about a phenomenon, such as “Why is the sky blue?” or “What causes cancer?,” and seeks to develop theories that can provide explanatory answers to such questions. A basic practice of the scientist is formulating empirically answerable questions about phenomena, establishing what is already known, and determining what questions have yet to be satisfactorily answered.	Engineering begins with a problem, need, or desire that suggests an engineering problem that needs to be solved. A societal problem such as reducing the nation’s dependence on fossil fuels may engender a variety of engineering problems, such as designing more efficient transportation systems, or alternative power generation devices such as improved solar cells. Engineers ask questions to define the engineering problem, determine criteria for a successful solution, and identify constraints.
Developing and Using Models	Science often involves the construction and use of a wide variety of models and simulations to help develop explanations about natural phenomena. Models make it possible to go beyond observables and imagine a world not yet seen. Models enable predictions of the form “if . . . then . . . therefore” to be made in order to test hypothetical explanations.	Engineering makes use of models and simulations to analyze existing systems so as to see where flaws might occur or to test possible solutions to a new problem. Engineers also call on models of various sorts to test proposed systems and to recognize the strengths and limitations of their designs.
Planning and Carrying Out Investigations	Scientific investigation may be conducted in the field or the laboratory. A major practice of scientists is planning and carrying out a systematic investigation, which requires the identification of what is to be recorded and, if applicable, what are to be treated as the dependent and independent variables (control of variables). Observations and data collected from such work are used to test existing theories and explanations or to revise and develop new ones.	Engineers use investigation both to gain data essential for specifying design criteria or parameters and to test their designs. Like scientists, engineers must identify relevant variables; decide how they will be measured, and collect data for analysis. Their investigations help them to identify how effective, efficient, and durable their designs may be under a range of conditions.
Analyzing and Interpreting Data	Scientific investigations produce data that must be analyzed in order to derive meaning. Because data usually do not speak for themselves, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Sources of error are identified and the degree of certainty calculated. Modern technology makes the collection of large data sets much easier, thus providing many secondary sources for analysis.	Engineers analyze data collected in the tests of their designs and investigations; this allows them to compare different solutions and determine how well each one meets specific design criteria—that is, which design best solves the problem within the given constraints. Like scientists, engineers require a range of tools to identify the major patterns and interpret the results.

<p>Using Mathematics and Computational Thinking</p>	<p>In science, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks, such as constructing simulations, statistically analyzing data, and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable predictions of the behavior of physical systems, along with the testing of such predictions. Moreover, statistical techniques are invaluable for assessing the significance of patterns or correlations.</p>	<p>In engineering, mathematical and computational representations of established relationships and principles are an integral part of design. For example, structural engineers create mathematically based analyses of designs to calculate whether they can stand up to the expected stresses of use and if they can be completed within acceptable budgets. Moreover, simulations of designs provide an effective test bed for the development of designs and their improvement.</p>
<p>Constructing Explanations and Designing Solutions</p>	<p>The goal of science is the construction of theories that can provide explanatory accounts of features of the world. A theory becomes accepted when it has been shown to be superior to other explanations in the breadth of phenomena it accounts for and in its explanatory coherence and parsimony. Scientific explanations are explicit applications of theory to a specific situation or phenomenon, perhaps with the intermediary of a theory-based model for the system under study. The goal for students is to construct logically coherent explanations of phenomena that incorporate their current understanding of science, or a model that represents it, and are consistent with the available evidence.</p>	<p>Engineering design, a systematic process for solving engineering problems, is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technological feasibility, cost, safety, esthetics, and compliance with legal requirements. There is usually no single best solution but rather a range of solutions. Which one is the optimal choice depends on the criteria used for making evaluations.</p>
<p>Engaging in Argument from Evidence</p>	<p>In science, reasoning and argument are essential for identifying the strengths and weaknesses of a line of reasoning and for finding the best explanation for a natural phenomenon. Scientists must defend their explanations, formulate evidence based on a solid foundation of data, examine their own understanding in light of the evidence and comments offered by others, and collaborate with peers in searching for the best explanation for the phenomenon being investigated.</p>	<p>In engineering, reasoning and argument are essential for finding the best possible solution to a problem. Engineers collaborate with their peers throughout the design process, with a critical stage being the selection of the most promising solution among a field of competing ideas. Engineers use systematic methods to compare alternatives, formulate evidence based on test data, make arguments from evidence to defend their conclusions, evaluate critically the ideas of others, and revise their designs in order to achieve the best solution to the problem at hand.</p>
<p>Obtaining, Evaluating, and Communicating Information</p>	<p>Science cannot advance if scientists are unable to communicate their findings clearly and persuasively or to learn about the findings of others. A major practice of science is thus the communication of ideas and the results of inquiry—orally, in writing, with the use of tables, diagrams, graphs, and equations, and by engaging in extended discussions with scientific peers. Science requires the ability to derive meaning from scientific texts (such as papers, the Internet, symposia, and lectures), to evaluate the scientific validity of the information thus acquired, and to integrate that information.</p>	<p>Engineers cannot produce new or improved technologies if the advantages of their designs are not communicated clearly and persuasively. Engineers need to be able to express their ideas, orally and in writing, with the use of tables, graphs, drawings, or models and by engaging in extended discussions with peers. Moreover, as with scientists, they need to be able to derive meaning from colleagues’ texts, evaluate the information, and apply it usefully. In engineering and science alike, new technologies are now routinely available that extend the possibilities for collaboration and communication.</p>

SEVEN CROSSCUTTING CONCEPTS OF THE FRAMEWORK

The organizational framework that connects knowledge into a coherent and scientifically based view of the world

Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

Cause and Effect: Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Scale, Proportion, and Quantity: In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

Systems and System Models: Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

Energy and Matter: Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

Structure and Function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

Stability and Change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

FOURTH GRADE OVERVIEW

The performance expectations in fourth grade help students formulate answers to questions such as: “What are waves and what are some things they can do? How can water, ice, wind and vegetation change the land? What patterns of Earth’s features can be determined with the use of maps? How do internal and external structures support the survival, growth, behavior, and reproduction of plants and animals? What is energy and how is it related to motion? How is energy transferred? How can energy be used to solve a problem?” Fourth grade performance expectations include **PS3, PS4, LS1, ESS1, ESS2, ESS3, and ETS1** Disciplinary Core Ideas from the NRC Framework. Students are able to use a model of waves to describe patterns of waves in terms of amplitude and wavelength, and that waves can cause objects to move. Students are expected to develop understanding of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation. They apply their knowledge of natural Earth processes to generate and compare multiple solutions to reduce the impacts of such processes on humans. In order to describe patterns of Earth’s features, students analyze and interpret data from maps. Fourth graders are expected to develop an understanding that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. By developing a model, they describe that an object can be seen when light reflected from its surface enters the eye. Students are able to use evidence to construct an explanation of the relationship between the speed of an object and the energy of that object. Students are expected to develop an understanding that energy can be transferred from place to place by sound, light, heat, and electric currents or from object to object through collisions. They apply their understanding of energy to design, test, and refine a device that converts energy from one form to another. The crosscutting concepts of patterns; cause and effect; energy and matter; systems and system models; interdependence of science, engineering, and technology; and influence of engineering, technology, and science on society and the natural world are called out as organizing concepts for these disciplinary core ideas. In the fourth grade performance expectations, students are expected to demonstrate grade-appropriate proficiency in asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information. Students are expected to use these practices to demonstrate understanding of the core ideas.

PS = Physical Science

LS = Life Science

ESS = Earth Space Science

ETS = Engineering, Technology, and Application of Science

Physical Science K-5 Progression

Physical Science	K	1	2	3	4	5
PS1 Matter and Its Interactions						
PS1A Structure and Properties of matter			X			X
PS1B Chemical Reactions			X			X
PS1C Nuclear Processes						
PS2 Motion and Stability: Forces and Interactions						
PS2A Forces and Motion	X			X		
PS2B Types of Interactions	X			X		X
PS2C Stability and Instability in Physical Systems						
PS3 Energy						
PS3A Definitions of Energy					X	
PS3B Conservation of Energy and Energy Transfer	X				X	
PS3C Relationship Between Energy and Forces	X				X	
PS3D Energy and Chemical Processes in Everyday Life					X	X
PS4 Waves and Their Applications in Technologies for Information Transfer						
PS4A Wave Properties		X			X	
PS4B Electromagnetic Radiation		X			X	
PS4C Information Technologies and Instrumentation		X			X	

Core Idea PS3

Energy

Essential Question: How is energy transferred and conserved?

Interactions of objects can be explained and predicted using the concept of transfer of energy from one object or system of objects to another. The total energy within a defined system changes only by the transfer of energy into or out of the system.

PS3.A: DEFINITIONS OF ENERGY

Essential Question: What is energy?

That there is a single quantity called energy is due to the remarkable fact that a system's *total* energy is conserved. Regardless of the quantities of energy transferred between subsystems and stored in various ways within the system, the total energy of a system changes only by the amount of energy transferred into and out of the system.

At the macroscopic scale, energy manifests itself in multiple phenomena, such as motion, light, sound, electrical and magnetic fields, and thermal energy. Historically, different units were introduced for the energy present in these different phenomena, and it took some time before the relationships among them were recognized. Energy is best understood at the microscopic scale, at which it can be modeled as either motions of particles or as stored in force fields (electric, magnetic, gravitational) that mediate interactions between particles. This last concept includes electromagnetic radiation, a phenomenon in which energy stored in fields moves across space (light, radio waves) with no supporting matter medium.

Motion energy is also called kinetic energy; defined in a given reference frame, it is proportional to the mass of the moving object and grows with the square of its speed. Matter at any temperature above absolute zero contains thermal energy. Thermal energy is the random motion of particles (whether vibrations in solid matter or molecules or free motion in a gas), this energy is distributed among all the particles in a system through collisions and interactions at a distance. In contrast, a sound wave is a moving pattern of particle vibrations that transmits energy through a medium.

Electric and magnetic fields also contain energy; any change in the relative positions of charged objects (or in the positions or orientations of magnets) changes the fields between them and thus the amount of energy stored in those fields. When a particle in a molecule of solid matter vibrates, energy is continually being transformed back and forth between the energy of motion and the energy stored in the electric and magnetic fields within the matter. Matter in a stable form minimizes the stored energy in the electric and magnetic fields within it; this defines the equilibrium positions and spacing of the atomic nuclei in a molecule or an extended solid and the form of their combined electron charge distributions (e.g., chemical bonds, metals).

Energy stored in fields within a system can also be described as potential energy. For any system where the stored energy depends only on the spatial configuration of the system and not on its history, potential energy is a useful concept (e.g., a massive object above Earth's surface, a compressed or stretched spring). It is defined as a difference in energy compared to some arbitrary reference configuration of a system. For example, lifting an object increases the stored energy in the gravitational field between that object and Earth (gravitational potential energy) compared to that for the object at Earth's surface; when the object falls, the stored energy decreases and the object's kinetic energy increases. When a pendulum swings, some stored energy is transformed into kinetic energy and back again into stored energy during each swing. (In both examples energy is transferred out of the system due to collisions with air and for the pendulum also by friction in its support.) Any change in potential energy is accompanied by changes in other forms of energy within the system, or by energy transfers into or out of the system. Electromagnetic radiation (such as light and X-rays) can be modeled as a wave of changing electric and magnetic fields. At the subatomic scale (i. e., in quantum theory), many phenomena involving electromagnetic radiation (e.g., photoelectric effect) are best modeled as a stream of particles called photons. Electromagnetic radiation from the sun is a major source of energy for life on Earth.

The idea that there are different forms of energy, such as thermal energy, mechanical energy, and chemical energy, is misleading, as it implies that the nature of the energy in each of these manifestations is distinct when in fact they all are ultimately, at the atomic scale, some mixture of kinetic energy, stored energy, and radiation. It is likewise misleading to call sound or light a form of energy; they are phenomena that, among their other properties, transfer energy from place to place and between objects.

Grade Band Endpoints for PS3.A

By the end of grade 2. [Intentionally left blank.]

By the end of grade 5. The faster a given object is moving, the more energy it possesses. Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (Boundary: At this grade level, no attempt is made to give a precise or complete definition of energy.)

PS3.B: CONSERVATION OF ENERGY AND ENERGY TRANSFER

*Essential Questions: What is meant by conservation of energy?
How is energy transferred between objects or systems?*

The total change of energy in any system is always equal to the total energy transferred into or out of the system. This is called conservation of energy. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Many different types of phenomena can be explained in terms of energy transfers. Mathematical expressions, which quantify changes in the forms of energy within a system and transfers of energy into or out of the system, allow the concept of conservation of energy to be used to predict and describe the behavior of a system.

When objects collide or otherwise come in contact, the motion energy of one object can be transferred to change the motion or stored energy (e.g., change in shape or temperature) of the other objects. For macroscopic objects, any such process (e.g., collisions, sliding contact) also transfers some of the energy to the surrounding air by sound or heat. For molecules, collisions can also result in energy transfers through chemical processes, which increase or decrease the total amount of stored energy within a system of atoms; the change in stored energy is always balanced by a change in total kinetic energy—that of the molecules present after the process compared with the kinetic energy of the molecules present before it.

Energy can also be transferred from place to place by electric currents. Heating is another process for transferring energy. Heat transfer occurs when two objects or systems are at different temperatures. Energy moves out of higher temperature objects and into lower temperature ones, cooling the former and heating the latter. This transfer happens in three different ways—by conduction within solids, by the flow of liquid or gas (convection), and by radiation, which can travel across space. Even when a system is isolated (such as Earth in space), energy is continually being transferred into and out of it by radiation. The processes underlying convection and conduction can be understood in terms of models of the possible motions of particles in matter.

Radiation can be emitted or absorbed by matter. When matter absorbs light or infrared radiation, the energy of that radiation is transformed to thermal motion of particles in the matter, or, for shorter wavelengths (ultraviolet, X-ray), the radiation's energy is absorbed within the atoms or molecules and may possibly ionize them by knocking out an electron.

Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution within the system or between the system and its environment (e.g., water flows downhill, objects that are hotter than their surrounding environment cool down). Any object or system that can degrade with no added energy is unstable. Eventually it will change or fall apart, although in some cases it may remain in the unstable state for a long time before decaying (e.g., long-lived radioactive isotopes).

Grade-Level Endpoints for PS3.B

By the end of grade 2.

Sunlight warms Earth’s surface.

By the end of grade 5.

Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.

Light also transfers energy from place to place. For example, energy radiated from the sun is transferred to Earth by light. When this light is absorbed, it warms Earth’s land, air, and water and facilitates plant growth.

Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy (e.g., moving water driving a spinning turbine which generates electric currents).

PS3.C RELATIONSHIP BETWEEN ENERGY AND FORCES

Essential Question: How are forces related to energy?

When two objects interact, each one exerts a force on the other. These forces can transfer energy between the objects. Forces between two objects at a distance are explained by force fields (gravitational, electric, or magnetic) between them. Contact forces between colliding objects can be modeled at the microscopic level as due to electromagnetic force fields between the surface particles. When two objects interacting via a force field change their relative position, the energy in the force field between them changes. For any such pair of objects the force on each object acts in the direction such that motion of that object in that direction would reduce the energy in the force field between the two objects. However, prior motion and other forces also affect the actual direction of motion.

Patterns of motion, such as a weight bobbing on a spring or a swinging pendulum, can be understood in terms of forces at each instant or in terms of transformation of energy between the motion and one or more forms of stored energy. Elastic collisions between two objects can be modeled at the macroscopic scale using conservation of energy without having to examine the detailed microscopic forces.

Grade Band Endpoints for PS3.C

By the end of grade 2. A bigger push or pull makes things go faster. Faster speeds during a collision can cause a bigger change in shape of the colliding objects.

By the end of grade 5. When objects collide, the contact forces transfer energy so as to change the objects' motions. Magnets can exert forces on other magnets or on magnetizable materials, causing energy transfer between them (e.g., leading to changes in motion) even when the objects are not touching.

PS3.D: ENERGY IN CHEMICAL PROCESSES AND EVERYDAY LIFE

*Essential Questions: How do food and fuel provide energy?
If energy is conserved, why do people say it is produced or used?*

In ordinary language, people speak of “producing” or “using” energy. This refers to the fact that energy in concentrated form is useful for generating electricity, moving or heating objects, and producing light, whereas diffuse energy in the environment is not readily captured for practical use. Therefore, to produce energy typically means to convert some stored energy into a desired form—for example, the stored energy of water behind a dam is released as the water flows downhill and drives a turbine generator to produce electricity, which is then delivered to users through distribution systems. Food, fuel, and batteries are especially convenient energy resources because they can be moved from place to place to provide processes that release energy where needed. A system does not destroy energy when carrying out any process. However, the process cannot occur without energy being available. The energy is also not destroyed by the end of the process. Most often some or all of it has been transferred to heat the surrounding environment; in the same sense that paper is not destroyed when it is written on, it still exists but is not readily available for further use.

Naturally occurring food and fuel contain complex carbon-based molecules, chiefly derived from plant matter that has been formed by photosynthesis. The chemical reaction of these molecules with oxygen releases energy; such reactions provide energy for most animal life and for residential, commercial, and industrial activities.

Electric power generation is based on fossil fuels (i.e., coal, oil, and natural gas), nuclear fission, or renewable resources (e.g., solar, wind, tidal, geothermal, and hydro power). Transportation today chiefly depends on fossil fuels, but the use of electric and alternative fuel (e.g., hydrogen, biofuel) vehicles is increasing. All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term. Technological advances and regulatory decisions can change the balance of those costs and benefits.

Although energy cannot be destroyed, it can be converted to less useful forms. In designing a system for energy storage, for energy distribution, or to perform some practical task (e.g., to power an airplane), it is important to design for maximum efficiency—thereby ensuring that the largest possible fraction of the energy is used for the desired purpose rather than being transferred out of the system in unwanted ways (e.g., through friction, which eventually results in heat energy transfer to the surrounding environment). Improving efficiency reduces costs, waste materials, and many unintended environmental impacts.

Grade Band Endpoints for PS3.D

By the end of grade 2.

When two objects rub against each other, this interaction is called friction. Friction between two surfaces can warm both of them (e.g., rubbing hands together). There are ways to reduce the friction between two objects.

By the end of grade 5.

The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use—for example, the stored energy of water behind a dam is released so that it flows downhill and drives a turbine generator to produce electricity. Food and fuel also release energy when they are digested or burned. When machines or animals “use” energy (e.g., to move around), most often the energy is transferred to heat the surrounding environment.

The energy released by burning fuel or digesting food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water). (Boundary: The fact that plants capture energy from sunlight is introduced at this grade level, but details of photosynthesis are not.)

It is important to be able to concentrate energy so that it is available for use where and when it is needed. For example, batteries are physically transportable energy storage devices, whereas electricity generated by power plants is transferred from place to place through distribution systems.

Core Idea PS4

Waves and Their Applications in Technologies for Information Transfer

Essential Question: How are waves used to transfer energy and information?

Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. Light and sound are wavelike phenomena. By understanding wave properties and the interactions of electromagnetic radiation with matter, scientists and engineers can design systems for transferring information across long distances, storing information, and investigating nature on many scales—some of them far beyond direct human perception.

PS4.A: WAVE PROPERTIES

Essential Question: What are the characteristic properties and behaviors of waves?

Whether a wave in water, a sound wave, or a light wave, all waves have some features in common. A simple wave has a repeating pattern of specific wavelength, frequency, and amplitude. The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which, for each type of wave, depends on the medium in which the wave is traveling. Waves can be combined with other waves of the same type to produce complex information-containing patterns that can be decoded at the receiving end. Waves, which transfer energy and any encoded information without the bulk motion of matter, can travel unchanged over long distances, pass through other waves undisturbed, and be detected and decoded far from where they were produced. Information can be digitized (converted into a numerical representation), sent over long distances as a series of wave pulses, and reliably stored in computer memory.

Sound is a pressure wave in air or any other material medium. The human ear and brain working together are very good at detecting and decoding patterns of information in sound (e.g., speech and music) and distinguishing them from random noise.

Resonance is a phenomenon in which waves add up in phase (i.e., matched peaks and valleys), thus growing in amplitude. Structures have particular frequencies at which they resonate when some time-varying force acting on them transfers energy to them. This phenomenon (e.g., waves in a stretched string, vibrating air in a pipe) is used in the design of all musical instruments and in the production of sound by the human voice.

When a wave passes an object that is small compared with its wavelength, the wave is not much affected; for this reason, some things are too small to see with visible light, which is a wave phenomenon with a limited range of wavelengths corresponding to each color. When a wave meets the surface between two different materials or conditions (e.g., air to water), part of the wave is reflected at that surface and another part continues on, but at a different speed. The change of speed of the wave when passing from one medium to another can cause the wave to change direction or refract. These wave properties are used in many applications (e.g., lenses, seismic probing of Earth).

Grade Band Endpoints for PS4.A

By the end of grade 2.

Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; it does not move in the direction of the wave—observe, for example, a bobbing cork or seabird—except when the water meets the beach. Sound can make matter vibrate, and vibrating matter can make sound.

By the end of grade 5.

Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.)

Earthquakes cause seismic waves, which are waves of motion in Earth's crust.

PS4.B: ELECTROMAGNETIC RADIATION

*Essential Questions: What is light?
How can one explain the varied effects that involve light?
What other forms of electromagnetic radiation are there?*

Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave pattern of changing electric and magnetic fields or, alternatively, as particles. Each model is useful for understanding aspects of the phenomenon and its inter-actions with matter, and quantum theory relates the two models. Electromagnetic waves can be detected over a wide range of frequencies, of which the visible spectrum of colors detectable by human eyes is just a small part. Many modern technologies are based on the manipulation of electromagnetic waves.

All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any given medium depends on its wavelength and the properties of that medium. At the surface between two media, like any wave, light can be reflected, refracted (its path bent), or absorbed. What occurs depends on properties of the surface and the wavelength of the light. When shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) is absorbed in matter, it can ionize atoms and cause damage to living cells. However, because X-rays can travel through soft body matter for some distance but are more rapidly absorbed by denser matter, particularly bone, they are useful for medical imaging. Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. This phenomenon is used in barcode scanners and “electric eye” systems, as well as in solar cells. It is best explained using a particle model of light.

Any object emits a spectrum of electromagnetic radiation that depends on its temperature. In addition, atoms of each element emit and preferentially absorb characteristic frequencies of light. These spectral lines allow identification of the presence of the element, even in microscopic quantities or for remote objects, such as a star. Nuclear transitions that emit or absorb gamma radiation also have distinctive gamma ray wavelengths, a phenomenon that can be used to identify and trace specific radioactive isotopes.

Grade Band Endpoints for PS4.B

By the end of grade 2.

Objects can be seen only when light is available to illuminate them. Very hot objects give off light (e.g., a fire, the sun).

Some materials allow light to pass through them, others allow only some light through, and others block all the light and create a dark shadow on any surface beyond them (i.e., on the other side from the light source), where the light cannot reach. Mirrors and prisms can be used to redirect a light beam. (Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.)

By the end of grade 5.

A great deal of light travels through space to Earth from the sun and from distant stars.

An object can be seen when light reflected from its surface enters the eyes; the color people see depends on the color of the available light sources as well as the properties of the surface. (Boundary: This phenomenon is observed, but no attempt is made to discuss what confers the color reflection and absorption properties on a surface. The stress is on understanding that light traveling from the object to the eye determines what is seen.)

Because lenses bend light beams, they can be used, singly or in combination, to provide magnified images of objects too small or too far away to be seen with the naked eye.

PS4.C: INFORMATION TECHNOLOGIES AND INSTRUMENTATION

Essential Question: How are instruments that transmit and detect waves used to extend human senses?

Understanding of waves and their interactions with matter has been used to design technologies and instruments that greatly extend the range of phenomena that can be investigated by science (e.g., telescopes, microscopes) and have many useful applications in the modern world.

Light waves, radio waves, microwaves, and infrared waves are applied to communications systems, many of which use digitized signals (i.e., sent as wave pulses) as a more reliable way to convey information. Signals that humans cannot sense directly can be detected by appropriately designed devices (e.g., telescopes, cell phones, wired or wireless computer networks). When in digitized form, information can be recorded, stored for future recovery, and transmitted over long distances without significant degradation known how fast sound travels in water and light travels in a vacuum. The better the interaction of the wave with the medium is understood, the more detailed the information that can be extracted (e.g., medical imaging or astronomical observations at multiple frequencies).

Grade Band Endpoints for PS4.C

By the end of grade 2.

People use their senses to learn about the world around them. Their eyes detect light, their ears detect sound, and they can feel vibrations by touch.

People also use a variety of devices to communicate (send and receive information) over long distances.

By the end of grade 5.

Lenses can be used to make eyeglasses, telescopes, or microscopes in order to extend what can be seen. The design of such instruments is based on understanding how the path of light bends at the surface of a lens.

Digitized information (e.g., the pixels of a picture) can be stored for future recovery or transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa.

Life Science K-5 Progression

Life Science	K	1	2	3	4	5
LS1 From Molecules to Organisms: Structures and Processes						
LS1A Structure and Function		X			X	
LS1B Growth and Development of Organisms		X		X		
LS1C Organization for Matter and Energy Flow in Organisms	X					X
LS1D Information Processing		X			X	
LS2 Ecosystems: Interactions, Energy, and Dynamics						
LS2A Interdependent Relationships in Ecosystems			X			X
LS2B Cycles of Matter and Energy Transfer in Ecosystems						X
LS2C Ecosystem Dynamics, Functioning, and Resilience				X		
LS2D Social Interactions and Group Behavior				X		
LS3 Heredity: Inheritance and Variation of Traits						
LS3A Inheritance of Traits		X		X		
LS3B Variation of Traits		X		X		
LS4 Biological Evolution: Unity and Diversity						
LS4A Evidence of Common Ancestry				X		
LS4B Natural Selection				X		
LS4C Adaptation				X		
LS4D Biodiversity and Humans			X	X		

Core Idea LS1

From Molecules to Organisms: Structures and Processes

Essential Question: How do organisms live, grow, respond to their environment, and reproduce?

All living organisms are made of cells. Life is the quality that distinguishes living things—composed of living cells—from nonliving objects or those that have died. While a simple definition of life can be difficult to capture, all living things—that is to say all organisms—can be characterized by common aspects of their structure and functioning. Organisms are complex, organized, and built on a hierarchical structure, with each level providing the foundation for the next, from the chemical foundation of elements and atoms, to the cells and systems of individual organisms, to species and populations living and interacting in complex ecosystems. Organisms can be made of a single cell or millions of cells working together and include animals, plants, algae, fungi, bacteria, and all other microorganisms.

Organisms respond to stimuli from their environment and actively maintain their internal environment through homeostasis. They grow and reproduce, transferring their genetic information to their offspring. While individual organisms carry the same genetic information over their lifetime, mutation and the transfer from parent to offspring produce new combinations of genes. Over generations natural selection can lead to changes in a species overall; hence, species evolve over time. To maintain all of these processes and functions, organisms require materials and energy from their environment; nearly all energy that sustains life ultimately comes from the sun.

LS1.A: STRUCTURE AND FUNCTION

Essential Question: How do the structures of organisms enable life's functions?

A central feature of life is that organisms grow, reproduce, and die. They have characteristic structures (anatomy and morphology), functions (molecular-scale processes to organism-level physiology), and behaviors (neurobiology and, for some animal species, psychology). Organisms and their parts are made of cells, which are the structural units of life and which themselves have molecular substructures that support their functioning. Organisms range in composition from a single cell (unicellular microorganisms) to multicellular organisms, in which different groups of large numbers of cells work together to form systems of tissues and organs (e.g., circulatory, respiratory, nervous, musculoskeletal), that are specialized for particular functions.

Special structures *within* cells are also responsible for specific cellular functions. The essential functions of a cell involve chemical reactions between many types of molecules, including water, proteins, carbohydrates, lipids, and nucleic acids. All cells contain genetic information, in the form of DNA. Genes are specific regions within the extremely large DNA molecules that form the chromosomes. Genes contain the instructions that code for the formation of molecules called proteins, which carry out most of the work of cells to perform the essential functions of life. That is, proteins provide structural components, serve as signaling devices, regulate cell activities, and determine the performance of cells through their enzymatic actions.

Grade Band Endpoints for LS1.A

By the end of grade 2. All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air. Plants also have different parts (roots, stems, leaves, flowers, fruits) that help them survive, grow, and produce more plants.

By the end of grade 5. Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (Boundary: Stress at this grade level is on understanding the macroscale systems and their function, not microscopic processes.)

LS1.D: INFORMATION PROCESSING

Essential Question: How do organisms detect, process, and use information about the environment?

An organism’s ability to sense and respond to its environment enhances its chance of surviving and reproducing. Animals have external and internal sensory receptors that detect different kinds of information, and they use internal mechanisms for processing and storing it. Each receptor can respond to different inputs (electromagnetic, mechanical, chemical), some receptors respond by transmitting impulses that travel along nerve cells. In complex organisms, most such inputs travel to the brain, which is divided into several distinct regions and circuits that serve primary roles, in particular functions such as visual perception, auditory perception, interpretation of perceptual information, guidance of motor movement, and decision making. In addition, some of the brain’s circuits give rise to emotions and store memories. Brain function also involves multiple interactions between the various regions to form an integrated sense of self and the surrounding world.

Grade Band Endpoints for LS1.D

By the end of grade 2. Animals have body parts that capture and convey different kinds of information needed for growth and survival—for example, eyes for light, ears for sounds, and skin for temperature or touch. Animals respond to these inputs with behaviors that help them survive (e.g., find food, run from a predator). Plants also respond to some external inputs (e.g., turn leaves toward the sun).

By the end of grade 5. Different sense receptors are specialized for particular kinds of information, which may then be processed and integrated by an animal’s brain, with some information stored as memories. Animals are able to use their perceptions and memories to guide their actions. Some responses to information are instinctive—that is, animals’ brains are organized so that they do not have to think about how to respond to certain stimuli.

Earth Space K-5 Progression

Earth Space Science	K	1	2	3	4	5
ESS1 Earth's Place in the Universe						
ESS1A The Universe and Its Stars		X				X
ESS1B Earth and the Solar System		X				X
ESS1C The History of Planet Earth			X		X	
ESS2 Earth's Systems						
ESS2A Earth Materials and Systems			X		X	X
ESS2B Plate Tectonics and Large-Scale System Interactions			X		X	
ESS2C The Roles of Water in Earth's Surface Processes			X			X
ESS2D Weather and Climate	X			X		
ESS2E Biogeology	X				X	
ESS3 Earth and Human Activity						
ESS3A Natural Resources	X				X	
ESS3B Natural Hazards	X			X		
ESS3C Human Impacts on Earth Systems	X					X
ESS3D Global Climate Change						

Core Idea ESS1

Earth's Place in the Universe

Essential Question: What is the universe, and what is Earth's place in it?

The planet Earth is a tiny part of a vast universe that has developed over a huge expanse of time. The history of the universe, and of the structures and objects within it, can be deciphered using observations of their present condition together with knowledge of physics and chemistry. Similarly, the patterns of motion of the objects in the solar system can be described and predicted on the basis of observations and an understanding of gravity. Comprehension of these patterns can be used to explain many Earth phenomena, such as day and night, seasons, tides, and phases of the moon. Observations of other solar system objects and of Earth itself can be used to determine Earth's age and the history of large-scale changes in its surface.

ESS1.C: THE HISTORY OF PLANET EARTH

Essential Question: How do people reconstruct and date events in Earth's planetary history?

Earth scientists use the structure, sequence, and properties of rocks, sediments, and fossils, as well as the locations of current and past ocean basins, lakes, and rivers, to reconstruct events in Earth's planetary history. For example, rock layers show the sequence of geological events, and the presence and amount of radioactive elements in rocks make it possible to determine their ages.

Analyses of rock formations and the fossil record are used to establish relative ages. In an undisturbed column of rock, the youngest rocks are at the top, and the oldest are at the bottom. Rock layers have sometimes been rearranged by tectonic forces; rearrangements can be seen or inferred, such as from inverted sequences of fossil types. Core samples obtained from drilling reveal that the continents' rocks (some as old as 4 billion years or more) are much older than rocks on the ocean floor (less than 200 million years), where tectonic processes continually generate new rocks and destroy old ones. The rock record reveals that events on Earth can be catastrophic, occurring over hours to years, or gradual, occurring over thousands to millions of years. Records of fossils and other rocks also show past periods of massive extinctions and extensive volcanic activity. Although active geological processes, such as plate tectonics ([link to ESS2.B](#)) and erosion have destroyed or altered most of the very early rock record on Earth, some other objects in the solar system, such as asteroids and meteorites, have changed little over billions of years. Studying these objects can help scientists deduce the solar system's age and history, including the formation of planet Earth. Study of other planets and their moons, many of which exhibit such features as volcanism and meteor impacts similar to those found on Earth, also help illuminate aspects of Earth's history and changes.

The geological time scale organizes Earth's history into the increasingly long time intervals of eras, periods, and epochs. Major historical events include the formation of mountain chains and ocean basins, volcanic activity, the evolution and extinction of living organisms, periods of massive glaciation, and development of watersheds and rivers. Because many individual plant and animal species existed during known time periods (e.g., dinosaurs), the location of certain types of fossils in the rock record can reveal the age of the rocks and help geologists decipher the history of landforms.

Grade Band Endpoints for ESS1.C

By the end of grade 2. Some events on Earth occur in cycles, like day and night, and others have a beginning and an end, like a volcanic eruption. Some events, like an earthquake, happen very quickly; others, such as the formation of the Grand Canyon, occur very slowly, over a time period much longer than one can observe.

By the end of grade 5. Earth has changed over time. Understanding how landforms develop, are weathered (broken down into smaller pieces), and erode (get transported elsewhere) can help infer the history of the current landscape. Local, regional, and global patterns of rock formations reveal changes over time due to Earth forces, such as earthquakes. The presence and location of certain fossil types indicate the order in which rock layers were formed. Patterns of tree rings and ice cores from glaciers can help reconstruct Earth's recent climate history.

Core Idea ESS2

Earth's Systems

Essential Question: How and why is Earth constantly changing?

Earth's surface is a complex and dynamic set of interconnected systems—principally the geosphere, hydrosphere, atmosphere, and biosphere—that interact over a wide range of temporal and spatial scales. All of Earth's processes are the result of energy flowing and matter cycling within and among these systems. For example, the motion of tectonic plates is part of the cycles of convection in Earth's mantle, driven by outflowing heat and the downward pull of gravity, which result in the formation and changes of many features of Earth's land and undersea surface. Weather and climate are shaped by complex interactions involving sunlight, the ocean, the atmosphere, clouds, ice, land, and life forms. Earth's biosphere has changed the makeup of the geosphere, hydrosphere, and atmosphere over geological time; conversely, geological events and conditions have influenced the evolution of life on the planet. Water is essential to the dynamics of most earth systems, and it plays a significant role in shaping Earth's landscape.

ESS2.A: EARTH MATERIALS AND SYSTEMS

Essential Question: How do Earth's major systems interact?

Earth is a complex system of interacting subsystems: the geosphere, hydrosphere, atmosphere, and biosphere. The geosphere includes a hot and mostly metallic inner core; a mantle of hot, soft, solid rock; and a crust of rock, soil, and sediments. The atmosphere is the envelope of gas surrounding the planet. The hydrosphere is the ice, water vapor, and liquid water in the atmosphere, ocean, lakes, streams, soils, and groundwater. The presence of living organisms of any type defines the biosphere; life can be found in many parts of the geosphere, hydrosphere, and atmosphere. Humans are of course part of the biosphere, and human activities have important impacts on all of Earth's systems.

All Earth processes are the result of energy flowing and matter cycling within and among Earth's systems. This energy originates from the sun and from Earth's interior. Transfers of energy and the movements of matter can cause chemical and physical changes among Earth's materials and living organisms.

Solid rocks, for example, can be formed by the cooling of molten rock, the accumulation and consolidation of sediments, or the alteration of older rocks by heat, pressure, and fluids. These processes occur under different circumstances and produce different types of rock. Physical and chemical interactions among rocks, sediments, water, air, and plants and animals produce soil. In the carbon, water, and nitrogen cycles, materials cycle between living and nonliving forms and among the atmosphere, soil, rocks, and ocean.

Weather and climate are driven by interactions of the geosphere, hydrosphere, and atmosphere, with inputs of energy from the sun. The tectonic and volcanic processes that create and build mountains and plateaus, for example, as well as the weathering and erosion processes that break down these structures and transport the products, all involve interactions among the geosphere, hydrosphere, and atmosphere. The resulting landforms and the habitats they provide affect the biosphere, which in turn modifies these habitats and affects the atmosphere, particularly through imbalances between the carbon capture and oxygen release that occur in photosynthesis, and the carbon release and oxygen capture that occur in respiration and in the burning of fossil fuels to support human activities.

Earth exchanges mass and energy with the rest of the solar system. It gains or loses energy through incoming solar radiation, thermal radiation to space, and gravitational forces exerted by the sun, moon, and planets. Earth gains mass from the impacts of meteoroids and comets and loses mass from the escape of gases into space.

Earth's systems are dynamic; they interact over a wide range of temporal and spatial scales and continually react to changing influences, including human activities. Components of Earth's systems may appear stable, change slowly over long periods of time, or change abruptly, with significant consequences for living organisms. Changes in part of one system can cause further changes to that system or to other systems, often in surprising and complex ways.

Grade Band Endpoints for ESS2.A

By the end of grade 2. Wind and water can change the shape of the land. The resulting landforms, together with the materials on the land, provide homes for living things.

By the end of grade 5. Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. Rainfall helps shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. Human activities affect Earth's systems and their interactions at its surface.

ESS2.B: PLATE TECTONICS AND LARGE-SCALE SYSTEM INTERACTIONS

Essential Question: Why do the continents move, and what causes earthquakes and volcanoes?

Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a coherent account of its geological history. This theory is supported by multiple evidence streams—for example, the consistent patterns of earthquake locations, evidence of ocean floor spreading over time given by tracking magnetic patterns in undersea rocks and coordinating them with changes to Earth's magnetic axis data, the warping of the land under loads (such as lakes and ice sheets), which show that the solid mantle's rocks can bend and even flow.

The lighter and less dense continents are embedded in heavier and denser upper-mantle rocks, and together they make up the moving tectonic plates of the lithosphere (Earth's solid outer layer, i.e., the crust and upper mantle). Tectonic plates are the top parts of giant convection cells that bring matter from the hot inner mantle up to the cool surface. These movements are driven by the release of energy (from radioactive decay of unstable isotopes within Earth's interior) and by the cooling and gravitational downward motion of the dense material of the plates after subduction (one plate being drawn under another). The plates move across Earth's surface, carrying the continents, creating and destroying ocean basins, producing earthquakes and volcanoes, and forming mountain ranges and plateaus.

Most continental and ocean floor features are the result of geological activity and earthquakes along plate boundaries. The exact patterns depend on whether the plates are being pushed together to create mountains or deep ocean trenches, being pulled apart to form new ocean floor at mid-ocean ridges, or sliding past each other along surface faults. Most distributions of rocks within Earth's crust, including minerals, fossil fuels, and energy resources, are a direct result of the history of plate motions and collisions and the corresponding changes in the configurations of the continents and ocean basins.

This history is still being written. Continents are continually being shaped and reshaped by competing constructive and destructive geological processes. North America, for example, has gradually grown in size over the past 4 billion years through a complex set of interactions with other continents, including the addition of many new crustal segments.

Grade Band Endpoints for ESS2.B

By the end of grade 2. Rocks, soils, and sand are present in most areas where plants and animals live. There may also be rivers, streams, lakes, and ponds. Maps show where things are located. One can map the shapes and kinds of land and water in any area.

By the end of grade 5. The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features where people live and in other areas of Earth.

ESS2.E: BIOGEOLOGY

Essential Question: How do living organisms alter Earth's processes and structures?

Evolution, including the emergence and extinction of species, is a natural and ongoing process that is shaped by Earth's dynamic processes. The properties and conditions of Earth and its atmosphere affect the environments and conditions within which life emerged and evolved—for example, the range of frequencies of light that penetrate the atmosphere to Earth's surface. Organisms continually evolve to new and often more complex forms as they adapt to new environments. The evolution and proliferation of living things have changed the makeup of Earth's geosphere, hydrosphere, and atmosphere over geological time. Plants, algae, and microorganisms produced most of the oxygen (i.e., the O₂) in the atmosphere through photosynthesis, and they enabled the formation of fossil fuels and types of sedimentary rocks. Microbes also changed the chemistry of Earth's surface, and they continue to play a critical role in nutrient cycling (e.g., of nitrogen) in most ecosystems.

Organisms ranging from bacteria to human beings are a major driver of the global carbon cycle, and they influence global climate by modifying the chemical makeup of the atmosphere. Greenhouse gases in particular are continually moved through the reservoirs represented by the ocean, land, life, and atmosphere. The abundance of carbon in the atmosphere is reduced through the ocean floor accumulation of marine sediments and the accumulation of plant biomass; atmospheric carbon is increased through such processes as deforestation and the burning of fossil fuels.

As Earth changes, life on Earth adapts and evolves to those changes, so just as life influences other Earth systems, other Earth systems influence life. Life and the planet's nonliving systems can be said to co-evolve.

Grade Band Endpoints for ESS2.E

By the end of grade 2. Plants and animals (including humans) depend on the land, water, and air to live and grow. They in turn can change their environment (e.g., the shape of land, the flow of water).

By the end of grade 5. Living things affect the physical characteristics of their regions (e.g., plants' roots hold soil in place, beaver shelters and human-built dams alter the flow of water, plants' respiration affects the air). Many types of rocks and minerals are formed from the remains of organisms or are altered by their activities.

Engineering, Technology and Application of Science K-5 Progression

Engineering, Technology and Application of Science K-5 Progression

Engineering, Technology, and Applications of Science	K	1	2	3	4	5
ETS1: Engineering Design						
ETS1A Defining and Delimiting Engineering Problems	X				X	
ETS1B Developing Possible Solutions	X		X		X	
ETS1C Optimizing the Design Solution			X		X	
ETS2: Links Among Engineering, Technology, Science and						
ETS2.A Interdependence of Science, Engineering and Technology						
ETS2.B Influence of Engineering, Technology, and Science on Society and the Natural World						

Core Idea ETS1

Engineering Design

Essential Question: How do engineers solve problems?

The design process—engineers’ basic approach to problem solving—involves many different practices. They include problem definition, model development and use, investigation, analysis and interpretation of data, application of mathematics and computational thinking, and determination of solutions. These engineering practices incorporate specialized knowledge about criteria and constraints, modeling and analysis, and optimization and trade-offs.

ETS1.A: DEFINING AND DELIMITING AN ENGINEERING PROBLEM

*Essential Questions: What is a design for?
What are the criteria and constraints of a successful solution?*

The engineering design process begins with the identification of a problem to solve and the specification of clear goals, or criteria, that the final product or system must meet. Criteria, which typically reflect the needs of the expected end-user of a technology or process, address such things as how the product or system will function (what job it will perform and how), its durability, and its cost. Criteria should be quantifiable whenever possible and stated so that one can tell if a given design meets them.

Engineers must contend with a variety of limitations, or constraints, when they engage in design. Constraints, which frame the salient conditions under which the problem must be solved, may be physical, economic, legal, political, social, ethical, aesthetic, or related to time and place. In terms of quantitative measurements, constraints may include limits on cost, size, weight, or performance, for example. And although constraints place restrictions on a design, not all of them are permanent or absolute.

Grade Band End Points for ETS1.A

By the end of grade 2. A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. Asking questions, making observations, and gathering information are helpful in thinking about problems. Before beginning to design a solution, it is important to clearly understand the problem.

By the end of grade 5. Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.

ETS1.B: DEVELOPING POSSIBLE SOLUTIONS

Essential Question: What is the process for developing potential design solutions?

The creative process of developing a new design to solve a problem is a central element of engineering. This process may begin with a relatively open-ended phase during which new ideas are generated both by individuals and by group processes such as brainstorming. Before long, the process must move to the specification of solutions that meet the criteria and constraints at hand. Initial ideas may be communicated through informal sketches or diagrams, although they typically become more formalized through models. The ability to build and use physical, graphical, and mathematical models is an essential part of translating a design idea into a finished product, such as a machine, building, or any other working system. Because each area of engineering focuses on particular types of systems (e.g., mechanical, electrical, biotechnological), engineers become expert in the elements that such systems need. But whatever their fields, all engineers use models to help develop and communicate solutions to design problems.

Models allow the designer to better understand the features of a design problem, visualize elements of a possible solution, predict a design's performance, and guide the development of feasible solutions (or, if possible, the optimal solution). A physical model can be manipulated and tested for parameters of interest, such as strength, flexibility, heat conduction, fit with other components, and durability. Scale models and prototypes are particular types of physical models. Graphical models, such as sketches and drawings, permit engineers to easily share and discuss design ideas and to rapidly revise their thinking based on input from others.

Mathematical models allow engineers to estimate the effects of a change in one feature of the design (e.g., material composition, ambient temperature) on other features, or on performance as a whole, before the designed product is actually built. Mathematical models are often embedded in computer-based simulations. Computer-aided design (CAD) and computer-aided manufacturing (CAM) are modeling tools commonly used in engineering.

Data from models and experiments can be analyzed to make decisions about modifying a design. The analysis may reveal performance information, such as which criteria a design meets, or predict how well the overall designed system or system component will behave under certain conditions. If analysis reveals that the predicted performance does not align with desired criteria, the design can be adjusted.

Grade Band Endpoints for ETS1.B

By the end of grade 2.

Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. To design something complicated, one may need to break the problem into parts and attend to each part separately but must then bring the parts together to test the overall plan.

By the end of grade 5.

Research on a problem should be carried out—for example, through Internet searches, market research, or field observations—before beginning to design a solution. An often productive way to generate ideas is for people to work together to brainstorm, test, and refine possible solutions. Testing a solution involves investigating how well it performs under a range of likely conditions. Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.

There are many types of models, ranging from simple physical models to computer models. They can be used to investigate how a design might work, communicate the design to others, and compare different designs.

ETS1.C: OPTIMIZING THE DESIGN SOLUTION

Essential Question: How can the various proposed design solutions be compared and improved?

Multiple solutions to an engineering design problem are always possible because there is more than one way to meet the criteria and satisfy the constraints. But the aim of engineering is not simply to design a solution to a problem but to design the best solution. Determining what constitutes “best,” however, requires value judgments, given that one person’s view of the optimal solution may differ from another’s.

Optimization often requires making trade-offs among competing criteria. For example, as one criterion (such as lighter weight) is enhanced, another (such as unit cost) might be sacrificed (i.e., cost may be increased due to the higher cost of lightweight materials). In effect, one criterion is devalued or traded off for another that is deemed more important. When multiple possible design options are under consideration, with each optimized for different criteria, engineers may use a trade-off matrix to compare the overall advantages and disadvantages of the different proposed solutions.

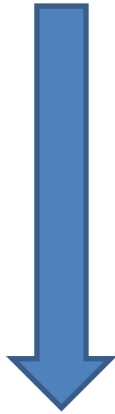
The decision as to which criteria are critical and which ones can be traded off is a judgment based on the situation and the perceived needs of the end-user of the product or system. Because many factors—including environmental or health impacts, available technologies, and the expectations of users—change over time and vary from place to place, a design solution that is considered optimal at one time and place may appear far from optimal at other times and places. Thus different designs, each of them optimized for different conditions, are often needed.

Grade Band Endpoints for ETS1.C

By the end of grade 2. Because there is always more than one possible solution to a problem, it is useful to compare designs, test them, and discuss their strengths and weaknesses.

By the end of grade 5. Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.

A Closer Look at the Scope and Sequence Fourth Grade Unit 1



This is a **performance expectation**. Performance expectations describe what students should be able to do at the end of instruction and incorporates a science and engineering practice, a disciplinary core idea (DCI) and a crosscutting concept. Performance expectations are not instructional strategies or objectives for a lesson. Instead, they are intended to guide the development of assessments. Clarification statements and assessment boundary statements are provided in the original documents to render additional support and clarification of the performance expectation.

4-PS3-1 4 = grade level
 PS3 = Core Idea
 1 = the number within the core idea (so this is the first performance expectation in the core idea ESS2)

4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

<p>Science and Engineering Practice</p> <ul style="list-style-type: none"> Constructing Explanations and Designing Solutions – Use evidence (e.g., measurements, observations, patterns) to construct an explanation. 	<p>what they will do</p>
<p>Disciplinary Core Ideas</p> <ul style="list-style-type: none"> PS3.A: Definitions of Energy - The faster a given object is moving, the more energy it possesses. 	<p>what they will understand</p>
<p>Crosscutting Concept</p> <ul style="list-style-type: none"> Energy and Matter – Energy can be transferred in various ways and between objects. 	<p>how they will organize and connect their knowledge</p>



ORGANIZING THEME/ TOPIC

FOCUS STANDARDS & SKILLS

Energy & Motion

Bring Science Alive!
Unit 2 Energy
Lessons 1-2

Suggested Time Frame: 14 days

4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

Science and Engineering Practice

- **Constructing Explanations and Designing Solutions** – Use evidence (e.g., measurements, observations, patterns) to construct an explanation.

Disciplinary Core Ideas

- **PS3.A: Definitions of Energy** - The faster a given object is moving, the more energy it possesses.

Crosscutting Concept

- **Energy and Matter** – Energy can be transferred in various ways and between objects.

4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.

Science and Engineering Practice

- **Asking Questions and Defining Problems** – Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.

Disciplinary Core Ideas

- **PS3.A: Definitions of Energy** - Energy can be moved from place to place by moving objects or through sound, light, or electric currents.
- **PS3.B: Conservation of Energy and Energy Transfer** - Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.
- **PS3.C: Relationship Between Energy and Forces** - When objects collide, the contact forces transfer energy so as to change the objects' motions.

Crosscutting Concept

- **Energy and Matter** – Energy can be transferred in various ways and between objects.

<p>Energy Transfer</p> <p>Bring Science Alive! Unit 2 Energy Lessons 3 - 4</p> <p>Suggested Time Frame: 13 days</p>	<p>4-PS3.2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat and electric currents.</p> <p>Science and Engineering Practice</p> <ul style="list-style-type: none"> • Planning and Carrying Out Investigations – Make observations to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. <p>Disciplinary Core Ideas</p> <ul style="list-style-type: none"> • PS3.A: Definitions of Energy - Energy can be moved from place to place by moving objects or through sound, light, or electric currents. • PS3.B: Conservation of Energy and Energy Transfer - Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. • PS3.B: Conservation of Energy and Energy Transfer - Light also transfers energy from place to place. • PS3.B: Conservation of Energy and Energy Transfer - Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. <p>Crosscutting Concept</p> <ul style="list-style-type: none"> • Energy and Matter – Energy can be transferred in various ways and between objects.
<p>Energy Transfer</p> <p>Bring Science Alive! Unit 2 Energy Lesson 5</p> <p>Suggested Time Frame: 7 days</p>	<p>4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.</p> <p>Science and Engineering Practice</p> <ul style="list-style-type: none"> • Constructing Explanations and Designing Solutions – Apply scientific ideas to solve design problems. <p>Disciplinary Core Ideas</p> <ul style="list-style-type: none"> • PS3.B: Conservation of Energy and Energy Transfer - Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. • PS3.D: Energy in Chemical Processes and Everyday Life - The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use. • ETS1.A: Defining Engineering Problems - Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. <p>Crosscutting Concept</p> <ul style="list-style-type: none"> • Energy and Matter – Energy can be transferred in various ways and between objects.

<p>Natural Resources</p> <p>Bring Science Alive! Unit 2 Energy Lesson 6 Suggested Time Frame:</p> <p>Suggested Time Frame: 6 days</p>	<p>4-ESS3-1. Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.</p> <p>Science and Engineering Practice</p> <ul style="list-style-type: none"> • Obtaining, Evaluating, and Communicating Information – Obtain and combine information from books and other reliable media to explain phenomena. <p>Disciplinary Core Ideas</p> <ul style="list-style-type: none"> • ESS3.A: Natural Resources - Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not. <p>Crosscutting Concept</p> <ul style="list-style-type: none"> • Cause and Effect – Cause and effect relationships are routinely identified and used to explain change.
<p>Earth's Changing Surface</p> <p>Bring Science Alive! Unit 3 Earth's Changing Surface Lessons 1-5</p> <p>Suggested Time Frame: 32 days</p>	<p>4-ESS1-1 Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time.</p> <p>Science and Engineering Practices</p> <ul style="list-style-type: none"> • Constructing Explanations and Designing Solutions – Identify the evidence that support particular points in an explanation. <p>Disciplinary Core Idea</p> <ul style="list-style-type: none"> • ESS1.C: The History of Planet Earth - Local, regional, and global patterns of rock formations reveal changes over time due to earth forces, such as earthquakes. The presence and location of certain fossil types indicate the order in which rock layers were formed. <p>Crosscutting Concept</p> <ul style="list-style-type: none"> • Patterns – Patterns can be used as evidence to support an explanation. <p>4-ESS2-1 Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind or vegetation.</p> <p>Science and Engineering Practices</p> <ul style="list-style-type: none"> • Planning and Carrying Out Investigations – Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. <p>Disciplinary Core Idea</p> <ul style="list-style-type: none"> • ESS2.A: Earth Materials and Systems - Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. • ESS2.E: Biogeology - Living things affect the physical characteristics of their regions. <p>Crosscutting Concept</p> <ul style="list-style-type: none"> • Cause and Effect – Cause and effect relationships are routinely identified, tested, and used to explain change.

<p>Patterns of Earth's Features</p> <p>Bring Science Alive! Unit 3 Earth's Changing Surface Lesson 6</p> <p>Suggested Time Frame: 7 days</p>	<p>4-ESS2-2 Analyze and interpret data from maps to describe patterns of Earth's features.</p> <p>Science and Engineering Practices</p> <ul style="list-style-type: none"> Analyzing and Interpreting Data – Analyze and interpret data to make sense of phenomena using logical reasoning. <p>Disciplinary Core Idea</p> <ul style="list-style-type: none"> ESS2.B: Plate Tectonics and Large-Scale System Interactions - The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features areas of Earth. <p>Crosscutting Concept</p> <ul style="list-style-type: none"> Patterns – Patterns can be used as evidence to support an explanation.
<p>Natural Hazards: Impacts on Humans</p> <p>Bring Science Alive! Unit 3 Earth's Changing Surface Lesson 7</p> <p>Suggested Time Frame: 7 days</p>	<p>4-ESS3-2 Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.</p> <p>Science and Engineering Practices</p> <ul style="list-style-type: none"> Constructing Explanations and Designing Solutions – Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. <p>Disciplinary Core Idea</p> <ul style="list-style-type: none"> ESS3.B: Natural Hazards - A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts. ETS1.B: Designing Solutions to Engineering Problems – testing a solution involves investigating how well it performs under a range of likely conditions. <p>Crosscutting Concept</p> <ul style="list-style-type: none"> Cause and Effect – Cause and effect relationships are routinely identified, tested, and used to explain change.

<p>Earth's Systems: Wave</p> <p>Bring Science Alive! Unit 4 Waves and Information Lessons 1 - 4</p> <p>Time Frame: 26 days</p>	<p>4-PS4-1 Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.</p> <p>Science and Engineering Practices</p> <ul style="list-style-type: none"> • Developing and Using Models – Develop a model using an analogy, example, or abstract representation to describe a scientific principle. <p>Disciplinary Core Idea</p> <ul style="list-style-type: none"> • PS4.A: Wave Properties - Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach. • PS4.A: Wave Properties Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). <p>Crosscutting Concept</p> <ul style="list-style-type: none"> • Patterns – Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena.
<p>Digitized Information</p> <p>Bring Science Alive! Unit 4 Waves and Information Lessons 5-6</p> <p>Suggested Time Frame: 14 days</p>	<p>4-PS4-3 Generate and compare multiple solutions that use patterns to transfer information.</p> <p>Science and Engineering Practices</p> <ul style="list-style-type: none"> • Constructing Explanations and Designing Solutions – Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. <p>Disciplinary Core Idea</p> <ul style="list-style-type: none"> • PS4.C: Information Technologies and Instrumentation - Digitized information can be transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. • ETS1.C: Optimizing The Design Solution – Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. <p>Crosscutting Concept</p> <ul style="list-style-type: none"> • Patterns – Similarities and differences in patterns can be used to sort and classify designed products.
<p>Plants and Animals: Structure and Function</p> <p>Bring Science Alive! Unit 1 Plant and Animal Structures Lessons 1-7</p> <p>Suggested Time Frame: 44 days</p>	<p>4-LS1-1 Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.</p> <p>Science and Engineering Practices</p> <ul style="list-style-type: none"> • Engaging in Argument from Evidence – Construct an argument with evidence, data and/or a model. <p>Disciplinary Core Idea</p> <ul style="list-style-type: none"> • LS1.A: Structure and Function - Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. <p>Crosscutting Concept</p> <ul style="list-style-type: none"> • Systems and System Models – A system can be described in terms of its components and their interactions.

Sight and Sense Receptors

Bring Science Alive!

Unit 1 Plant and Animal Structures
Lessons 8-9

Suggested Time Frame: 13 days

4-PS4-2 Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.

Science and Engineering Practices

- **Developing and Using Models** – Develop a model to describe phenomena.

Disciplinary Core Idea

- **PS4.B: Electromagnetic Radiation** - An object can be seen when light reflected from its surface enters the eyes.

Crosscutting Concept

- **Cause and Effect** – Cause and effect relationships are routinely identified.

4-LS1-2 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.

Science and Engineering Practices

- **Developing and Using Models** – Use a model to test interactions concerning the functioning of a natural system.

Disciplinary Core Idea

LS1.D: Information Processing - Different sense receptors are specialized for particular kinds of information, which may be then processed by the animal's brain. Animals are able to use their perceptions and memories to guide their actions.

Crosscutting Concept

- **Systems and System Models** – A system can be described in terms of its components and their interactions.

Materials for Investigations: It is recommended that you keep track of the materials you use throughout the year so that you can replenish the necessary materials for the following year. All expenses for materials will be paid for by the building. A unit by unit materials checklist is provided on our website.

TCI Kit Materials		Teacher/Student Provided Materials
Consumables Materials	Non-Consumables Materials	
Aluminum Foil, roll	Animal Cage, plastic	Celery
Bags, paper, pkg/50	Bottle, plastic with hinged cap	Scissors
Bags, plastic sandwich size, pkg/80	Forceps, pkg/6	Water
Cotton Balls, pkg/300	Spray Bottle	Red Food Coloring
Cup, plastic souffle, 4 oz	Ball, styrene, 2"	Blue Food Coloring
Detergent, liquid	Beaker, 250 mL	Newspaper
Feathers, down, pkg/200	Battery Connector, 9 V	Flowers
Knives, plastic, pkg/24	Bin, plastic, shoe box size	Tape
Pill or Sow Bugs Coupon	Buzzer	Colored Pencils
Toothpicks, flat, pkg/750	Light Sockets, miniature, pkg/6	Green Construction Paper
Tube, cardboard, 12"	Marbles, 1" pkg/6	Brown Yarn
Wax Paper	Motor, electric	Hole Punch
Balloons, round, pkg/6	Spring Toy, metal	String
Bowl, paper	Switches with clips, pkg/2	Crushed Leaves
Box, cardboard	Washers, 1-1/2", pkg/6	Potato or Apple Peel
Brass Paper Fasteners, pkg/100	<p>Non-consumables are the materials that will be used over and over. However, sometimes things break or get lost so you may have to purchase something from this list at some point. Again, most things can be purchased at Wal-mart or the Dollar Store but some may need to be purchased through Ward's Science at https://wardsci.com/.</p>	Paper Towels
Cardboard, corrugated, 30 cm x 50 cm		Straight Pin
CD Case		Masking Tape
Container, plastic, 2 qt		Rulers
File Folder		Utility Knife
Fishing Line		Construction Paper
Flour		Sticky Notes
Jar, plastic, 12 oz		Ice Cubes
Lid for 2 qt container		Grass Clippings
Meter Stick, folding		Paper Clips
Pans, aluminum	Soil and Potting Mix	
Paper Clips, small, box/100	Coffee or Tea	
Battery, 9V	Crayons/Markers/Colored Pencils	
Clay, modeling, pkg/4	Wipes/Paper Towels	
Clothespins, pkg/18	Coins	
Craft Sticks, pkg/30	D Batteries	
Cups, paper, 200 mL, pkg/25	Poster Paper	
Hand Lenses, pkg/6	Newspaper	
Light Bulbs, miniature, pkg/12	Scale	
Paper Clips, large, box/100	Objects to act as wind obstacles: model trees, houses, rocks, pebbles, paper tents, blocks. Etc.	
Plastic Wrap	Manila Folders	
Rubber Bands, #33	Rulers	
Straws, pkg/50	Pencils and Pens	
String, cotton	Straws	
Sand, medium grain		
Soil, potting		