Grade Four

Students in grade four continue to build their knowledge of physical, Earth, and life science through engaging in scientific practices and applying their scientific knowledge to engineering design problems. The fourth grade performance expectations are organized into a sequence of four instructional segments that utilize many science and engineering practices to explore energy and waves, use earth science **investigations** to design a solution to a geo-engineering problem, and deeply investigate animal and plant structures and functions. Emphasized in fourth grade are the crosscutting concepts of ***cause and effect***, ***patterns***, ***energy and matter***, and ***systems and system models***.

Table 2 summarizes the PEs included in each instructional segment and the crosscutting concepts that students may use as a tool to make sense of the disciplinary core ideas. These instructional segments are designed to be taught in this suggested sequence over the span of a school year, not taught individually. Where appropriate, PEs that integrate science ideas with engineering design are accompanied by one of the three PEs in grades three-five engineering design. The PEs marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.

Table 2: Instructional Segments in Grade Four

GRADE FOUR			
Instructional Segment 1: Exploring Energy	**Performance Expectations Addressed**		
	4-PS3-1, 4-PS3-2, 4-PS3-3, 4-PS3-4*, 4-ESS3-1, 3-5-ETS1-1		
	Highlighted SEP	**Highlighted DCI**	**Highlighted CCC**
	• Asking Questions and Defining Problems • Planning and Carrying out Investigations • Constructing Explanations and Designing Solutions • Obtaining, Evaluating, and Communicating Information • Developing and Using Models •	PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	• Energy and Matter • Cause & Effect
	Brief Summary		
	Energy comes in many forms including heat, light, mechanical, chemical, and electrical. Energy can be transferred from one object to another through a variety of mechanisms including through collisions, and it can be used to perform tasks. We rely on many different energy resources to power our world that have an effect on our environment.		
Instructional Segment 2: Waves	**Performance Expectations Addressed**		
	4-PS4-1, 4-PS4-3*, 3-5-ETS1-3		
	Highlighted SEP	**Highlighted DCI**	**Highlighted CCC**
	• Developing and Using Models • Constructing explanations and designing solutions	PS4.A: Wave Properties PS4.B: Electromagnetic Radiation PS4.C: Information Technologies and Instrumentation	• Patterns
	Brief Summary		
	Waves have regular patterns and motion. They can travel great distances without changing. We use waves to transfer information from one place to another.		
ment 3: The Earth is	**Performance Expectations Addressed**		
	4-ESS1-1, 4-ESS2-1, 4-ESS2-2, 4-ESS3-2*, 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3		
	Highlighted SEP	**Highlighted DCI**	**Highlighted CCC**

	• Planning and Carrying Out Investigations • Analyzing and Interpreting Data • Constructing Explanations and Designing Solutions	ESS1.C: The History of Planet Earth ESS2.A: Earth Materials and Systems ESS2.B: Plate Tectonics and Large-Scale System Interactions ESS2.E: Biogeology	• Cause & Effect • Patterns
	Brief Summary		
	Patterns in rock formations and fossils give clues to changes in the earth over time. Weathering and erosion help to shape the earth's surface and affect types of living organisms living in a region. Maps help to locate patterns of earth processes along plate boundaries. Knowledge of natural hazards can help humans design solutions to decrease their impacts.		
Instructional Segment 4: Structure and Function of Plants and Animals	**Performance Expectations addressed**		
	4-LS1-1, 4-LS1-2, 4-PS4-2		
	Highlighted SEP	**Highlighted DCI**	**Highlighted CCC**
	• Developing and Using Models • Engaging in Argument from Evidence	LS1.A: Structure and Function LS1.D: Information Processing	• Cause and Effect, • Systems and System Models
	Brief Summary		
	Plants and animals have internal and external structures to support survival, growth, behavior, and reproduction. Animals receive information through their senses, process the information in their brain, and respond to that information in different ways. Reflected light from objects that enter the eye allow objects to be seen.		

Grade Four – Instructional Segment 1: Exploring Energy

Though first introduced in kindergarten, grade four is the first time that energy is explored in depth. Grade four students ask questions, make observations and predictions, and construct explanations as they explore energy. Students engage in scientific experiences to help them answer questions such as: *What is energy and how is it related to motion? How is speed of an object related to the energy of the object? What happens to energy when objects collide? How is energy transferred? What natural resources provide energy and fuels and how do their uses effect the natural environment?*

Grade Four-Instructional Segment 1: Exploring Energy
How does motion relate to energy? *How is energy transferred, how does it move from place to place?*

What is the relationship between the speed of an object and the energy of that object? *What happens to energy when objects collide?* *How can one use energy to solve a design problem?* *How does human use of energy and fuels derived from natural resources affect the environment?*
Crosscutting concepts: *Cause and Effect, Energy and Matter*
Science and Engineering Practices: *Asking Questions and Defining Problems, Planning and Carrying out Investigations, Constructing Explanations and Designing Solutions, Obtaining, Evaluating and Communicating Information, Developing and Using Models*
Students who demonstrate understanding can: **4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object**. [Clarification Statement: Examples of evidence relating speed and energy could include change of shape on impact or other results of collisions.] [Assessment Boundary: Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.] **4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.** [*Assessment Boundary: Assessment does not include quantitative measurements of energy.*] **4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.** [Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.] [*Assessment Boundary: Assessment does not include quantitative measurements of energy.*] **4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.*** [Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound and a passive solar heater that

converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.] [*Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.*]

4-ESS3-1. Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment. [Clarification Statement: Examples of renewable energy resources could include wind energy, water behind dams, and sunlight; non-renewable energy resources are fossil fuels and fissile materials. Examples of environmental effects could include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels.]

Background for teachers

The major goals of this instructional segment should be for students to refine and develop their concept of energy and to notice and describe various ways in which energy manifests in systems. The concept of energy in everyday jargon overlaps with, but is not the same as, the concept of energy in science. The goal should be to help students recognize and distinguish the differences. In everyday conversation, we talk about needing energy (for example to move around), using energy, and generating or getting energy. In addition, we have a sense of "feeling energetic." Students may also have heard the idea that plants get energy from the sun. They may also be aware that food gives you energy. They may have preconceptions such as that a drink of water gives them energy. When we speak about electrical generation, we often refer to nuclear energy, solar energy, and wind energy, as well as energy generated using fossil fuels. We also talk about electrical energy. All of this language is familiar to many students at this grade level, so they have many overlapping and contradictory concepts about what energy is. The aim of this instructional segment is to start from where they are and help them distinguish between everyday usage and the scientific concept of energy.

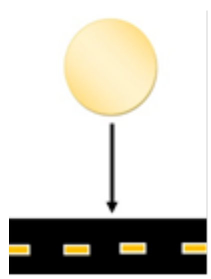
In this instructional segment, we first want to develop the ideas that:

- any moving object carries energy;
- the energy of a moving object is called motion energy or kinetic energy.
- for objects moving at the same speed, the more massive object has the motion energy
- for objects of the same mass, the motion energy increases rapidly with its speed

These ideas about the amount of energy an object carries are qualitative not quantitative at this grade level. In order to talk about amounts of energy, students also need to develop the idea that **energy has effects**. For example, something with more energy has more effect (e.g., does more damage when it hits a barrier or digs a bigger hole when it lands in a sand box). The idea that energy is transferred from one object to another when they collide is also developed in this part of the instructional segment. In addition, students will understand the idea that forces at a distance between objects (e.g., magnets) can also mediate the transfer of energy from one object to another.

The instructional segment next develops awareness of different ways energy moves from place to place. Energy is carried as: the motion energy or kinetic energy of a massive object; as radiation, such as light and radiant heat (infrared radiation); and as waves, such as an ocean wave or a sound wave. In an ocean wave or sound wave, the energy is in the motion of particles within the matter, which move back and forth or up and down while the energy moves from one place to another. Thus in this instructional segment, the concept of a wave moving in matter should begin to be developed with visible examples such as a water wave or a wave moving on a string. This concept is further refined in a later instructional segment at this grade level. When most students envision water waves, they think about a breaking wave, which is not, in physics terms, an example of wave motion. A breaking wave is a result of the wave being disrupted by meeting the rising sea bottom at the shore. To **develop a model** of wave motion, students need to work first with the example of waves transmitted along a rope. They can move on to creating water waves in the middle of an even depth container with a cork or other floating object bobbing up and down as the wave goes by. This idea of wave motion needs to be quite well established with visible examples before students try to develop the idea of sound as a pressure wave within matter. In order to understand this concept, students need to develop the idea that solid matter has internal structure.at the same time. They should also recognize that solid matter is not just one continuous rigid object. Students should also develop the idea that a louder sound represents more energy reaching the ear; and, likewise, a brighter light means more energy reaching the eye.

Finally, the instructional segment develops the idea that energy in one form can be transferred to an object as energy in another form. Below are three examples:

Type of Energy			Becomes
Energy of Motion		Collision	Heat and Sound
Light		Absorbed	Heats a Surface
Electrical Energy		Illuminates	A Light Bulb

Because energy cannot really be quantified at this grade level, students cannot develop a notion of conservation of energy, but instruction can and should lay the precursors of that idea. Students should understand that any time we need energy we have to get it from somewhere. A person cannot just make energy from nothing, and that after one “uses it” it is not “used up” but that it is still around in some distributed form in the local environment. Another idea students should understand is that every machine stops operating if fuel is not continually provided because friction converts the energy of the machine's motion to heat its motor or the surrounding environment.

The distinction between energy itself and energy resources is the next idea that needs to be developed in this instructional segment. Energy resources provide us with the energy that we can use to do useful things. This can be explained as a two-step process: one uses energy resources to generate electricity, and one uses electricity to run machines or provide light or heat. Energy resources can be food or fuel (i.e., things that one uses to extract energy by chemical processes of combustion or respiration) where the energy is used to drive a turbine to make electricity, run a car or some other engine, or allow an animal to maintain its body temperature and to move around. Other ways of generating electricity use the energy of sunlight (solar energy), the energy of moving air (wind energy), or the energy of falling water (hydro-electric) to make the electricity.

While the instructional segment does not introduce the notion of potential energy, it is probably necessary to introduce the notion of stored energy, for example to talk about energy that is stored in a battery, or in a stretched or compressed spring. However, one should be careful about using the language of energy stored in food or fuel. These are resources from which energy can be extracted only because we live in a world that is rich in oxygen. The energy is released in the chemical interaction of the food or fuel with the oxygen, but it is not "stored in fuel" any more than it is stored in the oxygen. It is not appropriate to introduce differences in chemical binding energy at this grade level, but it is helpful to avoid reinforcing the misconception that an energy resource is a form of energy. Teachers need to discuss the notion that energy is released by burning fuel, rather than from its reaction with oxygen, this will lay a foundation for students when the discussions of energy release in chemical reactions is covered at the later grades.

Description of Instructional Segment

This instructional segment on Exploring Energy is divided into three parts: Part 1- *Investigating Energy* includes investigating types of energy, energy transfer, the relationship of speed of an object to the motion of an object and collisions of objects. Part 2- *Energy Conversion Design Project* is an engineering activity in which students plan, design, build, and refine a device to solve a problem involving several forms of energy and energy transfers. Part 3-*Energy Resources and the Environment* involves students examining renewable and nonrenewable resources and how the uses of these resources affect the environment.

Investigating Energy

This instructional segment begins with a series of **investigations** in which students observe, **model,** and discuss situations where energy is transferred from one object to another, transferred from place to place, and transformed from one form of energy to another. The goal of the activities is for students to develop and refine their language for describing energy, their concept of what scientists mean when they use the term energy, and to begin to collect evidence that energy can be transferred from place to place by sound, light, heat, and electric currents (PE-4-PS3-2). Teachers can have students work in teams to visit stations where they are examine different ***systems***. Students will **model** each ***system*** observed to define and describe ways in which energy transferred and transformed (e.g., heat energy to motion). The systems chosen demonstrate different forms, transfers, and transformations of energy. A few examples of possible station include:

(a) energy of motion may become sound: one block collides into another block or a moving ball collides onto another ball
(b) elastic energy to motion: a rubber-band catapult or a trampoline
(c) light energy to heat: sunlight or a heat lamp on a surface
(d) chemical energy to heat and /or light: a hand warmer, a candle flame, a light stick
(e) light energy to electrical energy to sound: solar panel connected to a circuit ringing an electrically-operated doorbell
(f) wind energy to motion: blowing on a pin wheel; leaves moving on a tree
(g) motion into heat energy via friction: rubbing hands together, sliding object across surfaces such as sand paper and carpet

(h) mechanical energy to motion: wind-up devices such as fuzzy chicks, chattering teeth, cars and hand crank generators spinning a fan motor

(i) motion to sound: tuning forks.

Many other examples can be used, all with very simple materials. After visiting and writing observations at the stations, each group is responsible for communicating information about their final station to the class (obtaining, evaluating, and communicating information).

The teacher assigns group of students to record (1) the forms of energy observed, (2) changes they observed in the interactions, (3) the transfers of energy from one object to another or from one place to another, and (4) the transformations of energy (e.g., light to electrical energy). These lists become the basis for a whole class discussion, which the teacher uses to help students refine and organize their language and ideas about energy. As a complementary extension, students can use publically available simulations (e.g., PhET ”Energy Forms and Changes: Energy Systems”) to reinforce their ability to **model** and visualize energy forms and transfer. These energy activities also help to lay the ground work for the crosscutting concept ***energy and matter*** as students begin to build understanding of energy forms, transfers, and transformations.

Next, teachers ask students to **plan and carry out energy investigations** to **construct an explanation** based on their **evidence** that relates the speed of an object to the energy of the object (PE-4-PS3-1). An example might be observing objects landing in a bed of sand. Students will need to devise ways to observe falling objects at different speeds (e.g., slow, medium, and fast using a ramp) and make observations of the resulting sand and object. Students use these observations as they begin to collect **evidence** for their explanation of how the speed of an object relates to the energy of that object. Other **investigations** can include rolling marbles or toy cars down a ramp at different speeds into a paper cup cut in half. Students can devise methods to increase or decrease the speed of a marble or toy car and then describe the effect on the paper cup (e.g., how the marble moved the cup, the distance the cup moved related to the speed of colliding object). Students could roll marbles down a ramp from different heights and different angles to change speeds of the objects and continue to gather **evidence**. Though students may make measurements of the depth and width of the sand displaced or distance and time an object moved in these **investigations**, the students' observations and evaluations should be qualitative, not quantitative measurements of energy. These investigations relating the speed of an object to the energy of the object directly support the crosscutting concept ***cause and effect***. Cause and effect relationships are routinely identified and used to explain ***change***. Students will be changing the system they are studying and making observations to see what happens. A method to highlight and emphasize ***cause and effect*** is to keep a class chart recording these relationships or have students build a cause and effect chart in their notebooks as they conduct their **investigations**. The teacher can extend this activity to also develop the relationship between weight and energy for two different objects moving at the same speed. (At this grade level no distinction is made between mass and weight.)

Following the **investigations** relating speed of objects and energy of the object, students begin to ask questions and predict outcomes for the changes in energy when objects collide (PE-4-PS3-4). To generate initial **questions** students should make observations of various collisions. For example, students can observe a rolling ball colliding with a stopped ball, using a variety of balls of varying weights of the same size. Students could conduct **investigations** on the playground with various play equipment: bats and different sized balls, racquets and birdies, balls against stationary walls.This provides a rich opportunity for students to develop **questions** and predictions, which guide students to plan and **carry out further investigations** of various collisions. Students could keep an organized list or table of their questions and predictions in their science notebook throughout this investigation. Students could make additional observations of changes in energy involving collisions by watching Newton's Cradle (simulation or the actual device) or watching a video of a billiards game (see figures 10 and 11).

Figure 10: Example of Newton's Cradle

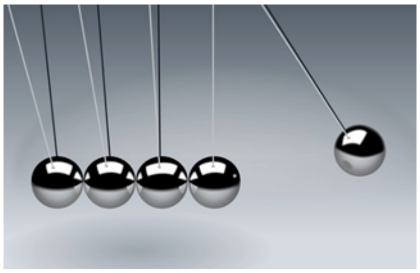


Figure 11: Example of Billiards

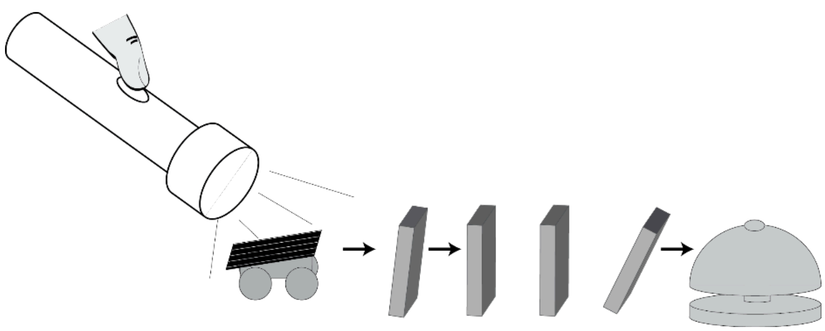
A final project may include the observation of a more complex device (directly or via a video) listing **questions**, making predictions and descripting outcomes of energy change due to collisions. This final project can incorporate different results that happen when objects collide and how they affect the speed and direction of each of the objects involved in the collision. An example could be the study of a of a car crash where there is transfer of energy, resulting in movement, change of shape of materials, and transformation of energy, motion to heat and sound.

Engineering Connection

In this engineering activity, an energy conversion design project, students apply their scientific ideas from Part 1 to design, test and refine a device that converts energy from one form to another (PE-PS3-4). An example could be designing a Rube

Goldberg Machine (e.g., wake-up machine, figure 12) from simple materials (battery powered fans, marbles, wind-up toys, light sources). The figure below depicts an example where mechanical energy from a student's finger is used to turn on a flashlight in which chemical energy is transformed in electrical energy, which is then turned into light energy. The light energy is absorbed by a solar cell, which converts it to mechanical energy, accelerating a small car into a line of up dominos. The dominos transfer mechanical energy between each other until the last domino transfers its mechanical energy to a bell, which creates a sound wave that "wakes us up."

Figure 12: Example of a Rube Goldberg machine: a flashlight (light energy) shines on a solar car that moves (mechanical energy) toward a series of dominos that fall down (mechanical energy) into a bell (sound).



Students in grade four design a device that has at least three types of energy and three types of energy transfers. Using the engineering design process, students **design**, build, test, and refine a device that meets the constraints and materials available. Students should be explicit with how many forms of energies are represented (transformed) and explain the energy transfers involved in their machine. This engineering project is another opportunity to support and utilize the crosscutting concepts, ***energy and matter*** and ***cause and effect*** as well as many science and engineering practices including **asking questions and defining problems**, **constructing explanations and designing solutions**, and **planning and carrying out investigations.**

Energy Resources and the Environment

Students engage in a short project to **obtain, evaluate, and communicate information** about fuels and other sources we use provide energy. For example the energy we use to move our cars or heat and light our homes is derived from natural resources. The use of these energy sources affect the environment (PE-4-ESS3-1). Students should examine at least one renewable and one non-renewable energy resource. Teams are assigned a renewable resource (e.g., wind, solar, water stored behind dams used to drive hydroelectric generation, biofuels), and non-renewable resource (e.g., fossil fuels such as gasoline, natural gas, or coal) to study. The information, obtained from print and digital sources, could include an overview of the type of energy, what the source of energy is used for (run car, generate heat, produce electricity), and how the use of the energy source affects the environment. Student teams would have an opportunity to make presentations about their topic at a class event such as an Energy Day. Energy Day is an opportunity to connect with families. It is a festival highlighting the students' engineering designs or provide an opportunity for them to communicate their information and results. Energy Day can have interactive demonstrations and exhibits where students teach their families about the various forms of energy, science, technology, efficiency, conservation, and careers in the energy industry.

ELA ELD Connection
As part of the project and using the information gathered, students write an opinion piece about supporting (or not supporting) the use of renewable or non-renewable energy resources.

Grade Four – Instructional Segment 2: Waves

Students continue their exploration of waves from first grade where they began to explore waves moving across the surface of water. In first grade, students observed that waves have regular patterns and motion. Sound can make matter vibrate, and vibrating matter can make sound. In grade four, students study wave patterns in more depth and the transfer of sounds.

Grade Four-Instructional Segment 2: Waves
What are the characteristic properties and behaviors of waves? *Where can we use patterns to transfer information?*
Crosscutting concepts: *Patterns*
Science and Engineering Practices: *Developing and Using Models; Constructing explanations and designing solutions*
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. [Clarification Statement: Examples of models could include diagrams, analogies, and physical models using wire to illustrate wavelength and amplitude of waves.] [*Assessment Boundary: Assessment does not include interference effects, electromagnetic waves, non-periodic waves, or quantitative models of amplitude and wavelength*.] **4-PS4-3 Generate and compare multiple solutions that use patterns to transfer information.*** [Clarification Statement: Examples of solutions could include drums sending coded information through sound waves, using a grid of 1's and 0's representing black and white to send information about a picture, and using Morse code to send text.] *The performance expectations marked with an asterisk integrate traditional science content with engineering through a science and engineering practice or disciplinary core idea.

Background for teachers

The instructional segment on energy at this grade level began to introduce waves as a way that energy is transferred from place to place. Students observed and **modeled** simple repeating waves to develop the concepts of wavelength and amplitude. They also developed the idea that as waves travel, the wave peaks pass a given point at definite frequency. Intensity is one more technical-term that students will need to talk about light and sound. The intensity of a wave is related to its amplitude and is proportional to the amount of energy carried by the wave for a given wavelength or frequency. (The precise relationships are not introduced at this grade level, but students' explorations of waves should help them recognize that the energy and intensity of the wave grows with increasing amplitude.) All of this terminology should be introduced as it is needed to describe and **develop models** of observed wave phenomena, not as a list of learned definitions. General features of wave behavior are also explored to develop the idea that waves can be reflected, absorbed, or transmitted through a change of medium, that waves of a similar type travel through one another without distortion and that waves move energy from one place to another without overall displacement of matter.

The second major idea in this instructional segment is that information can be communicated through encoded signals using devices that transmit, receive, and decode the signal. This concept can be explored first in terms of our natural methods of obtaining information about the world around us, and then in terms of encoded information that we use to communicate over long distances or over time. Starting with coded signals sent along a string as wave pulses, students can explore how wave properties make waves an ideal signal carrier, both because the variety of wave shapes allow the wave to carry a lot of quite information and because the waves travel and pass through one another without distortion.

Next the concept of sound as a pressure wave in a medium is developed. Again through various experiences that allow students to **develop models** of how the medium moves back and forth (vibrates) as the sound travels through it, and how the properties of sound (pitch and loudness) relate to the wave properties (pitch to frequency or wavelength, loudness to intensity or amplitude). Finally, the idea that everything we hear is a pattern of information encoded in sound which our ear detects and our brain decodes is developed. Experiences with musical instruments, particularly stringed and percussion instruments, support this idea. For example, the notion of drums sending coded messages can be related to Native American cultures who used this system. Morse code provides another example of digitized sound, sent as a series of short and longer wave pulses. Students at this age are often very interested in secret codes, and may enjoy developing their own versions of simple written codes (letter replacements) and using them to send messages to one another. They can also recognize that writing itself is a code, or a way we represent the sounds of words to store and send them over distances.

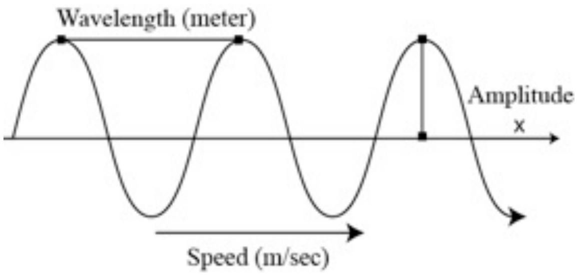
The discussion of encoding information, whether to be sent via waves, or wave pulses, or for storage, can also be related to computers and **computational thinking**. Teachers can help students develop the idea that a computer memory stores coded information and that programming a computer is developing a code to tell it how to manipulate and change its stored information to arrive at new results to store or display. The crosscutting concept of ***patterns*** fits well here.

Light and radio signals are formed from a wave of changing electric and magnetic fields that can travel through space with no supporting medium. This is a very abstract concept for fourth graders. However, they can recognize that light shows all the properties developed above with waves, if you relate color to frequency and brightness to intensity. Recognizing that light, like sound, is a major way we obtain information about the world around us, which our eyes detect and our brain decodes adds to the parallel. Students today are generally familiar with the idea of pixels and digitized pictures, which again can be introduced as a form of encoded information. Likewise the different coding methods of AM and FM radio signals can be explored as an extension to learning.

Description of Instructional Segment:

The fourth grade instructional segment on waves is divided into two parts, Part 1-*Wave Exploration* and Part 2-*Coded Message Challenge*. In part 1**-** Wave Exploration, fourth grade students **develop a model** of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move (PE-4-PS4-1) Figure 13 is a diagram of waves and their parts. This diagram identifies the wavelength, amplitude, and speed of a wave.

Figure 13: Diagram of waves and their parts



These wave stations, simulations, and demonstrations help students **develop a model** that waves are a way of moving energy from place to place and that waves have properties which will affect such things as how much energy is carried and the quality of sound (high/low frequency). In Part 2, the *Coded Message Challenge*, students generate and compare multiple solutions that use ***patterns*** to transfer information. Students will be given a message sending challenge as they generate and compare multiple solutions that use ***patterns*** to transfer information. (4-PE-PS4-3)

Wave Exploration

Student teams observe waves made with a rope, one end held stationary and other end moved up and down or side by side by another student. Students observe giant waves produced in the rope and then are challenged them to make more waves between the two people. Students **ask** and answer **questions** such as: *How do we know we have seen a wave? What helped make more waves between us? How can we change the number of waves? How can we change the height of waves?* Students draw diagrams to indicate their observations and write labels to identify elements (number of waves, peaks) in a two-dimensional figure. Students can also investigate what happens when a wave pulse is

> ELA ELD Connection
> Using a note-taking template, such as a T-chart, watch 2-3 different videos on waves. On the left hand side of the T, include broad concepts for waves, such as light waves; sound waves; characteristics of waves; behaviors of waves (reflected, absorbed, transmitted); examples of movement of energy. Possible sources of videos can be found on Vimeo, YouTube, or by recognized science experts (e.g., Bill Nye).

sent simultaneously by the students at either end of the rope. Students can observe how the pulses add or cancel as they pass through one another, but appear unchanged once they separate.

Computer simulations or class discussions can help to introduce and expand their knowledge and experience of wavelength and amplitude. They can also be used to introduce the concept of frequency, the rate (number per time period) at which wave peaks pass a given point. The mathematical relationship between wavelength, wave speed and wave frequency is above grade-level math, but students can recognize that for a given type of wave the frequency is higher when the wavelength is shorter. Students can also identify that the same wavelength (spacing between peaks) can have different amplitude (height of wave) and different wavelengths can have the same amplitude. Students can go back to their preliminary drawings of waves and identify the wavelength and amplitude noting any patterns they observed.

Students should experience the use of multiple physical **models** that make the movement of waves visible. Additional explorations can include:

(1) a tuning fork and water and looking for patterns between sounds and waves. Students record the common ***patterns*** they observed

(2) dropping small objects in a water container and observing regular patterns of motion made in water by disturbing the surface

(3) using an earthquake shake table or similar device, where students see that structures on beams at different heights vibrate differently with the same movement

(4) building and using various stringed instruments (cups and rubber bands, boxes and strings)

(5) looking at video clips of ocean waves that are small, medium or large where students state their observation of amplitude and wavelength. [Note: It is important to discuss the difference between the wave pattern in the deep ocean and what happens at the beach, where the wave pattern has been destroyed because it meets the shallow sea floor. The water breaking wave clearly moves

in the direction the original wave was travelling. For most students the breaking wave is part of their mental model of a wave.]

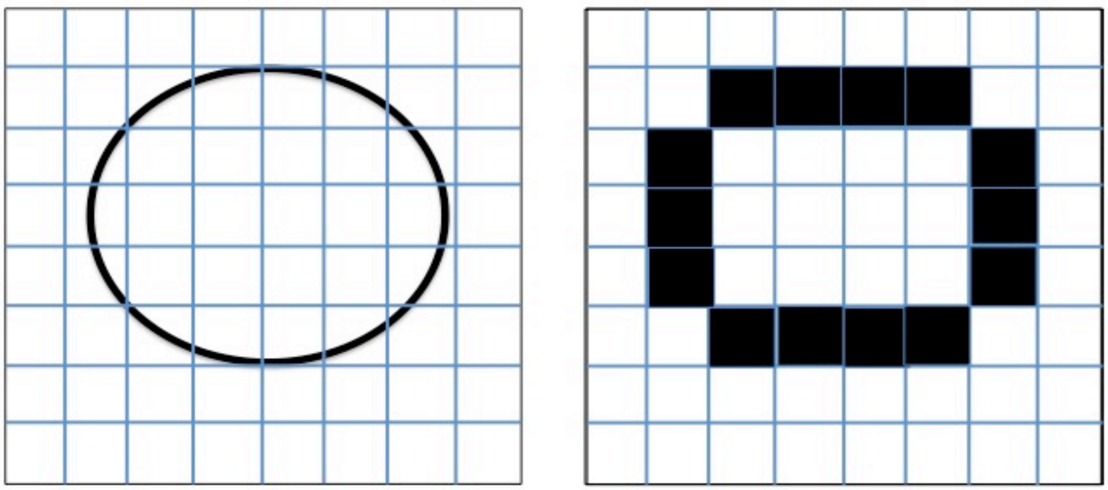
Students can investigate changes of wavelength by investigating waves in the context of drums or stringed instruments. The use of computer and physical models (e.g., PhET “Wave on a String”) helps students construct explanations based on familiar phenomena and support their **development of a model** of waves.

Further study of waves can include light and radio signals. Teachers can ask students to design and **carry out investigations** to answer the question “Does light behave like a wave?” The point here is not to try to model what kind of wave it is, but to recognize that it has all the wave properties just investigated for sound: waves reflect when they hit a surface, two waves can add up to make a bigger wave. Students can explore this concept by using flashlights covered with different colored transparent paper and mirrors to reflect the light and digital cameras. Students today are very familiar with pixels and digitized photographs and can recognize this as a method for encoding the information in a scene. Exploring black and white images encoded different size pixels can help make the coding aspect more readily visible.

Teachers can help students develop the idea that animals, including humans, use light and sound to obtain information about their surroundings. Students can then link this idea to the concept that all of this information comes in the form of varying wave patterns detected by our eyes or ears. This idea is then extended to the fact that light waves, radio waves, microwaves, and infrared waves are the basic features of everyday communication systems such as computers, radios, or cell phones. Most of these devices use digitized signals (i.e., information encoded as series of 0 and 1) as a more reliable way to store and transmit information over long distances without significant degradation or error. For example, a small group of students can develop their own Morse-code system to digitize short words and transmit that word to another group of students by using a flashlight or a drum.

Also, students can practice digitizing images by first drawing simple shapes on squared paper and then converting that image into a digitized one by darkening only the squares that do contain part of the original image (see figure 14). Students can make observations that the digitized image loses in resolution because it is now more edgy with respect to the original image, but a simple series of 0 and 1 for each line of the image is sufficient for somebody else to make an identical copy of the digitized image. Students can also experience that by increasing the power of the digitization (by reducing the size of the squares on the paper) the digitized image has better resolution, but it will take more time to transmit the higher-definition image via a series of 0 and 1.

Figure 14. Practice Sample of Recreating Digitized Images



Students will use **information** gathered in their explorations, simulations, demonstrations, text, and online resources to **develop a model** to describe ***patterns*** in terms of amplitude and wavelength and that waves can cause objects to move. Various materials can be given to students to create their **model** including: paper and pencil, pipe cleaners, clay, and string. Students can also create a kinesthetic **model**, acting out a wave and its properties and ***patterns***.

Coded Message Challenge

Students begin to explore the concept of information, starting with sending coded messages (for example Morse code, or a code they invent to say yes or no with wave pulses). This activity continues to develop the notion of sound as a wave phenomenon. Students begin to notice that all the properties of sound have wave-like properties. For example, that it can be used to send coded pulses (drumming). Waves have many different frequencies (using low pitches so students can notice the frequency of the vibration). Waves travel through solid materials as a vibration of the matter (but different from that in water waves, because there is little up and down movement but rather vibration in the direction of the sound travel). Some surfaces reflect waves and others surfaces can absorb waves. Students **develop and refine a model** of sound waves through multiple **investigations** of these phenomena. Students come to understand that sound is a major way we obtain information about the world around us, and that we use it to encode messages in language and music. They recognize that our ear receives the sound and our brain decodes it. This can be related to how various animals and birds use sound to warn them of predators, to hear prey, and to communicate with others of their species. At this point teachers can introduce the idea that language is a form of code, and that written language is yet another code used to store and send information over space and time.

Math Connection
Students are asked to encode messages. Relate these encoded messages to patterns in mathematics. Use mathematical patterns as background knowledge.

Engineering Connection

Teachers can challenge their students with a design problem that asks them to generate and compare multiple solutions that use ***patterns*** to transfer or communicate information (PE-4-PS4-3). For example, students can participate in a message-sending contest where each team must divide in two and send a message from one part of the team to the other part of the team around a corner of the building. An added challenge is that the message should not be recognized by any other team. Teachers utilize the engineering design cycle of defining the problem, identifying constraints, brainstorming to generate and compare multiple solutions that use patterns to transfer information, develop a prototype, test and refine. Teachers give them a variety of sound or light producing devices and materials to work with (mirrors, for example). They then work in groups to develop **solutions** for the problem and share their results with the class.

Grade Four – Instructional Segment 3: The Earth is Constantly Changing

Instructional Segment 3, *The Earth is Constantly Changing*, is an opportunity for the integration of science to be taught in conjunction with fourth grade's study of California history and geography. California is an amazing example of the interplay of all of the geological processes presented, challenging students to investigate the patterns of earth's features using maps and how rock formations and fossils help explain changes in the landscape.

Grade Four-Unit - Instructional Segment 3: The Earth is Constantly Changing
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 rock formations and fossils in rocks help to explain changes in a landscape?* *How can the engineering design process be used to solve a problem?*
Crosscutting Concepts: *Cause and Effect, Patterns*
Science and Engineering Practices: *Planning and Carrying Out Investigations, Analyzing and Interpreting Data, Constructing Explanations and Designing Solutions*
Students who demonstrate understanding can: 4-**ESS1-1 Identify evidence from patterns in rock formations and fossils in rock layers for changes in a landscape over time to support an explanation for changes in a landscape over time.** [Clarification Statement: Examples of evidence from patterns could include rock layers with marine shell fossils above rock layers with plant fossils and no shells, indicating a change from land to water over time; and a canyon with different rock layers in the walls and a river in the bottom, indicating that over time a river cut through the rock.] [*Assessment Boundary: Assessment does not include specific knowledge of the mechanism of rock formation or memorization of specific*

rock formations and layers. Assessment is limited to relative time.]

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. [Clarification Statement: Examples of variables to test could include the angle of slope in the downhill movement of water, amount of vegetation, speed of wind, relative rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, and volume of water flow.] [*Assessment Boundary: Assessment is limited to a single form of weathering or erosion.*]

4-ESS2-2 Analyze and interpret data from maps to describe patterns of Earth's features. [Clarification Statement: Maps can include topographic maps of Earth's land and ocean floor, as well as maps of the locations of mountains, continental boundaries, volcanoes, and earthquakes.]

4-ESS3-2 Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.* [Clarification Statement: Examples of solutions could include designing an earthquake resistant building and improving monitoring of volcanic activity.] [*Assessment Boundary: Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.*]

3-5-ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

This performance expectation does not have a clarification statement or an assessment boundary.]

3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

This performance expectation does not have a clarification statement or an assessment boundary.]

3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and

failure points are considered to identify aspects of a model or prototype that can be improved. This performance expectation does not have a clarification statement or an assessment boundary.]

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a science and engineering practice or disciplinary core idea.

Background for Teachers

The earth is constantly changing. The rocks that exist at a particular location can reflect the geological history of the site which can include volcanic activity, sedimentation, erosion, and uplift from earthquakes. Obsidian may indicate a previously active volcanic region, limestone may indicate an area that used to be an ocean floor, and granitic formations of the Sierra Nevada resulted from tectonic uplift, followed by erosion, and glaciation over an enormous amount of time.

Three main rock types, igneous, metamorphic, and sedimentary can be understood though careful study of the processes that formed them. These rocks are defined by their formation processes and can be identified by their physical characteristics.

Igneous rocks are formed from molten rock that cools. Igneous intrusive rocks cool slowly below the surface of the Earth and generally contain large interlocking mineral crystals. Granite is a common example of an igneous intrusive rock. Igneous extrusive rocks cool rapidly at Earth’s surface and generally contain mineral crystals too small to be seen with the naked eye. Some extrusive rocks have vesicles, making them light, such as pumice or lava rock.

Sedimentary rocks are forms when sediment is deposited, buried, and cemented together. It consists of sediment imbedded in a matrix of cement. The sediment can be large or small, or a combination of sizes. Common examples of sedimentary rocks are conglomerates (large pebbles), sandstone (sand grains), shale (clay particles), and limestone (shells or fragments of shells from marine creatures).

Metamorphic rocks are formed when a rock is deep underground and subject to high heat and pressure. The rock does not melt, but can become layered or change its appearance significantly. Metamorphic rocks can be more difficult to identify, as their physical characteristics are relatively diverse. They will not have vesicles or imbedded sediments, but may have flat or folded layers or visible mineral crystals.

Weathering and erosion are important phenomena occurring on Earth’s surface. Weathering is the breaking down of rocks by physical or chemical processes. Chemical weathering will dissolve the minerals in rocks into water or other liquids. Physical weathering will break rock into small pieces. Wind and water can slowly weather rocks, to make them smooth and rounded. Plant roots can grow and split a rock. Salt deposits or freezing water can exist in cracks in a rock to increase the fracture and eventually break the rock apart.

Erosion is the transport of rock sediments. Water flow is the most common cause of erosion. Sediments can be carried downstream by rivers and deposited into deltas and oceans. Rivers tend to flow more slowly as they get further downstream and get closer to their mouth. Larger sediment will thus be deposited further upriver, since the river must move rapidly to carry the heavier sediment load. Deposited sediments can then form into sedimentary rocks. Large sediment rocks like conglomerates tend to form upstream, while sandstones and shale will form downriver, where the smaller sediments are deposited by the slowing river. Erosion is defined by gravity, carrying sediment to lower elevations.

Because weathering and erosion change the physical characteristics and locations of rock, they can be identified by examining rocks, outcrops, and large scale topographical maps. These processes can remove or reduce rocks at a predictable rate, depending on the climatic conditions and the specific characteristics of the rock.

Ocean currents also cause erosion. Longshore currents carry sediment in the direction of current flow. This can transport large amounts of sand from one location to another. Engineers build groins to prevent the redistribution of sand.

Description of Instructional Segment:

This instructional segment on the changing earth can be broken into the following parts: Part 1: *Written in the Rocks*; Part 2: *Effects of Weathering and Erosion on Earth's Surface*; and Part 3: *Mapping Earth's Surface*. Instructional segment 3 opens with an engineering problem involving earth science studies.

Engineering Connection

Students are challenged to generate design solutions for a geotechnical engineering problem. To inform their design, (1) students are involved in **planning and carrying out investigations** exploring patterns in rocks and rock formations, (2) observing effects of weathering, and (3) **analyzing and interpreting data** from maps that represent Earth's changing landscape (Part 3). Design solutions could include structures such as a bridge to span a river, placement of a dam or dykes to hold water or to protect a community from flooding, or retrofitting a building to reduce the probability of severe damage from an earthquake. Teachers pose design problems to the students that involve them in science and engineering practices that include **planning and carrying out investigations** and **analyzing and interpreting data** in order to **construct explanations** and **design solutions** for their community. The design project drives students' **investigations** of Earth science with an emphasis on crosscutting concepts ***patterns*** and ***cause and effect***. At the end of this project, students are able to support an **explanation** that the Earth's landscape is constantly changing using **evidence** such as rock formation, types of rocks, and fossils.

To begin this instructional segment, the teacher poses an engineering design problem that helps to reduce the impacts of a natural hazard such as an earthquake, flood, or tsunami. Working in collaborative teams, students brainstorm initial ideas and sketch out preliminary **design solutions**. Next, students generate **questions** they have that will help to focus their scientific study of processes that shape the earth and to understand the constraints and criteria that will assist them in **designing a possible engineering solution**.

Written in the Rocks

As geo-engineers, students have to understand what clues to the Earth's surface they can gather from Earth materials. Students work in teams to **investigate** various types of rocks and ***patterns*** in rocks (example: layered rocks with and without shells and fossils, various types of rocks found in a canyon wall, rocks that have undergone erosion in rivers or ocean, lava rocks). From these initial observations students begin to ***ask questions*** that drive further research and classroom **investigations** to support an **explanation** that the surface of the Earth has changed over time and that rocks, rock formations, and what is in the rocks, give clues and **evidence** for changes in a landscape over time (PE-4-ESS-1). Student groups can use print and digital sources as well as rocks to integrate information that prepares them to write or speak about the subject knowledgeably (CCSS for ELA/Literacy R1.4.9, W.4.8). Students examine these types of rocks so they can identify and discuss the evidence for changes in the landscape over time and to support an explanation for these changes.

ELA ELD Connection
As part of an investigation about rocks, rock formations, and what is in rocks that provide evidence of changes in a landscape over time, students take notes, paraphrase, and categorize information by creating a *I Am a Rock* book. Students can write the information from the rock point of view (i.e., as a "sedimentary rock" or an "igneous rock") including how they are formed, how they change the landscape, what they are made up of, etc., along with pictures. A list of sources should be included at the end of the book.

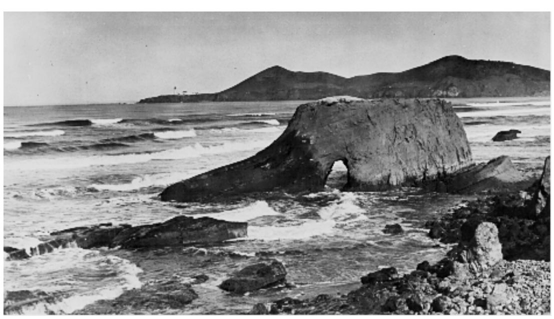
Though students will learn about and study igneous, sedimentary, and metamorphic rocks, it is important to emphasize is placed on the Earth processes that formed them and what can be understood about the geologic history of the earth through recognition of ***patterns*** and processes.

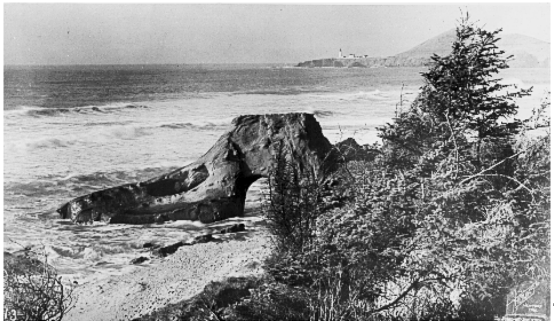
Effects of Weathering and Erosion on Earth's Surface

Students are given the opportunity to **plan and carryout investigations** that test the effects of water, ice, wind, or vegetation on soil erosion. Students will make observations and/or measurements to provide evidence of weathering or erosion (PE-4-ESS2-1). One way that this could be done is by using a stream table. Students **plan and carry out investigations** to examine the effect of water on the rate of erosion by testing variables such as type of Earth material, slope of stream table, rate of water flow, and vegetation in their stream table. These investigations directly support the crosscutting concept ***cause and effect***, and student-generated charts such as KLEWS (Hershberger and Zembal-Saul, 2015). The KLEWS chart (Know, Learning, Evidence, Wonder, Scientific Principles and Vocabulary) is an adaptation of the well-known KWL reading comprehension strategy that is adapted for science teaching that can support this important connection. Measurements during this **investigation** could include distance earth materials traveled, comparison of time and erosion observed in the stream table, and amount of materials moved during erosion process.

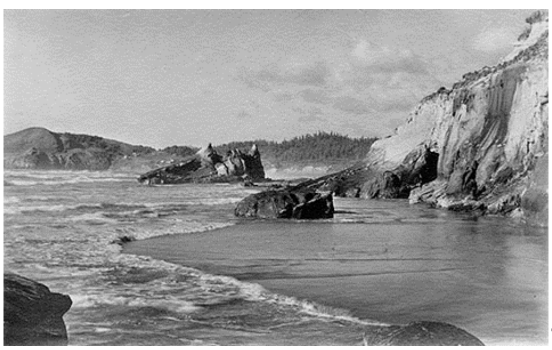
Investigations of erosion by, water, ice, wind, or vegetation can be done comparing images and using simulations. Below is an example (figure 15) of erosion of a sea stack over 100 years in Nye Beach, Newport, Oregon. Figure 16 pictures a simulated erosion of Yosemite Valley erosion, a glacier carved out the Yosemite Valley recognizable by its U shape.

Figure 15: Erosion of a Sea Stack Over 100 Years


1890’s

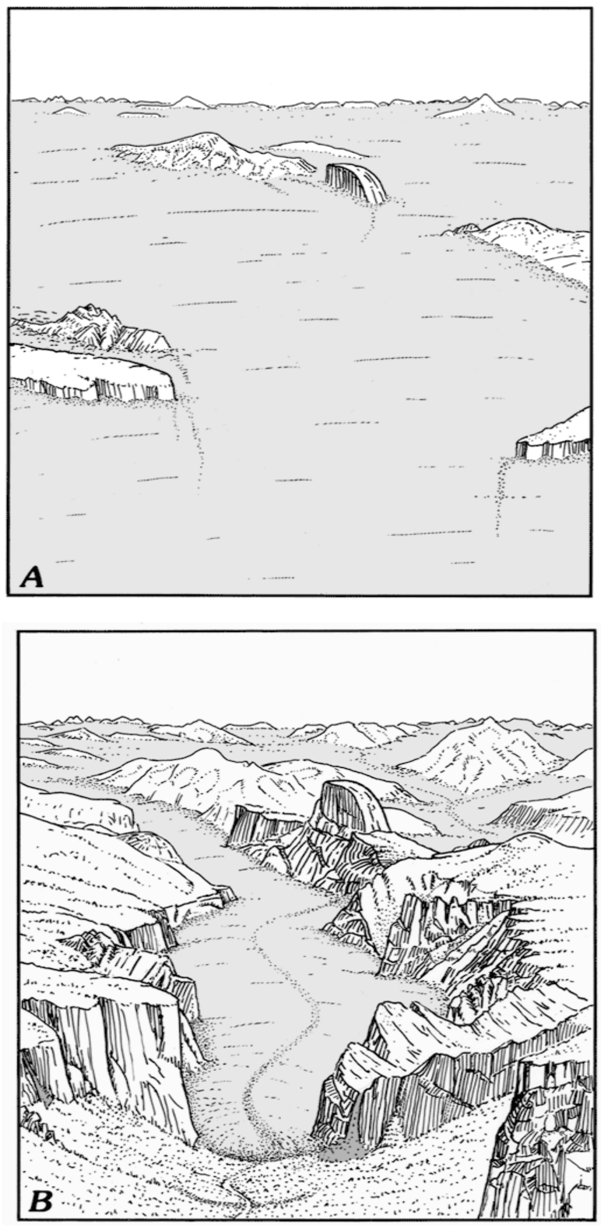

1910’s

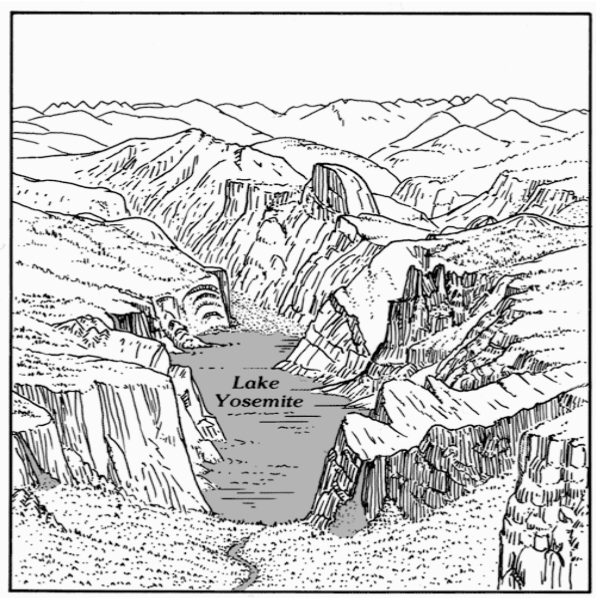

1910’s


1916

(U.S. Geological Survey 2015a)

Figure 16: A simulation of erosion is exemplified through the Yosemite Valley. (U.S. Geological Survey 2015b)





Sketches of Yosemite Valley area, showing extent of valley-filling Sherwin glacier (A, above), and lesser extent of Tioga glacier (B, below).

Students compare images to make observations and/or measurements that provide evidence of the effects of weathering. Computer simulations can help to **model** Earth's process and **data** can be collected by students that can be carefully **analyzed and interpreted** to inform their geotechnical engineering design project.

Mapping Earth's Surface

How do scientists and engineers identify and show ***patterns*** of Earth's features? Students can use maps to identify ***patterns*** and locations of mountains, earthquakes, volcanoes, and ocean ridges. By analyzing a simple topographic map from three-dimensional models of landforms, students are able to show and identify features such as changes in elevation, contours of mountains, and locations of rivers and streams (PE- ESS2-2). The use of computer mapping simulations can further help students describe and identify ***patterns*** of Earth's features.

Engineering Connection

Students use their Earth science **investigations** and their scientific study to identify a problem and inform their **design solutions** to reduce the impact of a natural hazard. The class begins the project by defining a simple human problem related to Earth features, for example by deciding to build a bridge across a river to connect to lands, or design a dam to provide electrical power, or design a new shopping mall or other building structure. The class will be challenged to identify possible patterns of naturally occurring hazards around the area (such as earthquakes, floods, or tsunamis) and their solutions should explicitly include design features that help to reduce the impacts of these natural hazards. The project includes specified criteria for success and constraints on materials, time, or cost. Students revise their original **design solutions** based on their scientific **investigations** and research and have an opportunity to present their revised solutions (along with a drawing or, if possible, an actual physical model) to the class (PE-4-ESS3-2). A final project may include the selection of their prototype as they plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a **model** that can be improved. Students might also determine any unintended negative consequences that result from their implemented **solution**.

Grade Four – Instructional Segment 4: Investigating Structure and Function of Plants and Animals

In this instructional segment students construct an **argument** that the internal and external structures of plants and animals function to support survival, growth, behavior, and reproduction. Students then **use a model** to describe how specialized structures in animals receive different types of information that assist in sensing their environment. There should be an emphasis on how animals receive information, process the information in their brain, and then respond the information in different ways. Finally, students study ***structure and function*** to **develop a model** to describe how light reflecting from objects and entering the eye allows objects to be seen. Emphasis throughout the instructional segment is on the crosscutting concepts of ***cause and effect*** and ***systems and systems models****.* Students **ask questions** like the following at this grade: *What structures help animals/insects eat? Why do plants have thorns? How do animals/people sense our environment? What help us eat or breathe?*

Grade Four-Instructional Segment 4: Investigating Structure and Function of Plants and Animals

How do external structures support the survival, growth, behavior, and reproduction of plants and animals?
How do internal structures support function in animals?
How do animals detect, process, and use information about the environment?
How does light play a role in what we see?

Crosscutting concepts: *Structure and Function, Systems and System Models*

Science and Engineering Practices: *Developing and Using Models, Engaging in Argument from Evidence*

Students who demonstrate understanding can:

4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. [Clarification Statement: Examples of structures could include thorns, stems, roots, colored petals, heart, stomach, lung, brain, or skin. Each structure has specific functions within its associated system.] [*Assessment Boundary: Assessment is limited to macroscopic structures within plant and animal systems.*]

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. [Clarification Statement: Emphasis is on systems of information transfer.] [*Assessment Boundary: Assessment does not include the mechanisms by which the brain stores and recalls information or the mechanisms of how sensory receptors function.*]

4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen. [*Assessment Boundary: Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or how the retina works.]*

Background for Teachers

Throughout its life, a plant or animal will undergo constant interaction with the biotic environment (other living things) and the abiotic environment (the physical environment around it). Being able to sense and respond to the environment is essential for survival. Over many generations, plants and animals can evolve adaptations that give them the best chance for survival within their environment.

Adaptation comes at a price. If an organism is highly adapted to one environment, it will not be able to thrive outside of that environment. For example, sloths are excellent climbers but can barely move around on the ground. This is of particular concern in the light of climate change. In many places on earth, temperatures are changing faster than plants and animals can adapt to the new conditions. These changes in temperature are putting many species under stress.

The ability to perceive light and form an image of the world is a fantastic adaptation common to many animals. The simplest eyes just detect light and dark, possibly helping the organism find a dark place to hide. Sea stars have a light detector (though not a true eye) at the end of each of their five legs. As eyes become more complex, the ability to distinguish different colors of light and to perceive shapes and contrasts becomes heightened. The human eye is a very complex structure but not, by any scope, the most sensitive eye on planet Earth. Other animals can see colors that humans cannot see and some see very well in low-light conditions where humans might be almost blind. In all eyes, vision begins when photons of light reflected off objects that enter the eye and are absorbed by receptor proteins in specialized cells. When a photon strikes one of these proteins, it induces a *chemical* change in the cell. Note that all cells have proteins, but only specialized cells in the eyes and other light-sensitive organs have proteins that change photons into chemical signals. The eye structure can be complex. For example, some eyes have lenses that help to focus the light on the receptor cells. But at the center of vision is light hitting a cell and inducing a chemical change in that cell. This chemical change leads to an electrical signal traveling to the brain where shapes and colors are perceived. Students may have a number of pre-conceived ideas about light and reflection that teachers may need to address.

Description of Instructional Segment:

This instructional segment, Investigating Structure and Function of Plants and Animals, contains three parts: Part 1- External Structures and Function of Plants and Animals**;** Part 2- Internal Structures and Function of Animals**,** and Part 3- Sensing the Environment

External Structures and Function of Plant and Animals

Constructing **arguments from evidence** begins with good **questions** from observations. Students begin with observations to develop **explanations** and **models** for how plant and animal ***structures function*** to support survival, growth, behavior, and reproduction. Students can begin their study by taking a walking field trip to a school or local garden, community park, or nature preserve. After a brief tour each student choses a plant or animal to carefully observe, sketch, and asks the question, *"How do the structures of this organism help it function?"* Continuing in the classroom, students can make further observations of a type of animal, such as an insect, and make careful drawings of an entire organism. They then **ask questions** about the ***function*** of these ***structures***. These questions then set the stage for gathering **evidence**. Based on further observations, research, and classroom experiences, students begin to construct an **argument** about the importance of specific ***structures*** of an insect to its survival, growth, behavior, and reproduction. Together, student teams could use a "Questions, Claims, and Evidence"

> Math Connection
> Draw lines of symmetry on different animals' faces, including humans. Discuss how the placement, size, and shape of eyes and ears on the head of each animal facilitate survival for prey species and for predator species in terms of sensing images and sounds. For example, predator species (cats) usually have eyes that are closer together for stereoscopic vision; while prey animals (horses) have eyes placed on the sides of their head to allow for a wider field of vision.

format to organize their **argument** that ***structures*** of their organism ***function*** to support survival, growth, behavior and reproduction.

After initial observations of one type of animal (insect), teams of students each **investigate** a different animal such as a worm, snail, bird, reptile, fish, or mammal, making observations and collecting **evidence** to construct an **argument** linking ***structures to function***. As students gather **evidence** of how animal structure allows for specific functions, the teacher gives them many opportunities to engage in discussions, providing **models** to support their scientific explanation. The same method of **investigation** could be used for plants. Students begin with careful observational drawings of plants and their specific structures and record questions they have about function. Growing plants from seed and observing the development of roots, stems, leaves, flowers, fruits, and seeds, can help to support construction of **arguments** for how specific plant ***structures*** support survival, growth, behavior, and reproduction. As a possible conclusion for part 1, student groups can participate in a meeting. Each team will be assigned one plant or animal they have observed and **investigated** and construct an **argument** that supports how their ***structures*** support life functions of that particular organism (PE-4-LS1-1). They will support the claims through **evidence** including observations and **models**. Additional ideas for engaging students in this instructional segment are provided in the following vignette: *Structures for Survival in a Healthy Ecosystem.*

Grade Four Vignette
Structures for Survival in a Healthy Ecosystem

Introduction

The vignette presents an example of how teaching and learning may look in a fourth grade classroom when the *CA NGSS* are implemented. The purpose is to illustrate how a teacher engages students in three-dimensional learning by providing them with experiences and opportunities to develop and use the science and engineering practices and the crosscutting concepts to understand the disciplinary core ideas associated with the topic in the instructional segment.

It is important to note that the vignette focuses on only a limited number of Performance Expectations. It should not be viewed as showing all instruction necessary to prepare students to fully achieve these performance expectations or complete the instructional segment. Neither does it indicate that the performance expectations should be taught one at a time.

The vignette uses specific classroom contexts and themes, but it is not meant to imply that this is the only way or the best way in which students are able to achieve the indicated performance expectations. Rather, the vignette highlights examples of teaching strategies, organization of the lesson structure, and possible students' responses. Also, science instruction should take into account that student understanding builds over time and that some topics or ideas require activating prior knowledge and extend that knowledge by revisiting it throughout the course of a year.

Days 1-2 - Structures for Survival.

Mr. F decided to use the California EEI unit, *Structures for Survival in a Healthy Ecosystem*, as the foundation for part one of his *Structure and Function of Plants and Animals* unit. He starts the unit by calling the students' attention to a word wall card for the word "structure" and reviews the definition. To help them clarify their understanding of the word structure, Mr. F asks the students to imagine that they are looking at their reflection in a mirror and examining their teeth, explaining that teeth are an example of a ***structure*** in the human body. He then leads a class discussion to check students' prior knowledge about the importance of organisms' internal and external physical ***structures*** by asking them to identify one of their favorite plants or animals and describe one of its external ***structures***. Mr. F explains that in this unit they will be making observations to help them develop **explanations** and **models** for how plant and animal ***structures function*** to support survival, growth, behavior, and reproduction.

Having planned ahead for a hands-on activity, Mr. F takes his students on a short walk around the schoolyard to observe some of the plants and animals that live nearby. They observe some birds flying by and he asks them to identify some of the external features of the birds, wings, beaks, and eyes. The students see a squirrel running across the grass so Mr. F asks them to identify some of the interesting features of the squirrel, long tail, big eyes, claws, and large ears. They have noticed the squirrel climbing up a big oak tree so he asks them to identify some of its external features.

When they returned to the classroom, with the students prompting him, Mr. F writes the names of the plants and animals they have observed on the whiteboard. He then asks the students to list and briefly describe some of the external ***structures*** they saw on these plants and animals. The students take out their science journals and draw one of the plants or animals they observed, including specific external ***structures*** that they label. (Ms. J, another fourth grade teacher, does not have time for her students to go outside for these observations and discussions so she has them do observations in the classroom involving their class aquarium, pet guinea pig, and plants in the garden box. Ms. W, who does not have any plants or animals in her classroom, uses the visual aids included in the EEI curriculum unit for the students' observations and discussion.)

Mr. F deepens the discussion by having the students explore the importance of these structures by answering several questions, including: "What is the use of the structure?" and "How does the structure help the plant or animal survive?"

The teacher distributes a student workbook to each student and tells them to turn to pages 8–9, where they will see a photograph of a Merriam's kangaroo rat, and asks them to label the major external ***structures*** of the animal, eyes, nose, feet, tail, and cheeks. Mr. F then has students write a sentence that explains how each ***structure*** helps kangaroo rats grow, reproduce, or survive. Because very few of the students are familiar with this animal, Mr. F explains that the cheeks of the kangaroo rat are important because they are used to gather the seeds from the desert floor that support its growth.

Day 3 – External Structures in Changing California Habitats.

Mr. F calls the students' attention to the habitats wall map and explains that this map shows 10 different habitats in California, as well as some of the animals and plants that live there. Mr. F points out that there are many different kinds of plants and animals and that different species live in different habitats, explaining that many have different external ***structures*** to survive, grow, and reproduce in the terrestrial, freshwater, or coastal and marine ecosystems where they live. As a means of more fully engaging them in this topic, he points out their local region and, using the map and their local knowledge, asks students to name some plants and animals that live there.

Mr. F divides the class into small teams and allows each team to select one of the plants or animals depicted in the package of EEI visual aids. Providing copies of these visual aids to the students, he instructs them to investigate and observe their organisms to begin collecting the evidence to construct their arguments about the function of one of its external ***structures***. As the culminating team activity, Mr. F assigns the teams to make a visual display, such as a poster, that depicts the plant or animal they investigated and labels several different external ***structures.*** (Note: In preparation for his lessons in part three of this unit, *Sensing the Environment,* Mr. F specifically asks the students to identify and describe the ***structure and function*** of the animals' sensory organs.)

Day 4 – Survival in Changing Habitats.

In order to reinforce what the students have learned about the effects of human activities on the environment (California Environmental Principle II), Mr. F asks them to recall their discussions during unit 1-part 3 *Energy Resources and the Environment*, about how energy consumption affects the environment (e.g., loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels). He then projects visual aids #44 and #45 from the *Structures for Survival in a Healthy Ecosystem* unit, and asks the students to review what Anna's hummingbirds need to grow, survive, and reproduce.

As an individual assessment, Mr. F requires each team member to write an **evidence-based argument** focused on one plant or animal and one of its internal or external ***structures***. He explains that the students' **arguments** must include the **evidence** they gathered in support of their point of view, and include their reasoning to support of the structure's role in survival, growth, behavior, and/or reproduction. Mr. F tells them that their writings must also include **evidence-based** responses to two questions: “If they are going to survive, grow, and reproduce, what do plants and animals need, in addition to the external ***structures*** we have learned about?” And, “How might human activities affect the environment and their selected plant’s or animal’s survival, growth, behavior, and/or reproduction.” This activity should help students develop their understanding that survival, growth, and reproduction of plants and animals depends on them having a healthy terrestrial, freshwater, or coastal and marine ecosystem in which to live.

Performance Expectations		
4-LS1-1 From Molecules to Organisms: Structures and Processes *Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. [Clarification Statement: Examples of structures could include thorns, stems, roots, colored petals, heart, stomach, lung, brain, and skin. Each structure has specific functions within its associated system.] [Assessment Boundary: Assessment is limited to macroscopic structures within from one of California's systems.]*		
Science and engineering practices	**Disciplinary core ideas**	**Cross cutting concepts**
Engaging in Argument from Evidence *Construct an argument with evidence, data, and/or a model.* *Use a model to test interactions concerning the functioning of a natural system.*	**LS1.A Structure and Function** *Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.* **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.*	**Systems and System Models** *A system can be described in terms of its components and their interactions.*

California's Environmental Principles and Concepts
Principle II: *The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.* **Concept a.** *Students need to know that direct and indirect changes to natural systems due to the growth of human populations and their consumption rates influence the geographic extent, composition, biological diversity, and viability of natural systems.*
Connections to the CA CCSS for ELA/Literacy: W.4.1, SL.4.5

Vignette Debrief

The *CA NGSS* require that students engage in science and engineering practices to develop deeper understanding of the disciplinary core ideas and crosscutting concepts. The lessons give students multiple opportunities to engage with the core ideas in life sciences related to how the internal and external structures of plants and animals support survival, growth, behavior, and reproduction, thereby helping students move towards mastery of the three components described in the *CA NGSS* performance expectation.

In this vignette, the teacher selected two performance expectations but in the lessons described above he only engaged students in selected portions of these PEs. Full mastery of these PEs will be achieved throughout subsequent units.

Students were engaged in a number of science practices with a focus on engaging in **argument from evidence**. Life science lends itself well to developing students' abilities to make oral and written **argument with evidence**, **data,** and the **use of models** to test interactions concerning the functioning of natural systems.

As students examined their own teeth, they began to understand the key scientific concept of ***structures,*** then expanding on this knowledge by observing the external features of local animals and plants. Students used their science journals to record information about what they observed to prepare them for a class discussion about how plants' and animals' internal and external structures support survival, growth, behavior, and reproduction.

In order to develop their abilities with science and engineering practices, their teacher discussed the importance of **evidence** in constructing scientific **arguments**, about the ***function*** of one of its external ***structures***. The students reinforced this practice as they constructed **evidence-based arguments** about the ***structures*** of the organisms they were describing.

Students also examined the crosscutting concept of ***systems and system models*** as they **investigated** the connections between an organism's internal and external ***structures*** and how human activities can influence their survival, growth, behavior, and reproduction. This also reinforced their developing understanding of California Environmental Principle II, Concept a, "*direct and indirect changes to natural systems due to the growth of human populations and their consumption rates influence the geographic extent, composition, biological diversity, and viability of natural system.*"

CCSS Connections to English Language Arts

Students used all of the evidence they gathered from their field trip, class discussions, and visual aids to construct an evidence-based argument about the role in the survival, growth, behavior, or reproduction of the external structures of their selected organisms. This connects to the *CA CCSS for ELA/Literacy* Writing standard (W.4.1). In addition, they developed visual displays to support their main ideas about the function of the external structures of their plants and animals, which corresponds to Speaking and Listening Standard 4 (SL.4.5).

Resources for the Vignette

- California Education and the Environment Initiative. 2011. *Structures for Survival in a Healthy Ecosystem.* Sacramento: Office of Education and the Environment.

Internal Structures and Function of Animals

How do we hear? How do we breathe? How does our blood move through our body? What internal ***structures*** allow these ***functions*** to happen? What ***structures*** do other animals have that allow them to ear, breath, and cause blood to circulate? These questions provide excellent opportunities to engage students in thinking and

investigating to construct **arguments** that animals have internal macroscopic ***structures*** to support life ***functions*** (4-LS-1-1). For example, students can use **models**, videos, simulations, and podcasts to **investigate** how we hear. This is an excellent way to connect exterior structures to interior structures. The exterior structures of the ear, pinna and ear canal, catch and funnel sound waves into the interior structures of the ear. These sound waves vibrate the tympanic membrane (eardrum) and engage the tiny bones (malleus, incus, stapes) to amplify the vibration from the ear drum. The stapes transfers the wave (mechanical energy) to the cochlea by pushing on it. The wave then travels through the fluid inside the cochlea engaging tiny hair-like cells that send messages to the brain resulting in what we hear. This example is also an ideal opportunity to connect to energy transfer (sound, mechanical, chemical impulses) 4-PS3-2 and the fourth grade study of waves (4-PS4-1 and 4-PS4-3). Investigations of hearing can expand to how other animals hear and the ***structures*** that allow them to do so.

Other examples of ***structures*** to be **investigated** could include heart, stomach, lung, and brain. Student activities depend on the highlighted ***structure***. Students should consider the ***structure and function*** of at least two examples, using **models** to understand how the ***structure functions*** and is part of a larger system. For lungs, students can use or make **models** of lungs such as two balloons in a chamber that model as the diaphragm is moved, the balloon inflates of deflates. They can observe their own respiration and chest movement and can follow the flow of air in and out of lungs. For heart, **models** of pumps and hoses can model pulse and circulation.

Students will conclude this part of the instructional segment by **constructing arguments** that animals have internal macroscopic ***structures*** to support life functions based on the **evidence** they collected through conducting **investigations,** using and building **models**, and a literature review.

Sensing the Environment

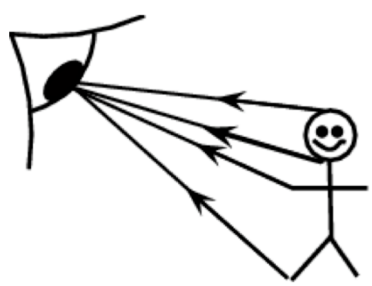
Students begin by **developing and using a model** to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways (4-LS1-2). It is important to note that the instructional focus is on the informational transfer, not the mechanisms of how sense receptors and brain function. Students continue by **developing a model** to describe that light reflecting from objects and entering the eye allows object to be seen (4-PS4-2).

Animals (and plants) have specialized structures that allow them to sense their environment. The environment is constantly giving signals (movement, temperature, color, sound) that animals receive through internal and external ***structures*** or sense receptors (eyes, skin, ears, hairs, tongue, antennae). This gathered information enters the brain, is processed, and the brain sends back information to guide the actions of that animal. The brain is continually receiving and responding to sensory input. To create an initial **model** for sensing the environment or informational processing, students can begin with a familiar experience to them such as touching and responding to a hot object (for example, a hand-warming pouch). Students draw their initial **model** by showing what they think is happening when they touch something hot, indicating in a sequence the initial touch with the object through the moment in which they pull away from the hot object. Further observations of the senses (smell of perfume, using taste testing PTC paper) and research help them **develop a model** of the process of input, informational transfer, and output. Students are given opportunities to **investigate** and research other animals (insects could be used again) to further **develop models** for informational processing. (See grade four Snapshot: *Exploring Behavior of Termites* at the end of this Instructional segment.) Students present their **models** for comparison. Informational processing provides a great opportunity to identify and highlight the crosscutting concept of ***cause and effect***. The study of informational processing continues in the middle school grades.

One of the ways that animals sense the environment is through sight. In grade four, students **develop a model** to describe that light reflecting from objects and entering the eye allows objects to be seen (PE 4-PS4-2). This performance expectation is an opportunity to connect to the study of ***structure and function*** of animals and sensing the environment to the specific process of how light reflection plays a part in what we see. Students are introduced to light and interaction of light with objects in grade one, and in grade four, they apply that understanding to how we see.

A common preconception that students have related to light and sight is that light comes from objects and that is the reason why we see them. Teachers can begin by instructing students to draw an initial **model** to explain how we can see ourselves in a mirror or how we see objects. Next, a powerful way to tap into student thinking and to begin to build conceptual understanding is through the use of science assessment probes to engage students and uncover their prior knowledge. Examples of two probes that provide good opening activities are “Apple in the Dark” and “Seeing the Light” (Keeley, Eberle, and Farrin 2005; Keeley 2012). “Apple in the Dark” provides a scenario which taps into student ideas about how we see light (Would you be able to see a red apple in a totally dark room?), and “Seeing the Light” asks students to identify types of objects and materials that reflect light. Each probe asks students to identify what they know and to detail their thinking behind their choices. The student feedback from these formative assessments can help to direct the series of experiments and observations that follow.

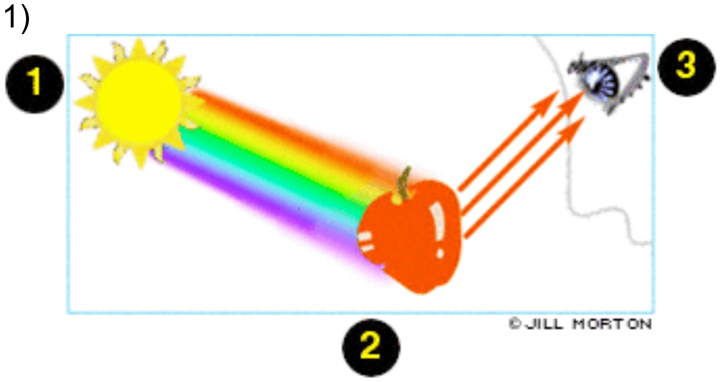
Figure 17: A drawing showing how we see a person missing the light source (sun or light bulb). (MST Workbooks 2015)



From these initial ideas, probes, and discussions students investigate reflection of light from various objects to develop an understanding that light travels in a direction and is reflected from some objects. Collaborative student teams begin to investigate reflection with flashlights and mirrors. They conduct an **investigation** by holding the flashlight at different angles and drawing diagrams representing their observations showing the trajectory of the light and indicating the source and the receiver of the light. They observe that the source of light travels in a straight line and is then reflected. At this point students will revise their **model** with their additional observational information using flashlights and mirrors.

They continue investigating the reflection of the flashlight on other surfaces including shiny surfaces (Mylar, glass, glossy paint) or objects (glass, crystal, leaves) and non-shiny surfaces (wood, dirt, eraser) noting that some materials are good reflectors and some are not good reflectors of light. Further **investigation** could include dimming or turning off lights and making observations of objects in dark with the flashlight on (object can be seen) and off (object cannot be seen or not seen as well). Finally students return to their initial **model** and make the final revisions based on their exploration of light and reflection. Student representations include the trajectory of the light from the source to the object and then to the eye of the observer. Students may need additional written explanations and reference materials to connect their own observations and diagrams to further deepen their understanding of how light reflecting from objects and entering the eye allows objects to be seen. (See figure 18) From these experiences and a review of text, student teams will develop their final **model** of how light reflecting from objects and entering the eye allows objects to be seen. Students could develop poster **models** that would be part of a gallery walk where the entire class would have a chance to review and respond to each **model**.

Figure 18: Model called a “Light ray diagram” of a light source 1 (sun), as it hits an object 2 (apple) and light from this object in then reflected to the observer 3 (person). (Color Matters 2011)



This part of the instructional segment has some strong ties to other Performance Expectations in fourth grade. Energy transfer (4-PS3-2) can be highlighted as students study light reflection. Some objects absorb light (black) as demonstrated by increased temperature and some objects reflect light (white) resulting in less of a temperature gain. Measuring the heat of objects as they receive the same amount of sunlight can help bridge life science to physical science.

As this instructional segment is concluded, students make observations to provide **evidence** that light reflecting from objects and entering the eye allows objects to be seen (4-PS4-2). Differences in the ***patterns*** of placement and size of the eyes (and ears) of predator and prey mammals and other animals can provide a bridge (4-LS1-1) that animals have internal and external ***structures*** that support survival, growth, behavior, and reproduction.

Grade Four Snapshot: Exploring Behavior of Termites

Introduction

Mr. S's 4th grade class is ready to begin to explore part 3- *Sensing the Environment*, the final section in instructional segment 4 *Structure and Function of Plants and Animals*. He is eager to make this a hands-on experience for students and wants to build from their initial study of the external ***structure and function*** of insects. Mr. S. is also very interested in students having hands-on experiences with live organisms and wants to begin to construct a series of lessons and **investigations** for his students to meet the performance expectation 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.*

At a recent national science conference, Mr. S conducted his own hands-on experience with an investigation involving termites. Pen lines were drawn in various shapes on a piece of paper and worker termites were released onto the paper. To everyone's amazement, the termites began to carefully follow the pen designs. Attendees began to **ask questions** and develop causes for why this might be happening. Was it the color of the pen or width of the pen line? Did the pen leave a groove in the paper to follow or did the termites "smell" the pen mark. Might there be another cause for this behavior by the termites? **Investigations** eagerly began to answer the many questions posed in the conference room. After further research, Mr. S. found out that worker termites secrete pheromones, chemical signals, to assist other termites' search for food and nest building. Termites use their antennae to detect these pheromones and process this chemical signal in their brain to help them find their way to food or the nest, as they are blind organisms. Certain inks in pens are closely related to the pheromones secreted by the termites! He saw this **investigation** as a great way for students to begin to explore informational processing in a hands-on way and to emphasize the crosscutting concept, ***cause and effect***.

Mr. S eagerly opened the class, "Let's do a quick review of what we know about the ***structures*** of insects: look into your notebooks and talk to your group. Each group should come up with two sentences about ***structures*** of insects." After several minutes teams of students were ready to report out about ***structures*** of insects. Mr. S's students work in well-organized science teams. Each member of the team has a designated job assignment that are rotated throughout the year (facilitator, reporter, materials manager, and recorder.) Team 5's reporter confidently stated that insects have three body segments: head, thorax, and abdomen. Team 2 made sure the class was reminded of the different type of legs that allowed insects to crawl, hop, or swim. Team 3 reported on the different types of antennae and how the variety of insect antennae helped the organisms sense their environment. Mr. S quickly typed into the classroom computer and projected the students' statements on the screen.

Mr. S continued, "Today we are going make observations and set up **investigations** to explore termites' ability to sense the environment!" Mr. S. projected several images of termites on the screen. "Have you ever seen termites before?" Mr. S asked. Anthony responded, "Last spring my parents had to call the *termite people* to clean the house. I didn't know we had termites. The whole house was covered in plastic." "Yes, we call that process termite disinfestation. It is quite common for wood houses to have termites living in them." He then directed the students to draw a simple figure of a termite on their notebook. They will label the parts of the insect later.

Next, to the amazement of the students, the teacher pulled out from inside a cabinet a tray containing several small containers. Something was moving in those containers!

(Note: If the teacher and/or school have concerns about students using live termites, the lesson can be adapted so only the teacher is responsible for handling the termites.)

"I am going to give each group a container with a few termites in it. Please, be gentle with them as I showed you earlier." The materials manager from each group quickly went to pick up a small container of termites from the teacher and returned to their table. He then directed the recorder in each team to draw a simple squiggle line on a piece of paper. The team facilitator carefully poured the termites from their holding container on to the paper and the remaining two students had small paintbrushes in hand to gently keep the termites on the paper. To the amazement of the students, the termites began to follow the pen design! Students recorded their observations and questions in their science notebook.

After five to ten minutes of observations, groups are asked to generate a list of questions about the termites and possible ideas that explain the ***cause*** for why the termites' behavior followed the drawings on the paper. Each reporter for the group offers an idea. "We think the cause maybe that termites follow a specific color, so I wonder if the changing color would make a difference in behavior" offers the team 2 reporter. Heather added to the list, "Team four thinks the brand of pen determines the cause for the termites to follow the lines." Jennifer poses the question, "Does it matter if the lines are straight or curved?" Other questions and causes include placement of termites on the paper, the width of the pen, the odor of the pen, the texture that the pen makes on the paper. From this discussion, Mr. S.'s students begin to develop ideas for **investigations.**

Example group data table

Color of writing implement	Trial 1-spiral # of termites following line	Trial 2- spiral # of termites following line
Blue sharpie		
Blue pencil		
Blue Ballpoint		
Blue Gel pen		

Each team chose one variable or cause to test and examine and report the result (effect) to the class. After a discussion led by Mr. S, each team creates a table to record the data for their experiment that includes the variable or cause they were testing and the number of termites that followed the line drawn. They also took observational notes during the testing time to further note the effect of the variable tested. After careful **investigation** and data recording, the groups carefully place the termites back into their containers and prepare to share their experimental results with the rest of the class.

What became clear from the classroom discussion is that the termites follow the lines that were drawn to certain types of ballpoint pen. Ballpoint pens cause the most amounts of termites to follow the lines that were drawn on the paper (effect).
They also noted that it did not matter if the design shape was curved or straight.

Mr. S. asks students to explain in their notebooks of how they think the termite is processing the sensory information to follow the trail that includes the **evidence** from their **investigations** and provides a ***cause and effect*** relationship. For several minutes the groups are busy sharing ideas, drawing, and revising their drawings.

Next, he provides each student with some background reading about how worker termites communicate with special chemicals called pheromones. The text describes how termites laid down these pheromones to communicate location of food or nesting locations. Termites' antennae are able to sense these pheromones, process this information in their brain, and the effect is termites are able to travel to specific locations. Student teams read the scientific information, use the information to inform their initial **model**, and Mr. S leads a class discussion to link the students' termite **investigation** to the big idea of informational processing.

Conclusion

The teacher provides each student team a packet with information regarding different insects to research and report back to the class. The report has to include a description of the specific informational processing pathways unique to their assigned insect.

This snapshot initiates the students' study of how animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways. It also involves students in the practice **of planning and carrying out investigations** and the crosscutting concept of ***cause and effect.*** Other organisms can be used to begin or extend this subject including the investigation of isopods (or isopods and beetles) and their response to moisture or temperature in the environment. Many resources highlighting the use, care and appropriate disposal of organisms in the classroom can be found on the web or in existing curriculum.