Grade Five

As the culminating grade in elementary school, the entire year draws upon patterns and understandings developed in prior grades. Students look at phenomena from previous grades from the central theme of the exchange of ***energy and matter [CCC-5]*** within ***systems [CCC-4]***. Table 41 shows an example of how instruction can be divided into instructional segments during grade five. The year progresses through systems of different ***scales [CCC-3]*** from tangible systems with chemicals in plastic zip bags in IS1 up to the scale of ecosystems in IS2 and then to the interacting subsystems of the entire planet in IS3. Instructional Segment 4 continues along this progression in terms of scale, but instead of tracking the flow of energy or matter within a system it focuses on the input of energy *into* the Earth system from the Sun and other stars in the sky.

The entire year has an emphasis on **developing and applying models [SEP-2].** The chapter on assessment (Chapter 7) presents several strategies for formative assessment of students' models of systems. Using pictorial models like concept mapping allow students to represent their mental models and be very explicit about how the different components in the system interact and exchange energy and matter.

Table 44. Overview of Instructional Segments for Grade Five

	**1** What is Matter Made of?	Students observe different materials and describe their differences. They investigate how materials change when they mix together. They learn to recognize chemical reactions and develop a model of matter being made of particles. These particles move and their arrangement changes, but their mass always stays the same.
	**2** From Matter to Organisms	Students make models that trace the flow of energy and matter in ecosystems. They investigate the needs of plants and gather evidence that all organisms produce waste. They explain how animals depend upon one another as components in an interconnected system.

	**3** Interacting Earth Systems	Students make models of the flow of energy and matter at the scale of the entire planet, and obtain information about a few example phenomena. They describe these phenomena in terms of interactions between different systems within the broader Earth system. They use their models to understand how humans impact these systems and develop solutions to minimize these effects.
	**4** Patterns in the Night Sky	Students ask questions and wonder about the night sky. They investigate the force of gravity and then analyze data to identify patterns related to Earth's motion. They gather evidence and make models showing that the brightness of a star depends on its distance from Earth.

Sources: Pixabay public domain images.

Grade Five – Instructional Segment 1: What is Matter Made of?

Grade five students delve into the most abstract scientific concept they have yet confronted, **developing and refining a model [SEP-2]** that describes matter as being made up of particles that are too small to see. By investigating a series of phenomena that emphasize the properties of materials and the ***conservation of matter [CCC-5]*** (the idea that material is not created or destroyed but just moves around within a system), students recognize that a model with matter as particles can explain many of the features they observe. This IS has three main sections that progress from the observable down to the abstract: (1) Describing materials; (2) Mixing and changing materials; and (3) Developing and applying a model of materials.

Grade Five – Instructional Segment One: What is Matter Made of?
Guiding Questions: *What causes different materials to have different properties?* *How do materials change when they dissolve, evaporate, melt, or mix together?* *What are the differences between solids, liquids, and gases?*
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 forms 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.]**

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.** **[Clarification Statement: Examples of models could include diagrams, and flow charts.]**

**California clarification statements, marked with double asterisks, were incorporated by the California Science Expert Review Panel

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
	PS1.A: Structure and	**Energy and Matter**

Developing and Using Models **Planning and Conducting Investigations**	**Properties of Matter** **PS1.B: Chemical Reactions**	**Systems and System Models** **Cause and Effect**
Highlighted California Environmental Principles & Concepts: **Principle IV The exchange of matter between natural systems and human societies affects the long term functioning of both.**		
CA CCSC Math Connections: 5.MD.3a,b; 5.MD.4		
CA CCSC ELA/Literacy Connections: SL.5.1, 4, 5		
CA ELD Connections: ELD.PI.5.1, 6		

Engineering Connection

Every material has specific properties. When students need to select the appropriate materials for an engineering challenge, their attention is drawn to these differences. This IS can begin by providing students different materials and giving them the challenge to construct a tall tower that can bear a heavy weight. Which materials are best suited to the task? Students can devise techniques for measuring or quantifying many of these properties. How can students combine materials or modify their structure so that they work better? They can increase the strength of paper by rolling it into tubes, index cards by gluing them together with glue sticks, or spaghetti strands by taping several together. Testing the structures using a consistent procedure allows students to identify the specific mechanism of failure such as crushing and buckling, stretching and tearing (3–5-ETS1-3). Do different materials fail in different ways?

From everyday experience, students can 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 one material is wood while another is stainless steel or aluminum. What properties can describe a substance, classify it, and differentiate it from others? The most visible property, color, has only limited use because it can be changed with a thin layer of paint over a solid or drop of food coloring in a liquid. Instead, students learn to ask more detailed questions about materials. Students apply and expand the vocabulary they learned in grade two to describe material properties (2-PS1-1), but now they are ready to be more quantitative about their descriptions, making measurements of certain properties and using them to distinguish between materials (5-PS1-3). Making precise measurements can be motivated by the constraints considered when **defining engineering problems [SEP-1]**. For example, if we need to design a spoon that will not heat up more than 10 degrees when placed in boiling water, which material works best? Students can measure the heat conduction properties of several materials using a consistent test. Students can measure the melting temperature of different materials such as wax, chocolate, and ice to decide which material would make the best decorative sculpture for a summer birthday party. Students can measure the strength of different materials to determine which one to use to support a bridge that will bend without breaking when a toy car drives across it. Students can identify "mystery" powders based upon how much of each powder they can dissolve in a cup of water or how the powder reacts with various other ingredients.

To motivate the next section about physical and chemical changes to materials, students can think about all the properties that change when they mix materials to bake a cake (which can be done in class if permitted by school rules). Students can explain their thinking about the formative assessment probe, "When you bake a cake, does the finished cake weigh more or less than the batter that you put in the oven? Does the batter weigh the same as all the raw ingredients separately?" Many students explain that the cake 'dries out' so it weighs less, but some may argue that it 'puffs up' and so it weighs more. The question motivates a series of **investigations [SEP-3]** exploring how the weight of a material changes (or does not) under different conditions. Students can make qualitative comparisons using simple mechanical balances with cups or platforms on either side or make more precise measurements using calibrated triple-beam or digital balances. Students can work with the familiar vocabulary of weight and do not need to learn the term 'mass' in grade five (the terms are used interchangeably in this IS). Students can compare the weight of objects at the same temperature and then heat or cool one of them to see if its weight changes. Some materials get hot enough that they melt. Does melting or freezing change the weight of material?

When collecting real data, there is always the possibility that real-world factors will interfere with the intent of an investigation. In this case, precise measurements by scientists reveal no difference as a material is heated or cooled, melted or frozen – a given amount of material always has the same mass. If students use precise digital balances, they may observe small differences between their measurements that represent measurement errors or the effects of condensation and evaporation. Before making measurements, teachers will need to set up the comparison by having students make repeated measurements of the same object to establish how big a change needs to be observed before they can be confident that the change is 'real' and not just the imprecision of the balance they are using. Similarly, they can emphasize the very large differences in properties between solids and liquids. Does the weight change as dramatically as the properties? Having students predict the ***magnitude [CCC-4]*** of differences ahead of time using this information gives them better context for **interpreting their data [SEP-5]**.

Next, students explore what happens when they mix substances together. How does mixing affect the properties and weight of the materials? Teachers give students substances to mix, some of which undergo chemical reactions and others that simply form mixtures. Students mix different combinations of mystery powders (such as baking soda, washing soda, flour, powdered lemonade, calcium chloride, corn starch, and Epsom salts), and liquids (water, vinegar, lemon juice, tincture of iodine, some mixed in with the juice from purple cabbage which changes color as the pH changes) together in plastic zip bags and observe what happens[1]. Some mixtures cause dramatic, unusual changes, reactions, while others are uneventful. Students should use their observations from before, during, and after mixing to support an **argument [SEP-7]** that a new substance formed (or did not form) when the powders and liquids were mixed together (5-PS1-4). They should notice patterns when certain groups of powders and liquids mix together and patterns in the types of unusual changes that can occur. Teachers can label these changes with the term 'chemical reactions' and discuss the meaning of each of the two words. Common signs of chemical reactions are temperature changes (cold and hot packs), formation of a gas (effervescent tablet and water), color change (metal rusting), formation of a solid (stalactites and stalagmites/hard water build up), a change in smell (baking cookies or bread), and/or emission of light (glow stick). Students should be able to observe all of these (except glowing light) from their mixtures in the bags and should be able to describe how the properties of the new substance(s) are different from the properties of the original ingredients.

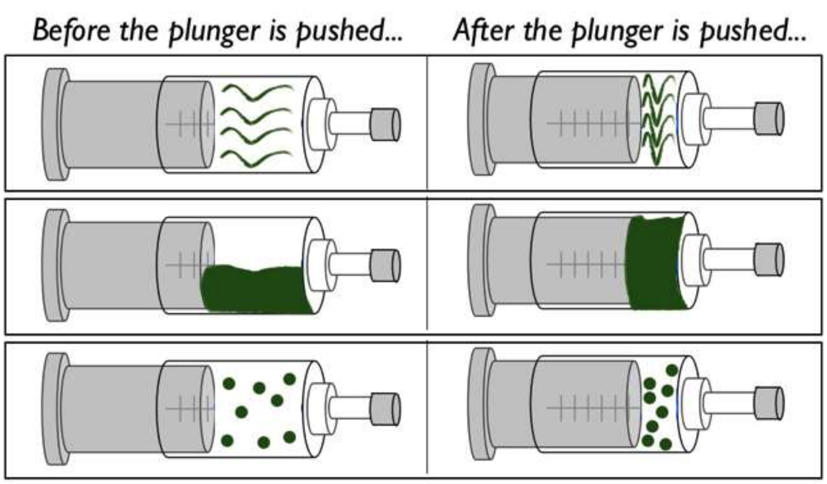
Clearly there are major changes inside some of the bags, but does the weight of the bag change? Students can measure the mass of the bags before, during, and after each reaction (5-PS1-2). Even in bags that fizz and puff up with gas, the weight does not change. Students can compare high quality 'brand name' plastic zip bags with cheaper versions and see that some bags leak gas more than others (causing the mass to slowly drop as the fizzing progresses). This observation leads to an important and often unexpected discovery: gas has mass. Students can confirm this idea by comparing the weight of an empty balloon to the mass of one blown up with air (hanging the bags on opposite ends of a meter stick, which when hung by a string from the center can be used as a balance). They can also confirm this by placing an empty cup on a balance, mixing chemicals that fizz in the cup, and watching the weight of the cup decrease as the reaction progresses. If they repeat this same reaction in a well-

[1] "Chemical Reactions: Investigating Exothermic and Endothermic Reactions." http://serc.carleton.edu/sp/mnstep/activities/19869.html

sealed bag, they will see that the mass stays constant. Based on their observations, students should be able to answer the original question about the weight of a cake and its ingredients—it may weigh less after cooking because some of the weight might have escaped into the air as a gas. The air in the room, however, would now weigh more (if you could measure it!).

While students have everyday experience with air as a gas, this is the first time that they explicitly explore the properties of gases in the *CA NGSS*. Students can explore different phenomena to characterize solids, liquids, and gases with the goal of describing and comparing their properties. Students can feel gases by moving their hand back and forth through the air, or constructing windmills or parachutes to show how air exerts forces on objects. To probe students' initial **models [SEP-2]** of what gases are, teachers can have them hold a syringe filled with air and then draw and label what is inside the syringe ("What would the air 'look like' if you could see it under a microscope? How can you draw it?"). Then, they hold their finger on the end of the syringe to trap the air inside and try to compress the plunger (they can make force diagrams using arrows like the diagrams in third grade 3-PS2-1). How does the air change? Students initial ideas vary, but they can all be guided to recognize that the amount of air in the syringe does not change because it cannot escape (Figure 417). But which of these models is correct?

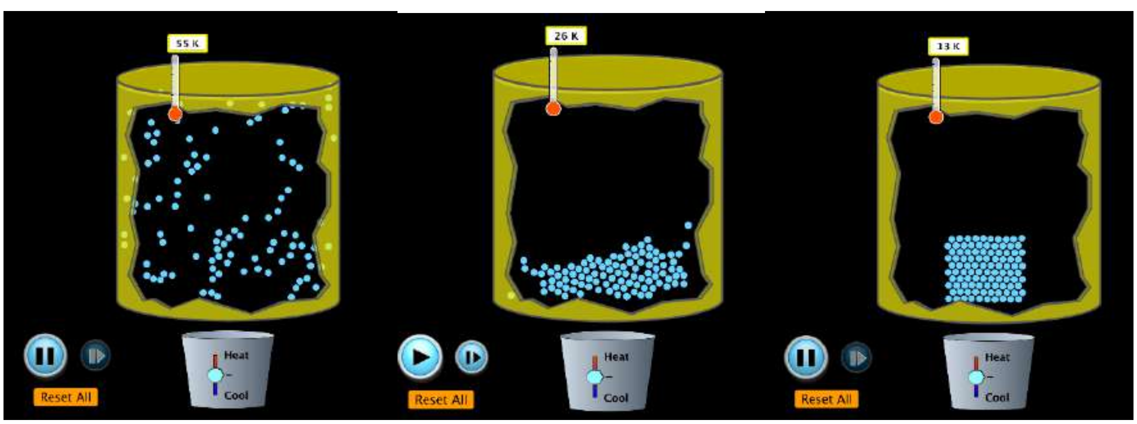
Figure 417. Facsimiles of Students' Initial Models of Air



Students correctly identify that the amount of material inside the syringe must be the same because nothing can escape. Students have different models of how that air ‘looks’ or is distributed inside the syringe.

To distinguish between the different models, students can observe dust settling in a room or smoke from a match after it has been blown out. Video clips of these phenomena up close[2] reveal something interesting: even as the overall motion of the particles is a downward drift due to gravity, some of the particles suddenly move up. Students know from grade three that the only way to make something move upwards is to push or pull it upwards. What can be pushing the dust? The answer is that particles of air that are too tiny to see even with a microscope crash into the larger dust particles and alter their paths. Students then investigate computer simulations of matter that show a particle model of materials[3] (Figure 418).

Figure 418. Computer Simulation of Particles of Neon in Three States: Solid, Liquid and Gas



Gas Liquid Solid

Source: PhET 2015b.

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[2] Search for “Dust, Brownian motion.” A good clip is at https://youtu.be/IJYbc_bQKbA?t=17m50s

[3] PhET Interactive Simulations (PhET). 2015. States of Matter: Basics. https://phet.colorado.edu/en/simulation/states-of-matter-basics (accessed July 30, 2015).

Students can now return to all the different phenomena they have investigated in this IS and look at them through the lens of the model. How do solids differ from liquids or gases? In the gas, there is so much empty space between the particles that we can often see right through it (which is why air is clear). In a solid, the particles are stacked in a defined structure and therefore are stronger and resist pushing and deforming more than liquids. How does the model explain the fact that weight stays the same even when you mix materials together, warm them up, cool them down, melt, or boil them? Each particle has its own weight which does not change as the particles move around. Each of these processes involves changing the position and speed of the particles, but does not affect their weight. Students can draw a model of an empty balloon and one filled with air using this model and it becomes much easier to explain why the full balloon weighs more – there are more particles of air inside. They can draw a sugar cube dissolving in water by representing the cube as an array of stacked particles that disperse from one another when they enter the water. Each individual particle is too small to see, though collections of many particles together are visible. This leads to a discussion of the word 'disappear' and its prefix (CA CCSS ELA/Literacy RF.3.3a) – while particles can disappear (i.e., stop being visible), they do not go away or get destroyed. This concept of the conservation of matter is fundamental to all science. It also is the foundation of CA EP&C IV: "The exchange of matter between natural systems and human societies affects the long term functioning of both." Pollution does not just "go away," it ends up in air, water, soil, and in our bodies. Just as students are able to trace individual particles of sugar as they dissolve in water, scientists can follow particles of toxic pollution throughout waterways, in the air, and even into the human body.

This IS emphasizes the evidence that builds up to a model and then the subsequent application of the model to explaining a wide variety of phenomena. Vocabulary is not a focus. At this grade level, the term 'particle' is used generically for the scientific terms 'atom' and 'molecule' because the distinction between them is beyond grade five. 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-related phenomena, and the nature of the differences between different elements is not stressed.

Fifth Grade Vignette: Pancake Engineering		
Performance Expectations		
Students who demonstrate understanding can: **3–5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.** **3–5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.** **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.** **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.] **This clarification statement is unique to *CA NGSS* and is not a part of the national NGSS.		
Highlighted Science and Engineering Practices	**Highlighted Disciplinary Core Ideas**	**Highlighted Crosscutting Concepts**
Defining problems **Designing Solutions** **Obtaining, evaluating, and communicating information**	**PS1.A Structure and Properties of Matter** **PS1.B Chemical Reactions**	**Scale, proportion and quantity** **Cause and Effect** **Systems**

CA CCSC Math Connections:

5.MD.3.a,b Recognize volume as an attribute of solid figures and understand concepts of volume measurement.

5.MD.4 Measure volumes by counting unit cubes, using cubic cm, cubic in, cubic feet and improvised units.

Introduction

What does cooking have to do with engineering? What effects do certain ingredients have on others? Mixing pancake batter creates a chemical system with interacting components, and each ingredient plays a different role within the system. This fifth grade activity merges scientific understanding of chemical reactions and systems with an engineering design challenge to make the perfect pancake.

Day 1: Define Criteria *"What does a perfect pancake look like?"* Students come up with the criteria for their ideal pancake: golden brown, fluffy, and tasty.	**Day 2: Plan Solutions** *"What happens when we mix two materials?"* Students investigate what happens when two ingredients are mixed together in order to understand the behavior of different ingredients. They vary proportions and identify trends. Finally, students try cooking their pancakes and discover something is missing.
Day 3: Create, Evaluate, and Improve *"What is the optimal proportion of ingredients?"* Students spend the lesson mixing ingredients, cooking the pancakes, evaluating the results, and making modifications to achieve their ideal pancake.	**Day 4: Communicate Results** *"What changes did I make?"* Students create a summary document explaining what they changed from one trial to the next. The class then compares recipes from the "best" pancakes to find patterns. Students then decide on three recipes to try to repeat and see if the results are the same.

Day 1 – Defining Criteria

Mrs. C always tells her students that "engineering is everywhere!" In this activity, students will engineer the 'perfect pancake'. Mrs. C assigns six students to read parts from a script where they play the roles of students waiting for their food at a pancake restaurant. The characters argue about whether they like their pancakes fluffy or thin and describe the 'secret recipes' used in their houses. Mrs. C shows a diagram of the stages of the engineering design process and asks students to discuss how different lines from the script relate to stages in the process. In order for Mrs. C's students to design the perfect pancake, they need to **define the problem [SEP-1]** by specifying the criteria (3–5-ETS1-1). How will they decide if they have succeeded? The class decides that the pancakes should be golden brown, fluffy, and tasty. But how will they measure these properties? For golden brown, the students decide that they can compare their pancake to a color palette that shows different shades of brown and agrees on a particular shade that they consider 'ideal.' A 'fluffy' pancake should rise tall; students decide to measure the pancake height by sticking a toothpick in the center and seeing how deep it goes by holding a ruler next to it. The last criteria of 'tasty' is subjective. Unlike science which strives to be completely objective, engineering deals with designing solutions that meet peoples' needs and desires. The engineers that design a car, for example, pay as much attention to the car's appearance as they do to its mechanical systems. Even though the criteria is subjective, students still need a way to track and record their opinions. They decide to rate the tastiness of the pancake using a one to five star scale.

Day 2 – Planning Solutions

Students do not get a recipe to follow – they will use a design process to eventually determine an ideal combination of ingredients. As in many design problems, students need to gather information about the materials available to them to plan their solution. Mrs. C provides students whole wheat flour, oat flour, water, and baking powder. Students choose two different ingredients to mix together and see what happens. Baking powder and water fizz, water and flour turn into thick dough, and baking powder and flour seem unchanged by their interaction. Different students test out different relative proportions of the ingredients and describe their results to the class so that they can identify ***trends or patterns [CCC-1]***. Mrs. C emphasizes that it is important that students measure carefully so that they can make meaningful comparisons between one recipe and another. In order to facilitate comparison, Mrs. C adds the constraint (part of **defining the problem [SEP-1]**) that every pancake must always use exactly one scoop of flour. Students can vary the other ingredients, but the flour must remain constant. Students notice that more baking powder causes more fizzing and that wheat flour seems to make thicker mixtures than oat flour when combined with identical amounts of water. After exploring the interactions, students observe what happens when different proportions are used. Mrs. C describes a pancake recipe as a chemical ***system [CCC-4]***. The ingredients are components of the system and today's tests characterize different interactions between the components when they are in simple two-ingredient systems. Students will combine these ideas into a **model [SEP-2]** of the full system as they adjust their recipes in the upcoming part of the lesson. Groups of students use their observations of the simple systems to decide the proportions of each ingredient to use for their first 'test pancake.' Their discussions are simple **arguments supported by observational evidence [SEP-7]**: "I think we should use two parts water to one part flour because the batter was too thick in the 1:1 mixture." Mrs. C helps students cook their one test pancake on the griddle. Watching the pancakes cook, every group's test pancake is a 'failure' because none of them turn brown! What could be missing from the system? Students measure the thickness, compare the white pancakes to the color chart, and record the results on a data sheet. Mrs. C tells students real engineers get excited when their design fails because it gives them the opportunity to learn more about the system and try again.

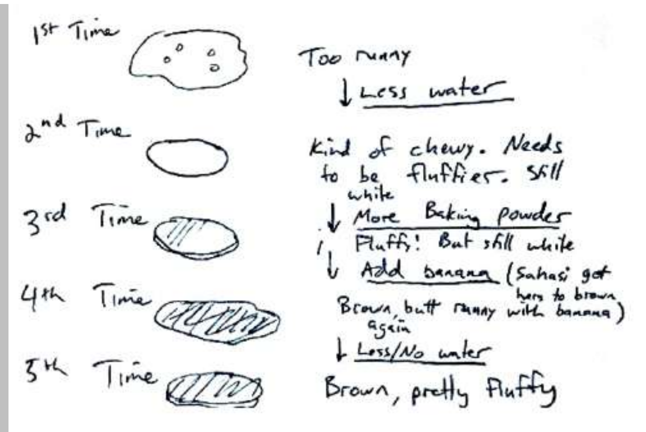
Day 3 – Create, Evaluate and Improve

Mrs. C wants students to experience the power of the iterative process of engineering. Clearly something was missing from their previous pancakes, so Mrs. C offers two additional ingredients today: pureed bananas (1 banana and ¼ cup water pureed in a blender) and vanilla extract. Students begin the lesson by mixing ingredients using the knowledge they gained about each ingredient in the prior lesson and adding the new ingredients. Parent volunteers help each student cook their pancake and evaluate the results (there are four cooking stations set up in different corners of the classroom). How fluffy is it? Is it golden brown? How does it taste? Mrs. C reminds the students to carefully write down the proportions they use after each attempt so that they can systematically change ingredients or proportions to see better results. One student adds a lot of vanilla ("because it's brown"), but his pancake still does not turn brown. Another student uses banana puree instead of water ("I love bananas") and her pancake is the first to turn a beautiful golden brown. Soon, students are experimenting with different proportions of banana and water. Mrs. C circulates while the pancakes are cooking, asking students to apply their mental model about the role of each ingredient by asking things like, "Looking at these two pancakes, which one do you think has more baking powder?", "Do you think that this pancake has any banana in it? How can you tell?", "Wow, that pancake is really thin. What do you think you could add to improve it?" Based on their discoveries and comparisons with peers, students make modifications to achieve their perfect pancake. Students enjoy eating their successes!

(Amount used in teaspoons)				
Water	2	1.5	1	0
Banana Puree	0	0.5	1	2

Day 4: Communicating Results

During Day 3, each student carefully documents their ingredients and results. Today, Mrs. C asks them to reflect on the sequence of mixtures they used. The students make a ‘storyboard’ showing the succession of pancakes. For each frame, the students describe in words how the pancake turned out. Mrs. C asks students to draw arrows between the frames describing what they changed and why they made that change from one trial to the next.



After they finish writing, the students compare all of the recipes and pick the best three that they want to try to repeat today as a class (3-5-ETS1-2). During the discussion, students must **support their choice with evidence [SEP-7]** from the recorded results. Mrs. C cooks the pancakes and one of the recipes turns out very different today than the previous day. Students discuss in groups why they think it might be different and come up with ideas about mistakes measuring ingredients and mistakes recording the results. Mrs. C emphasizes that careful measurements and documentation are essential skills that allow professional engineers to reproduce their solutions and share them with others.

Mrs. C wants students to discuss how pancake cooking relates to chemical reactions. She reminds students that a chemical reaction can change the way substances look, smell, feel, or taste. She tells them that there were at least three key chemical reactions that they could identify from the ingredient mixing and pancake cooking lessons. She instructs students to work in groups to fill in a table describing three different chemical reactions and how they recognize them.

	Evidence for chemical reaction	**Which ingredients reacted?**	**How did you determine which ingredients reacted?**
1	Batter consistency/texture changes	Flour & Water	Happened when we combined flour & water alone in Lesson 3. (the texture change is more dramatic in wheat flour than oat

			flour)
2	"Fluffing": Bubbles form in batter. (and more bubbles when temperature goes up)	Baking powder & Water	Baking powder fizzed when mixed with water in Lesson 3.
3	"Browning": Unusual color change on outside of pancakes.	Banana & ???	Only happened when we added banana.

Vignette Debrief

Students perform a complete engineering design process that employs a wide range of SEPs. They begin by **defining the problem [SEP-1]** as they develop criteria for making the perfect pancake (3–5-ETS1-1). They **conduct investigations [SEP-3]** into what happens when they mix the available ingredients and again when they cook their pancakes and record the results. They **ask a question [SEP-1]** at the end of Day 2 when they discover that all their pancakes are white: "What are we missing?", and this question motivates a change. They briefly engage in **arguments supported by evidence [SEP-7]** when they work with teammates to select proportions to test on Days 3 and 4, though this practice is not a major focus of the vignette. They iteratively **design a solution [SEP-6]** as they try out different proportions of ingredients to hone in on the perfect combination (3–5-ETS1-2, 3–5-ETS1-3). The changes they make are based on a mental **model [SEP-2]** of the chemical system and how each ingredient affects the system's behavior. They **analyze and interpret their data [SEP-4]** by reflecting on how their design changed from iteration to iteration on Day 4. Teachers could extend the lesson to include more **mathematical thinking [SEP-5]** by having students graph pancake thickness versus amount of water, or help them **communicate their findings [SEP-8]** by creating a cookbook that also explains the science behind pancakes.

The CCCs help draw students' attention to the physical processes at work. There is major emphasis on ***scale, proportion and quantity [CCC-3]*** throughout the ingredient exploration. Students think about their recipe as a chemical ***system [CCC-4]*** that has components (ingredients) and energy input (heat from the griddle). They adjust the amount of each ingredient, which ***causes***

different effects [CCC-2] on the pancake system (including the system properties of how it looks and tastes).The entire lesson sequence can be thought of as one large investigation into how the mixing of substances can cause changes that create a new substance (5-PS1-4). By discussing the physical properties of the raw ingredients, the batter, and the cooked pancakes, students can gain a better understanding of the structure and properties of matter (PS1.A). The table on Day 4 makes an explicit tie to chemical reactions (PS1.B). PS1.B does not occur in the foundation box for 5-PS1-4 in CA NGSS, but is a focus in middle school (MS-PS1-2). The motivation for including it here is that explicit instruction into the observable features of chemical reaction draws attention to the types of changes that can occur in substances. However, the discussion of chemical reactions should be limited to observations with the naked eye or other senses. In middle school, students learn to relate these observable changes to a model of interacting molecules, but that discussion is not part of fifth grade in the *CA NGSS*.

Resources for the Vignette

- Lesson plans with further guidance are at http://tinyURL.com/pancakeengineering
- Pictures are from Holliston Coleman, and Matthew d'Alessio, *California State University, Northridge.*

Grade Five – Instructional Segment 2: From Matter to Organisms

Prior to reaching grade five, students have developed understanding of the DCIs 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. Now, students tie all these ideas together with a **model [SEP-2]** that describes how ***energy and matter flow [CCC-5]*** within a ***system [CCC-4]***. They trace matter from nonliving sources (water and air), to plants, animals, decomposers, and back again to plants. They also use their models and look for evidence to describe how ***energy flows [CCC-5]*** from the Sun to plants to animals.

Grade Five – Instructional Segment 2: From Matter to Organisms
Guiding Questions: *What matter do plants need to grow?* *How does matter move within an ecosystem?* *How does energy move within an ecosystem?*
Students who demonstrate understanding can: **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.]** **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.] (Introduced but not assessed until IS3)**
The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	**Highlighted Disciplinary Core Ideas**	**Highlighted Crosscutting Concepts**
Developing and Using Models	**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** **PS3.D: Energy in Chemical Processes and Everyday Life** **ESS2.A: Earth Materials and Systems**	**Systems and System Models** **Energy and Matter**

Highlighted California Environmental Principles & 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.

Principle II The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

Principle III Natural systems proceed through cycles that humans depend upon, benefit from and can alter.

Principle IV The exchange of matter between natural systems and human societies affects the long term functioning of both.

Principle V Decisions affecting resources and natural systems are complex and involve many factors.

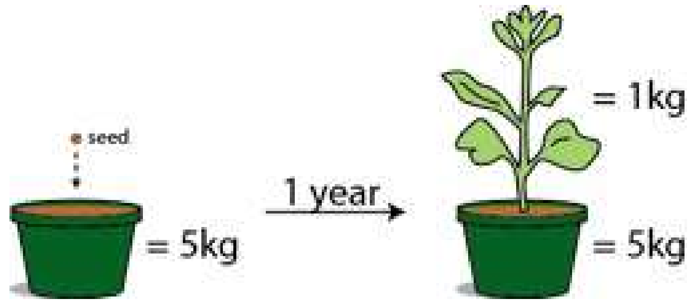
Students have specifically investigated the needs of plants in kindergarten and grade two. Teachers can probe their students' existing ideas about plants by asking students to provide evidence that makes them **agree or disagree with the claim [SEP-7]**, "Plants can grow without soil." Students can directly investigate the question by trying to germinate and grow seeds in a medium of wet paper towels (inside a CD case so that they can watch the process). They can also try to regrow lettuce, celery, or other plants in water alone by placing the bottom section of a head of lettuce into a cup of water (Figure 419). Students can track the weight of the plant and the weight of the water they add.

Figure 419. Lettuce Growing Without Soil

Source: Misella https://www.youtube.com/watch?v=PTsSVQYezeM

One of the first scientists to test out similar ideas was Jan Baptist van Helmont in the 1600s. 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 surprised to discover that the weight of the soil was still about 5 kg (Figure 420). 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 seems to be the most likely source. But his experiment showed otherwise. Where does the mass in plants come from? It must come from one or both of the plant's other needs for matter, air and water. By tracking the amount of water in their own experiments, students may be able to figure out the answer. Unfortunately, the experiment is quite challenging to do precisely because water evaporates so easily. Could students design a better experiment than either van Helmont's or their own to figure out the contributions to the plant's mass? Students will revisit this concept again in middle school when they develop a model of the chemical reactions by which atoms are rearranged from air and water molecules and transformed into plant molecules (MS-LS1-7).

Figure 420. Van Helmont's Experiment



Source: Original picture by Ed Himelblau.

During the days that it takes the seeds and lettuce to germinate and grow, students can perform other simple **investigations [SEP-3]** to track the ***flow of matter [CCC-5]*** into plants. They can place celery or flowers in colored water to see transportation of water into the celery or flower, or try to grow a plant in a closed container with no air flow into the container. As they add their own measurements from seeds and plants grown in water alone, students should have enough evidence to construct an argument that plants get the materials they need to grow primarily from air and water (5-LS1-1). At grade five, students do not distinguish components of air such as oxygen and carbon dioxide but can describe the gases generally as 'air.' Carbon dioxide in the air is a key ingredient in photosynthesis, a process used by plants to convert energy from the Sun into a form they can use to grow and reproduce. The DCI progressions from Appendix 3 of this *Science Framework* do not introduce the term photosynthesis until middle school. The rationale for this delay is to wait until the specific chemical process is introduced before giving it a label.

Since plants can survive with only air and water, can people? Students observed in kindergarten that all animals require food (K-LS1-1) because animals lack the ability to directly convert sunlight energy into usable energy. The next section explores the interdependence of animals and plants.

Plants within Ecosystems

Students constructed arguments that organisms interact with their environment in grade three (3-LS4-3). Now, students examine these dependencies in terms of the flow of energy and matter. There is no clearer illustration of the interdependence of organisms than a sealed glass sphere (Figure 421) containing algae, brine shrimp, some air and water. If plants consume air and water resources from their environment, how can they continue to survive in the sealed sphere? Won’t they run out of air? They would not survive alone, but the entire system can persist because the organisms exchange matter back and forth with one another. A system in which organisms interact and exchange matter and energy with each other and their environment is called an ecosystem.

Figure 421. A Sealed Glass Sphere Contains an Entire Ecosystem

Source: Ecosphere.

As animals eat plants, they consume all the matter in the plants. They can use this matter as raw material for growing their own body and they can metabolize it to convert it into usable energy. The same process occurs when animals eat other animals. Tracking which animals eat one another allows students to create a model of how energy and matter flow in an ecosystem. This

model [SEP-2] is called a food web. Students can construct food webs by making direct observations about what animals consume. Observations can be in small classroom ecosystems such as a terrarium or fish tank or, whenever possible, students should take field trips to observe plants and animals in more natural conditions (including urban environments like parks as well as nature centers and outdoor schools).

Students can draw a food web for the visible organisms in the sealed sphere ecosystem of Figure 421 – a very simple diagram showing brine shrimp eating algae. This relationship benefits the shrimp, but it does not explain how the algae (plants) continues to survive as it consumes all the air in the sealed container. A food web is not a complete model of the flow of matter in an ecosystem. The algae transform energy from the light entering the ecosphere, and all of the organisms, including plants, give off "waste."

To extend their models, students can investigate some of the waste products produced by plants. When students place a plastic bag over the leaves of a plant, the inside of the bag gets wet revealing that the plant gives off water. When they submerge *anacharis* (elodea) or rosemary plants in water, they observe tiny bubbles of gas released from the leaves. Students can measure the quantity of gas by counting bubbles or trapping the gas in an inverted test tube placed over the plant, recognizing that the rate of gas release depends on the amount of light shining on the plant. Is the gas that plants take in the same as the gas they release? Unfortunately, students do not have the tools to distinguish between these gases. They will have to wait to middle school to answer this question. Even without this information, students should be able to **explain [SEP-6]** 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). Similarly, they can integrate their own waste products into the model.

Because they are often not visible, few people are aware that decomposers play a very important role in the flow of matter and energy through ecosystems. Students can view a sample of the water (or at least a photograph or video of it) from a local pond, stream, or even a drainage ditch, under a powerful microscope (with magnification of at least 400x) and see tiny bacteria floating around. What do they eat? How do they fit into the model of energy and matter flow? Students discuss the possibilities and come up with four options: (1) they get energy from the Sun like plants; (2) they eat the algae; (3) they eat the brine shrimp; and (4) they eat the waste given off by the other organisms. They rule out the possibility that the bacteria eat the brine shrimp because the shrimp are still alive. Students must **obtain information [SEP-8]** to learn more about bacteria in order to choose from among the remaining options. While some single celled organisms can get energy from the Sun, bacteria do not. Many bacteria eat the waste from other organisms. Many bacteria live inside the human intestine and eat parts of our food that we cannot digest by ourselves. When an organism dies, the matter and nutrients that they have accumulated over their lifetime remain trapped in their body.

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, consume plant and animal bodies, releasing energy and nutrients in a form that makes them more readily accessible to other organisms. Without decomposers, dead plants and animals and their waste products would accumulate in ecosystems and the energy and matter they contain would not be available to other organisms. Students add decomposers into their ecosystem models.

Grade Five Snapshot: Cycles of Decomposition

Ms. D has coordinated with the staff at a local nature and they have identified a specific area where the class can **investigate [SEP-3]** food webs and observe an area where decomposition is an active process. On the day of the field trip, the nature center staff helps students identify several different producers and consumers. As students discover what lives in the area, they work together to create and discuss a food web.

Ms. D then asks, “What happens when one of the plants or animals in the food web dies?” The students look around for evidence of decomposition nearby. They identify fallen leaves, a rotting tree trunk, and a dead insect on the ground. Ms. D asks them what is happening to those objects, and leads them through a discussion about how the tree trunks, leaves, and animals are breaking down and reentering the soil.

When they return to the classroom after the field trip, Ms. D has them read an informational text about some of the organisms involved in decomposition and how they relate to the rest of the ecosystem[4]. She then projects different examples of decomposition in action[5] and asks the students to describe what they see. In each case, Ms. D asks students where does the matter come from and what happens to it after it decomposes. She emphasizes 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 practice **constructing explanations [SEP-6]** of the decomposition process, she distributes a drawing with a sequence of events that relate to decomposition[6] (leaves fall, worm eats leaves, worm feces fertilize soil, bird eats worm, etc.). Students have to write brief descriptions about each step and how it relates to the ***flow of energy or matter [CCC-5]*** in the ecosystem.

Ms. D leads a class discussion about the picture and asks students if they notice any patterns in the sequence of events. 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 [CCC-5]*** 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 [CCC-5]*** in the diagram is

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[4] EEI. “*Decomposition in the Forest*.” http://www.calrecycle.ca.gov/eei/UnitDocs/Grade04/42c/42cSW.pdf, p. 12.

[5] EEI. “*Evidence of Decomposition*” http://www.calrecycle.ca.gov/eei/UnitDocs/Grade04/42c/42cVA.pdf, pp. 2-4.

[6] EEI. “Breaking it down—In the Forest.” http://www.calrecycle.ca.gov/eei/UnitDocs/Grade04/42c/42cSW.pdf, p. 13.

an example of a ***cycle [CCC-5]***. She then writes a definition for the word “cycle” on the board, “a series of processes or events that typically repeats itself.”

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” (CA EP&C 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, including what we eat, the plants we can grow and the overall functioning of our economies and cultures (CA EP&C I). 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.

While students collected evidence that plants can grow for at least some time without soil, plants acquire some essential materials from the soil. Nitrogen, iron, and many other nutrients must be obtained from the soil (usually by the roots) because plants cannot survive without these. These nutrients, however, 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. Again, plants provide a means for animals to get many of the nutrients they need. For example, animals need very tiny amounts of metals like iron, zinc, and magnesium to survive, but they cannot get all the nutrients they need by just eating soil. To take these nutrients into their 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 their roots. Animals consume these nutrients when they eat plants, or eat other animals that have previously eaten plants. Students integrate this information into their model. How will they represent the fact that nutrients are only a tiny fraction of the plant's mass yet are important for plant growth and survival?

Students must now reflect on their models of ecosystems and develop ways to represent and **communicate [SEP-8]** them. They could play games (physical or kinesthetic models) where primary producers "take" energy from the sun, use some for growth and respiration and pass the rest to primary consumers and so on. The assessment chapter of this *Science Framework* (Chapter 7) includes a snapshot demonstrating how students can use a pictorial model generated on a computer to represent the energy flow in an ecosystem. They should be able to use their model to explain how the energy animals use to grow and survive originated as energy from the Sun (5-PS3-1).

This IS reflects one of the key instructional shifts of the CA NGSS of a focus on SEPs like developing and refining models. Rather than having teachers present students with a model of ecosystems and defining the vocabulary terms of producers, consumers, and decomposers as components of the system, students began with an incomplete model. As they explored different phenomena, they progressively revised and extended their model to include additional exchanges of matter. The model students have at the end of grade five is by no means complete – they will revise it in middle school and again in high school. Despite the fact that this research began in the 1600's with van Helmont, professional scientists are continuing to refine the models of mechanisms and relationships within ecosystems. As teachers focus on **developing and using models [SEP-2]**, students will gain useful insight into the nature of science as well as constructing their own understanding of DCIs about ecosystems.

Sample Integration of Science and ELD Standards in the Classroom*

Students have observed, through pictures and simulations, some representations of the movement of matter within ecosystems. Working in small groups, the students build on those experiences by using their science texts and notes as they collaboratively construct their models of how matter moves within ecosystems. Each group constructs an argument about its model, focusing on the movement of matter among plants, animals, decomposers, and the environment. Each group shares its model with another group, while the other group provides feedback based on a co-constructed set of criteria on: 1) presentation effectiveness, 2) the types of materials and representations used, and 3) whether the cycling of matter is accurate (5-LS2-1). During their conversations, the students refer to a large chart on the classroom wall that contains options for different language purposes, such as entering a conversation (e.g., "One/another piece of evidence that supports our argument is ___."); agreeing and disagreeing (e.g., "I can see your design has ___; however, ___."); or elaborating on an idea (e.g., "That's a good choice for ___, and I'd like to add that ___."). To support students at the Emerging level of English proficiency, the teacher asks each group to practice what each member of the group will share, and no member is permitted to opt out. The teacher has created heterogeneous groups, ensuring that each student at the Emerging level of English proficiency has a “language buddy” who is proficient in both English and the student’s home language. The teacher has also created a supportive environment so that the students work together to make sure that each of the other students understands and can communicate that understanding.

ELD Standards: ELD.PI.4.3

*Integrating ELD Standards into K–12 Mathematics and Science Teaching and Learning: A Supplementary Resource for Educators” Pages 248–49

Sample Integration of Science and ELD Standards in the Classroom*

Students who have worked in small groups to create models about the cycling of matter in ecosystems provide feedback to their peers, using appropriate verb tenses (e.g., "At first, the arrows you drew *were pointing* toward the soil. Now you *have changed* them, so I understand that materials from the water and air *go* into the plant.") (5-LS2-1). The teacher provides verbal support to students at the Emerging level of English proficiency by highlighting specific verb tenses for specific purposes in texts and speech.

ELD Standards: ELD.PI.4.3

*Integrating ELD Standards into K–12 Mathematics and Science Teaching and Learning: A Supplementary Resource for Educators" Pages 275-276

Grade Five – Instructional Segment 3: Interacting Earth Systems

Scientists have developed a way of thinking about the Earth as a system of systems (much like the human body is a system of systems). A system has internal components that interact with one another (like the water cycle on Earth or the nervous system in a human body), and a system also interacts with its surroundings (like when water in the water cycle causes a flood or when the nervous system causes a muscle to move). In this IS, students explore each of Earth's systems and how they work together to explain various phenomena. They then obtain information about the role of humans in altering natural interactions. Students finish with action plans about what they and their community can do to minimize the effects on humans and the impact of human activities on natural systems.

Grade Five – Instructional Segment 3: Interacting Earth Systems
Guiding Questions: *How can we represent systems as complicated as the entire planet?* *Where does my tap water come from and where does it go?* *How much water do we need to live, to irrigate plants? How much water do we have?* *What can we do to protect Earth's resources?*

Students who demonstrate understanding can:

5-ESS2-1. Develop a model using an example to describe ways 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. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [Assessment Boundary: Assessment is limited to the interactions of two systems at a time.]

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-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

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.

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.

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.

**California clarification statements, marked with double asterisks, were incorporated by the California Science Expert Review Panel

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
Developing and Using Models	**ESS2.A: Earth Materials and Systems**	**Systems and System Models** **Energy and Matter**

Obtaining, Evaluating, and Communicating Information	**ESS2.C: The Roles of Water in Earth's Surface Processes** **ESS3.C: Human Impacts on Earth Systems**	
Highlighted California Environmental Principles & 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. Principle II The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies. Principle III Natural systems proceed through cycles that humans depend upon, benefit from and can alter. Principle IV The exchange of matter between natural systems and human societies affects the long term functioning of both. Principle V Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.		
CA CCSC Math Connections: 5.MD.1; 5.MD.5b; 6.RP.3; 5.NF.2; 5.G.2; MP. 2, 6		
CA CCSC ELA/Literacy Connections: SL.5.1, 4, 5		
CA ELD Connections: ELD.PI.5.1, 6		

To begin, students visit a small "ecosystem" on their schoolyard. Their goal is to observe and list as many objects in the ecosystem as possible. Returning to the classroom, they look at pictures of more ecosystems (ideally a wide variety of local settings they have visited) and again make lists of all the components in each ecosystem. Students then work in teams to group all these different items into four or five categories. Students will have to formulate these categories themselves based on the similarities they think are most important between groups of objects on their lists. To help students understand the process of making and assigning categories, teachers can demonstrate the process by assigning different items to categories of color (which is not a very useful organizational scheme for scientists). Groups then **communicate [SEP-8]** their rationale for selecting their categories. Professional scientists came up with the categories of Earth's four major systems: geosphere, hydrosphere, atmosphere, and biosphere (Table 41). These “spheres” are no more ‘real’ than the categories students created – they are a consensus based upon evidence about how objects interact. In fact, some scientists argue that there should be a fifth sphere called the anthrosphere that highlights the importance of humanity and all its creations.

Table 45. Earth's Systems

Earth’s System	**Earth’s Materials**
Geosphere	*Rocks, minerals, and landforms* at Earth’s surface and in its interior, including soil, sediment, and molten rocks.
Hydrosphere	*Water*, including ocean water, groundwater, glaciers and ice caps, rivers, lakes, etc.
Atmosphere	*Gases* surrounding the Earth (i.e., our air)
Biosphere	*Living organisms*, including humans.

Students return to the photographs of the ecosystems and their lists, sorting the objects into the four different Earth systems. All four systems interact (exchange energy and matter) with all the other systems – they are completely interconnected, and as a result significantly influence each other. Students can try to identify some of these interactions in their ecosystem pictures. For example, a river flowing over rocks results and components of the hydrosphere causing erosion in the geosphere and helping support life in the biosphere. The water itself almost certainly comes from clouds in the atmosphere, and the cool water (along with shade from the trees of the biosphere) keeps the temperature low in the atmosphere immediately surrounding the river banks. Table 46 shows a scientist’s **model [SEP-2]** for different ***cause and effect relationships [CCC-2]*** between the different Earth systems. At grade five, students will not have background knowledge of all these interactions, but the blank table itself can prompt them to seek out these relationships. Each of the cells in the table describes one or more specific phenomena that students can investigate.

Students should be able to create a **model [SEP-2]** of how one or more phenomena exemplify interactions between different Earth systems (5-ESS2-1). Several processes such as the water cycle (MS-ESS2-4) and the global carbon cycle (HS-ESS2-6) involve complicated interactions between multiple Earth systems and are the focus of middle and high school lessons, respectively. Grade five students focus on simpler interactions between two Earth systems.

Table 46. Examples of Interactions Between Earth Systems

Effect *Cause*	**Geosphere**	**Hydrosphere**	**Atmosphere**	**Biosphere**
Geosphere	Rock cycle. Volcanoes erupt lava. Earthquakes thrust up mountains.	Topography affects where rivers go.	Volcanoes erupt gases. Mountains funnel winds and affect the movement of clouds.	Minerals in soil provide nutrients for plants.
Hydrosphere	Water erodes rocks.	Water cycle. Rivers flow into the ocean.	Water evaporates.	Water sustains all life.
Atmosphere	Chemical weathering of rocks. Wind erodes rocks.	Winds blow clouds.	Weather and climate cycles.	Air sustains all life.
Biosphere	Decomposers enrich soil.	Plant roots soak up water.	Plants give off water and gases as waste.	Food webs.

Opportunities for ELA/ELD Connections

In small groups, students choose and verbally describe and physically demonstrate the interactions between two of these four systems—geosphere, biosphere, hydrosphere, and atmosphere—using multimedia and/or visual displays. These demonstrations could include students recreating the interaction (e.g., one student is water and another student is wind) to illustrate what happens to land and ecosystems through weather and climate when two systems interact in the atmosphere.

ELA/Literacy Standards: SL.5.1, 4, 5

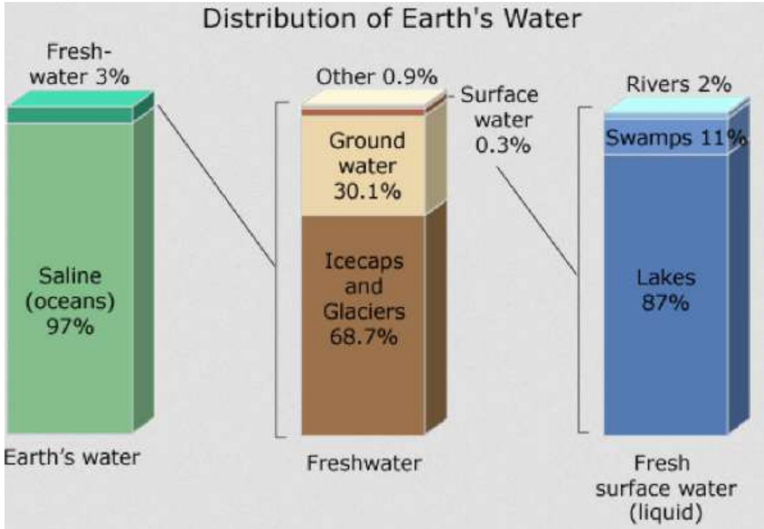
ELD Standards: ELD.PI.5.1, 6

One of the reasons for describing different Earth systems is to focus on their interactions and how they influence each other, especially the interactions that cross traditional disciplinary boundaries. Just as matter, like contaminants and pollution, crosses these boundaries (CA EP&C IV), the thinking of citizens of all ages and scientists must do so as well. Examples of contamination in the hydrosphere are tangible, as students already have mental models for how water flows and can extend those models to include interactions with other parts of the Earth system.

As part of their understanding of the hydrosphere, students must be able to describe where water is located on Earth. Students will build on this understanding in grade six when they develop a model of the water cycle (MS-ESS2-4) that describes how water moves within the hydrosphere and into other Earth systems. In addition to knowing where water is located, students should be able to use **mathematical thinking [SEP-5]** to describe the relative proportions of water found in different forms (

Figure 422). *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). Humans and all other life depend on this tiny fraction of Earth's water for survival (CA EP&C I). This relative scarcity is why drought and contamination are such important issues in California, and why human activities can have such large influences on natural cycles (CA EP&C III).

Figure 422. Distribution of Earth's Water



Ninety-seven percent of water is undrinkable (from the oceans) and only 3% is fresh water found in icecaps, ground, lakes, rivers and swamps. Source: U.S. Geological Survey 2015d.

Opportunities for Math Connections

In 5-ESS2-2, students do not study percentages or ratios until grade six. 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. 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.

Math Standards: 6.RP.3, 5.NF.2, 5.G.2, MP. 2, 6

Students can **obtain information [SEP-8]** about the source of their local tap water and which human activities are the primary users of the local water sources. What measures are taken to protect these sources? A field trip to a local wastewater treatment plant or a local farm that uses dry farming techniques can help students think about problems and solutions that help us protect our resources. Student work focuses on **obtaining, evaluating, and communicating information [SEP-8]** that shows how human activities in agriculture, industry, and everyday life have major effects on the land, vegetation, streams, underground water storage levels (aquifer), and ocean (CA EP&C II).

This focus on water is then broadened to consider other human impacts on all Earth ***systems [CCC-4]***. 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, emphasizing specific ***cause and effect [CCC-2]*** relationships where a particular technology or action (CA EP&C V) prevents the exchange of pollutants between different parts of Earth's systems or otherwise reduces human-induced ***changes [CCC-7]*** to these systems.

Opportunities for Math Connections

Students create a map of storm water flow on their schoolyard. Where does the water go when it leaves the schoolyard? What contaminants might it pick up and wash into the local waterways? (CA EP&C II). Using the area they **measure [SEP-5]** on a map of their schoolyard, students calculate the total volume of water that falls on their schoolyard or rooftop in a rainstorm. They **calculate [SEP-5]** how many 55-gallon rain barrels this water would fill up and how long this water would supply their school garden. Students then prepare a presentation to their school site council proposing the installation of a rainwater capture system on their schoolyard such as rain barrels or a cistern.

Math Standards: 5.MD.1; 5.MD.5b

Engineering Connection

As water passes through layers of the Earth in nature, contaminants are filtered out or settle. Sometimes, however, humans pollute the water with contaminants that are not naturally filtered out (CA EP&Cs II, IV). In order to protect the environment, humans also use water filtration to clean water so that we can use it or it can be returned to the natural environment. In 2014, California's Proposition 1 allocated almost $1.5 billion to groundwater cleanup efforts and future investments are also likely. Engineers will need to develop new techniques and procedures, and existing ones need to be refined to make them more effective and cheaper (CA EP&C V). In this activity, students play the part of groundwater contaminant engineers and design a simple filter to clean dirty or contaminated water[7]. Students **define the problem [SEP-1], gather information [SEP-8]**, **plan a solution [SEP-6]**, 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 [SEP-2]**, build it, test it, and then compare their filtered water against a color standard. Students can refine their design by trying to keep it effective but use less material.

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[7] Teach Engineering. 2013. "Hand-on Activity: Water Filtration." https://www.teachengineering.org/activities/view/water_filtration (Accessed May 25, 2016).

Grade Five – Instructional Segment 4: Patterns in the Night Sky

Each night, the Sun sets and the stars become visible. At first glance, stars appear to be randomly strewn about the sky with some shining brighter than others. As the human eye is drawn to patterns, ancient people imagined the brightest stars marking the outlines of animals and people. Modern students can use detailed measurements of where stars are in the night sky, how bright they are, and when they become visible to discover patterns in the motion of celestial bodies. Instructional Segment 4 provides the data and analysis that set the stage for much more sophisticated models of planetary motion and the origin of the Universe in the middle grades and high school. Instructional Segment 4 has three independent sections: (1) Gravitational Force; (2) Patterns of Motion; and (3) Brightness of Stars.

Grade Five – Instructional Segment 4: Patterns in the Night Sky
Guiding Questions: How far away are the stars? How can we tell? What trends and patterns are there in the movement of the Sun and stars?
Students who demonstrate understanding can: **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).]		
The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:		
Highlighted Science and Engineering Practices	**Highlighted Disciplinary Core Ideas**	**Highlighted Crosscutting Concepts**
Analyzing and Interpreting Data	**ESS1.A: The Universe and its Stars** **ESS1.B: Earth and the Solar System** .	**Patterns** **Scale, Proportion, and Quantity**
CA CCSC Math Connections: 4.MD.6; 5.NF.6; 5.G.2		

The night sky is full of wonder. Grade five students should begin by asking questions about the stars, the planets, and space exploration. During this segment, teachers should strive to relate the learning required in the *CA NGSS* to students' interests and emphasize questions about "how far?" and "how do we know?"

Gravitational Forces Pull Down

Grade five is the first time that students explicitly focus on gravity in the *CA NGSS*, though they may have used it as an example of a force in grade three. The gravitational force is an extension of other non-contact forces (a force that acts even when objects are not touching) that students investigated in grade three (magnetic and electrostatic electricity). Gravity has profound impact on our everyday lives and is also foundational to Earth's place in the Universe (ESS1), though the connection to planetary motion is beyond grade five. At this point, students just need to gather evidence that gravity always pulls objects downward. Since students cannot directly observe forces, they will need to apply their model that objects move in the direction in which forces are applied (3-PS2-1). Downward is a relative term – it refers to the center of the planet. For astronauts in orbit, the direction of 'down' is constantly changing as they circle around the planet.

Opportunities for Math Connections

Students can tie a string to a meter stick and attach a weight to the string. Using a carpenter's level (or calibrated smartphone app), students can arrange the meter stick so that it is perfectly horizontal. Then, students measure the angle between the meter stick and the string. Since gravity always pulls downward, the angle should always be 90°. Students will find it challenging to get precise measurements because the meter stick will not be exactly level and the string will swing back and forth. By sharing multiple measurements, students can see the power of averaging multiple results to minimize experimental error.

Math Standards: 4.MD.6

Earth Patterns: From a Day to a Year

Students observed the patterns of shadows, the Sun, and Moon in grade one (1-ESS1-2), but now they bring the more advanced quantitative skills to analyze the data. A fifth-grade class could partner with a first-grade class to collect observations. The fifth graders would prepare graphs and presentations and present them back to their first-grade buddies ('planet partners'?). Students can make graphs of the length of shadows throughout a day, the length of shadows at the same time every day for a month or more, or the number of daylight hours throughout the year. Students can use free planetarium software[8] to simulate measurements during the night. Each student could track a different star every two hours for a week's worth of nights (which is much quicker to do in a simulator than in real life!). After recording data, they can plot their star's position by its compass angle and observe how its position changes. What

[8] Stellarium, http://www.stellarium.org/ (Accessed May 25, 2016).

patterns do they recognize? How often do these patterns repeat? Can they predict the star's position 24 hours in the future? It will be in a similar position, but not identical. How about six months in the future? Some students will discover that their star is not visible six months later. This might prompt students to collect data at larger time intervals such as at the same time every month for a year or two. The goal is for students to recognize that there are multiple cycles of motion occurring simultaneously. The Sun and stars return to a similar location every 24 hours, but their position slowly migrates over the course of 365 days. Students will explain these patterns using a model in the middle grades, but students should recognize similarities between the behavior of the Sun and the stars. These similarities imply that whatever causes one to appear to move likely causes the others.

Opportunities for Math Connections

Students obtain information about sunrise and sunset times from an online database. They calculate the length of daylight by representing hours and minutes as mixed numbers (5.NF.6). They plot the number of hours of daylight versus the number of days since January 1 (numbers from 1-365) in the first quadrant of the coordinate plane. What ***trends or patterns [CCC-1]*** appear? Students **ask questions [SEP-1]** about what ***causes [CCC-2]*** these patterns. How long does it take for the pattern to repeat? Having different students use data from different years allows students to recognize that the pattern repeats almost exactly every 365 days.
Math Standards: 5.NF.6; 5.G.2

Far, Far Away

Ask students to draw what the night sky looks like and most of them will include a few bright stars surrounded by immense blackness (and possibly the moon, though it is a feature of the daylight hours as often as it is the night sky). If students observe the night sky through a small telescopes or even binoculars, they see that the dark sections of the sky are not as dark as they thought. They are filled with thousands of star and galaxies too far and too dim to see with the naked eye. Students can experience a similar phenomenon by making a **physical model [SEP-2]** of stars on the schoolyard using flashlights. Each student goes to a different place on the schoolyard and holds an identical flashlight. Students that are close together can see one another's flashlights shining, but it is hard to tell if distant flashlights are on or off at all. What would happen if one flashlight were brighter than the others? Students can refine their model for what determines the apparent brightness of a star to include both the amount of light energy released by the star (called 'absolute brightness' in astronomy) and how far the star is away from Earth.

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. By using models of how stars shine, astronomers can calculate how big a star is and they find that our 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. The farthest stars away in the Universe are hardly even visible with the best telescopes. When the Hubble space telescope pointed in the same spot in the darkest part of the sky for ten days straight, it gathered enough to see the faintest stars ever observed. This "Hubble Deep Field" image[9] is a profound reminder that even something that appears to be nothingness holds more complexity in it than we can imagine.

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[9] NASA. Hubble Deep Field. http://hubblesite.org/hubble_discoveries/hubble_deep_field/