Grade Five

There are three major crosscutting concepts that are being developed in grade five at a deeper level: ***systems and system models***, ***scale, proportions, and quantity***, and ***cause and effect***. However, ***matter and energy*** and ***patterns*** are also addressed in this grade. Students engage in simple **investigations** of small systems (e.g. potted plant) to larger ones like the make-up of their ecosystems and the ***flow of energy and matter*** in it. ***System models*** of the biosphere and how it interacts with the atmosphere, lithosphere and hydrosphere are developed*.* Student thinking and experiences demonstrate a stronger understanding of the links between ***matter and energy*** as it goes from smaller ***systems*** (molecular level) to larger ones (Sun and the stars). In this grade it is also the first time that students think of the connections of atomic level, microorganisms, amounts of water used per consumer to processes of the Earth's atmosphere and the Universe. Students in this grade apply ***scale, proportions, and quantity*** in all their science instructional segments. Measuring volumes of water and amounts of other materials help the student use ***mathematics and computational thinking*** to support their **investigations**. There is a strong focus on water in the three disciplines: physical, life and Earth sciences. Students investigate a familiar material and how it is found as a central piece in living organisms (plants and animals), use it to look for **evidence** of particles too small to be seen (breath on a mirror), and that freshwater is a scarce resource for humans on Earth.

Table 3 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 3–5 engineering design. The PEs marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.

Table 3: Instructional Segments in Grade 5

GRADE FIVE			
Instructional Segment 1: Matter and Interactions	**Performance Expectations Addressed**		
	5-PS1-1, 5-PS1-2, 5-PS1-3, 5-PS1-4, 3-5-ETS1-3		
	Highlighted SEP	**Highlighted DCI**	**Highlighted CCC**
	• Developing and Using Models • Planning and Carrying out Investigations	PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions	• Scale, Proportion and Quantity • Cause and Effect
	Brief Summary		
	All matter is made of particles that are too small to see. This particle model can be used to understand the properties of solids, liquids, and gases. One can use physical and chemical properties to identify substances. When chemical reactions occur, new substances are formed from starting substances, however the overall mass of matter remains unchanged (conservation of mass).		
Instructional Segment 2: From Matter to Organisms	**Performance Expectations Addressed**		
	5-LS1-1, 5-LS2-1, 5-PS3-1		
	Highlighted SEP	**Highlighted DCI**	**Highlighted CCC**
	• Developing and Using Models	PS3.D: Energy in Chemical Processes and Everyday Life LS1.C: Organization for Matter and Energy Flow in Organisms LS2.A: Interdependent Relationships in Ecosystems LS2.B: Cycles of Matter and Energy Transfer in Ecosystems	• Systems and Systems Models Energy and Matter
	Summary of DCI		
	Energy from the sun is captured by plants and that energy is released to animals from food. Matter cycles between air, soil, plants, animals, and microbes as these organisms live and die. Organisms are related in food webs. Multiple species of different types are necessary for a healthy food web.		
ment 3: Earth Syste ms	**Performance Expectations Addressed**		
	5-ESS2-1, 5-ESS2-2, 5-ESS3-1, 3-5-ETS1-3		
	Highlighted SEP	**Highlighted DCI**	**Highlighted CCC**

	• Obtaining, Evaluating and Communicating Information	ESS2.A: Earth Materials and Systems ESS2.C: The Roles of Water in Earth's Surface Processes	• Scale, Proportion and Quantity • Systems and Systems Models • Cause and Effect
	Brief Summary		
	The Earth's major systems (atmosphere, biosphere, geosphere, hydrosphere) interact to affect earth's materials and processes. Most of the water on the Earth is in the ocean. Most fresh water is in glaciers or underground. A tiny fraction is in streams, lakes, wetlands, and atmosphere. Human activities have major effects on the Earth's systems. Humans can protect Earth's resources and environments.		
Instructional Segment 4: Patterns in Earth & Space	**Performance Expectations addressed**		
	5-PS2-1, 5-ESS1-1, 5-ESS1-2		
	Highlighted SEP	**Highlighted DCI**	**Highlighted CCC**
	• Developing and Using Models	PS2.B: Types of Interactions ESS1.A: The Universe and its Stars ESS1.B: Earth and the Solar System	• Patterns • Scale, Proportion & Quantity • Systems & System Models
	Brief Summary		
	Gravitational force acts on objects near the Earth's surface. The orbits of Earth around the sun and the moon around earth cause predictable and observable patterns. The sun is a star and appears brighter that other stars because it is closer.		

Grade Five-Instructional Segment 1: Matter and Its Interactions

In this instructional segment on matter and its interactions, students plan and carry out investigations and engage in scientific experiences to help them answer questions such as: *What evidence is there that gases have mass or occupy a set volume? Why can air move an object? What happens to matter as it changes state, does its weight change? What happens to two substances as they mix? What evidence is there that a chemical reaction occurs? What are the properties of common materials?*

Grade Five-Instructional Segment 1: Matter and Its Interactions
What evidence is there that matter is made of particles too small to be seen? *When matter changes state, does its weight change?* *What happens when two different substances are mixed?* *How do we know when a chemical reaction occurs?* *When a chemical reaction happens properties are the same/different between the starting and ending materials?*
Crosscutting concepts: Scale and Proportion; Cause and Effect
Science and Engineering Practices: Developing and Using Models; Planning and Carrying out Investigations
Students who demonstrate understanding can: **5-PS1-1 Develop a model to describe that matter is made of particles too small to be seen.** [Clarification Statement: Examples of evidence supporting a model could include adding air to expand a basketball, compressing air in a syringe, dissolving sugar in water, and evaporating salt water.] [*Assessment Boundary: Assessment does not include the atomic-scale mechanism of evaporation and condensation or defining the unseen particles.]* **5-PS1-2 Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.** [Clarification Statement: Examples of reactions or changes could include phase changes, dissolving, and mixing that form new substances.] [*Assessment Boundary: Assessment does not include distinguishing mass and weight.*] **5-PS1-3 Make observations and measurements to identify materials based on their properties.** [Clarification Statement: Examples of materials to be identified could include baking soda and other powders, metals, minerals, and liquids. Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility; density is not intended as an identifiable property.] [*Assessment*

	Boundary: Assessment does not include density or distinguishing mass and weight.]
5-PS1-4	**Conduct an investigation to determine whether the mixing of two or more substances results in new substances.** [Clarification Statement: Examples of combinations that do not produce new substances could include sand and water. Examples of combinations that do produce new substances could include baking soda and vinegar or milk and vinegar.]
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.** [Clarification Statement: Examples of models could include diagrams, and flow charts.]

Background for teachers

The main goal of this instructional segment is for students to develop and refine the idea of ***conservation of matter*** and of particulate models for matter, without stressing the exact size and structure of the particles, but recognizing that they are so small that we cannot see them, even with the aid of a microscope.

Using a variety of **investigations** and observation, including observations of simulations, students develop distinct **models** for the substructure of solids and liquids and for gases, building on and going beyond the models from their earlier experiences with matter. Students do not intuitively have a particulate view of any type of matter. Solids and liquids look continuous, and gas as a collection of particles moving in space is even more difficult for them to visualize based on their experiences of air and their language about it. The activities in this instructional segment must involve multiple phenomena in which different types of particles interact, mix, and move around so that students need particulate **models** to explain what they observe. Teachers must carefully choose a phenomena to help students develop and apply the **models**. For example, recognizing how a particulate model of a gas explains phenomena such as air pressure. Students can **investigate** how air pressure changes when the same amount of air is compressed into a smaller volume, or when the closed container is heated at fixed volume. Students develop the idea that mass (or weight, since we do not need to distinguish them at this grade) is a proxy for how much matter is present. At this grade level, the terms “atom” and “molecule” may be familiar, but most students do not have a clear model of the distinctions between them. The generic term “particle” is used for either. Students need some names for the different types of particles in a mixture or solution (e.g., water particles, sugar particles, oxygen particles). However, the names of specific elements are introduced only as needed to describe and discuss their observations about matter phenomena, and the nature of the differences between different elements is not stressed. Students should understand that matter can disappear (that is ceases to be visible), for example, by dissolving, but that we know it is still there when we weigh the resulting solution. This idea builds on prior activities, with more visible matter and its changes (for example weighing ice, melting it, and weighing the water). This is an excellent opportunity to highlight ***scale, proportion and quantity*** relationships as well as ***patterns***.

The idea that materials have consistent properties and that we can often use these properties to identify what type of matter is present is also developed and made explicit in this instructional segment. Students know this in simple cases. They recognize and name a wide variety of materials without even thinking about how they do it. Teachers need to make the implicit knowledge explicit, asking students how they know that this is wood and that is stainless steel or aluminum. Next, the goal of the activities in this instructional segment should be to develop a broader and more explicit sense of what kinds of properties can be used to characterize a substance and what cannot. For example, the color of a solid does not tell us much because it can be changed with a thin layer of paint, but the color of a liquid may tell us something, but perhaps not everything we need to know about what it is. Working with solid materials students need to develop a set of concepts and a language for **investigating** and describing and classifying them. Properties include both intrinsic properties such as: Does it conduct heat or electricity well? Does it bend easily? Is it rigid or compressible? Is it attracted by a magnet? At what temperature does it melt? Chemical properties include: Does it dissolve in water or oxidize with air? The possible list is very long, and no student needs an exhaustive list, but the instructional segment must build a set of coordinated ideas about properties of matter and identification of different types of matter through a coherent set of activities and discussions.

Engineering Connection:

This instructional segment provides excellent opportunities for students to develop competency in engineering design by solving problems involving the properties of materials. For example, students can construct towers out of a variety of materials, such as newspaper and tape, popsicle sticks and glue, or straws and paperclips, to determine the how the properties of these materials do or do not lend themselves to constructing towers that are tall and that bear weight. Students will find that they can change the properties of materials by using them in different ways, such as increasing the strength of paper by rolling it into tubes, or increasing the strength of three index cards by gluing them together with glue sticks. Testing the structures to failure enable observation of failure points and failure modes, such as crushing and buckling, stretching and tearing, noting that different materials fail in different ways. At least some of the properties introduced need to be quantifiable and measureable, and students should gain experience in making such measurements on structures that they build.

Description of Instructional Segment:

By the end of grade five, students have developed the understanding that all matter is comprised of particles that are too small to be seen. Although these particles cannot be seen, they can be detected by other means (e.g., by weighing or by its effects on other objects). They are extending their knowledge of observable properties of matter (visual, aural, textural), its uses, and classification by origin (natural or manufactured) or state (solid or liquid). In addition, students begin exploring the ***effects*** of temperature on one substance and **develop a model** of what happens when two or more substances are mixed together. This instructional segment is divided in three parts: Part 1- Developing a Particulate Understanding of Matter**;** Part 2- Mixing Matter (Mixture/Chemical Reaction)**;** and Part 3- Conservation of Matter

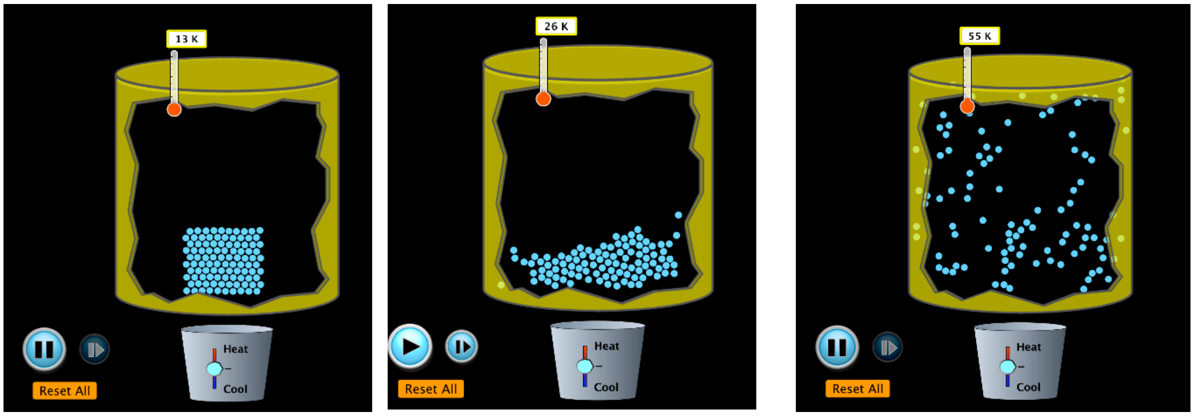
Developing a Particulate Understanding of Matter

Students should engage in investigations of phenomena that allow them to **develop a model** of matter which includes the idea that all matter is comprised of particles that are too small to be seen. **Models** at this grade level do not distinguish between atoms or molecules as particles, but students do develop **models** that explain major differences between the substructures of solids, liquids, and gases. In addition, students explore what happens to a substance (e.g., water) as it is heated or cooled. Students are not required to know specific atoms, molecular structures, or compounds, but can represent the particles in their models using undifferentiated particles drawn as dots or small spheres (or circles).

As a starting point for **developing these models**, students explore and **develop models** that help explain phenomena involving gases, such as wind, air pressure and hot-air balloons, and the motion of dust particles in air (known as Brownian motion, but students do not need to know this terminology). The goal is to develop **evidence** that gases consist of matter particles that are too small to be seen moving freely in space and that these particles are colliding with one another, dust particles as well as with the walls of their container. Activities that students could engage in to help develop this **model** could include: having students use a closed syringe that is half filled with air and try to compress the air (students should be encouraged to make force diagrams using arrows such as in the diagrams in third grade 3-PS2-1). They can also measure the mass of a balloon (or ball) before and after it has air in it; and/or to have students trying to blow up a balloon that is inside a plastic bottle. By the end of these activities, students should understand that air (and all gases) is made up of particles that are too small to be seen. In addition, they should be able to draw a diagram showing that the gas particles are not touching. This concept takes some work, most students find it hard to accept that the gas particles continually move around and do not simply fall to the bottom of the container if there is nothing there to hold them up. The idea that collisions among the gas particles maintain a distribution throughout the container needs to be developed through access to simulations as well as discussions about phenomena that provide evidence that can be explained using such a **model**. Students can further their understanding of gases by exploring the effects of heating a closed expandable system, such as a balloon over the top of a bottle, and seeing that the gas within the container expands to inflate the balloon as the container is heated. This helps students to develop the idea that the greater the temperature, the faster the gas molecules move.

After exploring gases, students should apply their newfound particle **model** to solids and liquids. One possible activity that students could engage in is to try to compress a liquid in a closed syringe. They can compare the amount of compression between the gas-filled syringe and the liquid-filled syringe to see that the liquid is much less compressible. This can lead them to the understanding that the particles in a liquid must be closer together than in a gas. Students should be able to draw representations of solids, liquid, and gas at the particulate level. Their **model** of a liquid should show a dense collection of particles that are free to move around relative to one another. The model of a solid should show particles connected in a network that maintains them, as if connected by a set of springs, so they can vibrate about their stable positions but rarely move from their place in the network. Figure 19 is a computer simulation model of neon in solid, liquid, and gas states.

Figure 19: Computer simulation of particles of Neon in three states: solid, liquid and gas (PhET 2015b)



Solid Liquid Gas

After exploring solids, liquids, and gases individually, students explore what happens when a single substance (e.g., water) is heated and cooled. Students should be able to draw pictures to explain the phase changes. In addition, students understand that the total number of particles remains the same during the process, but their positions and motion relative to one another change as more energy is added to the system. ***Conservation of matter*** can be demonstrated by having students weigh a piece of ice and then weigh the water after the ice melts. Students explore water in all three states and at least one other substance phase change in which only two states need to be visualized. Possible examples include solid wax melting to liquid wax, lava cooling and turning into rock, or rubbing alcohol evaporating. Students can then apply their particle **model** to explain more complex systems such as where the condensation on the outside of a cold glass comes from.

> ELA ELD Connection
> Have students, either in pairs or triads, research several sources (print and digital) for the meaning of the law of conservation of mass, summarize the meaning and using diagrams or examples, create a visual display. Students should provide a list of their sources on the display.

After students have developed their own initial **models**, the can use computer simulations to develop and refine their ideas and to connect their ideas to current scientific thinking. These **models** should allow students to see how temperature affects a given substance and what happens as it undergoes phase changes. This instructional segment is a good opportunity to develop ***systems and system models*** and ***structure and function***. By adding quantitative measurements students can apply *Standards for Mathematical Practice* such as reason abstractly and quantitatively (MP.2) and model with mathematics (MP.4).

Mixing Matter (Mixtures and Chemical Reactions)

Before students recognize **evidence** that chemical reactions have occurred, they need to be able to give detailed descriptions of pure materials like copper, zinc, water, salt and sugar. Teachers should give students the opportunity to observe and record physical properties of particular substances. Teachers can challenge student to identify the content of a sample of a pure substance based solely on their prior recorded observations of properties and their observation of the properties of the sample.

Students should engage in phenomena or problems (white powder mystery) that lead them to a series of **investigations** to learn what happens when they mix substances together. Examples include: (1) baking soda and vinegar;(2) salt and sugar; (3) baking soda and juice from lemons or oranges (citrus fruit); (4) iodine and starch; (5) effervescent tablets in water; (6) household liquids with cabbage juice; (7) glue and borax; and (8) sand and salt.

Mixing substances results in either the formation of a mixture, if the substances do not react, or the formation of new substances, if a chemical reaction occurs. Students should be able to recognize the **evidence** of a chemical reaction including: temperature change, emission of light, formation of a gas, color change, formation of a solid, and/or a change in smell. Chemical changes are always accompanied by physical changes. Teachers should place emphasis on having students give detailed descriptions of the physical properties (e.g., color, texture, granule size, state of matter) of starting and ending materials. Teachers should not expect their students to write or to understand written chemical equations or memorize the names of elements or the formula and structure of particular molecules. The idea that all matter is made up from a set of distinct types of atoms (known as elements) and that each type has a name (such as carbon, hydrogen, or oxygen) and the distinction between an atom and a molecule (a connected set of atoms) can begin to be introduced as these terms arise and are found useful to describe what is happening in chemical processes.

Students explore what happens when they mix substances together. Teachers give students substances to mix that undergo chemical reactions and others that form mixtures. Some possible substances for students to mix are marbles and sand (mixture), water and salt (mixture), baking soda and vinegar (chemical reaction), and/or baking soda, calcium chloride, and water or cabbage juice (chemical reaction). Teachers should encourage their students to describe what happens when different substances are mixed and determine signs which indicate that a chemical reaction has occurred and a new substance has formed. These signs include: temperature change (cold pack), emission of light (glow stick), formation of a gas (effervescent tablet and water), color change (metal rusting), formation of a solid (stalactites and stalagmites/hard water build up), and/or a change in smell (baking cookies or bread). Students should have the opportunity to observe a chemical reaction for each such indicator. In addition, students should understand that a mixture can be separated back into the pure substances that composed it, using the physical properties of the pure materials. Teachers can challenge their students to identify the physical properties of sand, salt, and water and then determine a way to separate a mixture of the materials back into its original pure components.

Conservation of Matter

Students already determined that when a mixture is formed or a phase change occurs, the total weight of the substance is conserved. Students should now engage in activities to show that when a chemical reaction occurs, the mass of the starting and ending materials is the same. This phenomenon is known as the law of conservation of mass.

The first reaction that students explore should be a reaction in which no gas is produced (e.g., mixing cabbage juice and lemon juice). This investigation allows students to build the idea that the mass of the starting and ending materials are the same. Students should then be presented with a reaction in which a gas is produced (e.g., baking soda and vinegar). For this reaction, the starting materials should be weighed along with the ending materials minus the escaped gas. Teachers should challenge their students to **explain** why the starting and ending materials weighed different amounts. They then should then design an experiment to show that the missing weight was due to escaped gas (for example, perform the reaction in a bag, which can contain the gas).

Students should then **develop a model** as to what happened during a chemical reaction and explain how this fits with the particle models of materials that they formed earlier in the instructional segment. Teacher should ask their students to provide **arguments from evidence** to support the idea that no matter was lost or destroyed during the chemical reaction, instead they were just rearranged.

Vignette Grade Five: Students' Performance Task on Chemical Reactions

Introduction

Mrs. K.'s fifth grade class is preparing for a summary assessment on their instructional segment "Matter and Its Interactions", known as a performance expectation task. The assessment includes investigations, designed to give students an opportunity to demonstrate their understanding of chemical reactions (DCI PS1.B: *When two or more different substances are mixed, a new substance with different properties may be formed*) through conducting a series of hands-on **investigations** to determine whether the mixing of two or more substances results in a new substance (PE 5-PS1-4*: Conduct an investigation to determine whether the mixing of two or more substances results in new substances.)*

Name:______________________

Starting Materials Observations:

____

____

Ending Materials Observations:

____

____

Based on my observations, I claim:

____

This evidence supports my claim:

____

____

Through a series of lessons prior to this performance expectation task, her students **developed and used a model** representing the particulate nature of matter, they engaged in hands-on **investigations** that led them to conclude that the total weight of matter is conserved during physical and chemical processes, and they developed language to describe properties of materials including color, phase, and solubility.

Most recently, the students completed a lesson on chemical reactions. In this lesson, students performed and observed several different chemical reactions. They discussed types of **evidence** they observed including changes in temperature, color, and phase (formation of insoluble solids and gases), or emission of light or sound. In each example, they were able to see that the end products of the reaction had different properties from the starting materials. They became familiar with using a data sheet Mrs. K prepared to collect observations and make claims (see example). She has developed an assessment rubric based on the data sheets.

For this performance expectation task Mrs. K has set up a demonstration "reaction station" in the front of the classroom and three different types of student "reaction stations" (see table) that will be set up throughout the room. Materials for each of the student "reaction stations" are in tubs for easy pick-up and distribution after the activity at the demonstration station is completed.

Demo Reaction Station	Match + Air
Station 1	$NaHCO_3$ solid (baking soda) + vinegar/cabbage juice mixture
Station 2	NaCl solid (table salt) + Sucrose (table sugar)
Station 3	4% borax solution + 50-50-50 Elmer's glue with water

Mrs. K's plan is to use the demo "reaction station," which includes the use of fire from a match, to model the activity and make sure students understand what is expected of them at the other stations. Also she will help them make connections to prior learning experiences. Then she will have students rotate through each of the student "reaction stations" in pairs. Students in her class are very familiar with stations and data recording. The following paragraphs describe how Mrs. K prepares students for the student "reaction stations."

Mrs. K begins, "Today we are going to do our chemical reactions performance expectation task. We will have four stations, one up front that we'll work on as a class and three for rotations. Similar to our reactions lab last week, you are going to mix two substances to see if a new substance is formed. Your job will be to observe phenomena and collect data that will allow you to make a claim about whether you think a chemical reaction happened and a new substance was made." After answering questions, students put on goggles and Mrs. K began with the demonstration station.

When all of the students are ready, she holds up a wooden match and begins. "We are going to start with a whole class experiment. We'll "mix" a match with air and try to determine if we can observe **evidence** of a chemical reaction. If there is **evidence**, then we can claim that most likely a new substance was formed." Putting the wooden match under her document camera, she continues "Let's start like we did with last week's activity, by observing our starting materials. Record three observations about this match and three observations about the air in this room. After you have a quick share out with your elbow partner, I'll draw sticks to share out classroom ideas.

After a few minutes, she draws a stick and asks David to share one of his observations about the match, "It's a match," he says. "That is true, but we need a physical property, will you share another observation?" "It is a stick and is yellow," he adds. She collects this idea on the board she says "Excellent observation!" Ideas were listed on the board. It has a red end; the middle looks like wood; it is a solid; it is likely made from more than one thing. Similarly, she collects observations about the air in the room: It is clear; you can't see it; it does not smell; and it is made of little particles. For the last observation she pointed out, "We know from our previous **model** that air is made of tiny little particles that we can't observe directly with just our senses. This is a very important idea." This final idea is very challenging for students and one that Mrs. K made sure to emphasize.

Before starting stations, students reviewed what they should look for to provide **evidence** for a chemical reaction: changing temperature, forming bubbles, changing color, changing phase. With additional prompting students added ideas about emission of light and making sound.

With goggles on, Mrs. K. lights the match and students begin to write down their observations. She blows the match out and places it under her document camera for students to continue their observations. She then draws sticks with students' names to collect observations from the class. "What was one thing you observed Kai?" "It was smoky, so I think the air changed." Kai answered. "Smokey is an excellent observation, and maybe the air changed, but that is more of a conclusion than an observation. Great start. Taiyo, would you share an observation?" she went on. "It got hot." Taiyo answered. "How do you know?" she probed. "Well it was on fire and things on fire get hot," he responded. "That is a good idea, but it isn't a direct observation. But you know what? I held the match and it sure did get hot, even if you all couldn't feel it directly." In addition students noticed: the color of the tip and wood changed to black; light came out of the match; the left over black stuff came off easily; it made a crackling sound; and the match changed shape ("it kind of curved like a banana" according to Jenny). Emily thought that the match looked smaller than the original and added: "Is there a way to weigh them?” Everyone thought it was a good idea and a few children got to report how they felt compared to each other.

“So did mixing a match with air result in forming a new substance? Did we observe evidence of a chemical reaction? Everyone -on your own- make an argument and support it with **evidence**.” After waiting a few minutes for students to make their claim and write down their **evidence** on their notebook, Mrs. K. initiated a class vote to indicate whether or not they thought a new substance had been made. One student stated, “It is different after mixing, the color changed and it got powdery. Also you said it got hot, so I think that is a change in temperature. Those are things that happen when you have a reaction, so maybe something new was made.” Other ideas offered by students were: The fire made light; the black stuff was very different than the yellow wood; maybe the smoke was something new made from the wood and air.

After the demonstration and discussion students began to rotate through three stations with lab partners. They made observations and recorded data at each station as they completed their performance expectation task.

Engineering Connection

The NGSS clarification statement for 5-PS1-4 provides examples of chemical reactions between milk and vinegar. While these are everyday materials, this is not a commonly observed everyday chemical reaction. Cooking a pancake, however, involves reactions that can be observed in real-time on a stovetop. Students can engage in a chemical engineering design challenge to make the "perfect pancake (d'Alessio and Coleman 2015)." Students begin by defining the problem as a list of specific criteria that describe pancake perfection (3-5-ETS1-2), as well as discuss how they will go about objectively measuring these properties. Students mix together ingredients in small paper cups with craft sticks to explore how different proportions of flour (gluten-free and regular), water, and baking powder affect the material properties of the batter. They employ their understanding of volume to the measure of ingredients (CA CCSSM 5.MD.4). They can begin to speculate about how different batter properties will translate into different pancake properties. Students investigate specific pancake recipes (with the introduction of bananas as a sweetener and vanilla for flavoring). The cooking process introduces new variables (cooking time, flipping procedure, etc.) and other irregularities of the real world (uneven heating by the griddle). Students take note of these issues as they test-cook their first batter and record results of their measurements. Students compare batter recipes and results with peers (3-5-ETS1-2), analyzing the data to identify trends and *patterns*. They then collaboratively construct a second round of pancake recipes and then keep iterating as they optimize multiple criteria through changes in recipe and procedure (3-5-ETS1-3). Once they have the perfect pancake, they are challenged to produce duplicate batches. With five simple ingredients, students become both celebrity chefs and chemical engineers.

Grade Five – Instructional Segment 2: From Matter to Organisms

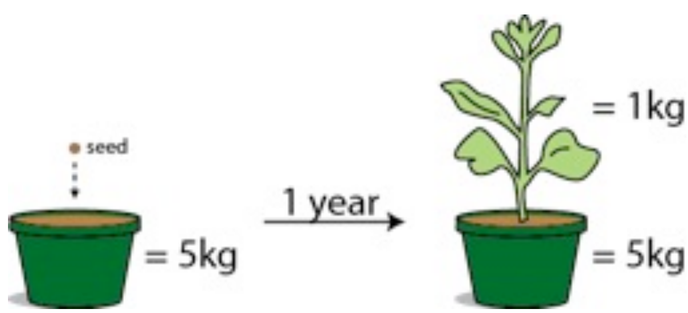
By the end of this instructional segment, students have developed the understanding that matter flows from non-living sources (water and air), to plants, animals, and decomposers. In addition, students use models and look for evidence to describe how ***energy flows*** from the sun to plants to animals. Students use their previous knowledge that all animals need food in order to live and grow, that they obtain their food from plants or from other animals, and that plants need air, water, and light to live and grow. They expand their knowledge to explain ***energy and matter flows*** in organisms and ***systems***. Students in grade five engage in scientific experiences to help them answer questions such as: *What matter does a plant need to grow? Where does the energy in food come from and what is it used for? How does matter move in an ecosystem?*

Grade Five-Instructional Segment 2: From Matter to Organisms
What matter does a plant need to grow? *Where does the energy in food come from and what is it used for?* *How does matter move in an ecosystem?*
Crosscutting concepts: Systems and Systems Models; Energy and Matter
Science and Engineering Practices: Developing and Using Models
5-LS1-1 Support an argument that plants get the materials they need for growth chiefly from air and water. [Clarification Statement: Emphasis is on the idea that plant matter comes mostly from air and water, not from the soil.] **5-LS2-1 Develop a model to describe the movement of matter among plants, animals decomposers, and the environment.** [Clarification Statement: Emphasis is on the idea that matter that is not food (air, water, decomposed materials in soil) is changed by plants into matter that is food. Examples of systems could include organisms, ecosystems, and the Earth.] [*Assessment Boundary: Assessment does not include molecular explanations*.] **5-PS3-1 Use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain body warmth) was once energy from the sun.** [Clarification Statement: Examples of models could include diagrams, and flow charts.]

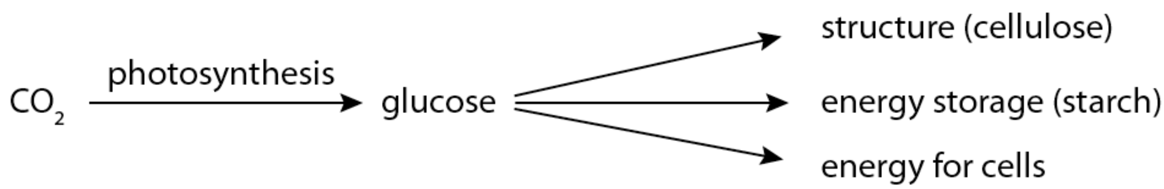
Background for Teachers

In the 1600s, Jan Baptist van Helmont conducted one of the earliest recorded biology experiments. He took about five kilograms (kg) of dry soil, put it in a pot, added water, and planted a tree in the soil. After a year the tree had gained about 1 kg of weight. Van Helmont carefully dried the soil and weighed it again. He was, perhaps, surprised to discover that the weight of the soil was still about 5 kg. The result must have been very confusing. As the plant builds its body, the raw materials for making wood, leaves, bark must come from *somewhere* and the soil must have seemed to be the most likely source. The idea that most of the dry weight (i.e., everything that is not water) came from the air and not the soil would have been very counterintuitive. In van Helmont's time people did not know that the air contained molecules like oxygen, carbon dioxide, and nitrogen. In a famous experiment a seed was planted in 5 kg of soil. After a year a 1 kg plant had grown. The soil still weighed approximately 5 kg suggesting that the mass of the plant was NOT derived from the soil (we now know that most of the plant structures are made from the carbon found in atmospheric CO_2) (figure 20).

Figure 20: Model of van Helmont's Experiment (Original picture by Ed Himelblau)



Plants build their structures out of sugar molecules. Sugar comes from photosynthesis. During photosynthesis, the plant combines carbon dioxide from the air with water from the soil to form glucose (a sugar molecule) with light providing the energy to power this chemical change. Once glucose is made, it can have several fates:



Glucose molecules can be made into cellulose. This is the main building material for plant cells. Most of the body of any plant is cellulose. Glucose can also be made into starch as a way of storing energy for later use by the plant. Finally, glucose can go directly into cells to power their everyday activity (plants produce their own food). This is especially important for cells in the root that never see the sun and cannot perform photosynthesis for themselves. Sugar made in the leaves of the plant is transported down to the roots. These various products of photosynthesis are also important for humans. Wooden houses, paper, and cotton cloth are all materials made from plant cellulose. Finally, most of the calories in the human diet come from starch in seeds like wheat, rice, corn, and other crops. One byproduct of photosynthesis is oxygen. Humans and other animals are dependent on the oxygen released during photosynthesis (as described later, this oxygen is essential for allowing us to release energy from our food).

It must be acknowledged that the plant does acquire some essential materials from the soil. Nitrogen, iron, and a host of other nutrients must be obtained from the soil (usually by the roots) and the plant cannot survive without these. However, these make up only a small fraction of the total mass of a plant. If van Helmont had had a sensitive enough scale he might have detected a tiny decrease in the weight of his soil.

The most important fuel for animal cells is glucose. While glucose could be artificially produced in a lab, most of the glucose we consume is derived from the starch in plants. Our cells ‘break open’ these glucose molecules using oxygen, releasing the energy stored in chemical bonds. So it is logical that if breaking up a glucose molecule *releases* energy, then making a glucose molecule must *require* energy (crosscutting concept of ***energy and matter***). The types of energy that make these sugar molecules are light energy and *solar* energy. When you eat an apple, the energy your body gets from the fruit is solar energy--it is solar energy that was absorbed by a leaf and stored as a sugar molecule.

Clearly our diets contain more than just glucose. Our diets include proteins, fats, and oils as well. These other energy sources get converted in our cells to glucose-like molecules and then are funneled into the main energy-releasing pathways for which glucose is the primary starting material.

When a plant or animal is alive it requires energy and matter to grow and maintain its body. Plants take the energy from light and store it as cellulose and starch, while at the same time acquiring essential nutrients from the soil. Animals get almost all the materials they need to survive from the food they eat (unlike plants, we cannot grow with just air, water, dirt, and sunshine). The result of all this is that a plant or animal represents a huge store of energy and nutrients. When an organism dies, the energy and nutrients do not remain there for long. Decomposition is the process that releases the energy and nutrients from dead tissue for use by growing organisms. Decomposers can be both microscopic (bacteria) and easily visible (fungi and mold), but they all do the same thing, release energy and nutrients from plant and animal bodies. A common misconception about worms is that they are decomposers. It would be more accurate to call worms 'detritivores' that *eat* decaying plants rather than breaking them down outside their bodies.

Nitrogen is one nutrient for which the central role of decomposition is especially well illustrated. Animals require a lot of nitrogen; nitrogen is a major component of the genes and proteins in our cells. Animals have only one source of this nitrogen: plants. Carnivores get their nitrogen from herbivores that get their nitrogen from plants. When an animal in nature dies and its body decomposes, the nitrogen from the body is released into the soil. Once in the soil, the nitrogen is once again available to plants through their roots.

Plants and animals need to obtain many other elements and small molecules from the environment. Again, plants provide a means for animals to get what they need. For example, we need very tiny amounts of metals like iron, zinc and magnesium to survive, but humans cannot just eat soil and get all the nutrients they need. To take these nutrients into our cells, the nutrients need to be incorporated into more complex molecules (sometimes called 'vitamins'). These complex molecules are synthesized in plants. Plants, on the other hand, are able to absorb individual metal atoms from the soil surrounding the roots. Plants *mine* the soil for raw materials then use those raw materials to build complicated molecules. Animals have to get most of their nutrients by eating plants.

Description of Instructional Segment:

This instructional segment, From Matter to Organisms, is divided in three parts: Part 1- From Non-living to Living**;** Part 2- From Plants to Environment**;** and Part 3- From the Sun to Animals

From Non-living to Living

Students should be given the opportunity to experience activities that show the flow of air and water into plants. Activities may include placing celery or flowers in colored water to see transportation of water into the celery or flower; trying to grow a plant in a closed container with no air flow into the container; placing a bag around the leaves of a plant to show the condensation collected; placing anacharis (elodea) or rosemary in an inverted test tube under light to see bubbles and count them; or measuring the weight of a growing plant in a controlled environment (like growing them on a CD case) as a function of time. Students should collect the **evidence** and **ask and try to answer questions** about what they think is happening.

In this grade, students talk about water as a familiar compound and about how it is transported by plants. They may also note that various fruit and vegetables contain juices that are mostly water. Students' **models** of the growth needs of plants and how they are supplied, may include pictures or diagrams with grade-level appropriate labeling (for example the bubbles produced by plant may be described as air); and likewise the failure to thrive of the plant in the closed container may be attributed to lack of air. Students at this grade are familiar with gases and gas properties, but their **investigations** do not distinguish components of air such as oxygen and carbon dioxide. Students should support an **argument** that plants need to take in air and water to function. They can **explain** that plants obtain matter as gases and water from the environment and release waste matter (gas, liquid, or solid) back into the environment (5-LS2-1).

From Plants to Environment

The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as “decomposers.” Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem**.** (5-LS2-1)

Students’ activities to develop these concepts may include developing a model of a food web by obtaining and evaluating information from several text on the same topic and then communicating a summary of that information to their classmate. This text-based activity should be complemented by direct observation from classroom-size ecosystems such as a terrarium for a lizard, or a fish tank, or a crayfish tank. Where possible, field trips to observe a farm or observe animals in situations that approximate their natural habitat (e.g., birds or squirrels in a park) should also be part of the instructional segment. Simple fermentations of cabbage to make Kimchee or vinegar from apple juice help the students connect chemical reactions (production of acetic acid measured with pH) and use of ***matter and energy*** in an ecosystem. Microscope observations can introduce students to the variety and ubiquity of microbial life forms that are useful to humans. Students’ work shows that ***matter cycles*** between the air and soil and among plants, animals, and microbes as these organisms live and die. Examples of food webs should include small and large systems, from a few organisms, to an ecosystem, and to the Earth. This is a good opportunity to use ***scale, proportion and quantity*** and to point to aquatic and terrestrial systems (***systems and system models***) and point to the differences in the models (**obtaining, evaluating and communicating information**).

Grade Five Vignette
The Flow of Energy and Decomposers

The vignette presents an example of how teaching and learning may look in a fifth 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.

Introduction

Day 1 – Oceans Alive.

Ms. D decided to use two California EEI units, *The Flow of Energy Through Ecosystems* and *Life and Death with Decomposers*, as the foundation for her From Matter to Organisms unit. She asks students to gather around and use the natural regions wall map to identify which of California's natural regions is the largest. The students identify one of the terrestrial ecosystems, so she points them to the ocean and coast, and mentions that this region is actually the largest natural region in California. This exercise gives Ms. D an opportunity to call students' attention to the crosscutting concept “***systems and system models***.” To initiate a class discussion she asks students to identify some of the components (organisms) pictured in the ocean diagram. Reminding them “a system can be described in terms of its components and their interactions,” Ms. D has students speculate about some of the interactions that might take place among these ocean organisms.

She continues by calling the students’ attention to word wall cards for the words “ecosystem,” “consumer,” and “producer” and reviews the definitions. Ms. D points to the inset on the map titled “Ocean Regions.” She tells students that they are going to learn about these words by reading an informational text about the Humboldt squid, an animal that lives in areas that are often difficult for scientists to study.

The teacher distributes copies of the story, “*The Mysterious Humboldt Squid*,” and explains that, as they are reading, they will highlight each of the organisms that they read about and identify them as producers or consumers. Once they have finished reading the text Ms. D shows the class the “marine organisms” visual aid and instructs them to use information from the story to identify the organisms as producers or consumers, thereby developing their abilities to quickly locate answers to questions from written text.

Day 2 – Where My Energy Comes From—Food Chains.

Ms. D reviews the word wall cards for “producer” and “consumer” on the board. She then adds the word wall cards for “herbivores,” “carnivores,” and “omnivores” beneath the card for “consumer,” explaining that these are three types of consumers, then has the students read the definitions.

The teacher distributes one of the fourteen “organism bank” information cards to pairs of students. She then has them draw on information from these different print sources and discuss whether their organisms are producers, herbivores, carnivores, or omnivores and has them put the pictures of their organisms under the appropriate headings. Ms. D uses this strategy to develop the students’ ability to locate an answer to a question quickly.

Ms. D tells students that they are going to use the “*Where I Get Energy*” information sheet to help them identify feeding relationships among the organisms they have been studying. She has pairs of students take the information card they used in the previous activity, choose an organism with which they think it has a feeding relationship, and briefly explain the relationship to the class. The teacher explains that the term for these feeding connections is “food chain,” and posts the word wall card on the board.

Building further on their ability to develop **models** that describe phenomena, in this case food chains, Ms. D has additional students continue this process by adding a third and then a fourth organism to the “chain” of feeding relationships. The teacher posts several of these food chains on the board and connects them with arrows representing the feeding relationships described by the students. This activity provides Ms. D an opportunity to call students’ attention to the crosscutting concept ***energy and matter***. She initiates a focused discussion about how their food chain **models** demonstrate how “matter is transported into, out of, and within systems.”

Day 3 – Connecting Food Chains.

Ms. D reminds the class about the earlier lesson when they learned how plants acquire material for growth. She then mentions that the feeding relationships they have been identifying that model how matter moves between plants and animals, and among animals.

She projects the “*Marine Ecosystem Food Web”* visual aid and asks students if what they are looking at is a food chain. Several of the students observe that the drawing shows many different lines and connections among the plants and animals. Ms. D posts the word wall card for “food web” and explains that the arrows on the visual aid represent a **model** of a “food web,” the many interconnected food chains in an ecosystem. Once they have a clear understanding of the food web, she asks them to follow the path from any of the animals and discover that the food for all of the animals can be traced back to plants. Ms. D follows that up with questions that help all of the students clarify that among the organisms represented in the food web, some animals eat plants for food and other animals eat the animals that eat the plants.

Day 4 –Decomposition in Action.

In order to solidify their understanding of food webs and begin her instruction on decomposition, Ms. D takes the class on a visit to a local nature center. In preparation, she has spoken to the staff and asked them to work with her to identify a specific area where the class can **investigate** food webs and observe an area where decomposition is an active process. One of the nature center staff takes the students out into a wooded area and helps them identify several different producers and consumers. As students discover what lives in the area the teacher asks them to work together to create and discuss a food web for this terrestrial ecosystem. With that complete, the center staff member asks them, "What happens when one of the plants or animals and the food web dies?"

Using definitions from her word wall cards, Ms. D introduces the students to two new terms "decomposers" and "decomposition." The staff member tells them to look around and see if they see any **evidence** of decomposition nearby, for example, leaves, a tree trunk, or a dead insect on the ground. She asks them what is happening to those objects, and leads them through a discussion about how the tree trunks, leaves, or animals are breaking down and reentering the soil.

Day 5 – Examining the Evidence.

When they return to the classroom after the field trip, Ms. D has them read the information text, "*Decomposition in the Forest*." She then projects her "*Evidence of Decomposition*" visual aids and asks the students to describe what they see. As they describe what they see, Ms. D explains that when matter decomposes it may seem to "disappear," but it is actually moving into a different part of the ecosystem releasing nutrients back into the soil, air, or water. To help the students solidify their understanding of the decomposition process, she distributes "*Breaking It down—in the Forest*" and has them follow the instructions to describe what is happening in the decomposition story.

In review, Ms. D instructs the students to look at the diagram on "*Breaking It down—in the Forest*" and make observations about any patterns they see. Several of the students comment that the drawing shows the ***matter flowing*** among plants, animals, and microbes as these organisms live and die. She asks, "Does this ***flow of matter*** occur only once or is it an ongoing process?" and leads the class in a discussion that helps students recognize that the ***flow of matter*** in the diagram is an example of a ***cycle***. She then writes a definition for the word "cycle" on the board, "a series of processes or events that typically repeats itself, such as the water cycle."

In order to help students recognize the importance of matter moving through ecosystems among plants, animals, and decomposers, Ms. D asks them, "What would happen if the cycle of matter flowing through ecosystems is interrupted by human activities?" This allows the students to begin building an understanding that human activities can affect "the exchange of matter between natural systems and human societies affects the long-term functioning of both" (California Environmental Principle IV).

Ms. D asks students to reflect on how decomposition is important to them, strengthening their understanding that "the ecosystem services provided by natural systems are essential to human life and to the functioning of our economies and cultures. (California Environmental Principle I, Concept b). Several students mention that the decomposition process is related to the compost pile that the class has been managing near their school garden. Some of the others discuss that they are surprised that by composting at home, they are keeping most of the plant materials from their meals and yards from going into the landfill and they think their gardens benefit from the nutrients in the compost.

Days 6-7 – Modeling the Movement of Matter.

The following week, Ms. D tells the class that they will be doing presentations that show **models** that describe the movement of matter among plants, animals, decomposers and the environment. She explains that their presentations need to include multimedia components, such as a PowerPoint presentation or visual displays, such as posters. The focus of these presentations is to be about how decomposition works, the benefits that humans gain from this process, and their predication about how human activities can affect the exchange of matter between natural systems and human societies. Ms. D lets the students know that their displays will be part of a science gallery walk that the school is holding later in the month.

Performance Expectations		
5-LS2-1 Ecosystems: Interactions, Energy, and Dynamics *Develop a model to describe the movement of matter among plants, animals decomposers and the environment. [Clarification Statement: Emphasis is on the idea that matter that is not food (air, water, decomposed materials in soil) is changed by plants into matter that is food. Examples of systems could include organisms, ecosystems, and the Earth.] [Assessment Boundary: Assessment does not include molecular explanations.]*		
Science and engineering practices	**Disciplinary core ideas**	**Cross cutting concepts**
Developing and Using Models *Develop a model to describe phenomena.*	**LS2.A Interdependent Relationships in Ecosystems** *The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a*	**Systems and System Models** *A system can be described in terms of its components and their interactions.* **Energy and Matter** *Matter is transported into, out of, and within systems.*

	relatively stable web of life. Newly introduced species can damage the balance of an ecosystem. **LS2.B Cycles of Matter and Energy Transfer in Ecosystems** *Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment.*	
California's Environmental Principles and Concepts		
Principle I: *The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.* **Concept b.** *Students need to know that the ecosystem services provided by natural systems are essential to human life and to the functioning of our economies and cultures.* **Principle IV:** *The exchange of matter between natural systems and human societies affects the long-term functioning of both.* **Concept a.** *Students need to know that the effects of human activities on natural systems are directly related to the quantities of resources consumed and to the quantity and characteristics of the resulting byproducts.*		
Connections to the CA CCSS for ELA/Literacy: RI.5.7, SL.5.5		

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 the flow of matter and energy in ecosystems, helping them to move towards mastery of the three components described in the *CA NGSS* performance expectation.

In this vignette, the teacher selected one performance expectation but in the lessons described above she only engaged students in selected portions of this PE. Full mastery of this PE will be achieved throughout subsequent instructional segments.

Students were engaged in a number of science practices with a focus on **developing and using models**. Life sciences lend themselves well to the use of models to describe systems and describe phenomena.

With guidance from their teacher, students developed **models** that describe phenomena, in this case food chains and food webs. They used these **models** to describe the movement of matter among plants, animals, decomposers and the environment. They made presentations about their **models** to explain how decomposition works and connected this information with California Environmental Principle IV to predict how human activities and "*the exchange of matter between natural systems and human societies affects the long-term functioning of both*."

Through their food chain and food web **models**, students examined the crosscutting concept of ***energy and matter*** to identify how matter is transported into, out of, and within natural systems. In addition, their understanding of the crosscutting concept of ***systems and system models*** was reinforced through their analysis of the flow of matter through marine ecosystems.

NGSS Connections to English Language Arts

Students used the text in *"The Mysterious Humboldt Squid" and "Decomposition in the Forest"* to determine how matter flows in both marine and forest ecosystems. This connects to the *CA CCSS for ELA/Literacy* Reading Informational Text standards (RI.5.7). In addition, they developed presentations including multimedia components or visual displays which summarized information about food webs and how human activities can influence them, which corresponds to Speaking and Listening Standard 5 (SL.5.5).

Resources for the Vignette

- California Education and the Environment Initiative. 2011. *The Flow of Energy Through Ecosystems.* Sacramento: Office of Education and the Environment.
- California Education and the Environment Initiative. 2011. *Life and Death with Decomposers.* Sacramento: Office of Education and the Environment.

From the Sun to Animals

As this point in the instructional segment, students engage in **investigations** that show that the energy released from food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water) (5-PS3-1). This part allows students to synthesize all the investigations and learning that they developed so far into a broad understanding that **matter and energy flow** among organisms. Activities may include games of simple food chains where primary producers "take" energy from the sun, use some for growth and respiration and pass the rest to primary consumers and so on. By working with utilize **models** to describe that the energy animals obtain from their food through digestive and respiration processes (used for body repair, growth, motion, and to maintain body warmth) was once energy from the sun. These students can obtain information from texts or digital media about a local ecosystem and they have to develop a model that supports understanding of how ***matter and energy flows*** by identifying the organisms living in that ecosystem and how one type of organism is linked to another. At the end of this part of the instructional segment, students present their diagrams, and write **argumentative** papers on the topic, supporting their point of view with reasons and **evidence**. (W.5.1)

At the end of this instructional segment, students demonstrate their understanding of how matter and energy flows in an ecosystem. Both plants and animals must take in air and water, plants need light, and animals need food. Anaerobic life, such as bacteria in the stomach, functions without air. Food provides animals with the materials they need for body repair and growth and is digested. In the respiration process, energy is released to maintain body warmth and for motion. Plants acquire their material for growth chiefly from air and water and process some of the matter they have formed as animals process food (through respiration) to provide the energy to maintain their internal conditions (e.g., at night).

Grade Five – Instructional Segment 3: Earth Systems and Process

To engage student interest, this instructional segment begins by alerting students to the importance of fresh water for people living in cities and farms, and the difficulties experienced by California residents during periods of drought. By the end of this instructional segment, students will have developed the understanding that Earth has a set of major subsystems. These Earth ***systems*** are connected and changes in one affect the others. The instructional segment begins with a focus on water and its distribution on Earth and importance to life. The instructional segment then develops ideas on how to protect this resource and others on the planet. This instructional segment incorporates an engineering design project that focuses on the environment. Students in grade five engage in scientific experiences to help them answer questions such as: *Where does my tap water come from and where does it go? How much water do we need to live, to irrigate plants? What can we do to protect our resources?*

> Math Connection
> In reference to ESS2-2, students do not study percent or ratio until Grade 6. Science teachers will need to provide some background math knowledge on this concept while teaching the science. Students will be able to compare fractions however.

Grade Five -Instructional Segment 3: Earth Systems and Processes
How much water can be found in different places on Earth? *How does matter cycle through ecosystems?* *What can we do to protect earth's resources?*
Crosscutting concepts: Scale, Proportion & Quantity; Systems & System Models; Cause and Effect
Science and Engineering Practices: Obtaining, Evaluating and Communicating Information
5-ESS2-2 Describe and graph the amounts and percentages of water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth. [*Assessment Boundary: Assessment is limited to oceans, lakes, rivers, glaciers, ground water, and polar ice caps, and does not include the atmosphere*.] **5-ESS2-1 Develop a model using an example to describe ways in which the geosphere, biosphere, hydrosphere, and/or atmosphere interact.** [Clarification Statement: The geosphere, hydrosphere (including ice), atmosphere, and biosphere are each a system and each system is a part of the whole Earth System. Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere.] [*Assessment Boundary: Assessment is limited to the interactions of two systems at a time.*] **5-ESS3-1 Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.** [*Assessment Boundary: Assessment is limited to oceans, lakes, rivers, glaciers, ground water, and polar ice caps, and does not include the atmosphere.]* **3-5-ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constrains 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 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.]

Background Information for Teachers

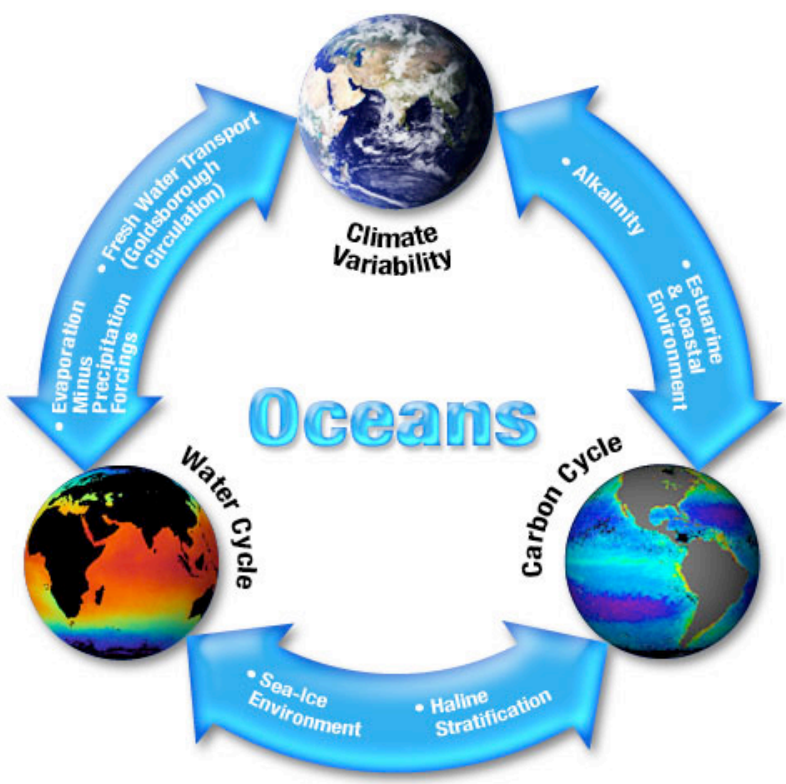
The Earth's major systems are the geosphere, the hydrosphere, the atmosphere, and the biosphere. The materials characterizing each system are summarized in the table below.

Earth's System	**Earth's Materials**
Geosphere	Solid rocks, molten rocks, soil and sediments.
Hydrosphere	Water in rivers, lakes, groundwater, etc. (fresh water), salt water, ice.
Atmosphere	Air surrounding Earth.
Biosphere	All living organisms, including humans.

These systems are interconnected in complex and dynamic ways and interact with each other over a wide range of time and spatial scales. In this unit, students will investigate several of these interactions (only two systems at a time) by making observations about the ***energy flow and matter cycling*** within and among Earth's systems. Solid rocks, for example, can be formed by the cooling of molten rock, or by the accumulation of sediments, or by the modification of existing rocks when exposed to intense heat, pressure, or interaction with water. Different types of rocks are produced under these different physical and chemical conditions.

The ocean is one of the major reservoir of liquid water, although salty water. The circulation on Earth's surface of ocean water at different temperatures (warmer at the Equator and cooler at the poles) allow to influence climate in different regions on Earth. This is an example (figure 21) of interaction between the hydrosphere, which received input energy from the sun, and the geosphere. This interaction may result in a more favorable regional climate where a rich variety of plants and other living organisms (biosphere) can thrive. The habitats in which the biosphere develops will in turn affect the atmosphere through the cycling of carbon and oxygen through respiration.

Figure 21: Dynamic interactions of the Earth's oceans. (Source: Wikipedia)



Water in other forms, such as lakes, rivers, ground water, glaciers, and polar ice caps, also contribute to ***cycling of matter*** among Earth's systems. Weathering and erosion processes, for example, break down rocks from mountains and plateau and transport those materials around Earth's surface.

At this grade level, emphasis is given to the identification of the system and the components of each system to determine patterns of interactions. A deeper understanding of the process energy flows due to the different physical properties of materials will be developed in grade six.

Description of Instructional Segment

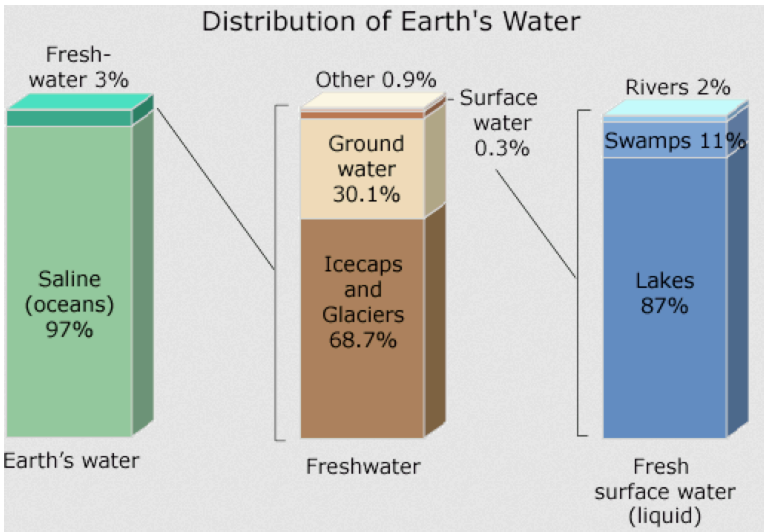
This instructional segment on earth systems and processes is divided in four parts: Part 1- Distribution of Water in Earth**;** Part 2- Interactions of Geosphere, Biosphere, Hydrosphere, and/or Atmosphere; Part 3- Protect Earth's Resources and Environment, and Part 4- Engineering Design Problem: Water Filtration

Distribution of Water on Earth

Students continue their experiences with water by looking at the amount of water available on the Earth (figure 22). Many activities can engage them in using relative ***proportions*** and **mathematical thinking** to help them describe the ratios in a graphical way. *How much water is in the ocean, glaciers, rivers, underground? How much is salt water?* Students describe and provide evidence that nearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere**.** (5-ESS2-2) They represent this real world problem by graphing points in the first quadrant of the coordinate plane and interpreting coordinate values of points in the context of the situation. (CA CCSSM5.G. 2)

> Math Connection
> Students could be challenged to find the state, country, or continent with the most/least amount of fresh water per person. Alternatively, students could be assigned a country or continent to investigate. Students could graph their results by liquid or ice form.

Figure 22: Distribution of Earth's water. 97% is undrinkable water (from the oceans) and only 3 % is fresh water found in icecaps, ground, lakes, rivers and swamps. (U.S. Geological Survey 2015d)



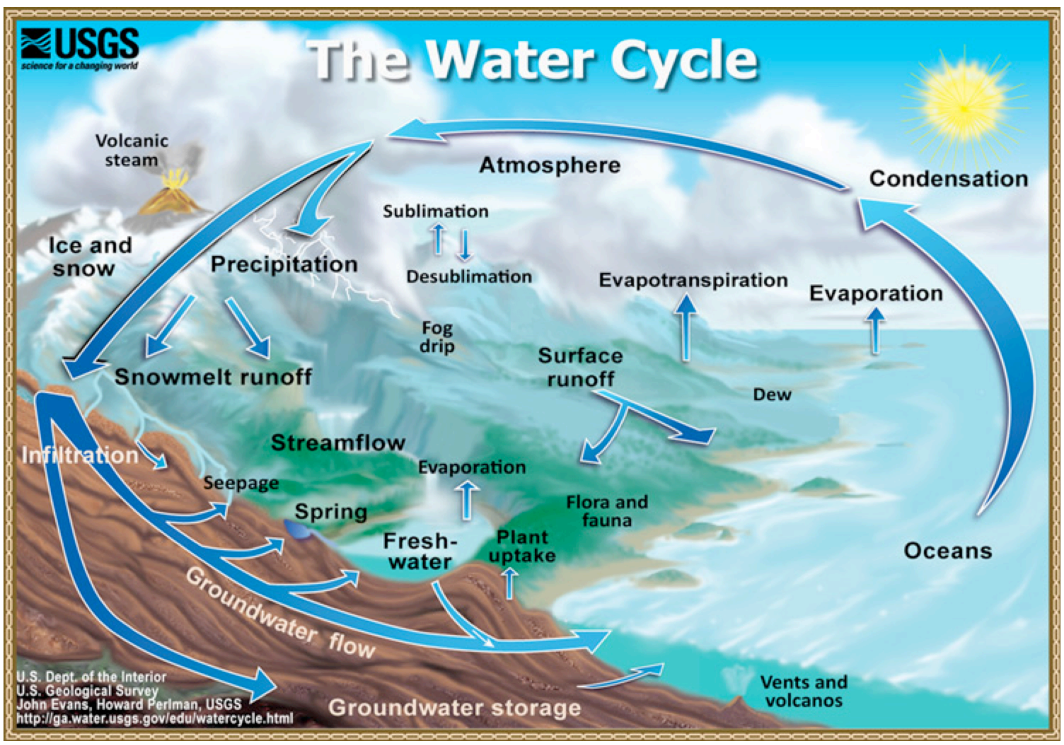
Interactions of Geosphere, Biosphere, Hydrosphere, and/ or Atmosphere.

Students connect their knowledge about water sources and distribution on Earth (hydrosphere) to water in the atmosphere and biosphere and its impacts on the geosphere. Through varied activities, students **develop and model** the concept of a water cycle (i.e., that water flows among and between these three systems through evaporation, condensation and precipitation), through plant and animal uptake of water, as well as through loss of water from the natural processes of waste disposal and conversion to other substances. Teachers should give students the opportunity to connect at least two ***systems*** and represent the flow of water between them with pictures and diagrams. Students then extend this model to encompass other ***matter flows*** and interactions among and between the

> ELA ELD Connection
> In small groups, students demonstrate the interactions between two of the systems: geosphere, biosphere, hydrosphere, and atmosphere, using multimedia and/or visual displays. This could include students reenacting the interaction, e.g., one student is the water and one is the wind and what happens when they interact in the atmosphere to land and ecosystems through weather and climate.

Earth's major subsystems. The Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These ***systems*** interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine ***patterns*** of weather. (5-ESS2-1)

Figure 23: The water cycle showing different areas of water from liquid to gas (evaporation: oceans, freshwater lake), gas to liquid (condensation: clouds) solid to gas (sublimation), solid to liquid (snowmelt runoff) and evapotranspiration (evaporation and plant transpiration). (U.S. Geological Survey 2015c)



Some student's preconceptions are based on simple circular diagrams where the sun is central to the picture (see picture above, figure 23). By looking at the diagram, they are induced to think that evaporated water goes back to the sun. Using these diagrams and having students explain why the picture represents incorrectly the water cycle is a good formative assessment tool for this topic and helps uncover student understanding.

Topics for student **investigations** could include: the influence of the ocean on ecosystems, landform shape, and climate; the influence of water and wind in the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a ***system*** and the student **models** support the development of their understanding of the multiple and complex interactions both within and among them. While the carbon cycle is not stressed in this instructional segment, it may be useful to introduce the notion that substances other than water have ***cycles and flows*** between and among Earth systems, and that carbon is another important case that they will study later. Underlying the interactions of two systems at a time is the crosscutting concept of ***cause and effect***. This crosscutting concept could be used in combination with that of ***energy flow and matter cycling*** to emphasize that transfer of energy and matter can be considered causes of events we observe (effects).

Protect Earth's Resources and Environment

In this part of the instructional segment the emphasis is placed on the human need for fresh water and the available supply of water due to human activity to obtain that resource. Student activities can include looking at the local source of tap water or visiting a local river, lake, or the ocean, or finding out which human activities are the primary users of the local water sources. A field trip to a local wastewater treatment plant or a local farm that uses dry farming techniques could help students think about problems and solutions that help us protect our resources. Student work focuses on **obtaining, evaluating, and communicating information** that shows how human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, underground water storage levels (aquifer), ocean, and atmosphere. This focus on water is then broadened to briefly consider other human impacts on Earth ***systems***, and even on ***systems*** outside the Earth. Group projects could investigate particular local resource issues and examine what individuals and communities are doing or could do to help protect Earth's resources and environments.

(5-ESS3-1) Students present their findings and solutions to each other. The crosscutting concepts of ***cause and effect*** and ***stability and change*** are good matches to this part.

Engineering Connection: Water Filtration.

Students focus on a natural resource and a natural process as the basis for an engineering design problem. Our Earth filters water as part of the water cycle. As water passes through layers of the Earth contaminants are filtered out or settle. Humans also use water filtration to clean the water we use. A simple water filtration project that asks students to clean dirty or contaminated water can give students the opportunity to **define the problem**, **gather information**, **plan a solution**, and design and carry out a prototype given a set of constraints or limits, such as available materials, money, and/or time. The students can then gather information, work in teams to brainstorm a number of solutions, and compare them against the criteria and constraints of the problem to see which is most likely to succeed. Students are given a sample of "dirty" water made of safe classroom materials like twigs, dirt, sand, brown liquids (tea) and are presented with the challenge of cleaning the water with available materials: cotton balls, coffee filter, etc. Students first design a working **model**, build it, test it and then compare their filtered water against a color standard. (Adapted from Engineering is Elementary 2012)

Grade Five – Instructional Segment 4: Patterns in Earth & Space

By the end of this instructional segment, students have developed the understanding that the forces that affect their everyday experiences (e.g. gravity) also affect larger ***systems*** like the Earth and stars (***patterns & systems and system models***). Students develop **models** and use them to explain everyday ***patterns*** like day and night and apparent movement of stars through the night and compare our star (Sun) to other stars in the sky. Students in grade five engage in scientific experiences to help them answer questions such as: *What forces affect the Earth? What are the meanings of the regular patterns of day-to-day and season-to-season? Why do stars move from one day to another?*

Grade Five-Instructional Segment 4: Patterns in Earth & Space
What forces are connected to the Earth? *How do lengths and directions of shadows or relative lengths differ in the day and night?* *How does the appearance of some stars change in different seasons?*
Crosscutting concepts: Patterns; Scale, Proportion & Quantity; Systems & System Models,
Science and Engineering Practices: Developing and Using Models
5-PS2-1 Support an argument that the gravitational force exerted by Earth on objects is directed down. [Clarification Statement: "Down" is a local description of the direction that points toward the center of the spherical Earth.] [Assessment Boundary: Assessment does not include mathematical representation of gravitational force.] **5-ESS1-2 Represent data in graphical displays to reveal patterns of daily changes in the length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.** [Clarification Statement: Examples of patterns in the sky could include the position and motion of Earth with respect to the sun and select stars that are visible only in particular months] [*Assessment Boundary: Assessment does not include causes of seasons.*] **5-ESS1-1 Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distance from Earth.** [Clarification Statement: Absolute brightness of stars is the result of a variety of factors. Relative distance from Earth is one factor that affects apparent brightness and is the one selected to be addressed by the performance expectation.] [*Assessment Boundary: Assessment is limited to relative distances, not sizes, of stars. Assessment does not include other factors that affect apparent brightness (such as stellar masses, age, stage).*]

Background for Teacher

The sun is only one of the vast numbers of starts in the Milky Way galaxy, which is only one of the vast numbers of galaxies in the universe. The regular patterns of motion of the sun and other stars in the sky (both during the day and night) can be observed from Earth and described. Because these regular patterns can be described, it implies that they can also be predicted.

The Earth rotates about its axis, causing the visible patterns of day and night. One way to describe the rotation of the Earth and the perceived motion of the sun is, for example, by making observations of the length and directions of the shadow of an object that is fixed with respect the Earth (such as a stick into the ground).

The night sky is mostly dark to our human eyes, except for the moon, planets, and bright stars. Small telescopes or even binoculars can reveal that the dark sky is not dark at all, but it is filled by thousands of star and galaxies too far and too dim to give an intense visual experience. The sun is the closest star to Earth and for this reason it appears larger and brighter than other any other stars in our galaxy. Furthermore, the sun is a medium-size type of star, and much larger stars exist in our galaxy. The amount of light (brightness) that the sun shines on Earth is then determined by its proximity to our planet.

Description of Instructional Segment:

This instructional segment on patterns in earth and space is divided in three parts: Part 1 - Finding the Gravitational Force; Part 2 - Earth Patterns: From a Day to a Year; Part 3 - Our Sun and Stars.

Finding the Gravitational Force

Students demonstrate how a non-contact force has effects on the Earth: the gravitational force. This is an extension of other non-contact force experiences that they developed in grade three (magnetic and electrostatic electricity) and are the foundations of Earth's place in the Universe (ESS1). Exploration of the gravitational force starts with the significance it has on our daily lives. Activities support the concept that the gravitational force of Earth acting on an object near Earth's surface, pulls that object toward the planet's center. Students can weigh

Math Connection
This instructional segment lends itself to the statistics area of mathematics. Students have been collecting and displaying data since kindergarten. They could discuss efficient and effective ways to collect data (evidence) and then display it in a graph or table so that it tells a story or paints a picture of the data that can be easily interpreted.

different objects or use weight on a string to look for their orientation with respect to position. “Down” is a local description of the direction that points toward the center of the spherical Earth. Extensions may include showing students videos of astronauts in the reduced gravity. There are videos of NASA’s Weightless Wonder jet where students can observe the consequences of reduced gravitational force http://www.wgte.org/wgte/groups/item.asp?item_id=6756. ***Cause and effect*** is one theme developed in this part.

Earth Patterns: From a Day to a Year

Students look for ***patterns*** of daily changes such as observing their shadow at different times of the day; students start collecting data from the beginning of the year. A schoolyard sundial will help students make accurate measurements in their notebooks. Figure 24 shows an example of a school human sundial.

Figure 24: Example of a school human sundial (Scientific Teacher 2011)

Students can also collect data of length of day and night over a period of time (month, season, and year) or measure the position of the sun at sunset time over the year. Students represent the **data** they collect in a graphical way and look for ***patterns***. They develop **models** to explain how orbits of Earth around the sun, and of the moon around Earth, together with the rotation of Earth about an axis between its North and

South poles, and the tilt of the Earth's axis relative to the plane of its orbit, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year. Students can observe the location and phases of the Moon over the course of a month, and relate this ***pattern*** to the moon's orbit around Earth. (5-ESS1-2) This is an extension of science **investigations** from K-2 when students explored ***patterns*** of movement of the sun, moon, and stars that can be observed, described, and predicted from Earth.

Students can also observe, describe, and predict patterns in the night sky. The movement of stars in the sky can be done in class by using simulators and asking each student to be responsible for tracking a star or group of stars over time for one night. Students' reports integrate information from several texts in order to **develop their models**. They write or speak knowledgably about the subject (RI.5.9), about their model and its implications, and how the **model** explains the observed ***patterns***.

Our Sun and Stars

Students' study of stars extends to the Sun. A class discussion on how the apparent brightness of a light changes as the light becomes more distant, is used to build the concept that similar stars may appear brighter or dimmer depending on how far away they are from Earth. This leads to the development of the idea that the Sun is just another star, but is so much brighter because it much closer to Earth than other stars. Stars differ greatly in their distance from Earth. (5-ESS1-1) Students seek information from text and on-line resources about other evidence (in addition to the daily ***patterns*** of apparent motion) that supports these conclusions. Local amateur astronomy groups often hold telescope viewing nights open to the public, and students should be encouraged to attend such an event where possible.

Science Literacy and English Learners

The vignette presents an example of how teaching and learning may look in a third through fifth grade classroom when the CA NGSS are implemented in tandem with the CA CCSS for ELA/Literacy and the CA ELD Standards. 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. An additional purpose is to provide examples of how language and literacy development are cultivated through interactive and engaging science literacy learning tasks. The vignette includes scaffolding approaches for English learner (EL) children. It is important to note that the vignette focuses on only a limited number of standards. It should not be viewed as showing all instruction necessary to prepare students to fully achieve NGSS performance expectations or complete the instructional segment. Neither does it indicate that the performance expectations should be taught one at a time. This vignette is based on similar CA NGSS Performance Expectations presented in this chapter's "Grade Three Vignette: Living Things in Changing Environments."

The vignette uses specific themes, but it is not meant to imply that this is the only way in which students are able to achieve the indicated performance expectations and learning target. Rather, the vignette highlights examples of teaching practices, lesson organization, and possible students' responses. Science instruction should take into account that student understanding builds over time and is extended by revisiting topics and concepts throughout the course of the year. In addition, some topics or concepts require different pedagogical and scaffolding approaches, depending on individual student needs. Finally, while the vignette provides several illustrations of sound instructional practices, it does not include everything that educators need to consider when designing and facilitating learning tasks. All learning environments should follow research-based guidelines.

Grade Span Three to Five Vignette: Integrated Science, ELA, and ELD
Biodiversity in Changing Environments

Background

Mr. B's third grade class is learning about how people's activities and behavior can change animal habitats. Mr. B's goal is to provide a variety of rich, hands on interactive learning experiences in which his students observe the natural world, learn from texts, discuss their thinking, and work collaboratively, all with the goal of making a positive impact on animal habitats through mitigating human damage. Mr. B wants his students both to learn about the area in which they live and understand that they can positively affect the environment through their words and actions. The big ideas that guide Mr. B's planning for the instructional segment are:

> *We can explain why some animals can survive well, some survive less well, and some cannot survive at all in different habitats*
> *We can explain how humans impact animal habitats and argue for protecting them by making evidence-based claims.*

Mr. B's class of thirty-four students is comprised of twenty native English speakers or students who are bilingual and proficient in English and fourteen students who are ELs. Of the twenty students proficient in English, the majority speak a non-standard variety of English or a language other than English with their families. Twelve of the ELs are at the Expanding or early Bridging level of English proficiency and use everyday English comfortably. Two of Mr. B's students have recently arrived in the United States and are at the early Emerging level of English proficiency. The majority of Mr. B's ELs and many of his bilingual students speak Spanish as their home language, but he has two students who speak Hmong as a home language. Mr. B's goal is for each of his students to successfully engage in the academic and linguistic content of the class, and he works hard to provide the supports necessary for them to succeed.

Lesson Context

Earlier in the year in a previous instructional segment, students began to learn about what plants need in order to grow and what they get from the ecosystems where they live. Thus far in this instructional segment. Mr. B's students have started to learn about the diversity of life in different habitats. He started the learning segment by taking his students on a field trip in which they spent the morning examining nearby habitats. In order to help his students become excellent observers and data collectors, he asked them to take their science notebooks with them to make notes, in whichever language they are most comfortable writing, and draw pictures about the plant and animal life they observed. The students examined the school garden, the neighborhood near the school, and a nearby wooded park. When they returned to the classroom, the students discussed the differences in the living things they observed in each habitat, and Mr. B led the class through a discussion that culminated in the jointly constructed statement: "Different numbers and types of living things, including plants and animals, live in different habitats."

Mr. B and his students have also read and collaboratively discussed two informational texts from the Education and the Environment Initiative (EEI), "Would Blackberries Grow…?" and "What a Joshua Tree Needs from the Desert." Mr. B has posted Word Wall Cards from the EEI materials, and he has helped the students add translations of the words in their home languages. Mr. B has taught these words to students, and he models how to use them as often as he can. Additionally, Mr. B has facilitated a discussion in which his students have connected their observations of the diversity of life in the habitats they observed and read about to the California Habitats wall map. The students have written sentences that describe the similarities and differences between what they observed on their nature walk and the plants and animals highlighted on the map.

The children are building both their science conceptual understandings and language and literacy skills, all of which they will use to they will use to create informational posters that include an evidence-based argument about how some animals survive well, less well, or not at all in a particular habitat; photographs or illustrations that show the animal habitats they have researched; data that show human impact on the habitat (graphs or tables); and suggestions for what students and their families can do to reduce the impact humans make on animal habitats. The students will present their posters to their families on the school's Family Science Exhibition Night. Each student will also write a letter to the editor of the local newspaper in order to engage the community to care about and protect local animal habitats. The following learning target and NGSS performance expectations guide teaching and learning for the lesson.

Learning Target: We will create posters that explain how humans affect animal habitats and suggest ways we can protect them. We will write letters to the editor arguing why we should protect animal habitats.
CA NGSS Performance Expectations: **3-LS4-3:** Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all. **3-LS4-4:** Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.

Lesson Excerpts

Since Mr. B's students have started to build up an understanding of animal and plant diversity in habitats, he is ready for them to begin examining the impact humans have on animal habitats. He posts three questions that the children will consider over the course of the next several days:

- How can human activities change the habitats where plants and animals live?
- How do these changes affect the survival of the plants and animals that live there?

Mr. B begins the lesson by asking the class to think about a human activity that might affect an animal's habitat. He first gives an example: When humans cut trees down to make things, like houses and paper, some animals might lose their homes. Then, he asks his students to think about as many ideas as they can and gives them a few moments to do so. As the students think, Mr. B checks in with his two students at an Emerging level of English language proficiency to ensure they understand the question. After the students have had time to think, Mr. B asks them to share with their partners using an open sentence frame in order to challenge them to include human impact and its effects:

When humans __________________ (cause), ____________ (effect).

He listens in as students share their ideas. He hears some students share an idea very similar to his, while other students say things such as, "When humans make a parking lot, and that's where there were trees before, I think it causes animals to lose their homes, like birds and squirrels and stuff," and "When humans put pollution in the air, because they're driving their cars a lot, I think the animals can get sick or die because they can't breathe."

Meaningful Interaction with Science Informational Texts:

Mr. B's next step is to help his class to understand deeply the relationship between an animal, the animal's habitat, and human actions that affect an animal's habitat. To help build his students' understanding, he chooses the relationship between the monarch butterfly, the milkweed plant, and the elimination of milkweed due to human use of weed killer.

Mr. B reads aloud the informational text *Monarch and Milkweed* by Helen Frost and Leonid Gore. He reads the text to the children as they sit on the carpet. He has pre-assigned students into heterogeneous partnerships so all students have thinking buddies, being cognizant of each student's level of English proficiency as well as science content knowledge. As Mr. B reads, he stops periodically to define words and to prompt his students to repeat words and definitions and to make an accompanying hand gesture that will help them remember the words. For example, when Mr. B comes to the word *migrate*, he says, "Migrate means to travel in a group from one place to another." He says the word clearly and then asks his students to chorally repeat the word and the definition while also making the motion of moving their hands from the center of their chest straight out away from themselves, making wriggle fingers to show both movement and that it is a group of many.

Throughout the book, Mr. B stops periodically to ask the students questions, allowing them time to think then share with their partners after each question, to ensure they understand the reading. He emphasizes how the illustrations can help the students understand the scientific concepts, as when an illustration shows the caterpillar inside the chrysalis.

When Mr. B gets to the end of the book, he asks his students to discuss with their partners the question: What would happen if most of the milkweed were gone? He listens closely as partners discuss. Once the students have had about a minute to discuss with their partners, he brings the class back together and asks a few partners to share out. Mr. B has an instructional routine in which when one partner shares, the other partner also has to share by adding on to his or her partner's response.

Mr. B calls on a pair of students, Veronica, who is at the early Emerging level of English language proficiency and has a grasp of some academic Spanish because of her schooling in Mexico, and her thinking buddy, Alicia, who is bilingual. Both girls speak Spanish as their home language.

> Mr. B: Veronica and Alicia, I would like you to respond. Which of you will go first? (Veronica and Alicia confer briefly.)
>
> Alicia: I'll go first and Veronica will add on. We think the butterflies will die.
>
> Mr. B: Yes, that does seem likely. I'd like to hear more. Why do you think the butterflies will die? Veronica, can you say more?
>
> Veronica: I…I think…
>
> Alicia: (whispering to Veronica to prompt her) I would like to add…
>
> Veronica: I would like to add…that…butterflies need milkweed to…*¿Cómo se dice sobrevivir*?
>
> Alicia: ¿Sobrevivir? Uh … Survive!
>
> Veronica: Butterflies need milkweed to survive, so…*cuando*…when the milkweed… (turning to Alicia) *¿Puedes decirlo tu*?
>
> Alicia: If all the milkweed is gone, the butterflies would die.
>
> Mr. B: Thank you, Veronica and Alicia. (Writes under the document camera, "Butterflies need milkweed to survive, so when the milkweed is gone the butterflies die." (To Veronica and Alicia) Is that right? (Both girls nod their heads). Let's see if we can expand on that idea a little bit. (Mr. B chooses another pair to share, Bryan and Santiago. Bryan is a native English speaker and Santiago is an English Learner at the early Bridging level of English proficiency). Bryan and Santiago, can you elaborate on Veronica and Alicia's ideas?
>
> Bryan: The butterflies are a special kind called monarch butterflies.

Mr. B: (Adds the word *monarch* before *butterflies* in Alicia and Veronica's sentence.) Thank you for being specific about the type of butterfly.

Santiago: I don't know what else to say.

Mr. B: Let's see if we can figure it out together. Can you say anything more about this idea of the butterfly surviving? Can we unpack that a little bit? (Picking up on the students' hesitation, Mr. B makes an adjustment to address vocabulary.) In fact, this might be a new word for some of us. Let's all say the word *survive*. (The class chorally says the word.) Survive means to continue to live. Let's all say that. Survive means to continue to live. (The class chorally repeats the definition.)

Mr. B quickly provides the sentence frame: "_____ helps ______ survive by …" He says, "We're going to practice using the word *survive*." He models, touching the appropriate part of the posted frame as he speaks, "Sunlight helps plants survive by providing energy for plants to turn into food." He has students take turns completing the sentence frame with their elbow partners for one minute. During this time, Mr. B pays particular attention to the sentences the ELs produce; he will use these observations when determining what kind of support to provide during subsequent tasks. Mr. B then gives students another 30 second to practice completing the sentence frame, this time focusing their sentences only on monarch butterflies.

Mr. B: Santiago, what is one way milkweed helps the monarch butterfly survive? I'd like you to use the stem "Milkweed helps the monarch butterfly survive by…" (Mr. B writes this stem under the document camera, under the sentence the class has started.)

Santiago: Umm. Okay. Milkweed helps the monarch survive by giving it…Can you go back to the page about the caterpillar?

Mr. B: (Opens the book to the page about the caterpillar.) This one?

Santiago: Yeah. Milkweed helps the monarch butterfly survive because…it hangs on the leaf.

Mr. B: The caterpillar is hanging there, yes. Let's brainstorm a list of all the ways the milkweed plant helps the monarch butterfly.

He writes, "The milkweed plant helps the monarch butterfly by providing a place for the caterpillar to hang while it grows." He prompts the class to echo read the statement; this practice gives all students an opportunity to develop their expressive reading skills. Mr. B continues to elicit responses from different students, supporting them as they develop their ideas and clarify their understandings about the importance of the milkweed plant to the life cycle of the monarch.

The next day, Mr. B has the class engage in an "Expert Group Jigsaw" reading using texts about threats to the monarch butterfly (including a Newsela article called "Scientists worry over disappearing monarch butterfly"). The children have engaged in this type of collaborative reading activity before and enjoy its game-like flavor. They take their science journals, which they will use for note-taking, as they convene in their expert groups. The process they use is as follows:

Expert Group Jigsaw Procedure
Step 1: Students read a text independently in their Expert Groups The expert groups convene. Sometimes, groups can be put together randomly (by counting off, for example). At other times, teachers may want to group students strategically in order to balance/leverage strengths, learning needs, and interests. Each person in the same expert group reads the same text, but each of the different expert groups read a different text. This could be

different sections from the same text, or it could be different texts that provide various lenses on the same topic. Each student reads their text independently, along with focus questions and a note-taking guide (graphic organizer) to take notes.

Step 2: Students become experts in their Expert Groups

In this step, each person is responsible for adding information from their independent reading, noting (in their note-taking guide) what others share, and building on what has been shared. After the initial sharing, the students move on to discussion questions about the text where they can delve deeper into the text together and further develop their expertise of the topic. At the end of this phase, the group members agree on key points they will each share in their jigsaw groups.

Step 3: Students share their expertise and learn from others in Jigsaw Groups

Students convene in their jigsaw groups, comprised of one (or two) people from each expert group. Each person shares their expertise while the others take notes and ask clarification or elaboration questions. Once each person has shared, the group may have an additional task, such as synthesizing the information that has been shared or discussing one or more of the big ideas from the different readings.

Step 4: Students share what they learned in their Expert Groups

Students reconvene in their expert groups and share what they each learned from their different jigsaw groups. Each person adds any new information to their note-taking guide and makes connections, asks questions, builds on ideas, etc.

After the class has researched the threats facing the monarch butterfly, Mr. B asks the students the two overarching questions for the instructional segment:

- How can human activities change the habitats where plants and animals live?
- How do these changes affect the survival of the plants and animals that live there?

The children discuss these questions in small groups of four students, who then have an opportunity to share out their responses.

Preparing to Create Posters

After his students have connected closely with the idea that humans can impact the habitats of animals, Mr. B wants to bring their understanding back to the animal habitats around the school.

Mr. B takes the class on a second nature walk. The students explore an unused parking lot near the school, and they make a return visit to the nearby wooded park. As they visit these sites, the students make notes and/or simple drawings in their science journals about the condition of the habitats and abundance of plants and animals in each.

Once the class returns to the classroom, Mr. B leads a Talking Points activity in order to help his students bolster their learning and understanding. In this activity, Mr. B writes a series of statements related to the lesson's learning goal, and students have to agree or disagree with the statement, using evidence to support their stance.

Mr. B writes the statements on a piece of paper under the document reader, revealing one at a time.

Both to prompt all students to include their rationale and/or evidence in their responses and to support ELs who may need help structuring their responses, Mr B includes sentence frames:

- Some habitats have more plants and animals than others. (I agree/disagree that some habitats have more plants and animals than others because ____________.)
- An animal's habitat helps it to survive, or live. (I agree/disagree that an animal's habitat helps it to survive because ____________.)
- Humans have no impact on animal habitats. (I agree/disagree that humans have no impact on animal habitats because ____________.)
- Humans can help make animal habitats healthier. (I agree/disagree that humans can help make animal habitats healthier because ____________.)

After he uncovers each statement, Mr. B asks the students to turn and talk with their thinking buddies. Mr. B makes a point to listen to all of his students' conversations, but he takes special care to ensure his EL students have understood the task and are actively participating.

As the students share out, Mr. B charts their ideas because he wants students to be able to use these ideas when they make their posters. He doesn't write the exact words the students say. Instead, he works with students to jointly construct statements, making sure to capture the students' intended meaning in error-free, grammatically sound sentences. He creates an anchor chart for each statement that includes different pieces of evidence students give to support their ideas. Two sample anchor charts for the statements are shown below.

Statement: Some habitats have more plants and animals than others.

We agree!

- We observed many different types of plants and animals in the park. We saw trees and ferns and squirrels and lots of different birds.
- We observed almost no plants or animals in the parking lot. Some weeds grew up through cracks. Only one bird was standing on the edge of the parking lot.

Statement: Humans have no impact on habitats.

We disagree!

- People paved the parking lot so no trees are left there. Without trees, many animals have no home.
- People killed milkweed with weed killer. Monarchs need milkweed to survive. Milkweed is important to the monarch habitat.
- People build whole cities and the animals have to find somewhere else to live.

After Mr. B works with his students to create each of the three anchor charts, he challenges them to come up with ideas about what they as individuals or as a class might do to decrease the effects of human activities on the habitats of plants and animals. Mr. B's class comes up with many great ideas, such as "Plant milkweed in the school garden," "Use less paper so we have to cut down fewer trees," and "Pick up trash from the park." Mr. B charts these ideas as well, leaving them up as support for when students create their own lists of suggestions for their posters.

Mr. B concludes that students are prepared to move into writing. He wants to support his students in successfully writing an informational report, so he brings out a model text that he has created. Mr. B wants to help his students learn about the features of the type of text they will write, but he wants students to use their own ideas for the text the write independently. So the model text is written in the style of an informational report, but it is on a subject the class studied earlier in the year – what plants and animals need to survive. The class examines the purpose of the text (to provide information), as well as the parts of the text, including the general topic statement, followed by several facts and details that support the topic, and then a concluding statement.

Before releasing students to write on their own, Mr. B leads his students through jointly constructing a text on a closely-related topic: How does a habitat help an animal survive? The students are sitting on the carpet next to their thinking buddy while Mr. B writes the text on chart paper. The class decides to focus their informational report on one animal with which they are all familiar—the monarch butterfly. Mr. B helps his students refine their thinking and phrasing, as necessary, as they work to jointly construct an informational report.

> Mr. B: We first have to tell our reader what we're going to be writing about. What could we say? (He gives students about ten seconds to think.)
>
> Npaim: We could say we're going to tell you all about monarch butterflies!
>
> Mr. B: That's certainly accurate! I wonder if there's a way that we can tell our readers a little bit more.
>
> Npaim: Oh! Their habitats. We're going to tell you all about the habitat of the monarch butterfly.
>
> José Luis: Yes, they have to have…what's it called? That milk plant?
>
> Adriana: Umm…milkweed!
>
> Mr. B. Thank you for sharing your ideas! Let's see if we can turn that into a sentence that makes us sound like scientists. What if we write, "The monarch butterfly depends on—that's another way to say *has to have*—milkweed to survive?"
>
> Npaim: But, we didn't use habitats.
>
> Mr. B: Thank you for that observation. Let's make sure we use the word habitat. Does anyone have any ideas on how to use the word habitat here?

Mr. B continues to facilitate the discussion as he and the class jointly construct the text, paying careful attention to the structure, thus apprenticing his students into using the language of science.

Once they have jointly constructed the text, Mr. B is releases most of the class to independently write the informational report that will go on their posters. He directs the students to the anchor charts on the walls as well as the Word Wall. His students also know that they can rely on one another as resources when they are writing. While most of the class is writing independently, Mr. B pulls a small group that consists of his students at the early Emerging level of English language proficiency and two other students whom he has determined need additional, customized support with their writing. With these students, he provides greater scaffolding throughout the writing process, first by helping them brainstorm and outline their ideas and then with more one-on-one support as they construct their informational reports.

Once students have finished their informational reports, Mr. B leads the class through a peer review, with the aid of a checklist of the features each report should include. He then delivers a mini-lesson on expanding their writing by adding details, after which each student expands at least one sentence in their informational reports.

Once students have finished revising their informational reports, they finish their posters by writing a list of ways humans can help restore or protect animal habitats. They also find pictures and draw illustrations that show the animals and habitats they wrote about. The students will present their posters to their parents at the school's Family Science Exhibition Night. They will lead their families on a gallery walk of the classroom, serving as docents, as they explain the posters and help them conduct some science investigation at the many stations around the room.

Collaborative Research Projects and Engaging the Local Community:

After researching and creating posters about the monarch butterfly and its habitat, the class delves into collaborative research projects in small groups (three to five children in each group). Mr. B invites several speakers to share their knowledge with the class, including a wildlife biologist from the local university and a docent from a local wildlife conservation center. After hearing and reading about different animal habitats that are under threat from human impact, in their small research groups, the children select a California animal habitat under threat, research it together, and individually write letters to the editor of the local newspaper in order to inform the public and engage them in thinking about environmental protection. In order to learn about how to write effective letters to the editor (arguments), Mr. B supports the students to analyze published letters written by other third through fifth grade students, such as the following:

Balance wildlife and energy needs

Wind power is both a valuable source of renewable energy and a terrible threat to birds and bats. Wind turbines – located particularly in the Altamount Pass, Tahachapi Mountains and the Montezuma Hills – kill birds in flight and they take up valuable habitat.

Wind turbines kill roughly 108,000 birds and thousands of bats each year in California. A recent study published in Biological Conservation says that while 10 percent of the United States wind energy is produced in California, 46 percent of all yearly wildlife kills are caused by California turbines.

Although there are other causes of bird deaths – like collisions with telephone wires and buildings and attacks by house cats and feral cats – turbines are an important problem, especially for raptors, which glide with the wind and are often found in windy places where the turbines are located.

California Department of Fish and Wildlife biologist Elliot Chasin says one solution is to cite wind farms in altered lands far from nesting habitats. Using shrouded turbines also helps birds avoid the blades. You can help by telling your elected officials that it is important to balance the needs of wildlife with the needs for renewable energy.

Braeden Ingram
Fifth-grader
Korematsu Elementary School

Pesticides can do great harm

My name is Emily Jiang and I am part of my school Nature Bowl team. I am currently working on an environmercial. That is an environmental report on a local issue. My issue is biomagnification and bioaccumulation of legacy pesticides.

Just to be clear, biomagnification is concentration on how a toxin moves up a food chain. Bioaccumulation is concentration on how a toxin gets from the environment to the first organism in a food chain. Legacy pesticides are a group of banned pesticides that include dichlorodiphenyltrichloroethane (DDT), the chlordanes and dieldrin. So if you put them together, it equals an amazing but deadly link.

Here's an example: If a sufficient amount of DDT was sprayed on a marsh to control mosquitos, then plankton will eat that, and then a clam will eat that plankton, and then a gull will eat that clam.

But then the amount of DDT in that gull will be lethal, killing that bird.

You see how big of a problem this is. But many people don't. They think that when they spray a pesticide onto some grass, or on a marsh, at most it will harm a small insect. That can cause a huge blowout, which will end up harming a much larger and threatened organism.

There are plenty of ways I am going to help. The best way will be to raise awareness. But what you can do is to tell your friends how big of a problem this is, and have them tell their friends. Hopefully, this will make people think twice about using dangerous pesticides like the legacy pesticides.

Thank you very much for taking part in helping our society.

Emily Jiang
Davis

Davis Enterprise, Sunday Forum, March 2, 2014 (permission to be sought to reproduce)

Some of the letters to the editor call for people to spread the word or call their local representatives. Others provide suggestions for taking action in daily life. After appropriate editing and revision activities are completed in their small groups, followed by writing conferences with Mr. B and parent volunteers (over the course of the next several months), each of the children's letters is published in the local newspaper and/or an online venue. In addition, the children are inspired by some of the letters they read to produce their own short "environmercials," which the principal of their school posts to the school website.

Teacher Reflection and Next Steps

During all of the conversations and tasks, Mr. B has been observing his students carefully so that he can plan appropriately for his students' learning for the rest of the instructional segment. He sees that some of his students are having trouble using sufficient details in their writing, while others are veering from the topic. This prompts him to design more tasks into future lessons that help his students use more details and stick more closely to the topic they are writing about. He knows from analyzing student writing and monitoring their conversations that most students understand the big ideas of the lesson, so he plans to design and implement more well-rounded lessons in which students have multiple opportunities to interact with one another as they work with science concepts in a real-world context.

During designated ELD time, Mr. B also uses his observations, notes, and the CA ELD Standards to plan focused language development lessons that build into or extend from his integrated lessons. He has noticed that the EL children at the Emerging level of ELD are using more and more everyday and social language, but need more support with academic vocabulary. He plans several vocabulary lessons for designated ELD time so that students have a range of opportunities to use the target general academic (Tier 2) and domain-specific (Tier 3) words, as well as lessons that look specifically at language features used within informational reports (e.g., subheadings to organize information, present tense, etc.).

Sources:

California Education and the Environment Initiative. 2011. Cycle of Life. Sacramento: Office of Education and the Environment.

California Education and the Environment Initiative. 2011. Flowering Plants in Our Changing Environment. Sacramento: Office of Education and the Environment.

California Education and the Environment Initiative. 2011. Open Wide! Look Inside! Sacramento: Office of Education and the Environment

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Explorit Center Nature Bowl: http://www.explorit.org/news/nature-bowl-at-explorit

Frost, Helen and Gore, Leonid. (year). Monarch and Milkweed.

Standards the vignette addressed:

CA NGSS Performance Expectations
3-LS4-3: Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all. **3-LS4-4:** Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used. ▪ Analyze and interpret data to make sense of phenomena using logical reasoning. (3-LS4-1) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems. ▪ Use evidence (e.g., observations, patterns) to construct an explanation. (3-LS4-2) **Engaging in Argument from Evidence** Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s). ▪ Construct an argument with evidence. (3-LS4-3) ▪ Make a claim about the merit of a solution to a problem by citing relevant evidence about how it	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. (secondary to 3-LS4-4) LS4.C: Adaptation For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all. (3-LS4-3) LS4.D: Biodiversity and Humans Populations live in a variety of habitats, and change in those habitats affects the organisms living there. (3-LS4-4)	**Cause and Effect** Cause and effect relationships are routinely identified and used to explain change. (3-LS4-2),(3-LS4-3) **Scale, Proportion, and Quantity** Observable phenomena exist from very short to very long time periods. (3-LS4-1) **Systems and System Models** A system can be described in terms of its components and their interactions. (3-LS4-4) --- ***Connections to Engineering, Technology, and Applications of Science*** **Interdependence of Engineering, Technology and Applications of Science on Society and the Natural World** ▪ Knowledge of relevant scientific concepts and research findings is important in engineering. (3-LS4-4) --- ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Science assumes consistent patterns in natural systems. (3-LS4-1)

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<td>meets the criteria and constraints of the problem. (3-LS4-4)

Planning and Carrying Out Investigations
Make observations (firsthand or from media) to collect data which can be used to make comparisons.</td>
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<td colspan="3">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. 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.</td>
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<td>CA CCSS for ELA/Literacy:
W.3.1 - Write opinion pieces on topics or texts, supporting a point of view with reasons …; W.3.2 - Write informative/explanatory texts to examine a topic and convey ideas and information clearly …; W.3.7 – Conduct short research projects that build knowledge about a topic …; SL.3.1 - Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 3 topics and texts, building on others’ ideas and expressing their own clearly …; RI.3.3 - Describe the relationship between a series of … scientific ideas or concepts …in a text, using language that pertains to time, sequence, and cause/effect.</td>
<td colspan="2">CA ELD Standards (Expanding):
ELD.PI.3.1 - Contribute to class, group, and partner discussions, including sustained dialogue …; ELD.PI.3.2 - Collaborate with peers on joint writing projects of longer informational and literary texts …; ELD.PI.3.4 - Adjust language choices … according to purpose (e.g., persuading, entertaining), social setting, and audience (e.g., peers versus adults), with moderate support from peers or adults; ELD.PI.3.6 - Describe ideas, phenomena (e.g., how cows digest food), and text elements …in greater detail based on understanding of a variety of grade-level texts and viewing of multimedia, with moderate support; ELD.PI.3.10 - a. Write longer literary and informational texts (e.g., an explanatory text on how flashlights work) collaboratively (e.g., joint construction of texts with an adult or with peers) and with increasing independence using appropriate text organization; ELD.PI.11 - Support opinions by providing good reasons and increasingly detailed textual evidence (e.g., providing examples from the text) or relevant background knowledge about the content; ELD.PII.3.1 - Apply understanding of how different text types are organized to express ideas … to comprehending texts and writing texts with increasing cohesion.</td>
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