# Grade Six – Preferred Integrated Learning Progression Course Model

This section is meant to be a guide for educators on how to approach the teaching of *CA NGSS* in grade six according to the Preferred Integrated Learning Progression model (see the introduction to this chapter for further details regarding different models for grades six, seven and eight). It is not meant to be an exhaustive list of what can be taught or how it should be taught.

A primary goal of this section is to provide an example of how to bundle the PEs into integrated groups that can effectively guide instruction in four sequential Instructional Segments. There is no prescription regarding the relative amount of time to be spent on each Instructional Segment. As shown in Figure 1, the overarching guiding concept for the entire year is that, “Climate arises from system interactions and strongly influences organism structures and behaviors.”

**GRADE 6 INTEGRATED STORYLINE**

**Climate arises from system interactions and strongly influences organism structures and behaviors.**

| | Life Science | Earth & Space Science | Physical Science | ETS |
|---|---|---|---|---|
| Unit 1 | **A cell, a person and planet Earth are each a system made up of subsystems.** | | | |
| | All living things are made of cells.<br>The body is a system made of multiple interacting subsystems. | Water continually cycles among the land, ocean and atmosphere.<br>Weather and climate involve interactions among Earth's subsystems. | | Design criteria<br>Evaluate solutions |
| Unit 2 | **Weather conditions result from the interactions among different Earth subsystems.** | | | |
| | | Changes and movements of water help determine local weather patterns.<br>Motions and interactions of air masses result in changes in weather conditions.<br>The ocean exerts a major influence on weather and climate. | Temperature is a measure of average particle kinetic energy.<br>Energy transfers from hotter regions or objects to colder ones.<br>Temperature change depends on the environment and type/amount of matter. | Design criteria<br>Evaluate solutions<br>Analyze data<br>Iteratively test & modify |
| Unit 3 | **Regional climates strongly influence regional plant and animal structures and behaviors.** | | | |
| | Variations of inherited traits arise from genetic differences.<br>Genetic factors and local conditions affect the growth of organisms<br>Organism structures and behaviors affect the odds of successful reproduction. | Interactions involving sunlight, the atmosphere, hydrosphere, geosphere & biosphere vary with latitude and altitude, and strongly influence regional climates.<br>The ocean exerts a major influence on climate.<br>Variations in density drive drive a global pattern of interconnected ocean currents. | The amount of energy transfer needed to change the temperature of matter depends on the nature of the matter, the size of the sample and the environment. | |
| Unit 4 | **Human activities can change the amount of global warming and its impacts on plants and animals.** | | | |
| | Local conditions affect the growth of organisms.<br>Plants and animals have behaviors and structures that lead to successful reproduction, but that may not be successful in the changing climate. | Human changes to Earth's environments can have different impacts on different organisms.<br>Burning of fossil fuels is a major cause of global warming. Applying knowledge wisely in decisions and activities can reduce the amount and impacts of climate changes. | | Design criteria<br>Evaluate solutions<br>Analyze data |

**Figure 1:** Storyline for Integrated Grade 6 showing the flow of the ideas and the distribution of disciplinary content within and across the Instructional Segments.

Students begin their explorations in Instructional Segment 1 (IS 1) by applying the crosscutting concept of ***Systems and System Models*** to different Earth science and life science contexts. A key understanding from IS 1 is that **systems** are made of component parts that interconnect with each other. Moreover each of the component parts is itself a system that is made of component parts. This notion of *systems within systems within systems* (also called nested systems) is particularly apparent in analyzing a "human being system" that is made of components called body systems (e.g., the circulatory system) that are made of organs (e.g., the heart) that are made of tissues that consist of different kinds of cells.

In IS 2, students apply the ***systems*** crosscutting concept to the topic of California weather. In Grade 5 students **developed models** of how various Earth systems interact. They also explored the reservoirs of the water cycle. In IS 2 students deepen their understanding by **analyzing** the processes of the water cycle and the physical science underlying these processes. These Earth science and physical science concepts are then applied to understanding weather in different California regions. ***Patterns*** of temperature and precipitation are **causally related** to geographical features such as proximity to the ocean, latitude, altitude, and proximity to mountains. The water cycle is also very important conceptually because of its central role in weather phenomena and because it provides an example of a ***property of a whole system*** that is different than the properties of its parts.

IS 3 extends the students' investigations of phenomena to the more general level of regional climate in different parts of the planet. At the level of climate, students can correlate the ***cause and effect*** relationships that **determine** regional climate patterns and the ***circulation of matter and energy*** by the atmosphere and ocean. Students also correlate ***cause and effect*** relationships between the climate of a region and the structures and behaviors of plants and animals that live in that region. Regional climate provides another compelling example of a property of a ***whole system***.

IS 4 concludes the year by ***scaling*** from the regional climate level to the level of global warming. In previous Instructional Segments, students had several opportunities to design solutions to problems primarily from engineering and technology perspectives. During IS 4, they have opportunities to work on projects related to monitoring an environmental issue and **designing solutions** to reduce the impacts related to that issue. Global climate change provides many interesting opportunities to further develop and apply skills relating to the technological and scientific aspects of **solving societal problems**. Global climate change also provides a real world context where some of the **criteria and constraints** can involve human psychological and social motivations and patterns of behavior that must be considered as part of the design in solving a problem. Table 1 provides a complementary overview of these four example Instructional Segments. Each Instructional Segment includes a listing of the Performance Expectations that are addressed, highlighted Science and Engineering Practices (SEP), Disciplinary Core Ideas (DCI), and Crosscutting Concepts (CCC). Detailed descriptions of each Instructional Segment begin immediately after Table 1.

**Table 1: Summary table for Integrated Grade 6**

<table>
<tr><td rowspan="6">Instructional Segment 1:<br>Systems and Subsystems in Earth and Life Science</td><td colspan="3">Instructional Segment 1: Performance Expectations Addressed</td></tr>
<tr><td colspan="3">MS-LS1-1, MS-LS1-2, MS-LS1-3, MS-ESS2-4, MS-ESS2-6, MS-ETS1-1, MS-ETS1-2</td></tr>
<tr><td>Highlighted SEP</td><td>Highlighted DCI</td><td>Highlighted CCC</td></tr>
<tr><td>• Developing and Using Models<br>• Constructing Explanations and Designing Solutions</td><td>LS1.A: Structure and Function<br>ESS2.C: The Role of Water in Earth’s Surface Processes<br>ESS2.D: Weather and Climate<br>ETS1.A: Defining and Delimiting Engineering Problems<br>ETS1.B: Developing Possible Solutions</td><td>• Systems and System Models<br>• Cause and Effect: Mechanism and Prediction</td></tr>
<tr><td colspan="3">Summary of DCI</td></tr>
<tr><td colspan="3">Earth systems and the water cycle are introduced in Instructional Segment 1, and provide contexts for increasing student skills in understanding, using and developing system models. The Earth systems introduced in Grade 5 are actually subsystems of the whole Earth system. An Earth system such as the geosphere is both a component of the whole Earth system and a system that is itself made of parts. In addition to being an example of “systems within systems within systems,” the Earth system contexts exemplify that a whole system has properties such as the water cycle that are qualitatively different than the properties of its parts.<br>These systems understandings and skills are further strengthened and extended by being applied to the life science contexts of cells and body systems. All living things are made of cells. This property of life is a whole system property that arises from the interactions of the parts of the cell with each other and with the environment. Similarly, body systems exemplify “systems within systems within systems.” The whole system property of a complex animal being alive results from the interactions of its different body systems with each other and with the environment.<br>Some dysfunctional organ and tissue systems can be replaced through organ donation and transplantation. A heart transplant can realign an entire human body by a strengthened cardiovascular system, a pancreas can restore a disrupted endocrine system, and a tendon can realign the musculoskeletal system.</td></tr>
</table>

**Instructional Segment 2: Earth System Interactions Cause Weather**

| Instructional Segment 2: Performance Expectations Addressed | | |
|---|---|---|
| **MS-ESS2-4, MS-ESS2-6, MS-PS3-3*, MS-PS3-4, MS-PS3-5, MS-ETS1-1** | | |
| **Highlighted SEP** | **Highlighted DCI** | **Highlighted CCC** |
| • Developing and Using Models<br>• Constructing Explanations and Designing Solutions<br>• Engaging in Argument from Evidence<br>• Obtaining, Evaluating and Communicating Information | ESS2.C: The Roles of Water in Earth's Surface Processes<br>ESS2.D: Weather and Climate<br>PS3.A: Definitions of Energy<br>PS3.B: Conservation of Energy and Energy Transfer<br>ETS1.A: Defining and Delimiting Engineering Problems<br>ETS1.B: Developing Possible Solutions | • Energy and Matter: Flows, Cycles and Conservation<br>• Cause and Effect: Mechanism and Prediction<br>• Scale, Proportion, and Quantity |
| **Summary of DCI** | | |
| Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation, and crystallization and precipitation. The complex pattern of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.<br>Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography.<br>The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.<br>Flows of matter and energy are related to the types, states and amounts of matter present. These factors also influence the relationship between the temperature and the total energy of a system.<br>Temperature is a measure of the average kinetic energy of particles of matter.<br>Students first experience connections between thermal energy and kinetic energy at the macroscopic scale where changes in motion energy of objects generally occur at the same time as changes in thermal energy.<br>The more precisely a design task's criteria and constraints can be defined, the more likely it is that the solution will be successful.<br>A solution needs to be tested and then modified on the basis of the test results in order to improve it. | | |

| Instructional Segment 3: Causes and Effects of Regional Climates | Instructional Segment 3: Performance Expectations Addressed | | |
|---|---|---|---|
| | MS-ESS2-5, MS-ESS2-6, MS-PS3-4,<br>MS-LS1-4, MS-LS1-5, MS-LS1-8, MS-LS3-2 | | |
| | **Highlighted SEP** | **Highlighted DCI** | **Highlighted CCC** |
| | • Obtaining, Evaluating and Communicating Information<br>• Developing and Using Models<br>• Engaging in Argument from Evidence<br>• Constructing Explanations and Designing Solutions | ESS2.C: The Roles of Water in Earth's Surface Processes<br>ESS2.D: Weather and Climate<br>PS3.A: Definitions of Energy<br>PS3.B: Conservation of Energy and Energy Transfer<br>LS1.A: Information Processing<br>LS1.B: Growth and Development of Organisms<br>LS3.B: Variation of Traits | • Cause and Effect: Mechanism and Prediction<br>• Patterns<br>• Energy and Matter: Flows, Cycles and Conservation<br>• Systems and System Models |
| | **Summary of DCI** | | |

| | |
|---|---|
| | Temperature is a measure of the average kinetic energy of particles of matter. The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.<br>Animals engage in characteristic behaviors that increase the odds of reproduction.<br>Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.<br>Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.<br>Organisms reproduce, either sexually or asexually, and transfer their genetic information to offspring.<br>Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring.<br>Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. Because these patterns are so complex, weather can only be predicted probabilistically.<br>The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. |

| Instructional Segment 4: Effects of Global Warming on Living Systems | Instructional Segment 4: Performance Expectations addressed | | |
|---|---|---|---|
| | **MS-ESS3-3 MS-ESS3-5, MS-LS1-4, MS-LS1-5, MS-ETS1-1, MS-ETS1-2** | | |
| | **Highlighted SEP** | **Highlighted DCI** | **Highlighted CCC** |
| | • Asking Questions and Defining Problems<br>• Obtaining, Evaluating and Communicating Information<br>• Developing and Using Models<br>• Engaging in Argument from Evidence<br>• Constructing Explanations and Designing Solutions | ESS3.C: Human Impacts on Earth Systems<br>ESS3.D: Global Climate Change<br>LS1.B: Growth and Development of Organisms<br>ETS1.A: Defining and Delimiting Engineering Problems<br>ETS1.B: Developing Possible Solutions | • Cause and Effect: Mechanism and Prediction<br>• Energy and Matter: Flows, Cycles and Conservation<br>• Stability and Change<br>• Systems and System Models |
| | **Summary of DCI** | | |

| | |
|---|---|
| | Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.<br>Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.<br>Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.<br>Animals engage in characteristic behaviors that increase the odds of reproduction.<br>Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.<br>Genetic factors as well as local conditions affect the growth of the adult plant.<br>The more precisely a design task's criteria and constraints can be defined, the more likely it is that the solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.<br>A solution needs to be tested and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. |

**Table 2 - Grade 6 Instructional Segment 1**

**Systems and Subsystems in Earth and Life Science**

**Guiding Questions:**

What is a system?

What is the value of creating a systems model?

How are living systems and Earth systems similar and different?

**Highlighted Scientific and Engineering Practices:**

1. **Developing and using models**

2. **Constructing Explanations and Designing Solutions**

***Highlighted Crosscutting Concepts:***

1. ***Systems and System Models***

2. ***Cause and Effect: Mechanism and Prediction***

**LS1-1.** **Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.** [Clarification Statement: Emphasis is on developing evidence that living things **(including Bacteria, Archaea, and Eukarya)** are made of cells, distinguishing between living and non-living things, and understanding that living things may be made of one cell or many and varied cells. **Viruses, while not cells, have features that are both common with, and distinct from, cellular life.]**

**LS1-2.** **Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.** [Clarification Statement: Emphasis is on the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.] [Assessment Boundary: Assessment of organelle structure/function relationships is limited to the cell wall and cell membrane. Assessment of the function of the other organelles is limited to their relationship to the whole cell. Assessment does not include the biochemical function of cells or cell parts.]

**LS1-3.** **Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.** [Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.] [Assessment Boundary:

Assessment does not include the mechanism of one body system independent of others. Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.]

**ESS2-4.** **Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.** [Clarification Statement: Emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. Examples of models can be conceptual or physical.] [Assessment Boundary: A quantitative understanding of the latent heats of vaporization and fusion is not assessed.]

**ESS2-6.** **Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.** [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.]

**ETS1-1.** **Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.**

**ETS1-2.** **Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.**

Significant Connections to California's Environmental Principles and Concepts:

None

## Instructional Segment 1 Teacher Background and Instructional Suggestions

The crosscutting concept of ***Systems and System Models*** is a very useful tool that can help learners to connect ideas within a topic and also across science disciplines. Integrated Grade 6 provides ideal opportunities for students to experience the value of this crosscutting concept and to deepen students' abilities to **use and develop system models**. Planet Earth, cells, and organisms are key contexts for the disciplinary core ideas within California Integrated Grade 6. These topics serve as excellent examples of

***systems*** because each of these systems has a fairly well-defined boundary, and each system also has recognizable component parts.

Figure 2 illustrates one of the key NGSS understandings about ***systems*** at the middle school level. As described in NGSS, “Systems may interact with other systems; they may have subsystems and be a part of larger more complex systems.” The components of a system are generally themselves systems that are made of parts. Body systems provide great examples of this feature of “systems within systems within systems.”

**Systems Within Systems Within Systems**

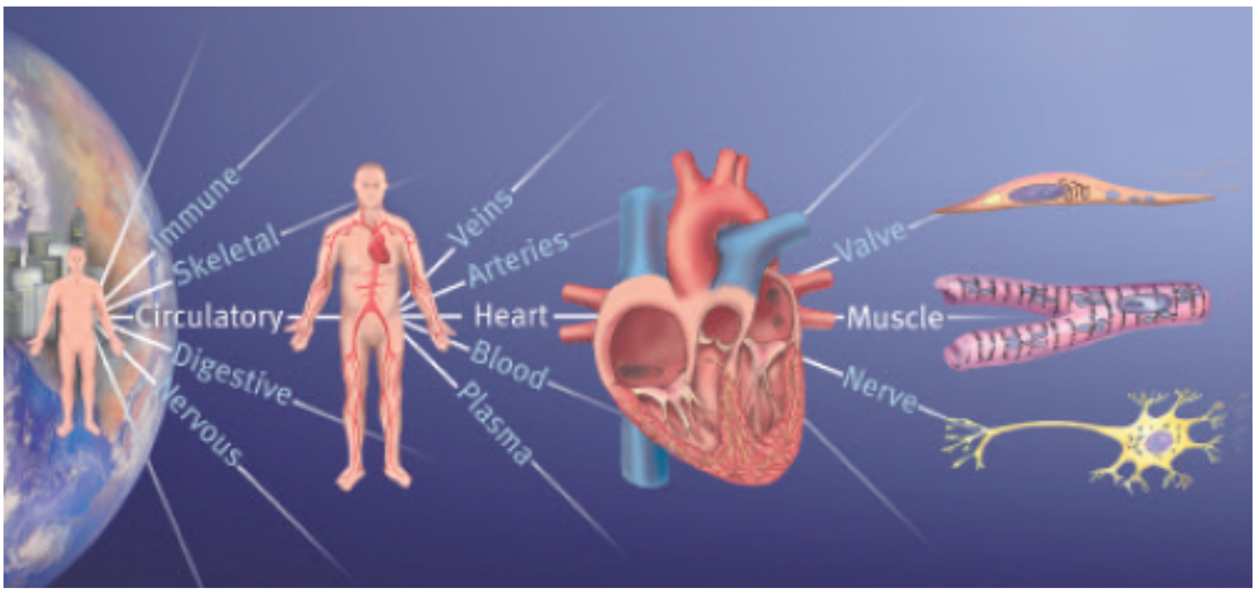


**Figure 2:** Body systems, such as the circulatory system, are examples of systems within systems within systems. (Illustration from *Dr. Art’s Guide to Planet Earth* courtesy of WestEd)

Students can **cite the circulatory system as evidence** that a person consists of body systems that are made of organs (e.g., the heart) that are made of tissues that are made of cells. An analogous situation applies with respect to ***Earth systems***. In Grade 5 students learned that planet Earth has four major systems:

* the geosphere (solid and molten rock, soil, and sediment);
* the hydrosphere (water and ice);
* the atmosphere (air); and
* the biosphere (living things, including humans).

An emphasis on planet Earth as a ***whole system*** marks a significant progression from middle school beyond the fifth grade level. From the “whole Earth” perspective, each of the Earth systems learned in fifth grade is now viewed as a component or subsystem of the larger scale planet system. Learners of all ages generally expect that definitions, especially in science, should be precise and either/or – that the geosphere, for example, is *either* its own system *or* a component of a larger system, but not both at the same time. Older grade levels in science often mark an advance beyond rigid “either/or” thinking toward “both/and” nuances and complexity. Students can **explain** how the geosphere is an example of being *both* an Earth system made of parts, *and* also a subsystem/component of the planet Earth system.

***System models*** are tools that scientists use to develop and share their understanding of the natural world. In using this tool, scientists, educators and learners have some flexibility in choosing the system boundaries and components depending on the purposes of their investigation. For example, a scientist who specializes in researching glaciers might describe Earth as having five major systems: geosphere, hydrosphere (just liquid water), cryosphere (Earth’s ice), atmosphere and biosphere. A scientist who specializes in researching the effects of human activities on the natural world might describing five Earth systems as: geosphere (solid and molten rock), hydrosphere (liquid and solid water), atmosphere, biosphere, and anthroposphere (human societies and their interactions with the natural world). While this adaptability is one of the strengths of systems modeling, it does present a challenge for learners who are trying to figure out what a system is.

Teaching about ***systems*** can begin by asking students to work individually and then in small groups to describe what systems they know about, and how they might **explain** what a system is. One typical kind of response is to equate systems with cycles such as a life cycle or a collection of circles like the solar system. This view gets broadened when other students provide examples of systems that are linear procedures to accomplish something, such as Emily’s daily system for preparing to go to school (see Figure 3).

**Emily's School Preparation System**

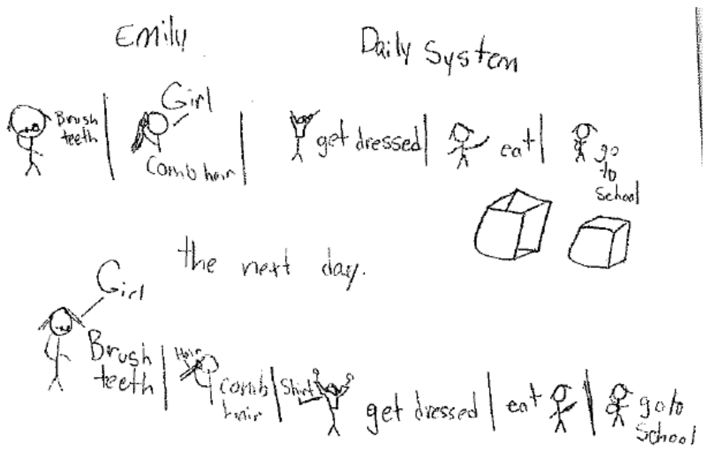


**Figure 3:** Emily's daily system to prepare for school. (Illustration from Making Sense of Science *Earth Systems* professional development course, courtesy of WestEd)

Student-generated or teacher-seeded examples of sound systems, computer systems, ecosystems, and body systems can help students to transition toward a broader consideration of systems. The teacher can then provide a background reading/writing assignment that establishes a working definition of a system as a group of things that connect or interact to form a whole. That reading also would emphasize five important features of ***systems***: boundaries, components, interactions, inputs/outputs, and one or more system properties.

Figure 4 illustrates these five ***system*** features as applied to a human person. Usually the components of a system are the easiest to identify. Some system boundaries are very obvious, as in this example, while others may require more thought. The systems modeler (scientist, teacher, student) has the most freedom in choosing the boundaries of the system based upon the goal of the modeling. In studying water, Table 3 indicates the boundaries that different people might choose because of the different goals of their investigations.

**Features of Systems**

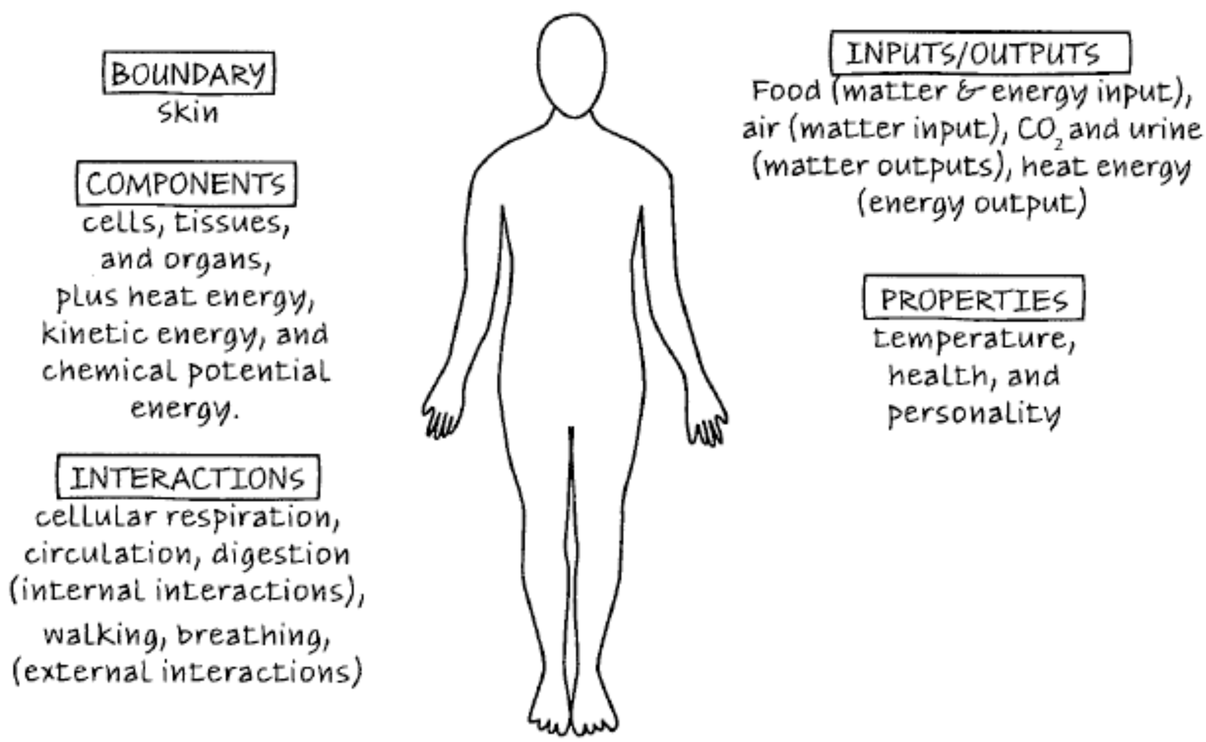


**Figure 4:** Features of a human person system. (Illustration adapted from Making Sense of Science *Weather and Climate* professional development course, courtesy of WestEd)

**TABLE 3: Different System Boundaries for Investigating Water on Earth**

| Investigation Topic | System Boundary |
|---|---|
| Changes in the water cycle due to global warming | Planet Earth |
| Using solar power to desalinate ocean water | A sunny beach on an island |

| | |
|---|---|
| Getting freshwater for a farm | Underground wells on the farm |
| Cleaning a city's sewage before it drains into the ocean | Output from city sewage facility |
| Surfing at the beginning and end of the day | Wave patterns on local beaches |

(Table 3 by Dr. Art Sussman, Courtesy of WestEd)

Using the guidelines provided by the working definition of a ***system*** and the five highlighted system features, the teacher can guide students to work in groups on **analyzing** and **modeling** different kinds of systems. These groups can then share with each other through gallery walks and other pedagogical methods to extend and deepen student proficiencies with respect to systems modeling. In IS 1, life science can provide many examples based on cells and on body systems. IS 2 provides additional detailed examples with respect to the water cycle and weather systems that then deepen student understanding of systems and system modeling as a crosscutting concept that applies in multiple disciplines. (The EEI Curriculum unit, Changing States: Water, Natural Systems, and Human Communities provides a variety of resources that can support this instruction.)

**Properties of Whole Systems**

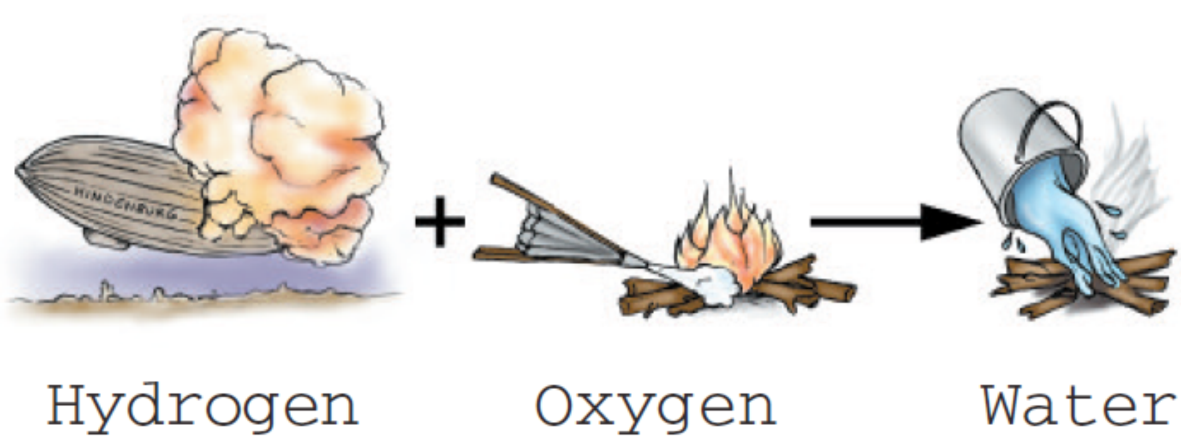


**Figure 5:** A whole system can have properties that are qualitatively very different than the properties of its parts. (Illustration from *Dr. Art's Guide to Planet Earth* courtesy of WestEd)

Students may initially struggle in describing a property of the ***whole system***. In part this difficulty can arise because the property of the whole system is often very different from the property of any of its parts. $H_2O$, the star of the water cycle, is a particularly good example of how different a whole system can be from its parts (Figure 5). The component parts of $H_2O$ are hydrogen and oxygen. Hydrogen is a gas that explodes. Oxygen is a gas that is necessary for fire. Combining these two gases produces a new system, a liquid that extinguishes fires.

Cells provide interesting examples of ***systems*** to study. The boundary of a cell is obvious, and the presence of a cell wall provides a useful way to differentiate plant cells from animal cells. For NGSS middle school, the assessed components are limited to the outer boundary, the nucleus, the chloroplast (site of photosynthesis) and the mitochondria (site of cellular respiration). The interactions, inputs and outputs vary depending on whether the cell is a unicellular organism, or a specialized cell within a multicellular organism.

The cell is often described as the building block of life. Students can be challenged to **describe and explain** a whole system property of a cell. Perhaps they will need prompting, but students should be able to explain that being alive is a property that the whole cell has that none of the cell parts by themselves have. The property of being alive ***arises from the interactions*** of all the parts of the cell with each other and with the environment. This system property of life is equally true for a multicellular organism. That organism's property of being alive is ***caused by*** and depends upon the interactions of its vital body systems with each other and with the environment.

**Engineering Connection**

Teaching about organ and tissue donation provides opportunities to connect learning about body ***systems*** with a socially beneficial topic that also has strong connections with engineering and technology. Donate Life California has an informative website that includes educator resources, notably an Interactive Body Tour (http://www.donatelifecalifornia.org/education/how-donation-works).

Students can work in groups to **research** and learn about organ and tissue donation related to different body systems and diseases. They can **create *system diagrams*** related to the different diseases and transplantation remedies as well as representing the system for soliciting donors, identifying recipients, and getting the organs/tissues to the patients in excellent condition and within the necessary **criteria and time constraints**.

If motivated in this direction, students can also **analyze** the outreach with respect to educating and motivating people to become donors. This enrollment of donors can also be analyzed as a system wherein students identify constraints and **propose solutions** to increase the number of people who volunteer to become donors. This kind of ***system modeling*** extends the crosscutting concept beyond physical science and engineering into applications of science intermixed with social science perspectives.

**Table 4 - Grade 6 Instructional Segment 2**

**Earth System Interactions Cause Weather**

Guiding Questions:

What is temperature?

Why is the weather so different in different parts of California?

How do models help us understand the different kinds of weather in California?

**Highlighted Science and Engineering Practices:**

**Developing and Using Models**

**Analyzing and Interpreting Data**

**Constructing Explanations and Designing Solutions**

**Obtaining, Evaluating, and Communicating Information**

***Highlighted Crosscutting Concepts:***

***Patterns***

***Cause and Effect: Mechanism and Prediction***

***Systems and System Models***

Performance expectations associated with this Instructional Segment:

**ESS2-4.** **Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.** [Clarification Statement: Emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. Examples of models can be conceptual or physical.] [Assessment Boundary: A quantitative understanding of the latent heats of vaporization and fusion is not assessed.]

**ESS2-6.** **Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.** [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect].

| | |
|---|---|
| **PS3-3.** | **Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. *** [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.] |
| **PS3-4.** | **Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.** [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.] |
| **PS3-5.** | **Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.** [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [Assessment Boundary: Assessment does not include calculations of energy.] |
| **ETS1-1.** | **Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.** |
| **ETS1-3.** | **Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.** |

Significant Connections to California's Environmental Principles and Concepts:

None

**Instructional Segment 2 Snapshot:**

**Motions and Thermal Energy**

This snapshot presents an example of how teaching and learning may look in the 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. A Snapshot provides fewer details than a Vignette (e.g., the Instructional Segment 2 Vignette "Interactions of Earth Systems Cause Weather").

Mr. A began Instructional Segment 2 by eliciting what students knew about the forms and transformations of energy based on daily experiences or what they remembered from classroom investigations in grades 4 and 5. He steered student small group discussions towards phenomena in their daily lives such as the warming effect of rubbing hands together or doing vigorous exercise. Building on those kinds of experiences, students **conducted investigations** that connected motions of objects with changes in thermal energy. Mr. A emphasized these ***energy transformations*** because these experiences from our ***macroscopic level of reality*** are necessary to help students connect the motion energy of ***invisible particles*** with the observed temperature of materials.

For homework, students read an illustrated one-page handout about a scientific paper published by Count Rumford in 1798. Count Rumford was born with the name Benjamin Thompson in Massachusetts. During the War of Independence, Thompson fought for the British against the American revolutionaries, and had to flee from his home to save his life.

In Europe after the war, Thompson became famous as a scientist and inventor and he was honored with the title and name of Count Rumford. In one famous public experiment, Count Rumford used the process of making a cannon to investigate the change of motion energy to thermal energy. He set up an experiment where a horse trotting in a circle caused a metal borer to dig a hole into an iron cylinder that was completely covered with water (Figure 6). All the people watching were amazed when the friction of the borer grinding into the cannon ***caused*** the water to boil.

**Count Rumford's Experiment**

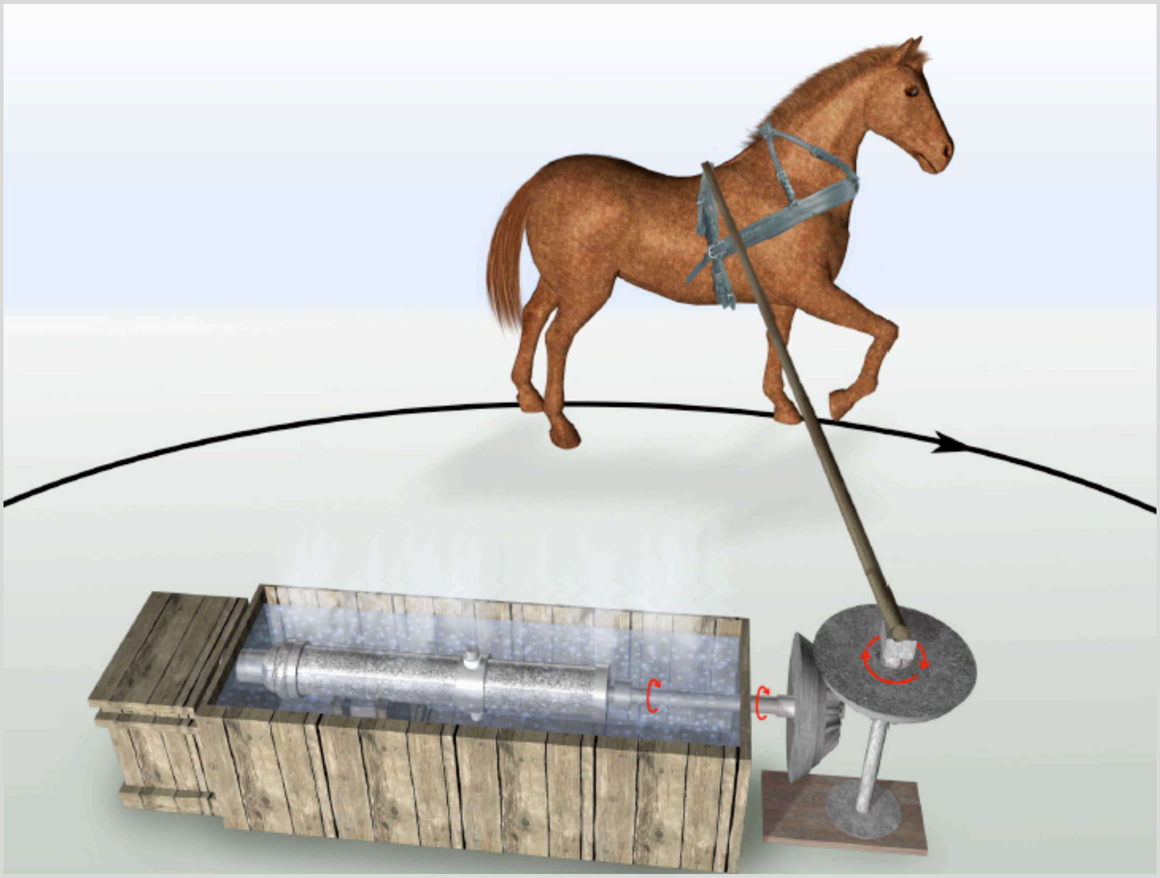

**Figure 6:** The kinetic energy of a horse moving in a circle heated water surrounding a cylinder of iron so much that the water boiled without any fire. (Illustration from *Dr. Art's Guide to Science*, courtesy of WestEd.)

The day after the homework reading, the students discussed in small groups the ***flows of energy*** that were involved in the making of the cannon. They **diagrammed** the ***cause and effect relationships*** that were happening at the ***macroscopic level*** (horse, metal boring machine, water) and also at the ***invisible level*** of the water particles. After extensive small group and teacher-facilitated whole class sharing of diagrams and discussions, they reached the following consensus statements:

* the motions that the people saw caused the heating and boiling that they could feel and see;

* at the macroscopic level (our level), kinetic energy of the horse transferred to kinetic energy of the iron boring machine which transferred to thermal energy of the water;
* at the particle level, kinetic energy of the boring machine transferred to kinetic energy of the water particles.

The following day, Mr. A introduced the design challenge for students in teams of three to **design, construct, and test a device** that either minimizes or maximizes the transfer of thermal energy. Mr. A facilitated a whole class discussion about **constraints** (such as safety, cost, class time, and availability of materials/equipment) and **criteria** for success. Student teams brainstormed the materials and the ***flows of thermal energy*** that they would investigate. In their initial design proposal, they **specified the materials and processes** they would use and how they would test their devices. Student teams provided most of the feedback to each other, with Mr. A intervening only as absolutely needed to keep the teams on task and within the criteria and constraints. The engineering challenge concluded with **student teams presenting** and comparing their project results and how their projects developed over time.

**NGSS Connections in the Snapshot**

**Performance Expectations**

**MS-PS3-3**. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. *

**MS-PS3-4**.Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

**MS-PS3-5.** Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

**MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural world.

**MS-ETS1-3.** Evaluate data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

**Disciplinary Core Ideas**

**PS3.A: Definitions of Energy**

**PS3.B: Conservation of Energy and Energy Transfer**

**ETS1.A: Defining and Delimiting Engineering Problems**

**ETS1.B: Developing Possible Solutions**

**ETS1.C: Optimizing the Design Solution**

**Scientific and Engineering practices**

**Asking Questions and Defining Problems**
*Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.*
**Planning and Carrying Out Investigations**
*Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.*
*Collect data about the performance of a proposed object, tool, process, or system under a range of conditions.*
**Analyzing and Interpreting Data**
*Analyze and interpret data to provide evidence for phenomena.*
**Constructing Explanations**
*Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.*
*Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.*
*Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.*
**Engaging in Argument from Evidence**
*Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.*
**Obtaining, Evaluating, and Communicating Information**
*Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations.*

**Crosscutting Concepts**
**Energy and Matter: Flows, Cycles, and Conservation**
*Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion).*
*The transfer of energy can be tracked as energy flows through a designed or natural system.*
**Cause and Effect**
*Cause and effect relationships may be used to predict phenomena in natural or designed systems.*
**Scale, Proportion, and Quantity**
*Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.*

**CCSS Connections to English Language Arts**
RST.6–8.7, 9; SL.6.1, 4

**CCSS Connections to Mathematics**
6.EE.1, 6.EE.2c

**Connection to CA ELD Standards:**

ELD.PI.6-8.1, 9

**Instructional Segment 2 Vignette:**
**Interactions of Earth Systems Cause Weather**

The vignette presents an example of how teaching and learning may look like in the 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 opportunity 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.

**First Learning Set**

The physical science concepts and engineering design practices in the “Motions and Thermal Energy” snapshot set the stage for exploring the water cycle, weather, and California climates regions. Since water plays such a large role in weather, the Instructional Segment 2 vignette begins with the water cycle. Students have already explored the reservoirs of the water cycle in Grade 5, but they have not deeply investigated the complexities of its flows and processes.

In small group and whole class discussions, students reviewed the reservoirs of the water cycle that they had learned in fifth grade. They described the physical state of water (solid, liquid, gas) in each of the reservoirs. However, even when they included the atmosphere as a reservoir of the water cycle, students tended to emphasize liquid water in clouds rather than the invisible water vapor gas in air.

Ms. L then got their excited attention by bringing out an insulated container that had dry ice in it. She poured 91% isopropyl alcohol into the container to create an extremely cold bath that bubbled. Something visible formed and flowed around the insulated container. Students described it as smoke or fog or steam. Ms. L challenged the students to make careful, detailed observations; to discuss these observations in small groups; and to make an **evidence-based claim** about the nature of the "smoke/fog/steam," or SFS as they started calling it in texting mode. She pointed out that while they were discussing, she would put some small pieces of dry ice into a latex-free surgical glove, and tie off the end of the glove. That way they could have some carbon dioxide gas to observe as well.

The students reached a general consensus that the SFS was visible, that it felt sort of cool and moist, and that it seemed to be flowing downwards around the container. They **argued with evidence** that the SFS could not be water vapor because it was visible. However, there was much more confusion than consensus about what the SFS could be.

When Ms. L lifted the hugely expanded glove, students laughed about its shape, and wanted to know more about the properties of carbon dioxide gas. Ms. L cut one of the glove "fingers" to be able to release the carbon dioxide in a controlled manner. As a whole class, students observed that the gas is invisible. After Ms. L extinguished a lit candle by "pouring" some of the invisible gas over it, they reached the **conclusion** that carbon dioxide gas must be heavier than regular air.

Students returned to their small groups to summarize all the pieces of evidence, and try again to make **claims and evidence** about the nature of the SFS. All the student groups realized that its visibility meant that SFS could not be water vapor or carbon dioxide. Gradually intra-group and cross-group discussions resulted in the conclusion that SFS must be water drops that condensed from water vapor in the air. One team made a **model drawing** showing a progression of three stages:

1) cold carbon dioxide gas flowing over the edge of the container and then sinking downward;
2) water vapor in the air cooling as the cold $CO_2$ gas contacted it; and
3) the cooled water vapor condensing into small drops (fog).

Ms. L concluded the lesson by putting a test tube of water with an inserted temperature probe into the dry ice/isopropyl alcohol bath. She showed how quickly the water froze. She called on students to read the temperature on the probe, and they noted that it was in minus degrees Celsius, meaning that it was colder than the freezing point of water. She took the test tube and carefully suspended it in warm water. Students recorded the increase in temperature as the super-cooled ice warmed towards zero degrees C. The following day the students reviewed the experiences from the previous day including the super-cooled ice and how its temperature started below $0^0$C. Students then worked in teams to slowly and steadily heat a mixture of ice and water, and to keep recording the temperature and to also record when melting was happening. The handout that she provided included a data table for recording temperature, elapsed time, and whether melting was happening. For safety reasons, the students had to stop their experiments when the temperature of their water reached $45^0$C.

Using graph paper, each student team **created a labeled graph** and entered their data on the graph. The students generally obtained graphs that showed a mostly flat temperature line near $0^0$C during the time of melting, and then a steady rise in temperature after all the ice melted.

Ms. L then asked the teams to predict on their graph what it would look like the next day when she demonstrated heating the water until it boiled and while it kept boiling. They also needed to note on their prediction when the boiling was happening just as they had noted when the ice was melting.

The following day the teams shared their predictions and their reasoning. Then Ms. L demonstrated the heating of water to the boiling stage and for a period of continued boiling. Students recorded the observed temperatures on their graphs, and compared the observations with their predictions. At the end of the demonstration, students discussed the results as a whole class.

The next day, Ms. L projected a graph of phase changes in water that was posted on the web by a chemistry teacher (Figure 7). Students discussed this graph in small groups, and wrote explanations for what they thought was happening in the parts of the graph labeled A, B, C, D and E.

**Heating Water from Below Freezing to Above Boiling**

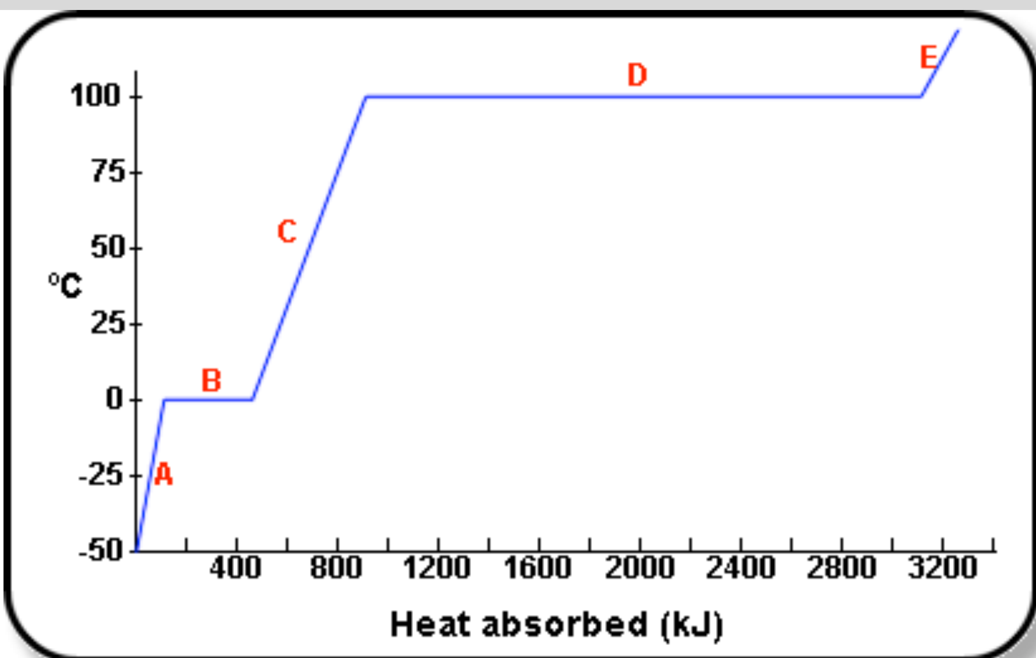


**Figure 7:**
Continuously adding thermal energy increases the temperature from super-cooled ice to superheated steam. Heating does not cause the temperature to significantly increase during the phase changes of

melting (B) and boiling (D). Heating when there is no phase change happening results in temperature increasing (A, C and E). (Illustration from Mr. Kent's Chemistry Page at http://kentchemistry.com/links/EnergyComplexCal/Problems.htm)

The students consistently identified temperature as a measure of the average kinetic energy of invisible particles of water. They correctly **related higher temperatures with increased particle motion**, and lower temperatures with decreased particle motion. Based on their own experiments and the teacher demonstration, students readily **explained** that the upward lines occurred when there was no phase change happening. They also readily stated that the flat lines at B and D occurred when there was a phase change happening. However, they had a hard time clearly explaining why the temperature was not increasing during melting and boiling even though more thermal energy kept being added.

**Energy Transfers and Phase Changes of Water**

**EVAPORATION**: Water (liquid) + Energy → Water (gas)

**CONDENSATION:** Water (gas) → Water (liquid) + Energy

**MELTING**: Water (solid) + Energy → Water (liquid)

**FREEZING:** Water (liquid) → Water (solid) + Energy

**Figure 8:** Evaporation and melting involve absorption of thermal energy. In contrast, condensation and freezing involve the release of thermal energy. (Illustration by Dr. Art Sussman, courtesy of WestEd)

Ms. L then projected a slide showing phase changes as a kind of physical reaction. Students discussed in groups how the arrow diagram on the top line of Figure 8 might help explain why the temperature remained fairly constant during evaporation even though thermal energy continued to be added. After five minutes, the student group that included Kelly started clapping and cheering. Other students asked them what had happened.

Kelly stood up and said that she thought they had finally explained it, but didn't know if they could repeat the explanation. After encouragement, she said, "The hot plate keeps giving off thermal energy. Usually that makes the water particles move faster, so then the temperature goes up. But once the water boils, the hot plate energy makes the boiling thing happen instead of making the particles move faster. So then the temperature does not change. I think I just said that the right way, didn't I?"

**Second Learning Set**

Ms. L began the next set of lessons by asking students how many different kinds of places they know about in California. The conversation led to a beginning list with names of some cities, and also some descriptions based on types of natural environments (beach, mountain, desert, redwood forest). She then distributed a map showing 16 different California Climate Zones (Figure 9), and had the students work in eight groups to identify the previously listed locations on the map, any new locations that the map made them think about, and also discuss what they thought a "climate zone" meant.

**California's Climate Zones**

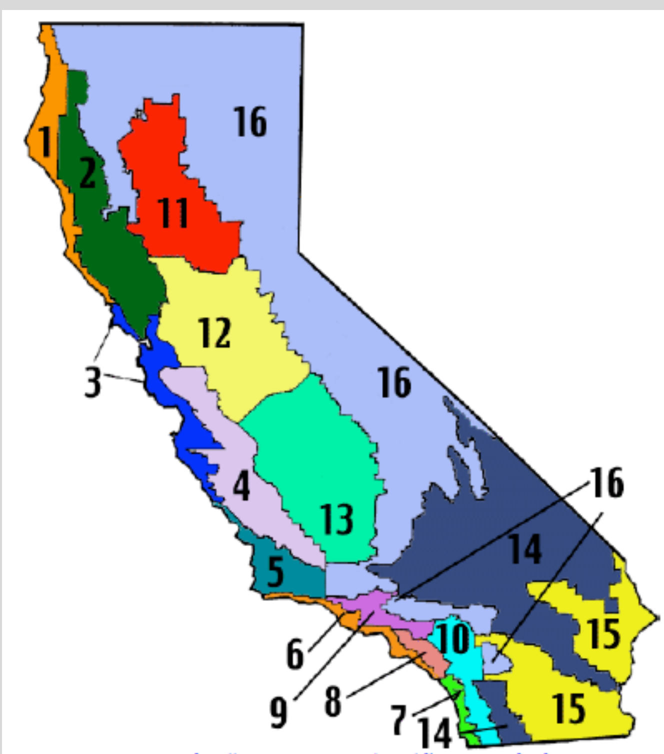

**Figure 9:** California can be described as having 16 different climate zones. Figure accessed from Pacific Energy Center's Guide to California Climate Zones at http://www.pge.com/myhome/edusafety/workshopstraining/pec/toolbox/arch/climate/index.shtml

After the students had time to engage with the task and do a preliminary whole class sharing, Ms. L provided a handout describing eight representative zones that she had condensed from the *Pacific Energy Center's Guide to California Climate Zones*. She used a combined student-choice/teacher-assignment technique to allocate the eight zones among the groups. Each team had to **research** their climate zone and develop posters **communicating** key features about their climate zone including topography, geographic locations, distinctive climate features, and representative **graphs** of annual temperatures/precipitation. They had to describe something new they had learned, and also at least one **scientific question** they had about that climate zone.

Students shared and learned about the different climate zones through a gallery walk of the posters, listening to presentations by the groups, and **asking questions** of the presenters. Facilitated whole class discussions helped summarize the differences between weather and climate, the different kinds of climate zones in California, and possible ***causes*** for the differences in annual temperatures and precipitation. Students highlighted key ***patterns*** (e.g., ***effects*** of latitude, altitude, closeness to the ocean, and closeness to mountains). Student teams also recorded any "***cause and effect*** why" questions they had about the data.

Toward the end of the week, each team **shared their "why" questions**. The questions tended to cluster into four groups:

* why it is so much colder in northern California than in southern California even though they are both in the same state;
* why places near the ocean have temperatures that change less between day and night;
* why higher altitudes have so much rain; and
* why the deserts are located where they are.

Ms. L concluded this discussion by saying that they would conduct some investigations during the next week to help answer the last three questions, and that they would cover the first question in their next Instructional Segment about climate around the world.

**Third Learning Set**

At the start of the third week, students **followed procedures** to investigate differences between heating air and heating water. They used an electric light to heat two identical bottles closed with rubber stoppers. One of the bottles was filled with water and the other bottle was filled with air. Their task was to **record and graph** the temperatures for 10 minutes while the light was on and then another 15 minutes after turning off the light. Ms. L called their attention to the data sheet and labeled graph that she had included in the written procedures. She told them that in future experiments the student teams would get to design their own data sheets and graph labels.

Both bottles started at a temperature of $20^{0}$C. With the light on, the temperature in the air bottle increased on average to $55^{0}$C while the temperature in the water bottle only increased on average to $23^{0}$C. After the lights was turned off, the air bottle temperature generally decreased about $30^{0}$C while the water bottle decreased on average only $1.5^{0}$C.

After doing the experiment, each student team **created and displayed** a poster showing their results. In their poster, they **made a claim** about the differences between heating air and heating water, and they wrote or illustrated the **evidence** for their claim. After a gallery walk and whole class discussion, the class reached a consensus **claim** that the same amount of added thermal energy ***caused*** the temperature of air to increase much more than the temperature of water, and that the water released its thermal energy much slower than the air did.

One student group agreed with the statement about the increase in temperature. However they **argued that the evidence** for a difference in cooling was very weak. It was not fair, they pointed out, to **compare cooling** from $55^{0}$C with cooling from $23^{0}$C. Ms. L took this unplanned opportunity of the excellent **student critique** to ask if there was a way to make a better comparison of the cooling rates of air and water.

Several student groups proposed pre-heating bottles of air and water to the same temperature, and then comparing their rates of cooling. A team of students volunteered to demonstrate the experiment the following day. Their subsequent demonstration confirmed that the same volume of water cooled at a much slower rate than the same volume of air.

Ms. L then introduced the term “heat capacity,” and challenged each student team to use the concept of heat capacity to **explain** the ***pattern*** that California locations near the ocean have less variation in day/night temperature than locations farther away from the ocean. Each team then **communicated** its explanation and reasoning to a different team.

Having discussed the temperature differences among California regions, students transitioned to their questions about the precipitation differences. Ms. L explained that they would have to learn about the concept of relative humidity in order to understand why higher altitudes have more precipitation. The student activity began with small group discussions about the term “humidity.” Students shared experiences they may have had with conditions of high and low humidity (e.g., a hot day where they sweated a lot compared with a hot day in the desert), and what they thought caused high and low humidity. After small group and whole class discussions, students reached a consensus that humidity was related to the amount of water vapor in the air.

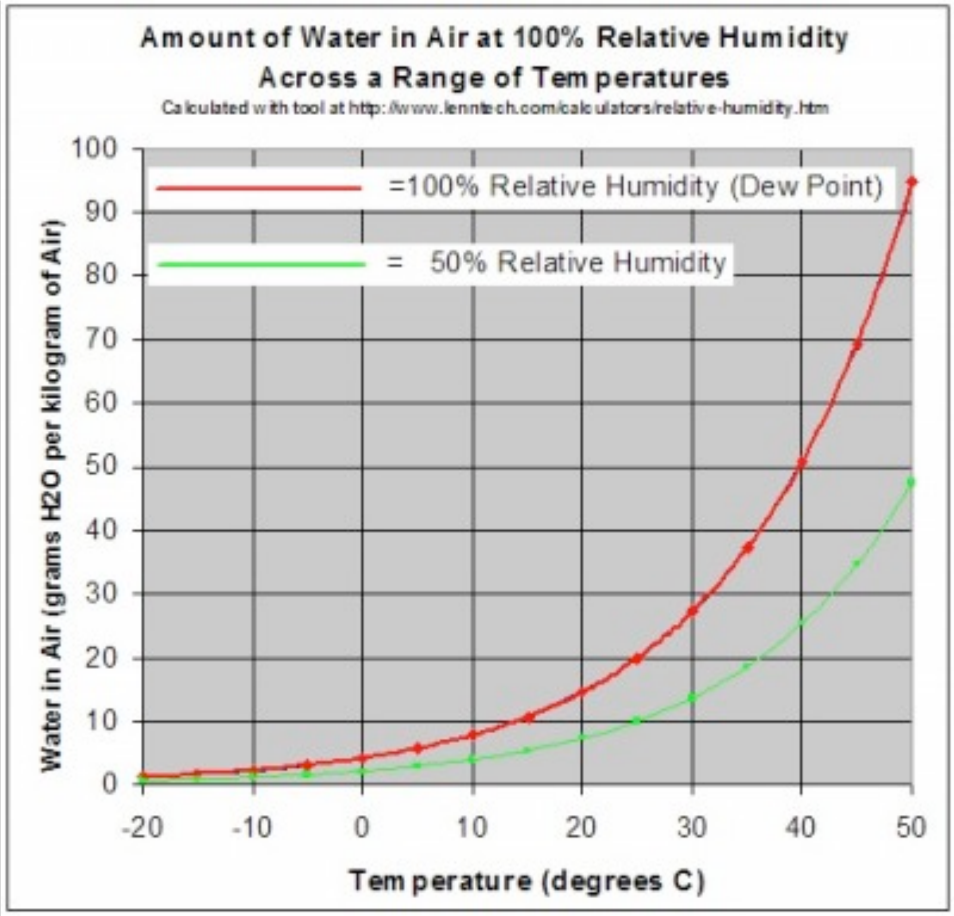


**Figure 10:** Grams of water vapor that a kilogram of air can hold at different temperatures. Red line indicates 100% relative humidity and green line represents 50% relative humidity. Figure courtesy of Cleaning Technologies Group accessed at [http://www.ctgclean.com](http://www.ctgclean.com).

Ms. L then distributed a graph of relative humidity comparing the amount of water vapor that air can hold at different temperatures (Figure 10). Each student team answered a series of questions about the data in the graph. These questions progressed in complexity starting with **identifying specific data on the graph** (e.g., the maximum amount of water that 1 kilogram of air can hold at different specific temperatures). More complex questions included students **predicting** what would happen to air that had a relative humidity of 50% at $36^0$C if it was cooled to $30^0$C, $26^0$C or $20^0$C. As part of the prediction, students had to include the **evidence** for their answers. The final written question for each team was to **communicate** in words and/or pictures a definition of relative humidity.

Student teams first worked among themselves and then shared with other teams as needed. Ms. L interacted with teams, helping them to focus on their tasks, and providing limited hints and guidance. At appropriate times, she initiated whole class discussions which eventually resulted in a class consensus on the meaning of relative humidity, and how that concept related to the higher levels of mountain precipitation ***caused by*** the cooler temperatures at higher elevations. Her final oral class question for that assignment related to explaining the ***pattern*** that the eastern side of California mountains, even at high elevations, have lower amounts of precipitation than the western side.

Based on the California climate data that they had learned, each of the student teams **drew a systems model** of the water cycle for a location in their assigned climate zone during two different seasons of the year. As a class, they began by reviewing the features of a systems diagram (boundary, components, inputs/outputs, interactions, and system property).

After the student teams had completed their initial models, Ms. L initiated an activity that would help them create more accurate and complex water cycle diagrams. She knew from experience and research that while students often can list the locations where water is located, they tend to have very limited or simplified ideas about the dynamic nature of the interconnections among these reservoirs. For example, even though they may have seen clouds disappear because of evaporation of their water back into the atmosphere, they tend to think that water in clouds can only precipitate.[1] Students also tend to think that water remains in a specific reservoir until it does the one process that could move it out of that reservoir. For example, they tend to model water in a river as only flowing into the ocean, whereas in reality the river water can evaporate, submerge under the surface, or be taken into the body of a plant or animal.

To help students consider these complexities, Ms. L led students through a simple

[1] Ben-zvi-Assarf , O. and Orion, N. (2005) A Study of Junior High Students' Perceptions of the Water Cycle. Journal of Geoscience Education, 53, 366-373. Accessed at http://www.nagt.org/files/nagt/jge/abstracts/Ben-zvi-Assarf_v53p366.pdf

kinesthetic game. Each student played the role of a water particle (or $H_2O$ molecule if students are comfortable with that terminology) and moved around the room through different stations that represented different places that water is located (ocean, plant, atmosphere, cloud, mountain glacier, polar ice cap, etc.). At each station, the student rolled dice and read from an instruction sheet whether they stayed at that station for another turn or moved to a different station via a water cycle process. In essence, the students became physical ***models*** of all the processes of the water cycle.

After the exercise, students commented about it and summarized what they had learned. Key points included:

* the number of inputs and outputs for the different reservoirs;
* the different residence times in the reservoirs;
* the changes in state associated with the water cycle interconnections;
* the cyclical, rather than linear, nature of the water cycle; and
* the role of gravity in ***causing*** precipitation, downhill flow of surface water, infiltration of surface water into the ground, and downhill flow of glacial ice.

After this kinesthetic lesson, student teams returned to their regional water cycle diagrams and incorporated more of these interconnections, inputs and outputs. Students then **shared their regional water cycle diagrams, critiqued and extended each other's presentations**, and achieved a more complete group understanding of water cycle reservoirs and processes. As a whole class activity, they **created a color-coded map** representing the average annual precipitation that included all of their California regions. To create this representation, they needed to collaborate on deciding the **range of values** to use, and how to **represent** the entire spectrum of data. They compared their whole class model with a representation that Ms. L had downloaded from the internet (Figure 11), which they then used to complete and **revise** their state map.

**Average Annual Precipitation in California**

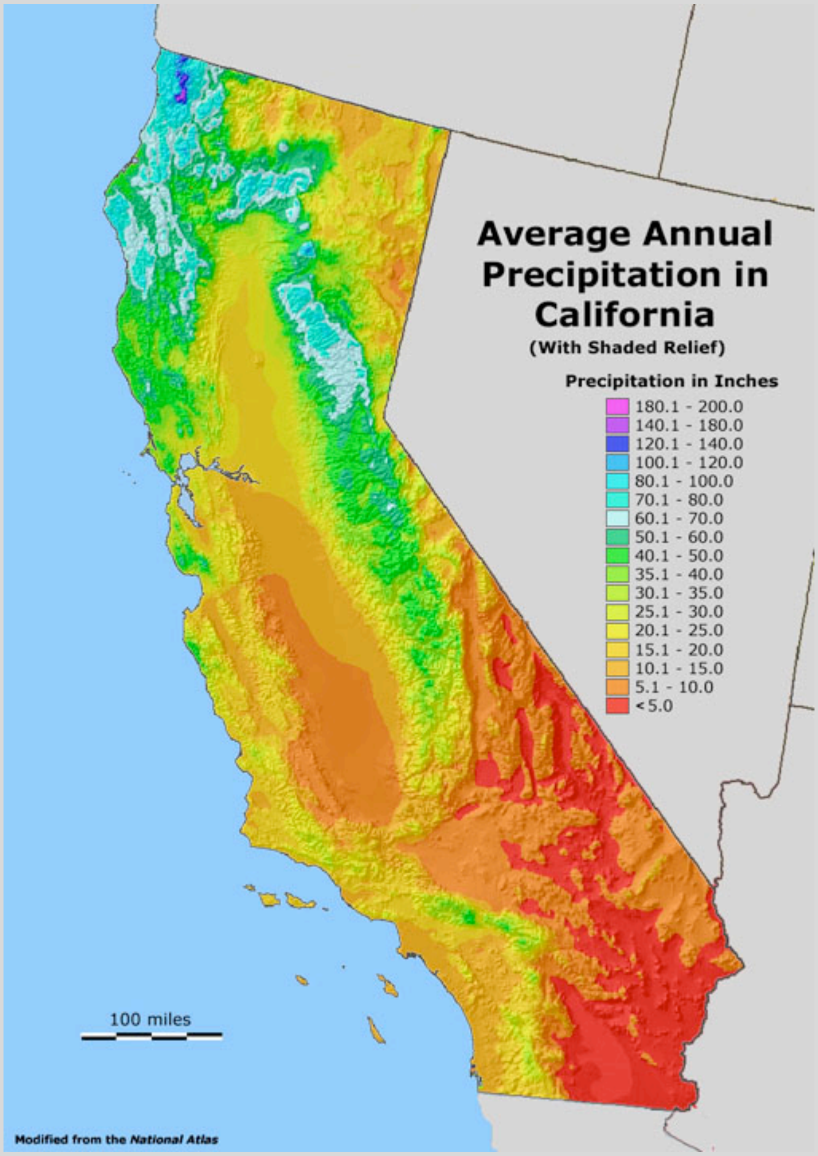


**Figure 11:** Color-coded map of average annual precipitation in different California regions with mountains indicated by shaded relief. Courtesy of GeologyCafe.com accessed from http://geologycafe.com/california/maps/california_precipitation&relief1.htm

This part of their Instructional Segment on weather and the water cycle concluded with **presentations** that the class made for different audiences about California climate and precipitation. In each presentation, students highlighted the ***patterns*** of temperature and precipitation in each of the eight California regions that they had investigated. They also **explained** the different factors that were involved in ***causing*** significant climate patterns such as comparatively small variation in coastal day/night temperatures, high levels of mountain precipitation, and the rain shadow effect of coastal and Sierra Nevada mountains on the Central Valley and on Eastern California respectively.

**NGSS Connections in the Vignette**

| **Performance Expectations** | | |
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| **MS-ESS2-4 Earth's Systems**<br>*Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.*<br>**MS-ESS2-6 Earth's Systems**<br>*Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates*.<br>**MS-PS3-4 Energy**<br>*Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.* | | |
| **Science and engineering practices** | **Disciplinary core ideas** | **Crosscutting concepts** |
| **Asking Questions**<br>*Ask questions that arise from careful observations of phenomena, models, or unexpected results to clarify and/or seek additional information.*<br><br>**Developing and Using Models**<br>*Develop and use a model to describe phenomena.*<br><br>**Planning and Carrying Out Investigations**<br>*Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for* | **ESS2.C The Roles of Water in Earth's Surface Processes**<br>*Water continuously cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.*<br>*Global movements of water and its changes in form are propelled by sunlight and gravity.*<br>*Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living* | **Patterns**<br>*Patterns can be used to identify cause-and-effect relationships.*<br>*Graphs, charts, and images can be used to identify patterns in data.*<br><br>**Cause and Effect: Mechanism and Explanation**<br>*Cause-and-effect relationships may be used to predict phenomena in natural or designed systems.*<br><br>**Systems and System Models** |

| | | |
|---|---|---|
| *evidence that meet the goals of the investigation.*<br><br>**Analyzing and Interpreting Data**<br>*Analyze and interpret data to determine similarities and differences in findings.*<br><br>**Constructing Explanations**<br>*Construct an explanation using models or representations.*<br><br>**Engaging in Argument from Evidence**<br>*Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.*<br><br>**Obtaining, Evaluating, and Communicating Information**<br>*Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations.* | *things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.*<br><br>**PS3.A Definitions of Energy**<br>*Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.*<br><br>**PS3.B Conservation of Energy and Energy Transfer**<br>*The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.* | *Systems may interact with other systems; they may have subsystems and be a part of larger complex systems.*<br>*Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy, matter, and information flows within systems.* |
| **Connections to the CA CCSSM:**<br>**6.NS.7b, 6.NS.8, 6.EE.9, 6.SP.4** | | |
| **Connections to CA CCSS for ELA/Literacy:**<br>**RST.6–8.1, 4; WHST. 6–8.1, 7; SL.6.1, 2, 3** | | |
| **Connection to CA ELD Standards:** | | |

**Vignette Debrief**

In this multi-week vignette, the learning experiences extend the physical science concepts that had been introduced in the previous Snapshot (e.g., the qualitative understandings of the latent heats of vaporization and fusion associated with MS-ESS2-4). As the students became more engaged with the content and comfortable with the underlying physical science concepts, they began to have larger roles in **designing and conducting** the investigations. One example is the unexpected student contribution to critiquing and investigating the differential cooling of water and air (MS-PS3-4).

In the beginning of the second learning set, students were introduced to the representations and information about different California climate regions. From that point on, the teacher had a less direct instructional role and more of a guiding/facilitating role. Students ***researched*** information about the regional climates, identified ***patterns***, discussed possible **explanations** for the patterns, and **used evidence** to support their explanations and claims.

In the process, students **developed system models** of their regional climates and engaged with key factors that ***cause climate patterns***, such as increased precipitation at high elevations. The observed weather and climate effects in California latitude, altitude, proximity to the ocean, and locations of mountains all set the stage for deeper explorations in Instructional Segments 2 and 3 of the ***patterns that determine regional climates*** (MS-ESS2-6).

**Connection to CA ELD Standards:**

ELD.PI.6-8.1, 9, 10b

**Instructional Segment 2 Teacher Background and Instructional Suggestions**

Distinguishing thermal energy, heat and temperature is potentially the most confusing issue associated with the physical science in this Instructional Segment. NGSS tends to restrict the use of the term “heat” to being a verb (“to cause the temperature to increase”) rather than a noun (“an amount of energy associated with a sample of material”). In NGSS, thermal energy is the preferred noun term. A fire can heat (verb) a substance by transferring thermal energy (noun) to it. A large cool volume of water is likely to have more total thermal energy (noun) than a much smaller volume of hot water.

As discussed in both the Snapshot and the Vignette, temperature is a macroscopic property that is related to the average kinetic energy of the particles of a substance. In grade 5, students learned that objects that they could see or touch have kinetic energy when they move. When students learn in grade 6 that temperature is related to the average kinetic energy of the particles in a system, they are extending this kinetic energy concept to the invisible molecular scale. For teachers, it can be helpful to know that in a solid, this motion is an internal vibration within an atom or between atoms in a molecule. In a liquid or a gas, this motion is both vibration internal to the particles and the energy of the particles moving through space.

The Crosscutting Concept of "***Scale, Proportion, and Quantity***" at the middle school level includes the notion that, "Time, space and energy phenomena can be observed at various scales using models to study systems that are too large or too small." Clearly this concept applies when we relate the macroscopic property of temperature with the submicroscopic motions of particles.

This scale CCC also applies when we ***compare the scales of climate and weather***. In general, climate is a description that covers a relatively long period of time (30 years to millennia) and often applies across relatively large geographic areas. In contrast, weather generally refers to the atmospheric conditions at a specific location during a very short period of time.

Figure 11, the color-coded map of Average Annual Precipitation in California, is an example of a model that describes phenomena (climate properties) that occur at scales that are too ***spatially and temporally large*** to directly observe. This kind of map is a ***systems model*** that is especially useful and prevalent in Earth and Space science. Color-coded maps can display a huge amount of data in ways that reveal important ***patterns*** related to spatial location. Students may initially respond to the aesthetics of the colors rather than the science patterns and the vast amounts of data that these kinds of ***models*** summarize and communicate. Each small area of color corresponds to a calculated average based on many locations that measured and recorded the amount of precipitation each day for decades or perhaps a century or more.

While this kind of color-coded modeling representation is also used to some extent in other scientific disciplines, its special appropriateness in Earth and Space Science topics helps reveal a ***general principle about crosscutting concepts***. While CCCs do apply across many disciplines, they still may apply in somewhat different ways and extents in the different scientific disciplines.

Returning to Figure 11, there are various ways to classify climates that result in somewhat different numbers and boundaries of California climate regions. Nonetheless, the main message is that California is unusual in having so many different kinds of climate that are close to each other. Instructional Segment 2 takes advantage of this situation to introduce students to different climate phenomena that share the engaging property of being associated with the home state. (The EEI Curriculum unit, Precipitation, People, and the Natural World provides a variety of resources that can support this instruction.)

Another factor that helps unite the grade 6 weather and climate instruction is that performance expectation MS-ESS2-6 is so central to understanding regional and global climate that it is included in Instructional Segment 1, Instructional Segment 2, and Instructional Segment 3 of this model of Integrated Grade 6. Instructional Segment 1 includes this MS-ESS2-6 because this PE broadly refers to the different Earth systems that are components of the whole Earth system introduced in that Instructional Segment. Instructional Segment 2 includes this PE because it cites many of the factors that help determine California climate regions such as the effects of latitude and altitude, and the role of the ocean in stabilizing day/night temperatures. Finally, Instructional Segment 3 includes this PE because it includes many of the factors that influence climate globally such as the atmospheric winds and oceanic currents that move vast amounts of thermal energy around the planet.

The CCC of ***Systems and System Models*** that featured so prominently in Instructional Segment 1 still has a very significant presence in Instructional Segment 2. It is a vital and underlying aspect of many of the other CCCs. For example, the quotation about the Scale CCC directly refers to “using models to study systems.” Descriptions of the ***Energy and Matter CCC*** refer often to tracking the flows of energy and matter into and out of systems. Finally, each of the California regional climates investigated in

Instructional Segment 2 is an example of a whole system property that emerges or arises from the interactions of the components of the regional system with each other and with the incoming sunlight.

Sunlight plays an enormous role in weather and climate that is addressed in depth in Instructional Segment 3. For Instructional Segment 2, the large influence of sunlight is most apparent in instruction related to the water cycle. MS-ESS2-4 highlights the special role of sunlight in driving the phase changes that occur as water moves in multiple pathways between the reservoirs of the water cycle. The first learning set in the Instructional Segment 2 vignette focused on these phase transitions and the associated movements of thermal energy, almost all of which entered the Earth system in the form of sunlight.

The force of gravity also **causes** movement of water between reservoirs of the water cycle. Most students can explain the role of gravity in causing precipitation ("raindrops fall") or surface water ("rivers flown downhill"), but they often overlook the crucial role that gravity plays in the infiltration of surface water into the groundwater, the flow of groundwater itself through tiny pores (similar to the way a saturated sponge drips water down out of the bottom), and the flow of ice downhill in glaciers (illustrated by time-lapse videos of glacier movements).

To emphasize these ***cause and effect relationships*** involving gravity and sunlight, students can create skits of different water cycle processes where two students play the roles of gravity and of sunlight while the other students actors play the role of individual water molecules that move between props representing different water cycle reservoirs. Student actions and words help convey the roles of gravity and sunlight in the matter and energy flows of the water cycle.

Because of the water cycle, Californians are able to obtain a steady supply of fresh water for drinking, irrigation, industrial, and agricultural uses (*California EP&C III*). Even in years with abundant precipitation, California still draws water from a total of seven nearby states in addition to its own supply[2]. Of the developed water supply for the state, more than 75% of it goes to agriculture and helps California grow more food than any other state.

[2] Nature Conservancy (2012), Where does California's water come from? Land conservation and the watersheds that supply California's drinking water. Accessed at http://www.nature.org/media/california/california_drinking-water-sources-2012.pdf

**Table 5 - Grade 6 Instructional Segment 3**

**Causes and Effects of Regional Climates**

**Guiding Question:**

Why is the climate so different in different regions of the planet?

How do people predict the weather?

Why are organisms so different in different regions of the planet?

What makes organisms so similar to but also different from their parents?

What makes animals behave the way they do, and how does their behavior affect their survival and reproduction?

**Highlighted Science and Engineering Practices:**

**Obtaining, Evaluating and Communicating Information;**

**Developing and Using Models;**

**Engaging in Argument from Evidence;**

**Constructing Explanations and Designing Solutions**

***Highlighted Crosscutting Concepts:***

***Cause and Effect: Mechanism and Prediction;***

***Patterns;***

***Energy and Matter: Flows, Cycles and Conservation***

***Systems and System Models;***

Performance expectations associated with this Instructional Segment:

**ESS2-5.** **Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.** [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.]

**ESS2-6.Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.** [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect].

**PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.** [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.]

**LS1-4 Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.** [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds, and creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.]

**LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.** [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.] [*Assessment Boundary: Assessment does not include genetic*

| | |
|---|---|
| | *mechanisms, gene regulation, or biochemical processes.*] |
| **LS1-8.** | **Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.** [Assessment Boundary: Assessment does not include mechanisms for the transmission of this information.] |
| **LS3-2.** | **Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.** [Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.]. |
| Significant Connections to California's Environmental Principles and Concepts: | |
| None | |

**Instructional Segment 3 Teacher Background and Instructional Suggestions**

In Instructional Segment 2 students **analyzed climate data** for eight different California regions. As a result of that analysis, four key factors were identified as having strong ***causal effects*** on regional climates: 1) latitude; 2) altitude; 3) proximity to mountains; and 4) proximity to the ocean.

Instructional Segment 3 extends the California analysis to the ***scale*** of regional climates around the planet. Students begin with examining the effects of latitude (very apparent in Figure 12), and also times of the year related to latitude. The spatial and temporal aspects of latitude relate primarily to the position of the planet in its annual orbit around the Sun, particularly as the annual orbit affects the angle of incoming sunlight. One anomaly with respect to the generally applicable ***pattern*** of the latitude effect is also apparent from **analysis of global maps** such as Figure 12, namely that areas of high elevation have much colder temperatures than lower elevation areas at the same latitude. The investigation of high altitude climates naturally also leads students to generalize the ***pattern*** that mountains have strong ***effects*** on nearby lower elevations, especially with respect to the amount of precipitation that the lower elevations receive.

## Average Annual Temperatures

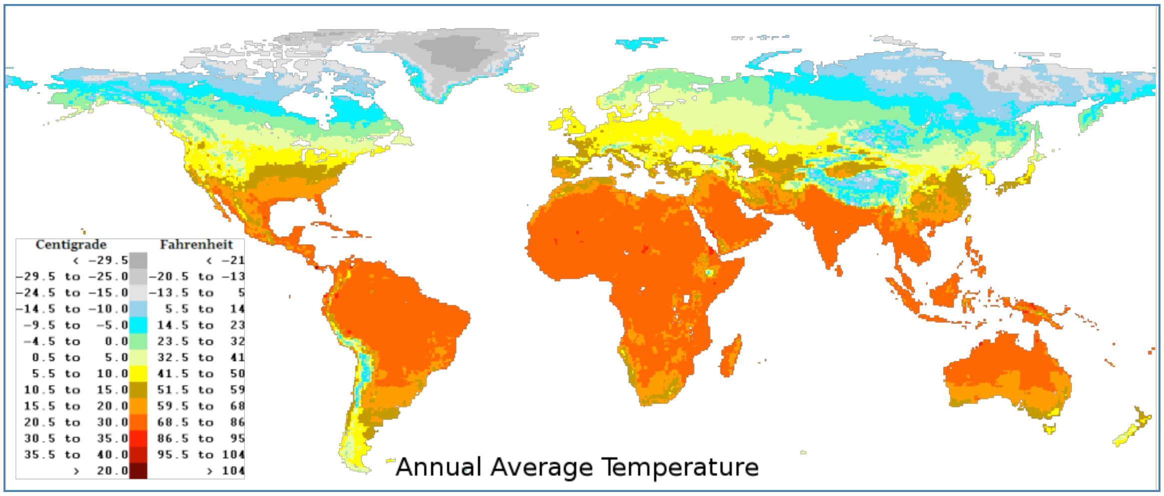



**Figure 12:** Color-coded map of average annual temperature around the world. Note the major effect of latitude, and the colder high elevation regions, such as the Himalayas in Asia. Accessed from http://www.climate-charts.com/World-Climate-Maps.html

In Instructional Segment 2 students **described** that areas close to the ocean had smaller differences in day/night temperatures than inland areas and **used evidence** from heat capacity experiments in their **explanations** that the oceans retain thermal energy absorbed during the daytime much longer than the land and the air. The ocean warms the nearby air at night, thereby keeping the night temperatures closer to the daytime temperatures. In Instructional Segment 3, students extend their analysis of ocean effects on temperature by **investigating** the effects of ocean currents that transport thermal energy from equatorial regions to colder temperate regions. This analysis is then connected to the more global ***scale*** of ocean currents and wind patterns.

Having attained deeper understandings of the many intersecting factors and Earth system interactions that ***cause*** regional climates, students then focus on the ***effects*** that these very different regional climates have on organisms. In grade 4, students cited internal and external structures of plants and animals as **evidence** that organisms have structural adaptations that support survival, growth, behavior, and reproduction. In grade 5, students **developed models** that described how organisms survive only in environments in which their specific needs can be met.

Students deepen and revisit these concepts in grade 6 Instructional Segment 3 by **investigating** plant and animal structures and behaviors through the multiple life science lenses of variations in traits, heredity, and reproduction. This life science component of the integrated Instructional Segment 3 concludes with an **analysis** of various animal reproductive behaviors. Animals that have complex nervous systems (note connection with grade 6 Instructional Segment 1) can respond to stimuli quickly and with more flexible options, and can also optimize their reproductive behaviors based on reliable memories of past experiences with members of their local group. Keeping this broad outline of the Instructional Segment 3 sequence in mind, we now transition to exploring more deeply the effects of latitude on climate. The reddish areas in Figure 12 clearly indicate that latitudes closer to the equator are generally much warmer than latitudes that are much further north or south. The large northern continental areas colored in green/blue clearly have the coldest average annual temperatures.

We can safely assume that California students know that the northern hemisphere experiences colder conditions in the winter months between November and March. Students who live in low altitudes may not appreciate the magnitude of the temperature changes between winter and summer. Students may also not know whether the seasons are the same or different near the equator or in the southern hemisphere. Student groups can **make predictions** about ***temperature patterns*** in all these different locations and then **research** the monthly average temperatures of selected cities in the USA and most world countries.[3] Based on their research, student teams can **communicate evidence-based conclusions** how different regional temperature ***patterns*** vary by latitude.

[3] World-Climate at www.climate-charts.com has abundant data for the USA and countries/cities around the world.

### Earth's Annual Orbit Around the Sun

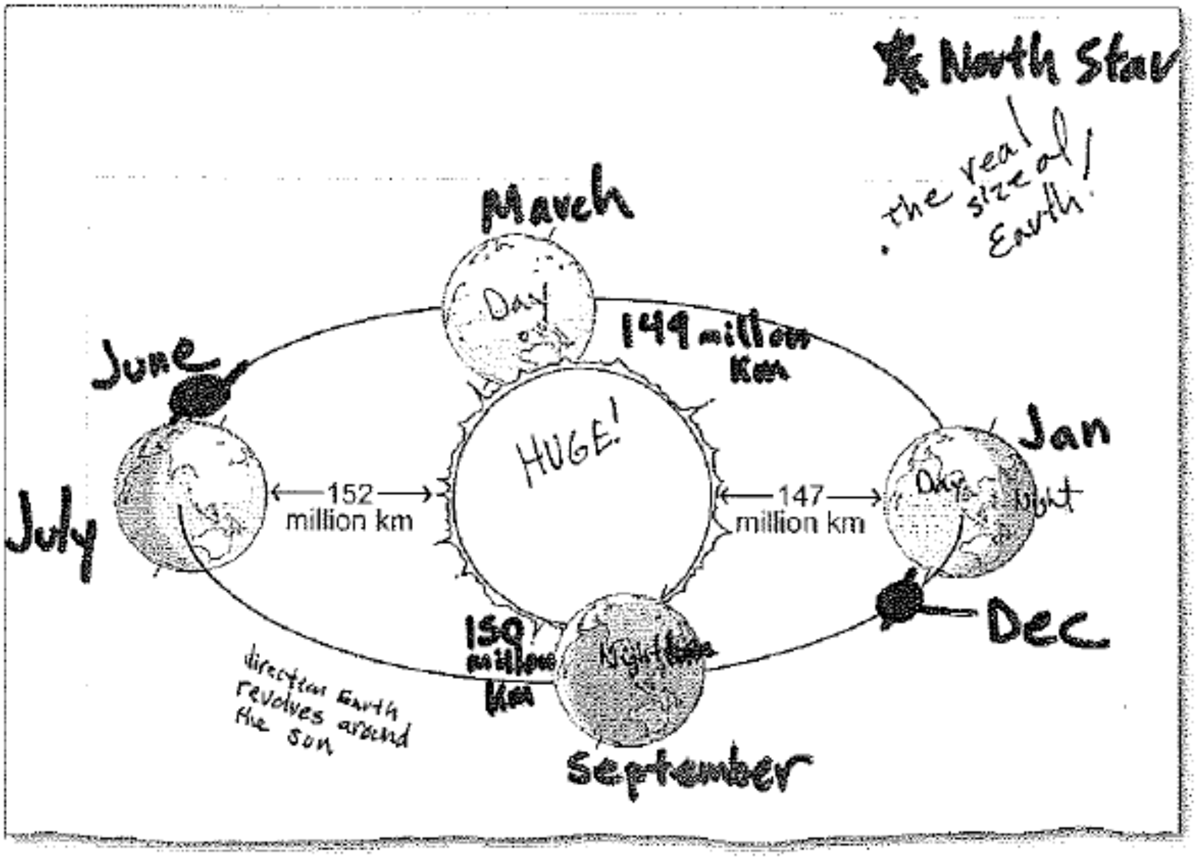



**Figure 13:** The trip that Earth makes around the sun each year. Note the dot showing the more correctly scaled size of Earth relative to the sun, and the tilt orientation toward the North Star. (Illustration from Making Sense of Science *Weather and Climate* course, courtesy of WestEd)

Teachers can distribute a handout such as Figure 13 that is a **model** that can help address many misconceptions. Note, for example, that Earth's distance from the sun is actually greater in the Northern Hemisphere summer than it is in the winter. The dot showing the real scaled size of the Earth relative to the sun also helps establish the correct size comparison. It is also valuable to always include a position for the North Star so students can see that Earth's tilted axis always points in that same direction (technically $23.5^0$ North) as the planet orbits the sun.

Students can then **investigate** the angle of sunlight at different latitudes at a specific time of year, such as the Spring or Autumn Equinox. While we do introduce seasons in integrated grade 6 to teach about the climate effect of latitude, the deeper exploration of seasons happens in grade 8 when students investigate the Earth-Sun system more intensively. The key concept in grade 6 is that equatorial latitudes receive much more direct sunlight annually than temperate or polar latitudes.

**Angle of Incidence Assessment Probe**

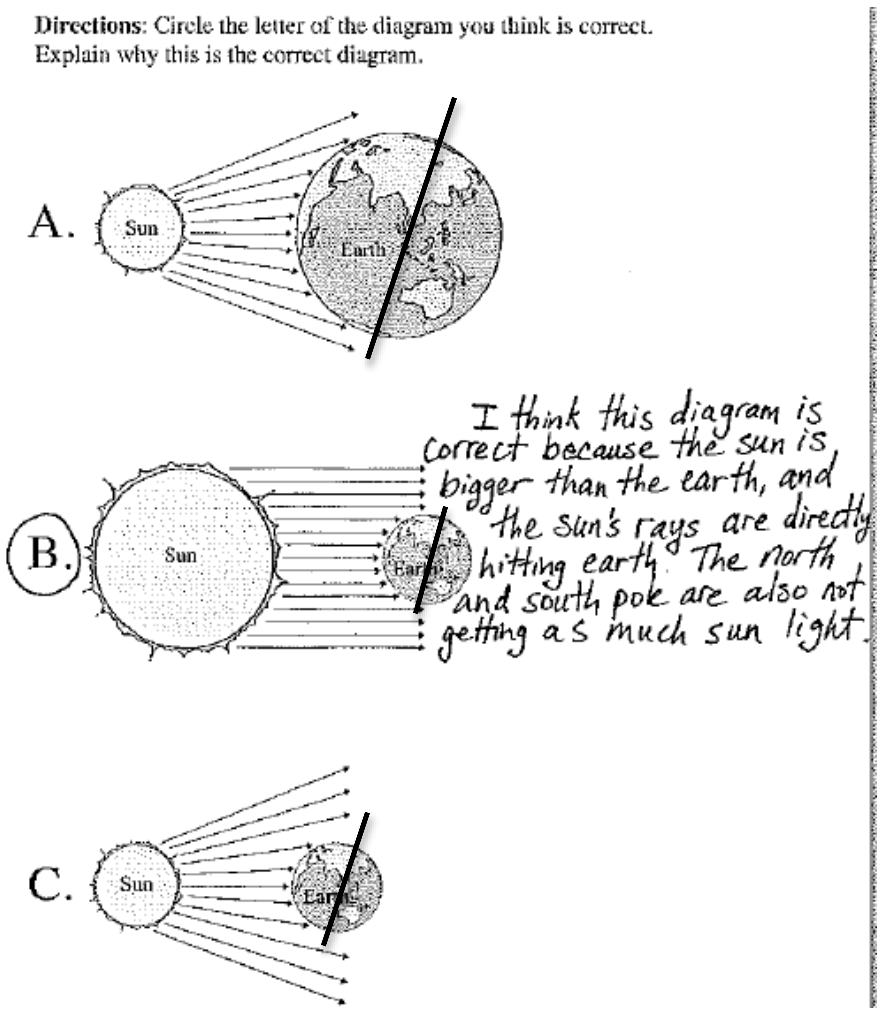



**Figure 14:** A sample correct student response to an assessment probe about angle of incidence of sunlight at different latitudes. (Illustration from Making Sense of Science *Weather and Climate* course, courtesy of WestEd)

Students can **investigate with different models** how the angle of incidence ***affects*** the intensity of illumination by using various light sources (flashlight with narrow light opening, light bulb, sunlight) and illumination targets (globe, foam ball with marked latitudes, solar cells). Teachers can use a formative assessment probe (Figure 14) to assess student understanding. In the same classroom, a different student answered that A is correct because, "I think in December the light doesn't reach up to the northern pole. It's cold up there because the light would not reach it." Based on this kind of assessment, teachers can decide how to proceed with the instructional sequence, such as having the student **investigate** a different model to compare the sizes of the sun and Earth, and reason about how the angle of incidence changes with latitude.

## Thermal Energy Moves In Three Ways

| WAYS THERMAL ENERGY MOVES | Physical Science | Examples |
|---|---|---|
| CONDUCTION | Warm object touches cooler object and makes it warmer. Electromagnetic waves not involved. | Hot sand burns your feet.<br>Hot ground warms air that touches it.<br>Handle of heated pan becomes hot. |
| CONVECTION | Warm liquid or gas flows into cooler area and makes it warmer. Electromagnetic waves not involved. | Warm air rises and is replaced by cooler air.<br>Hot water in heated pot rises from bottom to top. |
| RADIATION | Objects do not touch each other. Electromagnetic waves radiate from warmer object, are absorbed by cooler object, and make it warmer. | Sunlight heats your body.<br>Standing near a hot wall or hot cliff.<br>A wood fire or an outside gas or electric heater heats your body. |

**Table 6:** Contrasting the three different ways that thermal energy moves from warmer objects to cooler objects based on the underlying physical science. (Table by Dr. Art Sussman, courtesy of WestEd.)

Movements of thermal energy are major factors in ***causing*** the observed ***patterns of regional climates***. One major concept is that ***thermal energy moves*** from warmer locations/objects to cooler locations/objects. A related major concept is that these movements of thermal energy occur in three distinct ways (Table 6). Students can **investigate** and **research** each of these three ways of heating, **create a brief report** about one or more of them, and **explain** the differences in terms of the underlying science. Given the state of their physical science knowledge, the mechanisms need to be stated in fairly general terms. For example, conduction and convection can be described in terms of particles vibrating or moving, and radiation can be described as waves of energy similar to sunlight that move through space and transfer energy.

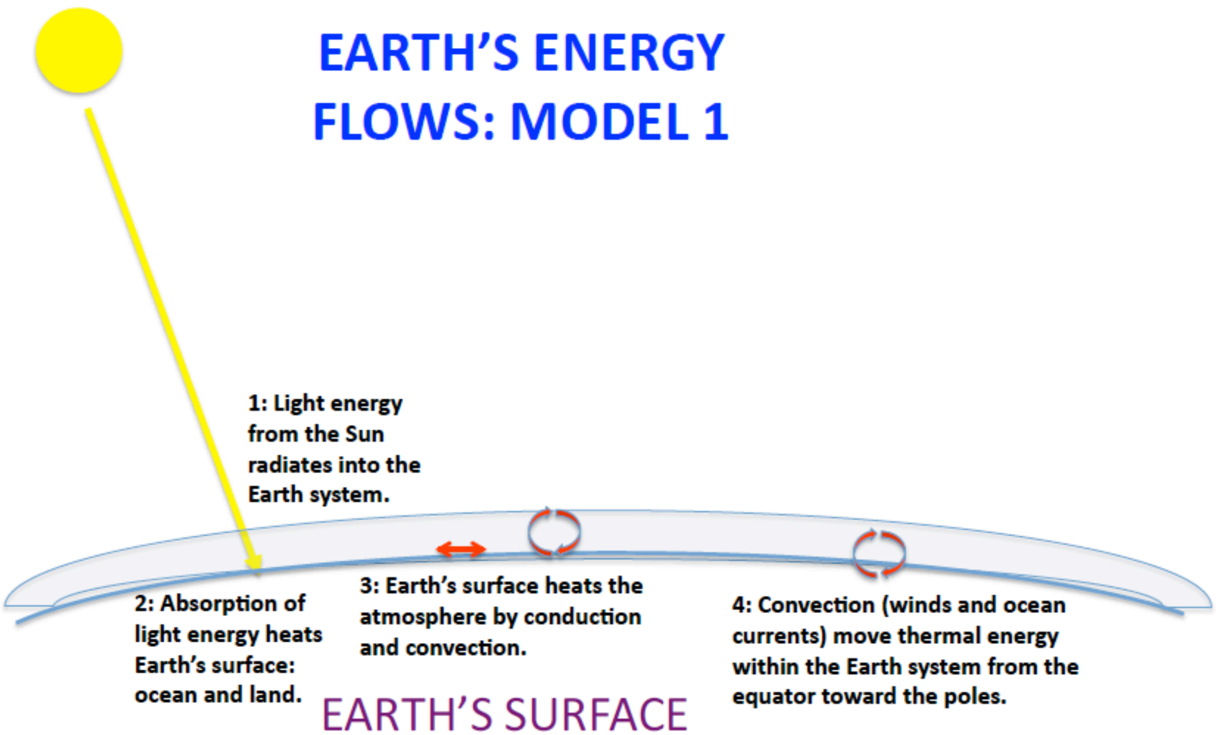



**FIGURE 15:** A simplified model illustrating energy flows that have major effects on weather and climate. (Illustration by Dr. Art Sussman, courtesy of WestEd.)

Students can **reflect on and discuss** a ***simplified model*** to **apply their experiences and knowledge** of the three modes of thermal energy movement to the context of the Earth system (Figure 15). Sunlight travels as radiation from the Sun to enter the Earth system where it initially mostly heats the surface (ocean and land). Earth's surface transfers some of the thermal energy to the atmosphere by conduction, and convection then moves that energy within the atmosphere.[4]

The teacher can prompt students to think about and discuss concept number 4 in Figure 15, the transfer of thermal energy by convection. Why does thermal energy move from the equator toward the poles? Student **explanations** should include the **evidence from prior investigations** that equatorial regions receive much more direct sunlight, and also the major concept that ***thermal energy moves*** from warmer regions toward colder

[4] In Instructional Segment 4, students will learn via Model 2 that radiation from Earth's surface also plays a very significant role in heating the atmosphere and in Earth's global climate.

regions. Students may be confused that there is still such a big latitudinal difference in temperature despite the convection from the equator to the poles. In actuality, the poles would be much colder and the tropics much hotter if winds and ocean currents did not move thermal energy away from the equator.

**Thermal Energy and Wind Convection Cells**

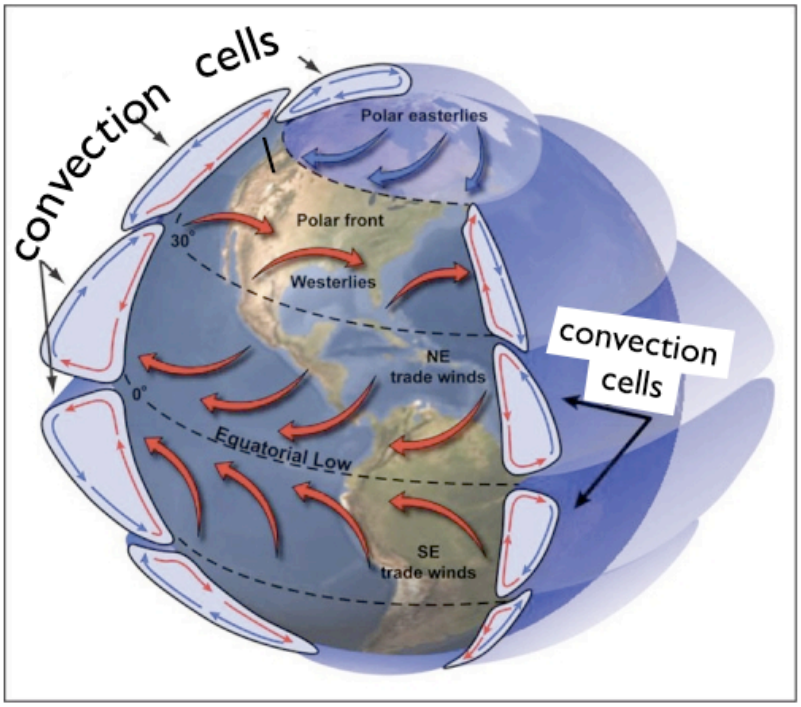



**FIGURE 16:** Wind convection in the atmosphere moves thermal energy from the equator toward the poles (skinny red and blue arrows in the convection cells). Image credit: (GOV) NASA, accessed at: [https://www.nc-climate.ncsu.edu/edu/k12/.atmosphere_circulation](https://www.nc-climate.ncsu.edu/edu/k12/.atmosphere_circulation).

In the atmosphere, the wind convection from the equator toward the poles actually happens via sequential "steps" that are called convection cells (Figure 16). In this illustration, the equator appears closer to the top than is usually shown, and can be identified as the dotted line passing through Mexico and a little below Florida. The two convection cells just north and just south of the equator each have skinny red arrows representing warm air traveling toward the poles and skinny blue arrows representing colder air from the polar regions traveling toward the equator. The illustration shows three sequential convection cells connecting the equator and South Pole. Similarly, three sequential convection cells connect the equator and the North Pole, but only two of these are visible in Figure 16.

This illustration also shows thicker arrows that represent winds that blow east and west. If simple convection were the only process controlling air movements, all wind would flow in the north-south direction, but we know that is not true. Earth's rotation modifies this path. The assessment boundary for *MS-ESS2-6* states that "Assessment does not include the dynamics of the Coriolis effect," so the exact details of this process are not essential for students, but is included here for curious teachers and students.

Air rotates around the Earth just like the planet rotates around its axis. The atmosphere races around the equator at 1,700 km/hr to complete one full rotation in 24 hours, but it hardly needs to move at all near the poles. As a parcel of air travels north or south from the fast moving equator towards the poles, it is moving faster in the direction of Earth's rotation than the ground underneath it. From our perspective on the surface, it appears to be veering off in the direction of Earth's rotation. Air moving from the poles towards the equator is moving slower than the ground underneath it, so it gets 'left behind' and appears to make a turn away from the rotation direction. Together, these deflections set up predictable bands of wind direction near the surface, and also give rise to the jet streams in the upper atmosphere.

Transitioning from this global view back to a more regional perspective on climate, students can revisit Figure 12 with its color-coded global map of average annual temperatures. Students can discuss in groups any aspects of Figure 12 that raise **questions** for them. The instructional goal is to discuss the effects of altitude, which appear in Figure 12 as blue areas north of India and on the west coast of South America. These blue areas are the most blatant departures in Figure 12 from the general ***pattern*** of latitude determining climate. If students get too sidetracked with discussing other minor climate discrepancies, teachers always have the option to guide instruction into the most productive directions.

Students may be able to share based on personal experience that mountain temperatures tend to be cooler than temperatures at lower elevations. A very important climate consequence of the colder temperatures at higher altitudes is that rising air becomes colder and can hold less water vapor (see Figure 10 in Instructional Segment 2 correlating relative humidity and temperature). ***As a result*** of this cooling, water condenses, clouds form, and there is a much greater likelihood of precipitation in the forms of rain or snow. The **analyses** of California climate regions revealed this correlation of increased precipitation with higher elevations.

Two ***generalizations*** could emerge from consistent research. If wind from a moist area is blowing towards a mountain range, it is very likely that there will be high amounts of precipitation on the side of the mountains that the winds first hits (called windward or upwind). The other side of the mountain (leeward or downwind) tends to be much drier because most of the water vapor has condensed and precipitated on the other side of the mountain. On the other hand, if the wind blowing towards the mountain has very low humidity, then it is likely that both sides of the mountain will be dry. This condition tends to occur in the middle of continents or locations where the prevailing winds tend to blow toward the ocean.

The temperature and amount of humidity in a mass of air reflects where that mass of air first formed. If it first formed over a warm ocean, the air mass will be warm and humid. If it first formed over a dry continental area, the air mass will be dry and its temperature will depend on whether the continental area was hot or cold. Using animations of real-time satellite observations[5]), students **collect data** about the movement of large air masses, noticing that the most intense precipitation and weather events occur where air masses collide (*MS-ESS2-5*). These observations form the evidence that can be used to construct a more complete ***explanation*** or a ***model*** of the relationship between air masses and changing weather conditions (Table 7).

[5] NOAA, Geostational Satellite Server: GOES Western U.S. Water Vapor and Visible. Accessed at http://www.goes.noaa.gov/browsw3.html

| TABLE 7: Air Movements and Weather | | | |
|---|---|---|---|
| **CONDITION** | **AIR MOVEMENT** | **WEATHER** | **SAMPLE LOCATION** |
| Convection cell near equator | Warm moist air rising | Thunderstorms; Heavy precipitation | Equatorial Pacific Islands |
| Convection cell at $30^0$ latitudes | Dry air sinking | Desert | Sahara Desert Arabian Desert |
| Warm air mass and cold air mass collide | Warm air rising | Clouds and precipitation likely | Variable |
| Windward side of coastal mountain | Moist air rising | Rain and/or snow | California Coast and Sierra Nevada |
| Leeward side of mountain | Dry air sinking | Clear weather | Central Valley Southwest US desert |
| High pressure system | Air sinking | Clear and sunny weather | Variable |
| Low pressure system | Air rising | Cloudy and wet weather | Variable |

(Table 7 from Dr. Art Sussman, courtesy of WestEd)

Final Note re Weather in Instructional Segment 3: The clarification statement for *MS-ESS2-5* indicates that students will not be assessed on weather map symbols. This is largely a reaction to the fact that these symbols are no longer necessary for illustrating weather patterns in the digital age. For example, real-time wind patterns are indicated with animations of the flow of individual particles[6] or with familiar rainbow color scales[7]. These visualization tools allow teachers to spend more time helping students ***recognize and explain patterns*** with less time devoted to memorizing symbols.

**Organism Traits, Heredity and Reproduction**

Climate and major geographical features are key abiotic factors that strongly ***influence*** the kinds of organisms can live in an environment. These same factors also help ***determine*** the organism structures and behaviors (adaptations) that will have the most success with respect to survival and reproduction. Teams of students can **research** a

[6] Viégas, F. and Wattenberg, M., Wind Map, accessed at http://hint.fm/wind/
[7] Beccario, C., Earth, accessed at http://earth.nullschool.net/#current/wind/surface/level/

distinctive environment (e.g., an island near the equator), and organize and communicate information about the plant and animal traits that promote success in that environment. Sharing across teams that have investigated very different kinds of environments can then lead to generalizations about significant ***patterns***.

In addition to a general emphasis on adaptations that promote growth and survival (LS1-5), Instructional Segment 3 Performance Expectations emphasize **evaluating** factors that promote reproductive success (LS1-4) and **analyzing** different modes of reproduction (LS3-2). This focus on reproduction helps highlight a general ***pattern*** that biotic factors have a strong influence on organism traits. Organisms from different species can strongly ***determine*** organism structures and behaviors that promote successful growth, survival and reproduction. The interactions of plants and animals involved in pollination provide great examples of organisms from species ***causing*** changes in each other's biological structures and behaviors in the service of plant reproduction. As will be described later, sexual selection by females provides dramatic examples of organisms from the same species ***causing*** changes in biological structures and behaviors.

Organism structures and behaviors are features that generally apply to all members of a species. Examples of human features are eye color, body size, blood type, abd personality such as introversion/extroversio. If a feature normally has a pattern of varying among individuals, then we describe those variations as being traits of that feature. For example, each different blood type is a trait, as is each different eye color or hair color. Many features vary across a very wide spectrum of possibilities, and we usually clump these variations into groups that we generalize and simplify, such as describing people's height feature as being very short, short, average, tall, or very tall.

Discussions of traits can get side-tracked by either/or arguments about the roles of genes and the environment in determining traits. Early in Instructional Segment 1, this kind of "either/or" issue arose with respect to the geosphere being either a component or a system, while in fact it is both a component of the whole Earth system and also a system made of parts. Many features and processes of the natural world occur across a very wide spectrum of possibilities. In the case of organism traits, there are some traits that are essentially all genetic (e.g., blood type) and other traits that have a very large environmental component (e.g., large muscles due to exercise or being able to play the guitar). Most traits are a combination of genetic and environmental influence, and can be placed somewhere along the spectrum between the extremes examples (Figure 17).

**Cat Example of Continuum of Traits**

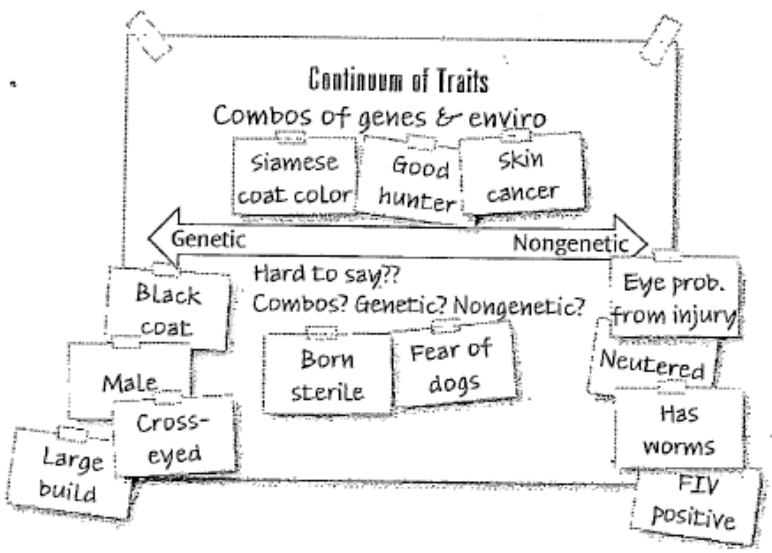



**Figure 17:** Some traits are essentially all genetic, and some are mostly environmental. Most traits are strongly influenced by genes and the environment. (Illustrations from Making Sense of Science *Genes and Traits* course, courtesy of WestEd.)

With respect to genes, students typically learn about genes by **analyzing** the results of Mendel's experiments with pea plants. In analyzing these or other classic examples of genetic experiments, students often use Punnett squares to **predict or explain** the traits in progeny, and then **conclude based on evidence** that some gene alleles are recessive, others are dominant, and some do not fit the dominant/recessive dichotomy. Classic genetics tends to reinforce a misconception that each trait is caused by one gene. Students may also hold a parallel misconception that each gene influences only one trait. Students can counter these misconceptions by **citing evidence** such as that the ABCC11 gene on chromosome 16 influences the type of earwax a person has and also the amount of underarm odor. Figure 18 contrasts incorrect and correct concepts about the ***causal linkages*** between genes and traits.

**Incorrect and Correct Ideas about Genes and Traits**

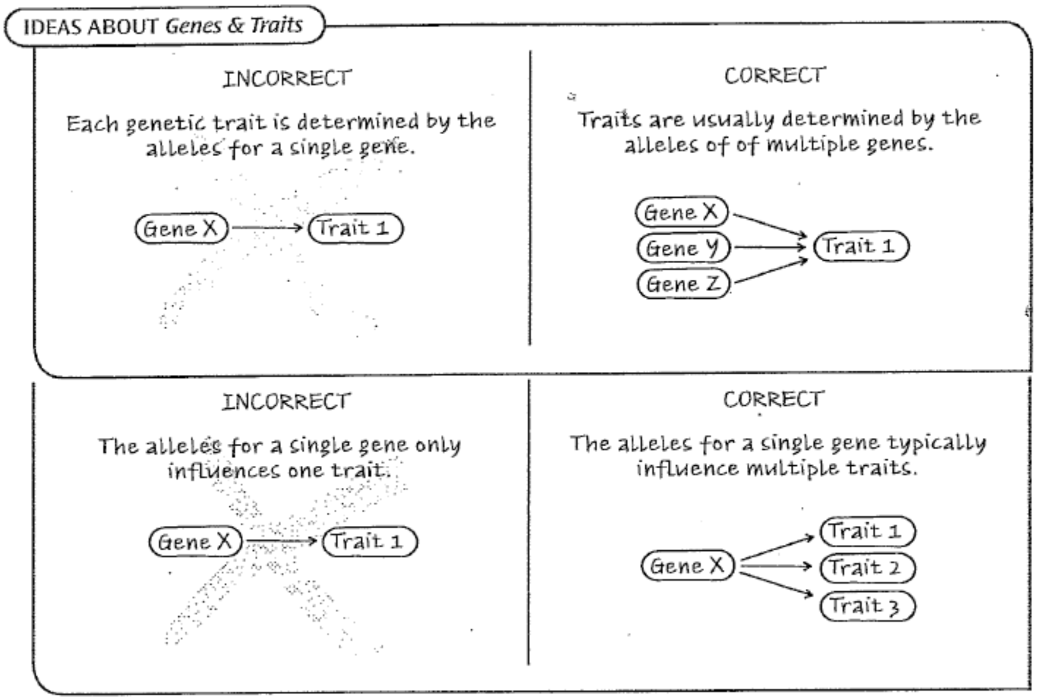



**Figure 18:** Multiple genes typically determine a specific trait, and an individual gene typically influences multiple traits. (Illustration from Making Sense of Science *Genes and Traits* course, courtesy of WestEd.)

**Instructional Segment 3 Snapshot**

**Asexual and Sexual Reproduction**

This snapshot presents an example of how teaching and learning may look in the 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. A Snapshot provides fewer details than a Vignette (e.g., the Instructional Segment 2 Vignette “Interactions of Earth Systems Cause Weather”).

Ms. Z wanted to use an engaging activity to help students transition from their analyses of the causal connections between genes and traits to comparing asexual and sexual reproduction. Basing the activity on an interactive lesson from the University of Utah Learn.Genetics website,[8] Ms. Z provided background information about reproduction in sunflowers, earthworms, strawberries, and whiptail lizards. Students discussed in teams how to describe the reproductive process in each organism (asexual, sexual, or both) and the **evidence** for their categorizations. Whole class sharing resulted in common answers and evidence. Small student teams then had time to explore the website (possibilities would be in computer lab, in class with tablets, at home, in a library) in order to select two organisms that have different processes of sexual reproduction.

The following day, student teams **made system models** of the reproduction processes for each of their two selected organisms. Each of the system models had to **explain why** the progeny would have identical or different genetic information from each other. Students posted one of their system models on the wall, and then individually walked around the room, and **analyzed** each posted model. They pasted Post-Its next to the models with any questions or **disagreements they had with respect to the conclusions and/or evidence**. After the presenters had time to look at the Post-Its, the whole class paid attention as each presenting team **appropriately responded** to the comments.

**NGSS Connections in the Snapshot**

**Performance Expectations**
**MS-LS3-2**. Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with identical genetic information.

**Disciplinary Core Ideas**
**LS1.B: Growth and Development of Organisms**
**LS3.B: Variation of Traits**

**Scientific and Engineering practices**
**Developing and Using a Model**
*Develop and/or use a model to predict and/or describe phenomena.*
*Develop a model to describe unobservable mechanisms.*
**Constructing Explanations**
*Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an*

[8] Sexual vs. Asexual Reproduction accessed at: http://learn.genetics.utah.edu/content/variation/reproduction/

*explanation for real-world phenomena, examples, or events.*

**Engaging in Argument from Evidence**

*Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.*

**Crosscutting Concepts**

**Patterns**

*Macroscopic patterns are related to the nature of microscopic and atomic-level structure.*

*Patterns may be used to identify cause-and-effect relationships.*

**Cause and Effect**

*Cause and effect relationships may be used to predict phenomena in natural or designed systems.*

**CCSS Connections to English Language Arts**

**ELA: WHST.6–8.7, 9; SL.6.2, 5**

**Connection to CA ELD Standards:**

ELD.PI.6-8.1, 9

**CCSS Connections to Mathematics**

None

Sexual reproduction in animals can then lead to investigations that link back to the body systems concepts in Instructional Segment 1. Students **analyze** each of the reproductive processes described in the Snapshot lesson to compare all animal behaviors that play a significant role in the reproduction. In order to do so, the students **discuss the criteria** for how they will categorize different kinds of behavior. If students have difficulty suggesting valuable criteria, the teacher can prompt the discussion with examples that exemplify choice, rigid instinctive behavior, memory, reasoning, and flexibility. Students can do more **research** about some of the examples that may lead to surprising findings, such as the amount of navigation, memory, analysis, learning, and communication involved when a honeybee chooses where to fly to from the hive to gather nectar.

At the teacher's direction, students **extend their investigations** into behaviors by focusing on female choice in reproduction (not including humans). Key factors related to these investigations include stimuli provided by the male, female sensory receptors, female behavioral response, and female memory. The teacher provides a list of possible examples (such as bowerbirds, peacocks, fruit flies, and vervet monkeys). For example, female vervet monkeys respond more favorably to males that show caring behavior toward infants. As a result, male vervet monkeys behave better toward infants when a female is watching. Student teams pick one of the suggested examples of female choice or a different one that they independently **researched and evaluated**.

After the teams have conducted the first round of research, the whole class decides on the criteria for a complete investigation and report. The teacher may exercise male or female choice whether to post the wording of PE MS-LS1-8 and also whether to allot extra credit for teams that provide information about the nervous ***system components that enable the investigated animal behavior***. Teams extend and conclude their investigation by **developing and presenting a report** to the class about their example of female choice including **explaining the evidence and reasoning** how the behavior affects the probability of successful reproduction (MS-LS1-4).

These life science learning experiences in grade 6 provide a foundation for deeper explorations in grade 7 (PEs and DCIs focused on LS2: Ecosystems) and in grade 8 (PEs and DCIs focused on L3: Heredity and L4: Biological Evolution).

1066

| Table 8 - Grade 6 Instructional Segment 4<br>Effects of Global Warming on Living Systems |
|---|
| **Guiding Question:**<br>How do human activities affect Earth's systems?<br>How do we know our global climate is changing?<br>**Highlighted Science and Engineering Practices:**<br>**Asking Questions and Defining Problems;**<br>**Obtaining, Evaluating, and Communicating Information;**<br>**Developing and Using Models;**<br>**Engaging in Argument from Evidence;**<br>**Constructing Explanations and Designing Solutions**<br>***Highlighted Crosscutting concepts:***<br>***Cause and Effect: Mechanism and Prediction;***<br>***Energy and Matter: Flows, Cycles and Conservation;***<br>***Stability and Change;***<br>***Systems and System Models***<br>**ESS3-3.** **Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.*** [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]<br>**ESS3-5.** **Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.** [Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.]<br>**LS1-4** **Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors** |

**and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.** [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds, and creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.]

**LS1-5.** **Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.** [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.] [*Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.*]

**ETS1-1.** **Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.**

**ETS1-2.** **Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.**

**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.

**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.

**Instructional Segment 4 Teacher Background and Instructional Suggestions**

Instructional Segment 2 introduced concepts related to weather and to California regional climates. Instructional Segment 3 maintained a focus on regional climate but also introduced global considerations with Figure 15 (Earth's Energy Flows: Model 1) and the global convection cells in Figure 16. Instructional Segment 4 expands the ***scale*** by including the ***flow of energy*** by radiation from Earth's surface to outer space in Mode 2 of Earth's Energy Flows (Figure 19).

Students can **reflect on and discuss** Model 2 by first comparing it with Model 1 (Figure 15). They should note that radiation has been added as one significant way that Earth's surface ***transfers thermal energy*** to the atmosphere (small upward red arrow associated with point number 3). Similar to sunlight, this arrow represents electromagnetic radiation. This radiation is in the longer wavelength part of the infrared (IR) region. It is has a longer wavelength than sunlight and is less energetic. Gases in the atmosphere, especially water vapor and carbon dioxide, absorb the IR that radiates from the surface, and this absorption heats the atmosphere. This natural process, the

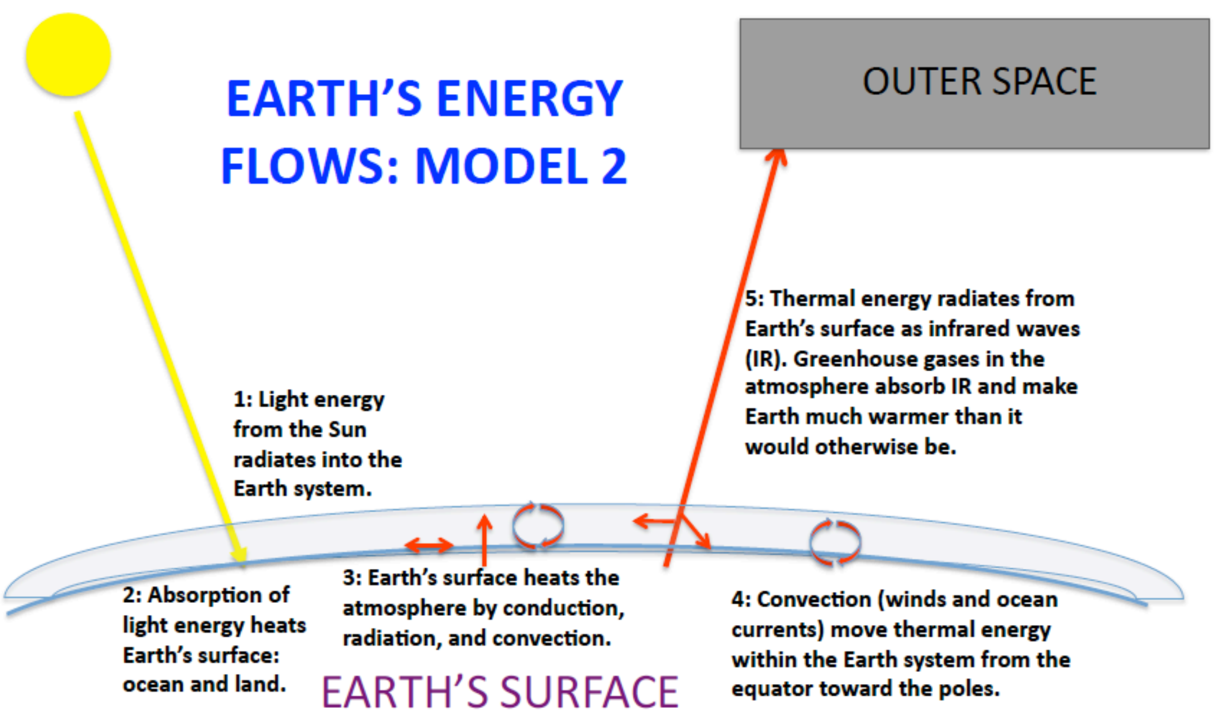



**Figure 19:** A more accurate model of Earth's energy flows that includes radiation of thermal energy and the greenhouse effect. (Illustration from Dr. Art Sussman, courtesy of WestEd.)

famous greenhouse effect, **causes** Earth's temperature to be warm enough for today's web of life. Without this natural greenhouse effect, Earth's average surface temperature would be $0^0$F. At this temperature, the planet would be so cold that practically all water on Earth would freeze, the oceans would be filled with ice, and life as we know it would not exist.

Students can **research** the electromagnetic spectrum (Figure 20) as a very important example of a feature of the universe that spans a huge ***scale of values***. The EM spectrum includes radio waves that are about a thousand times longer than visible light whose waves are a thousand times longer than the waves of X-rays whose waves are much longer than the most energetic waves (gamma rays). Each of these kinds of waves travels at the speed of light (as fast as anything can go) and does not lose energy as it travels (even over large distances such as from the Sun to Earth).

**The Electromagnetic Spectrum**

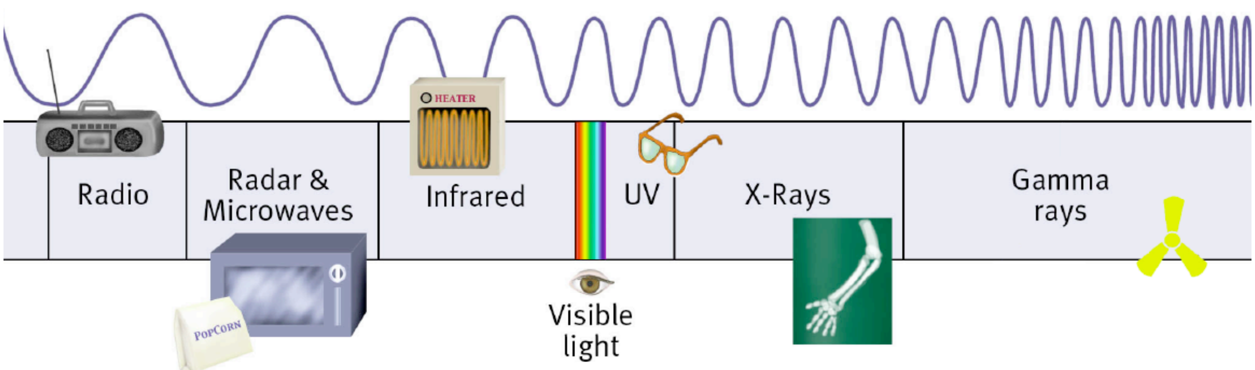



**Figure 20:** The electromagnetic spectrum spans a huge range of wavelengths. Wavelengths cannot be drawn to scale. (Illustration from *Dr. Art's Guide to Science*, courtesy of WestEd.)

Students should be able to **explain and illustrate** that all objects, including themselves, constantly emit infrared radiation. They should **model** that as this IR travels through the atmosphere, it gets absorbed and trapped by greenhouse gases, which then emit IR in all possible directions (back towards the surface, horizontally within the atmosphere, and also towards outer space). Eventually infrared radiation leaves the atmosphere and goes to outer space. This infrared radiation is the only way that the energy that entered the Earth system in the form of absorbed sunlight can leave the Earth system. Without this escape mechanism, the oceans would have boiled away and the surface would be blazingly hot. Without the greenhouse effect trapping the exiting infrared radiation, Earth would be a frozen wasteland.

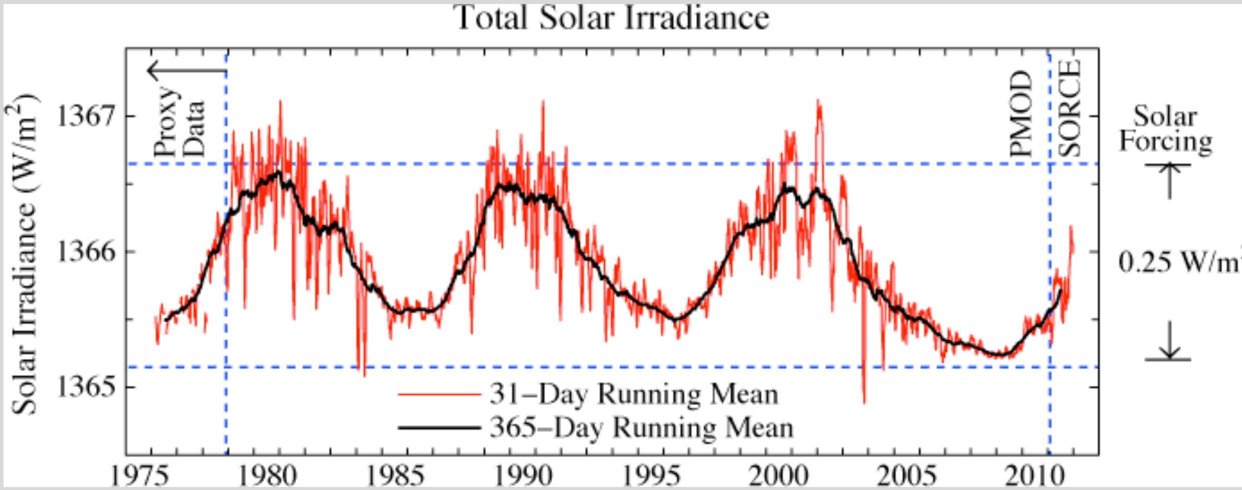
**Instructional Segment 4 Snapshot 1**

**Global Warming**

This snapshot presents an example of how teaching and learning may look like in the 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. A Snapshot provides fewer details than a Vignette (e.g., the Instructional Segment 2 Vignette “Interactions of Earth Systems Cause Weather”).

Performance Expectation MS-ESS3-5 focuses on students “asking questions to clarify evidence of the cause of global warming.” Ms. D’s students analyzed the Figure 19 model of Earth’s energy flows. They discussed in small groups the ***changes in energy flows*** that could logically ***cause global warming***. One student group used an analogy with a family’s budget. The change in amount of money they had depended on how much came into the family and how much left the family. The amount that they circulated within the family did not change how much money the family had. By analogy, students **concluded** that changes in flows associated with part 3 (conduction, convection and radiation within the Earth system) were within the “planet Earth family” and would not directly change Earth’s global temperature. On the other hand, changes to the amount of solar energy entering the Earth system ***could directly change*** Earth’s global temperature. Similarly, a change to the amount of energy leaving the Earth system could also directly change Earth’s average global temperature.

**Changes in Sunlight and Global Temperature**




**http://data.giss.nasa.gov/gistemp/2011/Fig9.gif**

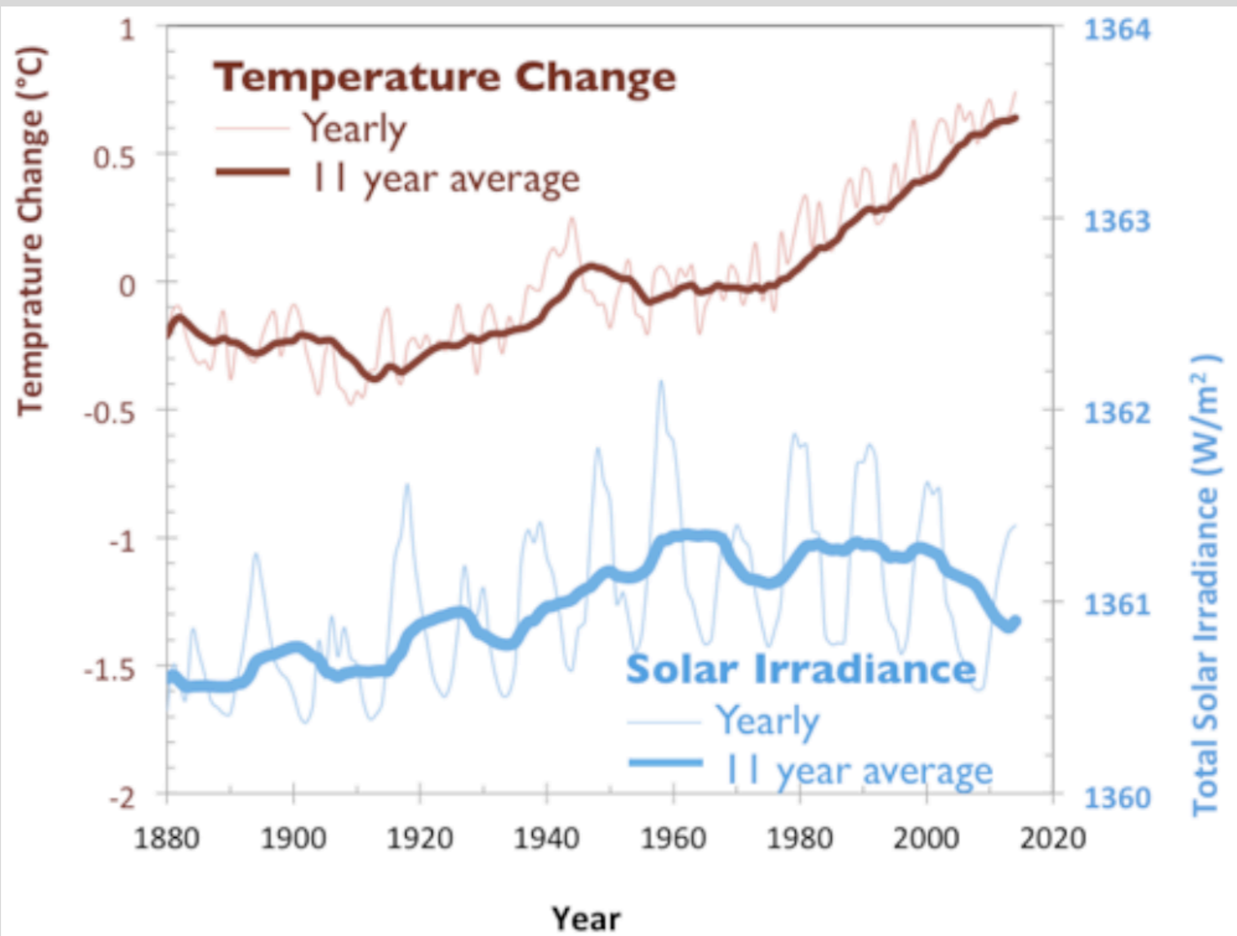



**Figure 21:** The increase in global average temperature compared with changes in solar output during the same time period. (Courtesy of Dr. Matthew D'Alessio)

As a result of this analysis, **students decided to focus their questions** on whether there have been changes to the entry of solar energy or the exiting of thermal energy. Several student teams downloaded graphs that provided **evidence that they used in making the claim** that changes in solar energy were not responsible for the rise in global temperatures (Figure 21). In fact, the data show that the energy from the Sun had actually decreased during the past 50 years, a time period when global temperatures increased the fastest.

This evidence led students to focus on the exiting of energy from the Earth system (long red IR radiation arrow from Earth's surface to Outer Space in Figure 19). Different teams found a **variety of graphs** from government and scientific sources providing evidence that today's global warming is caused by increases in "heat-trapping greenhouse gases," especially carbon dioxide (Figure 22).

**Global Temperature and Carbon Dioxide Over the Past 1,000 Years**

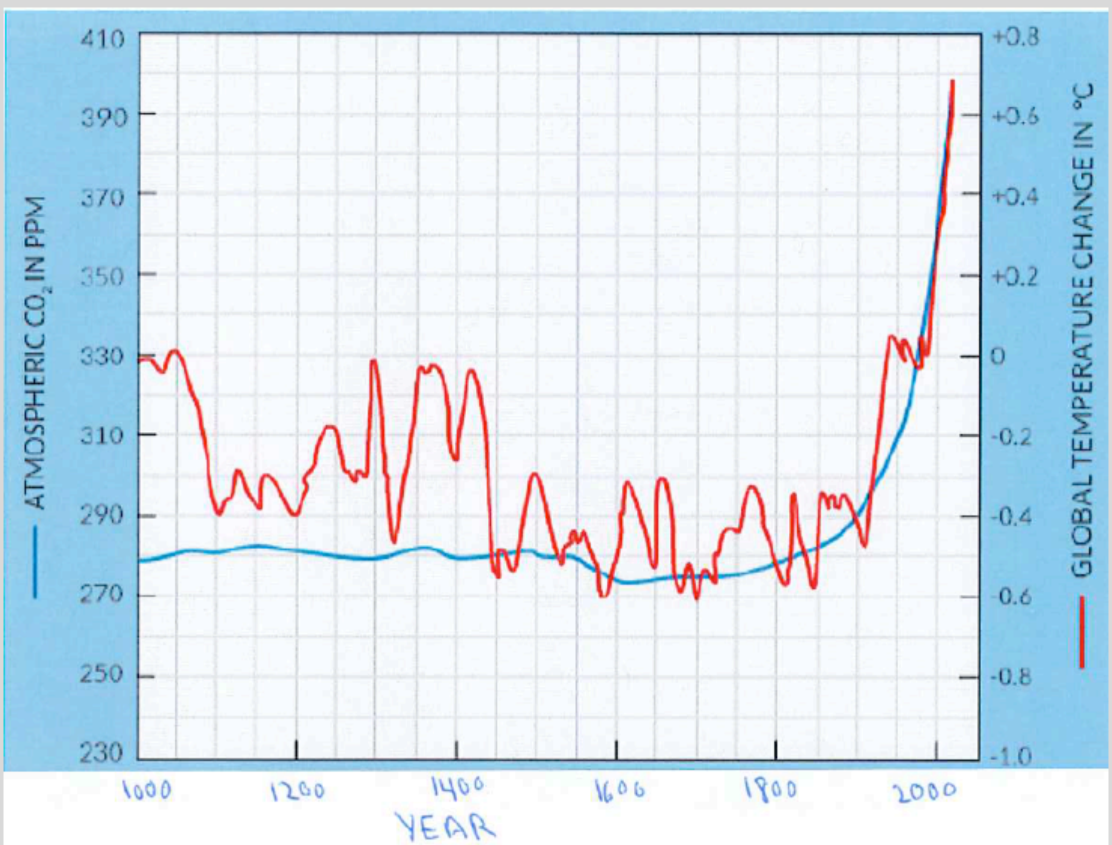



**Figure 22:** Graph shows the $CO_2$ concentration in the air (blue) and average global temperature increase (red) between the years 1000 and 2013. (From Dr. Art Sussman, courtesy of WestEd)

Students also found some websites that claimed either that global warming was not happening or that any warming that was happening was not caused by human activities. These websites led to discussions about how to **evaluate** information related to science, especially connected with topics that are socially controversial. Students shared information from other classes about carefully analyzing the sources of information, especially from the Internet. The teacher shared information about the consensus of more than 95% of climate scientists that global warming is happening, and that it is caused by human activities, especially the combustion of fossil fuels. Students then researched the topic of greenhouse gases, and confirmed that the greenhouse effect is a natural process that actually is vital for making Earth warm enough for anything like today's complex web of life. Some students used the phrase, "You can have too much of a good thing" when they explained how increasing the greenhouse effect could be a major problem.

**NGSS Connections in the Snapshot**

**Performance Expectations**
**MS-ESS3-5**. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

**Disciplinary Core Ideas**
**ESS3.D: Global Climate Change**
**PS3.B: Conservation of Energy and Energy Transfer**

**Scientific and Engineering practices**
**Developing and Using a Model**
*Develop and/or use a model to predict and/or describe phenomena.*
*Develop a model to describe unobservable mechanisms.*
**Analyzing and Interpreting Data**
*Analyze and interpret data to provide evidence for phenomena.*
**Constructing Explanations and Designing Solutions**
*Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.*
*Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.*
**Engaging in Argument from Evidence**
*Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model of a phenomenon or a solution to a problem.*
*Respectfully provide and receive critiques about one's explanations, procedures,*

*models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.*

**Crosscutting Concepts**

**Energy and Matter: Flows, Cycles, and Conservation**

*Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion).*

*The transfer of energy can be tracked as energy flows through a designed or natural system.*

**Cause and Effect**

*Cause and effect relationships may be used to predict phenomena in natural or designed systems.*

**Stability and Change**

*Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.*

*Small changes in one part of a system might cause large changes in another part.*

*Stability might be disturbed by large sudden events or gradual changes that accumulate over time.*

**Systems and System Models**

*Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy, matter and information flows within systems.*

**CCSS Connections to English Language Arts and Mathematics**

The *CA NGSS* promote a vision of science learning as an interdisciplinary undertaking and each standard includes the connections to the *CA CCSS for ELA/Literacy* and the *CA CCSSM. The snapshot highlights the dynamic integration of science with English language arts and math standards to ensure student learning across disciplines.*

RST.6–8.1, 6, 7

CA CCSSM 6.EE.9

Organisms have structural and behavioral adaptations that help them succeed and reproduce in their current environment (MS-LS1-4). The climate changes that have already happened are affecting behaviors of species, especially with respect to timing of migrations, blooming, and maturing of seeds. Computer analyses of business-as-usual climate change scenarios project more dramatic and rapid changes that are likely to have deleterious effects on many organisms (MS-LS1-5).

Each of the integrated middle school grades includes performance expectations that relate to human impacts on the environment. These are generally associated with MS-LS2 Performance Expectations (Ecosystems: Interactions, Energy, and Dynamics) and MSS-ESS3 Performance Expectations (Earth and Human Activity). In addition to the Global Climate topic highlighted in the previous Snapshot, Integrated grade 6 includes MS-ESS3-4 focused on designing a method for monitoring and minimizing a human impact on the environment. The following Snapshot addresses that PE and has an emphasis on engineering design.

**Instructional Segment 4 Snapshot 2**

**Monitoring and Minimizing Human Environmental Impacts**

This snapshot presents an example of how teaching and learning may look like in the 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. A Snapshot provides fewer details than a Vignette.

Following their investigations related to global warming, students in Ms. D's class became concerned about the ways that climate change can harm organisms and ecosystems. Monarch populations west of the Rocky Mountains escape winter by flying very long distances to California. The students live in P, a coastal town with one of the major California winter nesting areas for monarch butterflies. They were very concerned when they learned that climate change was ***affecting organism migrations***.

Students in Team A already volunteered with the local conservation group to protect their public Monarch protection area. The scale of the global climate change issue inspired them to think at a ***broader scale*** about all the places that the butterflies needed during the summer and on their long journey to Central and Southern California. They decided to gather information about the major threats that the butterflies faced on their long journey, and to network with schools on that pathway to collaborate on monitoring the Monarch population, the local threats to the Monarchs (especially related to habitat, food and climate), and possible local solutions to those threats.

Students in Team B argued that the Monarchs, and lots of other organisms, needed long-term solutions to climate change especially switching to renewable energy sources, and they **gathered information** about making electricity from solar photovoltaic cells. The school was in the process of seeking funds to purchase and install some solar cells. Team B started investigating how much extra solar electricity the school could get if the solar cells tracked the sun during the day rather than remaining stationary, and whether those **gains would be worth the cost** and any other issues related to the placement of the solar cells.

Students in Team C had learned about a different school in the county that had instituted a successful major energy saving program. They wanted their school to monitor and minimize consumption of electricity and natural gas. Team C started **analyzing data about the school energy sources and consumption**, and what resources in the school and community were available for collaboration, especially the local utility company. They were particularly interested in digital devices that could monitor and control consumption of energy.

Ms. D assisted the school teams, especially with helping them establish a shared understanding about clearly articulating the **criteria** that could be used to evaluate the success of their project and the **constraints** that could limit and impede success. In addition to collaborating and sharing within their team, the students also had regular meetings to share across the teams so they could gain insights and feedback from a larger and more diverse group. Ms. D also encouraged the three teams to include in their criteria and constraints the longer-term prospects for each of their projects, and how they could use different communication systems to implement their project and begin to support its sustainability.

**NGSS Connections in the Snapshot**

**Performance Expectations**

**MS-ESS3-3**. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

**MS-LS1-5.** Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
**MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to secure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
and genetic factors influence the growth of organisms.
**MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

**Disciplinary Core Ideas**
**ESS3.C: Human Impacts on Earth Systems**
**LS1.B: Growth and Development of Organisms**
**ETS1.A Defining and Delimiting Engineering Problems**

**Scientific and Engineering practices**
**Asking Questions and Defining Problems**
*Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.*
**Analyzing and Interpreting Data**
*Analyze and interpret data to provide evidence for phenomena.*
*Analyze data to define an optimal operational range for a proposed object, tool, process, or system that best meets criteria for success.*
**Constructing Explanations and Designing Solutions**
*Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.*
*Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.*
*Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.*
*Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model of a phenomenon or a solution to a problem.*
*Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.*

**Crosscutting Concepts**
**Stability and Change**
*Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.*
*Small changes in one part of a system might cause large changes in another part.*
*Stability might be disturbed by large sudden events or gradual changes that accumulate*

*over time.*
**Cause and Effect**
*Cause and effect relationships may be used to predict phenomena in natural or designed systems.*
**Systems and System Models**
*Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy, matter and information flows within systems.*

**CCSS Connections to English Language Arts**
**WHST.6–8.7, 8, 9**

**Connection to CA ELD Standards:**
ELD.PI.6-8.1

**CCSS Connections to Mathematics**

6.SP.1–5

The focus in Instructional Segment 4 on monitoring/minimizing human environmental impacts as well as on global climate change complete the year's science education and reconnect with the systems thinking explored in Instructional Segment 1, especially the emphasis on ***properties of the whole system***. Earth's web of life is a whole system property that emerges from the interactions of organisms with each other and with the huge diversity of Earth environments. Global climate is a whole system property that emerges from the interactions of the Earth subsystems with each other and with the inflow of sunlight. Human actions can change the Earth system's components and interactions in ways that profoundly alter organisms and climate at local, regional and global levels. Integrated grade 6 can help build a middle school foundation of science and engineering understandings and practices related to citizenship and sustainability that can grow in depth in the succeeding middle school and high school grades. (Two EEI Curriculum units, Energy: It's Not All the Same to You and Responding to Environmental Change provide a variety of resources that can support this instruction.)