IS4

Integrated Grade Eight Instructional Segment 4: Sustaining Local and Global Biodiversity

This instructional segment features a very important concept related to the CA NGSS Earth and Space Science domain: Earth and Human Activity. Increases in human population and in per-capita consumption of natural resources impact Earth's systems (MS-ESS3-4). In this instructional segment, students revisit life science concepts that they explored in IS3: *changes in environmental conditions alter populations of organisms and can cause extinction* (MS LS4 4 and MS-LS4-6). Fortunately, modern technologies, such as using digitized signals to encode and transmit information (MS-PS4-3), can help us monitor, understand and reduce these impacts.

INTEGRATED GRADE EIGHT INSTRUCTIONAL SEGMENT 4: SUSTAINING LOCAL AND GLOBAL BIODIVERSITY

Guiding Questions

- What are the characteristic properties and behaviors of waves?
- What human activities harm Earth's biodiversity and what human activities help sustain local and global biodiversity?
- How does communication technology encode information and how can digital technologies be used to help sustain biodiversity?

Performance Expectations

Students who demonstrate understanding can do the following:

MS-LS4-4. Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. [Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.]

MS-LS4-6. Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time. [Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations.]

MS-ESS1-1. Develop and use a model of the Earth-Sun-Moon system to describe the cyclic patterns of lunar phases, eclipses of the Sun and Moon, and seasons. [Clarification Statement: Examples of models can be physical, graphical, or conceptual.].

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

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MS-PS4-1. Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [*Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.*]

MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [*Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.*]

MS-PS4-3. Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog sign. [Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in Wi-Fi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [*Assessment Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.*]

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 environment that may limit possible solutions.

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

**The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or Disciplinary Core Idea.*

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

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models [SEP-4] Analyzing and Interpreting Data [SEP-5] Using Mathematics and Computational Thinking [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-7] Engaging in Argument from Evidence [SEP-8] Obtaining, Evaluating, and Communicating Information	LS4.B: Natural Selection LS4.C: Adaptation ESS1.A: The Universe and Its Stars ESS1.B: Earth and the Solar System ESS3.C: Human Impacts on Earth Systems PS4.A: Waves Properties PS4.B: Electromagnetic Radiation PS4.C: Information Technologies and Instrumentation ETS1.A: Defining and Delimiting Engineering Problems ETS1.B: Developing Possible Solutions	[CCC-1] Patterns [CCC-2] Cause and Effect [CCC-6] Structure and Function [CCC-7] Stability and Change

Highlighted California 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.

CA CCSS Math Connections: 6.RP.1, 3, 6.SP.5, 6.EE.6, 7.EE.3,4, 7.RP.2, 8.F.3, MP.2, MP.4

CA CCSS for ELA/Literacy Connections: RST.6–8.1, 9, WHST.6–8.1, 2, 9, SL.8.1, 4, 5

CA ELD Connections: ELD.PI.6.1, 5, 6a–b, 9, 10, 11a

Students begin by watching an animation of net primary productivity, a quantity related to the amount of photosynthesis occurring at different locations around the world (NASA, http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link26). Students can recognize the obvious cycles of the seasons, but they can also notice the effects of deforestation, desertification, and climate change. For this instructional segment, the anchoring phenomenon is that plants go through seasonal cycles where productivity peaks in the Northern Hemisphere around July and the Southern Hemisphere around January. During the instructional segment, students will explain the large seasonal signal and zoom in to design solutions for problems causing some of the smaller scale changes. This video is remarkable not only because of the Earth system interactions captured, but also in the technology involved in making the observations. Net primary productivity is actually a measure of the amount of carbon dioxide released into an area. How can scientists measure the concentration of a gas at every point around the planet? The answer is that the carbon dioxide gas interacts with light in certain ways that enable scientists to detect the amount of the gas in the air using a satellite with a sophisticated camera.

Students **obtain information [SEP-8]** about the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite and how it observes photosynthesis across the entire planet each month while orbiting 700 km above the surface. The details of the sensor and the frequency of light it uses are outside the assessment boundaries for the middle grades, but one of the major reasons that DCI PS4 is so prominent in the CA NGSS is that we want our students to understand how different wave-based technologies have completely transformed the way we do science, communicate, and live. Before students can explain the features in the anchoring phenomenon, they need to further develop their models of wave properties and behavior. The vignette below uses scientific monitoring of a different life science phenomena to introduce sound waves and other waves such as radio waves.

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Performance Expectations

Students who demonstrate understanding can do the following:

MS-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).] (revisited from grade six)

MS-PS4-1. Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.]

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MS-PS4-2. Develop and use a model of the Earth-Sun-Moon system to describe the cyclic patterns of lunar phases, eclipses of the Sun and Moon, and seasons. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [*Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.*]

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 environment that may limit possible solutions.

**The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or Disciplinary Core Idea.*

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

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models [SEP-5] Using Mathematics and Computational Thinking	ESS3.C: Human Impacts on Earth Systems PS4.A: Waves Properties PS4.B: Electromagnetic Radiation ETS1.A: Defining and Delimiting Engineering Problems	[CCC-1] Patterns [CCC-6] Structure and Function

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

CA CCSS Math Connections: 7.SP.1-3, 8.SP.4

CA CCSS for ELA/Literacy Connections: ELD.PI.8.1, 2, 4, 6a–b, 9

CA ELD Connections: RI.8.2, RI.8.8, SL.8.1, 4, 6

Introduction

This vignette flows from IS3, in which students explored the evolutionary history of several species. Sharks are one of the most ancient vertebrate species with approximately 400 million years of history.

Mrs. G transitioned her students to the next unit on waves, being mindful that she wanted to build in a strong nature of science connection to this part of the unit (Science is a Human Endeavor: *advances in technology influence the progress of science*, and Science Addresses Questions About the Natural and Material World: *science knowledge can describe consequences of actions but does not necessarily prescribe the decisions that society takes*). She decided to help her students see the application of understanding waves in answering some of the biggest questions beach visitors, beach city leaders, and biologists are asking today about sharks: Why

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are we seeing so many white sharks, *Carcharodon carcharias*, off the coast of California?

5E Lesson Design—This sequence is based on an iterative 5E model. See the "Instructional Strategies" chapter for tips on implementing 5E lessons.

Day 1: Questioning Claims about Shark Encounters

Students read an article about a string of recent shark sightings and then shared their own tales about sharks. They asked questions about how they could distinguish fact from fiction.

Day 2: Data with More Questions than Answers

Students tried to interpret a graph of the number of reported shark captures, but found that many factors influenced the data set itself.

Day 3: Locating with Sound

Students watched a video about an autonomous underwater vehicle that tracks and films sharks. They used models to reverse-engineer how the device locates the sharks using sound waves.

Day 4: Obtaining Information about Tags

Students researched about how different types of electronic tags and receivers use wave technology to collect and transmit information to scientists.

Days 5–6: Light and Sound

Students obtained information about light and sound and then planned an investigation to explore the differences in how they travel through salt water.

Days 7–8: Interpreting Shark Data

Students explored new understandings from this technology.

Days 9–10: Applying Understanding to a Different Population

Students applied new understandings and predicted possible trends in shark populations on the East Coast.

Days 11–12: Educating Different Audiences

Students considered the question, Now that we have better information on white sharks, what type of information is important for the public to know? to probe thinking as to why sharks are important and human actions that affect the population and created a public service announcement to target a specific audience.

Day 1: Questioning Claims about Shark Encounters (Engage)

Everyday phenomenon: Sharks have been seen at California beaches recently.

To pique interest and provide all students with background on a real-world phenomenon, students read a short article on recent shark sightings (Rocha 2015). Students excitedly shared stories they have heard about white sharks, many of which were outlandish and eventually led to rumors about sharks attacking or eating humans. Mrs. G simply solicited

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information from the students and let the excitement in the room build. Mrs. G then began to direct the conversation. After everyone agreed that sometimes people embellish stories and some things may not be true, Mrs. G asked how students could distinguish accurate information on sharks from the fantastical stories friends and families share. How could they tell if there were more shark encounters this year than in the past? After several months in Mrs. G's class, they all called out, "We need data!"

In groups, students discussed how they could build an accurate record of information on white sharks that had visited the coast in recent history (for the past 100 years). At the middle grades level, students should be able to **ask questions [SEP-1]** that help them identify evidence that can support an argument. Students struggled with this question once they realized that Google didn't exist 100 years ago. As she visited teams, Mrs. G asked students to think if there was anyone who would have had consistent access to the coast and might have documented information on sharks. Students continued to stumble, but came up with ideas such as lifeguards or someone who lives at the beach—but they acknowledged that they probably couldn't see sharks very well from the shore.

In one team, Minh had a different idea. She often went to the pier to fish with her family and sometimes caught small "sand sharks." She explained that even her grandfather told stories of catching sharks when he was a small boy in Vietnam. Mrs. G asked if Minh would mind sharing with the class. As Minh began, José's eyes lit up and he began frantically waving his hand. He, too, went fishing with his uncle, who owned a sport fishing charter boat. His uncle kept a log of what everyone caught. When the boat returned to the dock, they had to report what they caught on the trip, and sometimes there was someone at the dock who inspected their buckets. The class quickly began to realize that fisher logbooks might be a good source of information.

Day 2: Data with More Questions than Answers (Explore)

Anchoring phenomenon: The number of shark sightings increased dramatically in 1980 and goes up and down over time.

Mrs. G provided students a graph with observations of reported shark catches over the last 100 years (figure 5.54). Once students had a chance to examine and discuss it with their team. Mrs. G asked the class where the title was and students realize it was at the bottom. "Does anyone have any idea what 'temporal trends' means?" she asked. One student suggested temperature and several agreed. Mrs. G continued, "What if I told you the word came from a Latin word, *tempus*?" Kim, a music student, replied, "Is that like tempo? We use that word in music, it like, deals with time or something." "Oh, good connection, Kim," said Mrs. G. "It does have to do with time, so here we are looking at temporal trends, or trends over time." She asked students to share what they think *YOY*, *Juvenile*, *Subadult-adult*, and *Unk* represented on the graph. She asked students to discuss if they should focus on the height of each bar, or the height of the overall total. "I would be afraid of a white shark no matter what age it is,"

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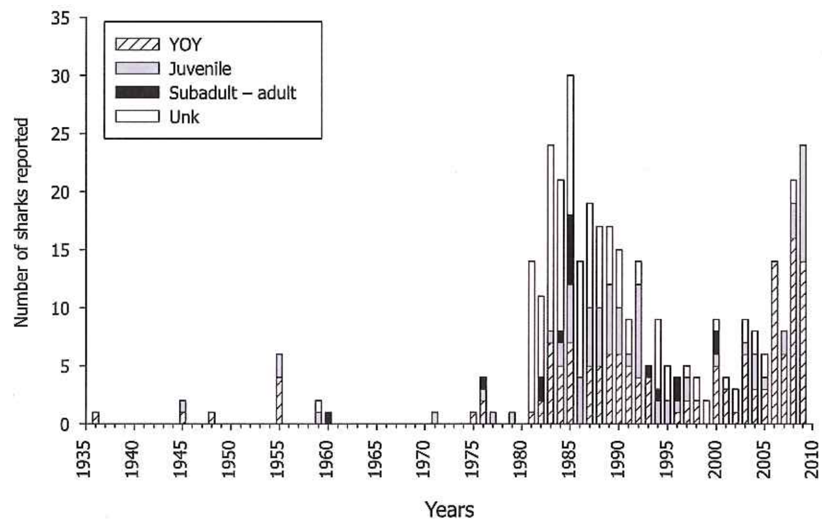
offered José. Mrs. G emphasized that students need to focus in on the information in the data that would help them answer their questions about whether or not sharks are becoming more common along the California coastline and they could ignore the extra details for now.

Figure 5.54. White Shark Captures in Southern California from 1935–2009



Source: Lowe et al. 2012

Mrs. G asked students to view the data through the lens of cause and effect [CCC 2] and record questions in their science notebooks. Using protocols they established earlier in the year, students in each team helped each other generate ideas. Students invited each other to share an idea before any one person shared more than one idea, and they often invited someone who is reluctant to share or to be the first one to speak. Mrs. G overheard Minh's group. Minh restated the question for Maria, an English language learner who was often reluctant to speak, "Maria, what is your question about this?" Pointing to the data in the figure, she said, "This is the effect. What was the cause?"

Students began working and charting questions: Why were there so few sharks reported before 1980? Why do the numbers of sharks reported go down in the late 1990s through the early 2000s? Why were there so many young sharks and so few adults? Students were then asked to narrow down to one question, and consider possible causes or factors that could

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have led to that result. Mrs. G selected one group's chart to share with the class because it allowed her to focus on a key issue:

Question: Why were there so few sharks reported before 1980?

Possible causes:

- There weren't very many white sharks.
- People didn't fish as much.
- Fewer people lived in California so there weren't as many fishermen.
- There wasn't good fishing technology before 1980 so it was harder to catch a white shark.
- There wasn't someone to track information and computers were not common before 1980.
- Some people caught white sharks to sell them.
- Once people learned about sharks they were scared and they wanted to kill sharks.

Mrs. G asked students to look at this team's list of possible causes and divide them into two categories: inconsistency in the data set and an actual change in the number of sharks. Both were possible, so students needed more information about their data set.

Students read an article Mrs. G adapted from a paper written by researchers at California State University, Long Beach and the Monterey Bay Aquarium reviewing the history of white sharks in California (Lowe et al. 2012). Each team was asked to read a part and then **report a key finding [SEP-8]** on the class white board. From this, students commented on how messy and confusing the data can be and how there was a lot of information they had to take into account to make sense of it without misinterpreting it. For example, in some cases it might have looked like the white shark population was increasing, yet at the same time the population of humans living and playing at the coast increased, which could have resulted in increased reports. They were shocked to learn that a movie had an impact on the data. The release of the movie *Jaws* resulted in an increase in white shark reporting in the early 1980s, as people set out to kill white sharks. Some of this increase was due to more sharks tangled in commercial fishing nets as demand for human consumption and updated fishing technology increased (EP&C II). Students acknowledged that relying on fishing data was helpful because we could start to build some understanding, but it did not give them a very clear sense of what is actually going on with respect to white shark behavior.

Day 3: Locating with Sound (Explain)

Investigative problem: Sharks are hard to track and identify.

Mrs. G asked, "Can you think of a way we might get some more reliable data? We can't go back in time, but we can collect better data in the future."

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Students began sharing ideas and Victor suggested using drones to track sharks, and the class erupted in laughter. Mrs. G smiled and said, "Victor is on to something! Drones work in the air, and some lifeguards have tried using a drone rather than sending a lifeguard out on a jet ski just to see where they are. Even with a drone, however, we can't see the sharks if they aren't near the surface. Can you think of something that could work in the water?" Victor then suggested an underwater robot.

Investigative phenomenon: An underwater robot can track sharks using sound waves.

Mrs. G showed a short video clip about the Woods Hole Oceanographic Institution's robotic shark tracker (underwater autonomous vehicle), REMUS (Woods Hole Oceanographic Institution 2014). Students recorded "aha moments" and questions in their notebooks as they watched the video.

Mrs. G asked students what information about sharks they think REMUS could provide. The excited students began listing things like sharks are awesome, sharks can bite hard, and sharks don't like the robot. Mrs. G asked students to turn their list of into specific **questions [SEP-1]** about sharks that they could investigate. They returned to these questions on day 6.

Mrs. G returned to the original question of finding and tracking sharks. It is true that sometimes the shark came to attack the robot, but most of the time the robot sought out the sharks. The video briefly mentioned that the robot had a sensor for locating sharks based on acoustic technology (sound waves). Students were surprised that sound can travel through water, but Mrs. G challenged them to try it out next time they are in a swimming pool or bathtub by submerging their head and then tapping on the wall with a metal spoon. Her students complained that they want her to prove it right then, so Mrs. G filled up a tub of water and clinked together two metal spoons in the middle of the tub so that students can put their ear up against the wall of the tub to hear it. Mrs. G introduced the concept that "sound waves are *transmitted* through water" to explain this phenomenon?

Mrs. G asked students to draw a **model [SEP-2]** on their white board of how they think that the robot could use sound to locate the shark. Students were pretty confused, but Mrs. G helped prompt students to think creatively. Different groups had different models, with some "listening" for the shark with a microphone and others showing a sonar-style device. Mrs. G told students that the devices could only detect sharks from a limited distance away and she had them use their model to write an explanation in their notebook about why. She told them that their explanation should use an energy diagram like the one they learned about earlier in the year. Most students recognized that the sound waves are a form of energy and that this energy must "die out." In groups, students discussed how to represent "die out" in terms of energy and decided that the energy must be absorbed by some other object (probably the water molecules). What could they do to their **system [CCC-4]** to detect sharks from further away? Mrs. G was trying to get students to consider the amplitude of the sound waves and how

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they relate to energy (MS-PS4-1). For a sonar system, for example, they could increase the amplitude of the pulse they send out. Mrs. G asked students to add representations of the sound waves to their diagram where they indicate how the amplitude changes at different points along its path. What would be some challenges the robot would need to overcome in order to send out higher amplitude waves? Students offered good ideas about possibly disturbing the sharks or other marine wildlife with the loud noises, but she directed them towards the idea that the robot would need to use more energy (higher amplitude = higher energy) and would run out of batteries.

Mrs. G showed a quote from a Web page that says REMUS relies on an electronic device, a "transmitter tag," attached to the shark (but her quote provides no other details). Mrs. G asked students what they think this tag does and had them modify their diagram to show a tag transmitting a signal that the REMUS receives. Mrs. G reminded students how quickly cell phones run out of charge when someone talks on them constantly and asked for students to think about how they could extend the battery life on the tag even further. Mrs. G then shared another quote from the REMUS Web page that described how the tags attached to the shark did not send out a constant signal, but instead waited to receive a signal from the REMUS robot. That way, they used much less energy in "standby" mode than they would transmitting constant pulses. The sensor on the robot recorded how long it takes for the sound energy to return after sending its initial pulse and from which direction the return pulse arrives in order to determine the sharks distance and direction. The direction sensing worked a lot like the two human ears spaced a short distance apart (structure and function [CCC-6]); the REMUS robot referred to this distance as an "ultra-short baseline." Mrs. G had students act out the direction sensing process by making a physical model [SEP-2] with one student blindfolded playing the part of the robot and another playing the part of the shark. When the robot claps, the shark claps back.

Day 4: Obtaining Information about Tags (Explore)

Investigative phenomenon: Some tags use radio waves to transmit information.

Now that students knew that tags existed, Mrs. G told them that these devices attached to a shark's fin could actually record all sorts of information and send it back to scientists. She asked them to record ideas in their notebook about what sort of data the tag could collect. She partnered students who had mobile devices with those who didn't to obtain information [SEP-8] about what shark tags actually measured, and suggested they look up SPOT and PAT tags as these were commonly used on white sharks. The students developed a list of things the tags could measure such as temperature, depth, and light intensity. On one team, Trinh wondered aloud how this would tell them anything about what was going on with the shark and how they would get the information from the tag. Her teammate, Oscar, reading from his phone, said, "The SPOT tags transmit using radio waves and so the shark would have to be at the surface to transmit to a satellite. When it swam up to the surface, we would know where

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the shark was, but the PAT tags were designed to pop off and float to the surface." Trinh commented, "That's strange, why does it have to transmit at the surface? Don't waves travel underwater?"

Days 5–6: Light and Sound (Explore/Explain)

Investigative phenomenon: You can hear the buzz of an electronic timer that is under water, but a radio receiver cannot detect radio waves when it is submerged in salt water.

Although her students had heard of radios before, the idea of thinking of these as waves was new for them. They studied waves in grade four, but assessment was limited to mechanical waves (4-PS4-1). For the rest of the period, Mrs. G gave the class time to dig deeper into radio waves and sound waves and explore the phenomenon of what happens to waves in water. She asked them to think of objects in the classroom that used radio waves and those that used sound waves. A student thought of a radio and grabbed a small hand-held AM/FM radio. One student questioned if radio was the same as sound. Acknowledging this, Mrs. G asked him to think of something that had sound that wasn't a radio. He grabbed the class digital timer. Mrs. G had a large saltwater tank set up that had been donated to the class, already filled with a saltwater solution she made that morning. She set out zip-top bags and asked students to **investigate [SEP-3]** the differences between radio waves and sound in water. As they worked, she asked them to record procedures, predictions of what would happen when they submerged devices, and give a rationale for their thinking. After each team confirmed that everyone had supported the predictions with rationale, students held the devices in the center of the tank, surrounded by about a foot of water on all sides. To their delight, they could no longer hear the radio after submerging, but could hear a faint buzzer of the timer. Mrs. G had students document the differences in how radio waves and sound waves traveled through salt water versus air by filling in a table in their science notebooks using the terms *absorbed* and *transmitted*. Their investigations and this video (http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link27) helped give students ideas for revising the models they started on day 3. Some of the students remembered from grade four that light is a wave and wondered if it was absorbed or transmitted in the water.

After a laser safety reminder, Mrs. G encouraged students to shine a laser through the saltwater tank. They didn't notice anything unusual, but Mrs. G told them that there are some important effects of light that shark taggers must consider. Mrs. G called students back to their teams and showed the class a photo of a researcher on a boat trying to tag a shark in the water. She asked them to consider the challenges the researcher had in this task. Students commented that they would be afraid to be so close to a shark and it would be hard because the boat is moving. Mrs. G hinted that there is one more challenge they might not have thought of. She had a student from each group pick up a clear cup of water with a penny at the bottom and bring it back to their table. She then passes out a straw to each team and instructs

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the students to stand directly over the cup and quickly thrust it in to spear the "shark" right on Abraham Lincoln's eye. The students were surprised that they all missed. Mrs. G asked them to view the straw at eye level and Victor shouted, "It's crooked!" Mrs. G confirmed his observation and said, "What you are calling *crooked*, scientists call refraction." Mrs. G then had her students use the PhET simulation "Bending Light" (http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link28) and asked students to make a model in their notebooks of what happens when light goes from air to air, from air to water, from air to glass. She then asked students to make three separate **models [SEP-2]** in their notebooks that **predict [CCC-2]** what would happen if light goes from air to an acrylic block, from air to a wood block, and from air to an aluminum block. Once all of the students in a team had made their predictions, they got a laser and set of blocks, tried it out, and updated their models in their notebook.

Bringing students back to the challenge of tagging a shark from the surface of a boat, she passed out an index card to each team and asked them to compose a tweet to the @CSULBSharkLab. She promised to really tweet the one in the class that best demonstrates an understanding of how light's behavior made it hard to tag sharks.

Days 7–8: Interpreting Shark Data (Explore/Explain)

Investigative phenomenon: White sharks spend lots of time near the shore where fishing regulations prevent the use of entanglement nets.

What have scientists learned from tracking sharks? Is the shark population actually increasing? How does this information help protect the sharks? Mrs. G designs a jigsaw activity where teams divide up into groups of experts that **obtain information [SEP-8]** to answer one the following four questions (with key highlights of what they might find in parentheses):

- As California has grown, has commercial fishing grown, too? (Fishing expanded greatly in the 1970s but was so successful that many fish populations crashed, leading to increased regulations. The commercial halibut catch in California in 2015 was less than half of what it was in the 1990s.)
- How do the commercial entangling nets work? (Large nets left out for as long as several days entangle hundreds of fish at a time and sometimes catch white sharks as well.)
- What laws govern commercial fishing? (In 1994, laws passed that prohibit entangling nets in the shallow water within three miles of the coast.)
- What happens to a white shark when it gets caught by a fishing net? (Some die before the net is brought back to the boat and some get released back into the water.)

Back in their home teams, expert students taught each other about their assigned topics. Together, students made important connections to ideas that related to consumer demand and certain fishing techniques impacting the food source of young great whites. Mrs. G then

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passed out copies of an article from a newspaper that described a study conducted by a graduate student at the CSULB Shark Lab that looked at geo-positioning data from tagged juvenile white sharks (Dulaney 2013). Mrs. G carefully selected figures from the source article (Lyons et al. 2013) and had her students **analyze and interpret [SEP-4]** some of the original tracking data. They found that young sharks spend a surprising amount of time swimming in the shallow water where boats are prohibited from casting nets (within 3 miles of shore). Students constructed an **argument from this evidence [SEP-7]** that the shark population was increasing, and that the increase was a direct result of the laws that have created protected "shark nurseries."

The tracking data also allowed scientists to monitor the fate of sharks that were accidentally caught and released (if the tracker kept going, the shark must have survived). **Interpreting the data [SEP-4]**, students found that sharks had a high chance of survival, and that sharks were more likely to die when nets were left out for longer periods (like 1–2 days) than when the nets were pulled in after just a few hours. They would revisit this finding on day 11.

Days 9–10: Applying Understanding to a Different Population (Elaborate)

Investigative phenomenon: Shark populations in Cape Cod have also changed in recent decades.

Mrs. G told students that as newly minted shark experts, they had been hired to study sharks in Cape Cod, Massachusetts, where there had been frequent sightings of great white sharks in recent years. Were the same factors **causing [CCC-2]** a similar **trend [CCC-1]** as in Southern California? What information would they want to know about the Cape Cod population? Given information about abiotic factors of Cape Cod, could they predict details about the Cape Cod population? Knowing more about the Cape Cod population, what type of tracking device (including details about type of wave and why) would they design to best study them (**planning an investigation [SEP-3]**, **engaging in argument from evidence [SEP-7]**)?

Days 11–12: Educating Different Audiences (Evaluate)

On the final days of the lesson sequence, Mrs. G reminded her students that there were many misunderstanding about sharks at the beginning of their studies. She posed a question, "Now that we have better information on white sharks, what type of information is important for the public to know?" Students in the class had a few moments to record their thinking in their notebooks and the class discussed. Mrs. G asked the teams to think about what they had learned and introduced them to their challenge: Create a public service announcement (PSA) to help educate different audiences in the community. Students decided which audiences would be important to target for this message, created a storyboard to organize their message, and got to work. Groups targeted the fishing industry, lawmakers, and other beach visitors. Mrs. G provided a rubric to help students focus as they worked and provided

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check-in opportunities where teams updated her on their progress and got feedback. The students then proudly shared their PSAs at the school's family science night later that month.

Vignette Debrief

The overall structure of this vignette used a real-world phenomenon in life science to motivate a technological solution using principles of physical science. In the vignette as written, students did not get to answer all the questions introduced by the anchoring phenomenon because changing shark populations and behavior are more closely aligned with performance expectations in grades six (MS-LS1-4) and seven (MS-LS2-1; MS-LS2-4). Teachers could easily extend the lesson to interpret actual data from shark populations to resolve some of the initial questions raised on days 1–2.

This vignette illustrates the CA NGSS vision of blending SEPs, DCIs, and CCCs. While the lesson narrative describes this blend, the sections below focus on relevant aspects of each dimension in isolation, along with ties to the CA CCSS and the EP&Cs.

SEPs. The students in the vignette engaged in many SEPs, thereby building a comprehensive understanding of what it means to do science. The initial focus of the vignette was to identify data that could help students answer a scientific question (**planning investigations [SEP-3]**) and to select the appropriate technology for a device that can provide that information (days 1–2 and 6–7). After learning about a puzzling phenomenon about shark populations, students **asked questions [SEP-1]** on day 2 about the shark siting data they had **analyzed [SEP-4]** and again on day 3 as they were motivated to learn about sharks. On day 4, they **developed models [SEP-2]** of how the REMUS robot transmitted and received information from the sharks. They **conducted simple investigations [SEP-3]** on days 5–6 about light, sound, and radio waves in water. They ended with a **communication product [SEP-8]** that presented both their model and their investigation plan in one authentic public service announcement.

CCCs. The initial motivation for the sequence involved asking questions about **stability and change [CCC-7]** on day 2 when students examined data about shark populations. Students eventually used the tracking data to infer the **cause [CCC-2]** of these changes. In addition to this scientific problem, the vignette focused a lot on understanding the science and engineering aspects of the tracking devices, highlighting how technology facilitates scientific observation as part of the Nature of Science CCC, **Influence of Science, Engineering, and Technology on Society and the Natural World**. The vignette treated shark-tracking technology as a **system [CCC-4]** and students traced out the **flow of energy [CCC-5]** (by sound and radio waves) on days 3–4 when they explained how REMUS and other shark tags work. The foundation box for MS-PS4-2 attributed **structure and function [CCC-6]** to MS-PS4-2 because the structure of materials determined how they would interact with light and sound, though this CCC was not a major theme emphasized throughout the vignette.

DCIs. Shark tags sent information via mechanical (sound) or electromagnetic waves (light and radio), introducing students to basic wave properties (PS4.A). These waves interacted with objects and the media through which they travel, being transmitted, absorbed, or reflected

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(PS4.B). On day 3, students explored the tag transmissions in terms of energy. They identified that higher amplitude waves contain more energy (PS4.A; MS-PS4-1) by discussing how higher amplitude signals would drain batteries more quickly because they require more energy. Students also represented how amplitude decreases with distance as the water absorbs some energy.

In helping students develop models of wave behavior, this vignette went beyond the assessment boundary of MS-PS4-2. That performance expectation stated that wave behavior will only be addressed for light and mechanical waves—introducing the electromagnetic spectrum was beyond the middle grades level. Mrs. G decided that this phenomenon was compelling and included many important aspects of the Evidence Statement for MS-PS4-2. In days 5–6 when students explored sound and light waves, Mrs. G specifically avoided the discussion of the electromagnetic spectrum because the details are complex and more appropriate for high school.

Physical science DCIs about waves are strongly tied to specific life science questions about shark behavior. Shark tags provided data about shark behaviors that increase their odds of survival and reproduction such as migration over large areas, giving birth in warmer waters that influence growth rate, predatory strategies of hiding and attacking, and cooperative hunting (LS1.B Growth and Development of Organisms). In Integrated Grade Six, students constructed arguments about how such behaviors help animals survive (MS-LS1-4), and this vignette focused on **planning an investigation [SEP-3]** using shark tags that would provide evidence for such arguments.

By confronting the environmental impact of fishing on shark populations through monitoring (tags) and mitigation (public service announcement), students achieve MS ESS3-2 (revisited from grade six) and gain a better idea of human impacts on the Earth system. This vignette's focus on the biosphere is outside the recommendations and intent of the clarification statement that focus on the physical aspects of Earth systems, but this application of the Earth and space science principles to a life science realm is an excellent way to revisit this grade six performance expectation and the human impacts of ESS3.C.

On days 9–10, students performed some engineering design thinking where they had to select the appropriate technology (radio or sound waves) that best met the criteria for investigating the Cape Cod sharks (ETS1.B). In this case, students defined these criteria based on whether or not the device could transmit measurements that supported the scientific investigation (ETS1.A).

EP&Cs. Humans influence shark populations directly through fishing and indirectly through pollution, climate change, and alterations to marine habitat (EP&C II). Students discussed the effects of fishing on shark populations from days 7–8, and then reconsidered specific actions that could minimize human impacts on days 11–12 when they created their final communications product.

CA CCSS Connections to English Language Arts and Mathematics. Throughout the lesson sequence, students read informational articles to obtain information about shark populations (RI.8.2,8). They analyzed data to infer possible causes of the rise and fall of shark populations in Southern California at various points in time (7.SP.1-3). Students engaged in

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structured discourse with teams, including the jigsaw activity on days 6–7 (SL.8.1). Students also crafted a persuasive public service announcement targeting a specific audience based on robust evidence (SL.8.4, 6).

Reference:
Developed by Jill Grace.

Resources:

Dulaney, Josh. 2013. "CSULB Shark Lab Study: Young Great Whites Surviving Fishing Nets." *Long Beach Press Telegram*. http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link29.

Lowe, Christopher G., Mary E. Blasius, Erica T. Jarvis, Tom J. Mason, Gwen D. Goodmanlowe, and John B. O'Sullivan. 2012. "Historic Fishery Interactions with White Sharks in the Southern California Bight." In *Global Perspectives on the Biology and Life History of the White Shark*, by Michael L. Domeier. Boca Raton, FL: CRC Press, 169–185.

Lyons, Kady, Erica T. Jarvis, Salvador J. Jorgensen, Kevin Weng, John O'Sullivan, Chuck Winkler, and Christopher G. Lowe. 2013. "The Degree and Result of Gillnet Fishery Interactions with Juvenile White Sharks in Southern California Assessed by Fishery-Independent and –Dependent Methods." *Fisheries Research* 147 (October 2013): 370–380.

Rocha, Veronica. 2015. "13 Young Great White Sharks Spotted off Huntington Beach." *Los Angeles Times*. http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link30

Woods Hole Oceanographic Institution. 2014. "REMUS SharkCam: The Hunter and the Hunted." Posted at *Vimeo*, http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link31

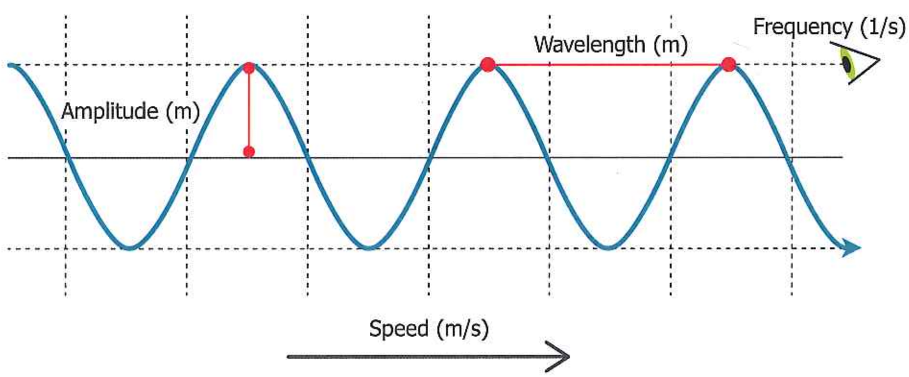
Water Waves

Over the course of this instructional segment, modeling activities should begin with mechanical waves propagating in a matter medium that is visible (such as water waves), then waves that propagate through a matter medium that is invisible (such as sound waves moving through air), and finally wave models of light. **Investigations [SEP-3]** with real-world objects can be complemented with technology. Computer or smartphone apps provide interactive simulations of simple waves (see http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link32), ripple tanks (Falstad n.d.) or even display the waveforms of sound recorded by microphones so that students can use their personal technology as an oscilloscope to visualize waveforms of noises in the room.

Students **investigate [SEP-3]** a variety of waves they can generate and observe in a flat-bottomed water container (ripple tank). Students observe and discuss general wave properties that they observe including absorption, reflection, transmission of one wave through another, and even make observations that prepare them for the high school understanding of waves by observing how the simultaneous production of multiple waves produces complex waveforms. Placing floating objects at the surface and drops of colored dye below the surface allows students to track the motion of particles within the tank. These observations of phenomena should provoke students to **ask questions [SEP-1]** about wave behaviors. Each group of students could use a digital camera to create a short video clip of a surprising or exciting observation that they would like to understand further. These questions can form the organizing **structure [CCC-6]** for the instructional segment, and teachers can revisit these questions and the emerging explanations.

Waves are part of many different physical processes, but they all share some common aspects related to shape, direction of motion, and how the motion changes over time. By generating simple waves on a stretched rope or spring, students should be able to describe some of these features of waves. Discussions within and among groups can help elicit common observations about the height, speed, and spacing of waves. Similar features were probably observed in ripple-tank investigations. Student teams can then **develop a model [SEP-2]** of a typical wave and compare the ones they developed with the standard diagrammatic representation of wave shape as a regularly spaced series of peaks and valleys (figure 5.55). Students compare terms they used with the vocabulary that is commonly used to describe the shape of a wave and how it changes over time.

Figure 5.55. Model of a Typical Wave



Some properties that distinguish waves from each other include wavelength, amplitude, frequency, and speed of wave movement. Diagram by M. d'Alessio.

Having become familiar with the properties of waves and having developed ways to represent and describe travelling waves, students are ready to think about and to model waves and/or wave pulses as carriers of **energy [CCC-5]**. They can readily recognize that a wave or wave pulse of water in the open ocean transmits energy (in the form of motion of the medium): they can see the motion of the water up and down by observing a boat bobbing at the surface (motion = kinetic energy). They can also see that more of this up-and-down motion results from a higher amplitude, thus qualitatively connecting the growth in amplitude of the wave to an increase in the energy it transmits (MS-PS4-1). Students can quantify this representation by dropping different size objects into a tank and measuring the height of waves generated (perhaps with the aid of digital photography to allow more precise measurements of the fast-moving waves).

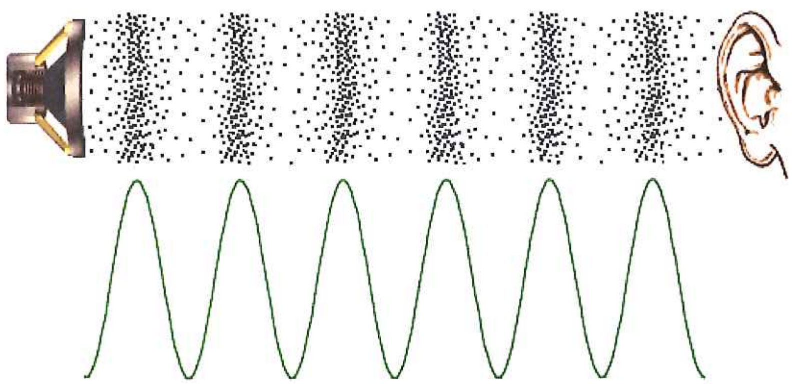
Students' models [SEP-2] of wave motion, amplitude, and energy [CCC-5] can help them explain [SEP-6] why waves break at the beach (enabling California's famous surfing and other beach play). Surfers know that the water in a breaking wave is moving toward the beach (which pushes their surfboard forward), but that out beyond the breakers, the water is not moving toward the beach! Surfers wait beyond the breakers and bob up and down until a good wave arrives, and then they paddle forward into the location where waves begin to break. When the water gets shallow enough, there is not enough room for the wave to move up and down over its full amplitude, and it begins to interact with the sand below. The wave can no longer have all its kinetic energy continue as up-and-down motion, and some of the energy gets transferred into forward motion that begins to "tip the wave over" and cause it to "break."

Students can investigate [SEP-3] this phenomenon in a ripple tank by introducing a sloping bottom spanning about a third of the tank length and creating waves by moving a flat object up and down at the other end of the tank. They can observe the relationship between the locations where the sloped bottom begins and where waves begin to break, and vary the slope angle to measure its effect on the waves. These discussions and investigations are necessary since most students need help understanding that the wave movement transfers the wave energy, but the medium of the wave (in this case, water) can move in a different direction than the energy flow. In a water wave, the water moves up and down perpendicular to the energy flow. Students can gather evidence [SEP-7] to show that the medium doesn't move far by watching floating corks bob up and down as waves travel across the ripple tank. Students may cite evidence of objects washing ashore at the beach that contradicts this statement. These objects are evidence of other processes such as ocean currents and waves breaking (it turns out that what we call waves at the beach do not meet the standard physical science definition of a wave—they are more complex because they interact with the seafloor and beach itself).

Sound Waves

Sound waves introduce a different kind of wave that students can investigate [SEP-3]. While water waves are easily recognizable as waves, students need evidence to believe that sound transfers energy as a wave. Since students' models of waves include motion, they may wonder what is moving in the sound wave. Students can readily feel the movement as sound passes through a solid. Students can also observe the driving energy of sound by using slow-motion video clips to observe the vibrations of speakers or by simply placing paper scraps on top of a large speaker. Students can use these observations to **develop a model [SEP-2]** of sound traveling as the back-and-forth motion within a solid material (figure 5.56). Students can then readily generalize this **model [SEP-2]** to **explain [SEP-6]** how sound travels through a gas, where the movement of air must be happening but cannot be seen.

Figure 5.56. Model of a Sound Wave in Air



Two representations of how sound travels as a wave in air. Source: Pluke 2012

We can think of sound as a traveling wave of pressure differences in the air. The black dots in figure 5.56 represent air molecules packed together very tightly or less tightly. **Because of [CCC-2]** the vibrations in the speaker, the air varies in density in a wave-like **pattern [CCC-1]**. The dots and the wave-line provide two complementary ways to **model [SEP-2]** the fluctuations in the density of the air molecules. This wave pattern of density fluctuations of air molecules causes vibrations within the ear that **result in [CCC-2]** our conscious perception of sound (Integrated Grade Six MS-LS1-8). Note that the air molecules do not travel from the source of the sound to the ear.

Students can compare similarities and differences between water waves and sound waves. They should be able to **communicate [SEP-8]** using words or diagrams that both of these wave patterns transfer energy through a medium across a distance, and that the individual particles move only a very small distance. In both cases, waves reflect or are absorbed at various surfaces or interfaces, and two waves can pass through one another and emerge undisturbed. In the case of a water wave, the particles move perpendicular to the wave direction. In the case of a sound wave, the particles move parallel to the wave direction.

A surprising phenomenon related to the transmission of energy [CCC-5] by sound waves is the event in which a singer is able to break a glass using the sound of his/her voice. In order to explain [SEP-6] how the glass breaks, students will model [SEP-2] the transformation of energy and its propagation as a wave through the air to the glass. First, they will include the vibration of the vocal cords and how that vibration is transferred to the molecules of air. Then, they will model how that vibration travels through space by compression and expansion of air molecule density that reaches the glass. Finally, the students' models will represent the transfer of energy from the vibrating air molecules to the molecules in the glass.

Light Waves

The idea that light is also a wave phenomenon can best be developed by the fact that it shows all the behaviors of waves (reflection, absorption, transmission through a medium such as glass, and carrying energy [CCC-5] from place to place; MS-PS4-2). The obvious question, What is the moving medium in a wave pattern for light? is difficult to answer at this grade level. In light, the "movement" is actually the changing pattern of electric and magnetic fields travelling across space or through some forms of matter. Students know that these fields are related to energy after their investigations in IS2, but the assessment boundaries for the middle grades MS-PS4-1 and MS-PS4-2 explicitly state that electromagnetic radiation (including a discussion of the electromagnetic spectrum) is not assessed in the middle grades. For grade eight students, visible light serves as a familiar form of energy and an example of how electromagnetic radiation can transfer energy very quickly across huge distances.

Light travels in straight lines, until it encounters an object where its energy can be absorbed, reflected back, or be transmitted through the material. Students can perform investigations [SEP-3] to compare the different effect of mirrors and different color paper on the path of light. Students can draw diagrams to model [SEP-2] each situation, tracing the path of light and how energy [CCC-5] is transferred to different objects based upon the interaction between the light and the materials (MS PS4 2). In fourth grade, students already began developing a model of how light allows objects to be seen (4-PS4-2), and teachers should connect to that earlier learning experience to emphasize that reflection is crucial because we only see objects after they reflect light back to our eyes. Eyes perceive waves with different frequencies as different colors, and each wave's amplitude is observed as light's brightness.

Opportunities for ELA/ELD Connections

During the instructional segment, have students develop a sequenced set of illustrations with accompanying content vocabulary to convey their understanding of waves. Students can use concept maps, word webs, or graphic organizers (e.g., Frayer Model) to identify corresponding types, examples and nonexamples, definitions, illustrations of a concept, or essential (or nonessential) characteristics. These strategies help all learners develop effective vocabulary-learning strategies as they acquire content knowledge.

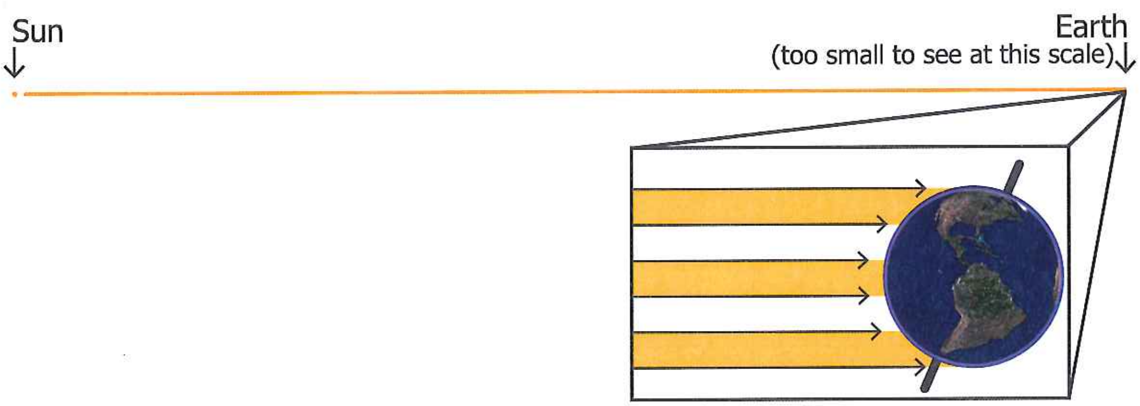
CA CCSS for ELA/Literacy Standards: RST.6–8.4; L.6–8.4

CA ELD Standards: ELD.PI.6–8.6

A Model of Seasons

Knowing that light is energy that travels in straight lines, students can **develop a model [SEP-2]** of how differences in the distribution of **energy flow [CCC-5]** cause seasons. Students combine models of Earth's climate from grade six with models of the Earth-Sun system from IS1. We know that Earth is tilted a fixed amount of 23.5° relative to the plane of its orbit (figure 5.57) because one star in the sky barely ever moves as the Earth rotates each night—the North Star. Students will hopefully ask, Why is Earth's rotation axis tilted? and teachers can turn this around and tell them to **ask more specific questions [SEP-1]** through the lens of individual CCCs: What could **cause [CCC-2]** the Earth to tilt (impact, gravitational attraction, etc.)? Do other planets exhibit a similar tilt establishing a solar-system wide **pattern [CCC-1]**? Is the tilt stable, or does it **change [CCC-7]**—and does the timing of this change give clues to the cause of the tilt in the first place?

Figure 5.57. Earth–Sun System Scale



A scale illustration of the Earth–Sun system (top). The Sun is 5 pixels wide and the Earth is 1075 pixels away, but is only 0.05 pixels wide, which is too small to display. At this scale, it is easier to recognize that rays of sunlight arrive at Earth as parallel rays at all latitudes (bottom). Diagram by M. d'Alessio.

Students can make these connections using a physical model where their own body represents the motion of the planet (Space Science Institute, Kinesthetic Astronomy at http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link33). They tilt their bodies toward or away from the Sun at the same 23.5° tilt as the Earth and move around Earth's orbit, making sure that their tilt axes always point towards the North Star. As they move from one side of the Sun to the other, they see how the angle of the Sun's rays **changes [CCC-7]** in the different hemispheres: in the northern hemisphere summer, the tilt brings the angle of the Sun's rays closer to 90° while it makes the angle smaller in the Southern Hemisphere. Computer simulations allow students another way to visualize these changes (NOAA, Seasons and Ecliptic Simulator, http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link34).

Learning a scientifically accurate model for the seasons is often impeded by students' incoming preconceptions (documented vividly in the short documentary *Private Universe*, Harvard-Smithsonian Center for Astrophysics, at http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link35 and in review articles at http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link36). Most notably, students often incorrectly believe that the Earth is closer to the Sun in summer and farther in winter. In this example course sequence, seasons are deliberately placed in a separate instructional segment from the discussion of orbits in order to increase the association between seasons and Sun angle instead of reinforcing an incorrect connection between seasons and orbital distance. Nonetheless, many students will still harbor this preconception and it must be addressed. Interactive 3-D simulations have been shown to help students confront this preconception.[2] In these virtual worlds, students view the Sun–Moon–Earth **system [CCC-4]** from various viewpoints and control different aspects, including rotation and revolution rates, and inclination of Earth's spin axis. The story of seasons is mostly a story of light and energy absorption. Emphasis should be placed on the intensity and duration that sunlight shines on a particular patch of Earth's surface. Because Earth's tilt causes the Sun to appear to travel across the sky along a different path during summer versus winter, the Sun shines for more hours during the day (causing longer duration sunlight) and from higher angles in the sky (causing more sunlight to appear more intense in a given patch of the surface). Together, these give rise to warmer summers and cooler winters.

Students return to the anchoring phenomenon and **explain [SEP-6]** the dramatic seasonal shifts in primary productivity in the two hemispheres during a year. By using simple

2. Something similar to this simulation is located here: http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link88, but it is described in Bakas and Mikropoulos 2003.

computer applets, they can determine the total amount of solar energy per square meter that different cities receive during each month of the year. They use these quantitative [CCC-3] data as evidence to support their explanation [SEP-6] of why the primary productivity remains high year round near the equator. They continue to ask questions [SEP-1] about some of the specific features they observe in the movie, many of which remain unanswered but could inspire further investigation in the capstone project at the end of the instructional segment.

Integrated Grade Eight Snapshot 5.10: School Solar Energy Project

Anchoring phenomenon: How much energy will solar panels on our school rooftop provide?

Mr. S invited a rooftop solar panel installer to visit his classes. In the days before their visit, the students prepared a list of questions [SEP-1] about the factors that affect the amount of energy the panels can generate. When they arrived, they gave a short presentation about solar energy and then went onto the roof to make measurements. The installer emphasized the importance of the angle of the Sun and that buildings with a flat roof like the school need a special platform that tilts the solar panels towards the Sun. A few days later, the solar installer sent the results from computer calculations to Mr. S with graphs of the amount of energy the panels would collect at different times during the year based on the position of the Sun and nearby trees that shade the panels (EP&C III). Students drew models [SEP-2] of light traveling in straight lines from the Sun to the rooftop (PS4.B), indicating how trees would absorb the solar energy when the Sun is in some positions but not in others based on its predictable movement throughout the day and year (ESS1.A). In essence, students were repeating the investigations of shadows from grade one (1-ESS1-1) with a more sophisticated level of understanding.

Investigative phenomenon: Solar panels produce different amounts of energy at different times of year.

The class worked to interpret [SEP-4] the graphs so that they could explain [SEP-6] the systematic variations during the year (ESS1.A) using their models [SEP-2] of the Earth–Sun system (MS-ESS1-1) and the paths of light (PS4.B) from the Sun to the Earth (MS-PS4-2). They drew models [SEP-2] that illustrated how the angle of the Sun's rays affects the amount of energy converted to electricity much like this angle affects Earth's temperature throughout the seasons and at different latitudes (MS-ESS2-6). Their models also showed how trees absorb light energy when the Sun is in some positions but not in others based on its predictable movement throughout the day and year. In essence, students were repeating their investigations of shadows from grade one (1 PS4-3; 1-ESS1-1) with a more sophisticated level of understanding.

Mr. S had arranged for the students to present the information to the local school board that makes decisions about how money is spent (EP&C V). Different groups set to work on an executive summary, a presentation, and a poster that **communicated [SEP-8]** the report's findings. Through a peer review and feedback process, the class revised each product and selected a team of students to make the formal presentation. The school board voted unanimously to allocate funds to install solar panels and the students tracked the installation progress. The following year, the students analyzed the actual energy production from their panels from day to day and month to month to recognize the **patterns [CCC-1]** in solar energy input.

Waves Can Encode and Transmit Information

How exactly does the MODIS satellite detect the amount of CO_2 in the air and transmit this information back to Earth? After having researched water waves, sound, light and electromagnetic radiation (EM), students can be challenged to summarize the characteristics of each of these with respect to wavelength/frequency, amplitude, and wave speed.

The students work in groups, share their drafts across groups, critique each other based on evidence, and compare finished drafts with respect to advantages and disadvantages. Table 5.13 illustrates one kind of summary.

Table 5.13. Characteristics of Waves

TYPE OF WAVE	WAVELENGTH/FREQUENCY ASSOCIATED WITH	AMPLITUDE ASSOCIATED WITH
Water wave	Physical distance between top of water waves	Height of the physical wave
Sound wave	Pitch of the sound	Loudness of the sound the sound
Light wave	Color of the light	Brightness of the light
All EM waves	Type of EM wave (x-ray, UV, light, IR, microwave)	Intensity of that EM wave

Table by Dr. Art Sussman, courtesy of WestEd.

A different summary might highlight other features of waves: (1) waves are repeating quantities; (2) waves interact with materials by being transmitted, absorbed, or reflected; (3) waves can transfer **energy [CCC-5]** over long distances without long-distance movement of matter; and (4) waves can be used to encode and transmit information.

Once students recognize that light and sound are waves, they can **communicate [SEP-8]** that even in the absence of modern technologies, each of us is constantly interacting with invisible waves of energy. All the information and experiences that we get through sight or hearing come to us as waves that our senses and nervous systems enable us to detect and experience. A string-and-tin-can "telephone" or a stringed instrument can provide a quick and very direct experience that waves can communicate information.

Students can research and report on how early technological devices captured sounds, images, and other information in mechanical ways. For example, an early clock had an inside pendulum whose movements resulted in the hour and minute hands that moved around on the face of the clock. Thomas Edison captured words and music by using a needle to convert the waves of air vibrations into bumps and valleys that he engraved into wax or tin. Then a needle on a sound player could respond to the engraved bumps and valleys, and create vibrations that he amplified back into the original sound. Photographers reproduced images by capturing and focusing light on material embedded with chemicals that reacted to the presence of light.

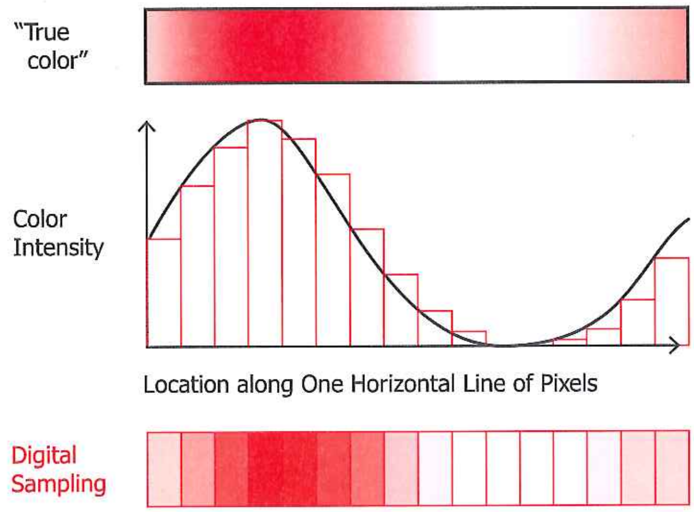
Students can compare the advantages and disadvantages of the earliest mechanisms of transmitting information to the beginning ages of radio to today's wireless cell phones and tablets. Historical examples of encoded information in wave pulses (e.g., drum or smoke signals, the invention of Morse code and early telegraph systems) can be helpful to develop both the idea of information in a waveform and the idea of encoding information. Finding out about and understanding the difference between AM and FM radio signals may serve as an activity. Students should be able to **model [SEP-2]** the conversions starting with the vocal chords of a singer in a studio to sound waves to electromagnetic radio waves being transmitted through antennas or wires to a radio device that converts those electromagnetic waves back to vibrations in a mechanical speaker eventually resulting in people hearing the song in the comfort of their home.

Today's advanced technologies such as cell phones and tablets use digital means to encode and transmit sound and images. Students are probably aware that pictures they see on a screen are encoded in pixels. Each pixel is a very tiny colored dot that is so close to its neighbors that the viewer sees what looks like a sharp, perfectly smooth image. A typical medium-quality photo on a screen may consist of 400 vertical rows of pixels, and each row may have 300 pixels located horizontally next to each other (a total of 120,000 pixels).

Figure 5.58 shows a wave line that corresponds to the color of 300 pixels in one horizontal line of a photo. The height of that line at any point specifies the color intensity at a point along the line. The horizontal position specifies where that point is horizontally located on the line. The rectangular boxes sample the average value of the color at

13 different locations, and summarize the color at each of those 13 locations as a number. Specifying the color of only 16 pixels along a horizontal line would result in a very fuzzy image. For a medium-quality photo image, the wave would be averaged at 300 different locations to obtain 300 numbers that specify the color of each pixel on that horizontal line. That process would be repeated vertically 400 times to have a specific color designation for each of the 120,000 pixels that make up a beautiful screen image.

Figure 5.58. Digitizing a Screen Picture



The features of an electromagnetic wave can be converted into numbers that change over a spatial location. These numbers can then be converted into computer-friendly digital formats so a very clear image can be displayed on a screen. Diagram by M. d'Alessio and A. Sussman.

When an image or a sound has been entirely represented by numbers, we say that it has been digitized. Computers store data as a sequence of zeros and ones. The zeros and ones are called digits, which is why the files of information are called digital files. These digital files can hold an incredible amount of information in a very small space. For example, one tablet can store in its memory a large number of books, audio CDs, and even movie files. In addition, each of these digital files can be copied, edited (changed), and transmitted.

Digital technologies enable people today to obtain and manipulate information in previously unimaginable ways. Students should be able to **evaluate the claim [SEP-7]** that digitized signals offer significant advantages with respect to encoding and transmitting information (MS-PS4-3). In the vignette that concludes the middle grades progression, student groups engage with a design challenge focused on sustaining Earth's systems in which they use and **evaluate information [SEP-8]** at least one digital technology in researching their challenge and **designing their solution [SEP-6]**.

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Performance Expectations

Students who demonstrate understanding can do the following:

MS-LS4-4. Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. [Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.]

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.] (Revisited from grade six)

MS-PS4-3. Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. [Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in Wi-Fi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [*Assessment Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.*]

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 environment that may limit possible solutions.

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

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

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-7] Engaging in Argument from Evidence [SEP-8] Obtaining, Evaluating, and Communicating Information	LS4.B: Natural Selection ESS3.C: Human Impacts on Earth Systems PS4.C: Information Technologies and Instrumentation ETS1.A: Defining and Delimiting Engineering Problems	[CCC-1] Patterns [CCC-2] Cause and Effect [CCC-6] Structure and Function [CCC-7] Stability and Change

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Highlighted California 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 complex and involve many factors.

CA CCSS Math Connections: 8.SP.2, 4

CA CCSS for ELA/Literacy Connections: RST.6–8.1, 2, 7, 9; RI.8.3; SL.8.1, 4, 6; WHST.6–8.2, 7-9

CA ELD Connections: ELD.PI.6–8.1, 9

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Introduction

By the end of grade eight, students can approach new phenomena, recognize how different parts of the Earth system are interacting in the situation, draw on DCIs from all disciplines of science and engineering to explain the mechanisms driving these interactions, and design solutions to problems that they identify and constrain. This capstone project puts them to work at using all their understanding from grades K–8.

Day 1: Analyzing Per-Capita Consumption

Students calculate per-capita consumption of different countries, develop and critique different ways of communicating these data, and ask questions about trends they see.

Day 2: Introducing Capstone Projects

Ms. D provides the background about the capstone project and students read and discuss five environmental case studies.

Day 3: Focus on Solutions

Students read about five case studies of communities that have developed solutions to environmental problems. Students brainstorm ideas for their capstone projects.

Days 4–8: Collaborative Work Sessions

Teams work collaboratively and the teacher helps focus and guide students.

Day 9: Project Presentations

Students prepare final presentations for a school science night.

Day 10: Synthesis

Students from different project groups combine together to identify common elements in the projects and identify how the projects relate to the EP&Cs.

Day 1: Analyzing Per-Capita Consumption

Anchoring phenomenon: Different countries consume radically different amounts of energy per capita.

How many people live on planet Earth? Where in the world do they live? Ms. D facilitated the discussions and appropriately guided them towards information about specific countries (e.g., the United States, China, Mexico) and also about parts of the world (e.g., Africa, Pacific Islands, Europe). She charted their comments, and then asked students if they had any ideas about which areas consumed the most resources and why. After a while, students concluded that for each country or continental area, they should probably get quantitative [CCC-3] data about total consumption and per-capita consumption.

Ms. D provided each group of students with information about world populations (available at Data from the Population Reference Bureau report accessed at http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link37) and about consumption of natural resources in the year 2013. In both

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cases, the datasets included information at the country level (e.g., Brazil) and at a regional level (e.g., South America). The consumption data were reported as the number of millions of metric tons of carbon dioxide emitted from the consumption of energy resources (see Data from the U.S. Energy Information Administration accessed at http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link38). Because the total amount of data from the sources was somewhat overwhelming and also not 100 percent consistent with respect to country/region designations, Ms. D had compiled the data to cover seven distinct regions, and had highlighted within each region significant representative countries.

Student groups **analyzed the data [SEP-4]** that Ms. D had provided, **calculated [SEP-5]** per-capita consumption as the ratio of the emissions and population, and then developed a poster to **communicate [SEP-8]** the differences to their classmates. Some student groups chose color-coding maps to compare per-capita consumption. Other groups superimposed on global maps pictorial ways to represent total consumption by a country or region. This representation helped them compare geographic size with consumption total. A less visually oriented group created a summary table (table 5.14).

Table 5.14. Per-Capita Consumption

Region, *[An example country]*	Population in 2013 *(number of people)*	Total CO_2 Emitted in 2013 *(tons)*	Per-Capita Emission of CO_2 *(tons/person/year)*
Africa *[Nigeria]*	1,100 million *(174 million)*	1,268 million *(96 million)*	1 *(0.5)*
Asia *[China]*	4,302 million *(1,357 million)*	18,909 million *(10,246 million)*	4 *(8)*
East Europe *[Russia]*	295 million *(144 million)*	2,713 million *(1,789 million)*	9 *(12)*
West Europe *[Germany]*	190 million *(81 million)*	1,466 million *(759 million)*	8 *(9)*
South America *[Brazil]*	401 million *(196 million)*	1,188 million *(502 million)*	3 *(3)*
Middle East *[Saudi Arabia]*	251 million *(30 million)*	1,716 million *(543 million)*	7 *(18)*
North America *[USA]*	352 million *(316 million)*	5,660 million *(5,184 million)*	16 *(16)*

Table by Dr. Art Sussman, courtesy of WestEd with data from the Population Reference Bureau 2013 and Population Reference Bureau 2016.

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The whole class then did a gallery walk where they examined each of the posters and listened to the group's presentation about their chart. The students discussed the benefits and disadvantages of each representation of the data. Students asked questions, and wrote down notes about specific pieces of the data that they noticed in each representation. After the gallery walk and while the charts were still visible, the whole class discussed the most important **patterns [CCC-1]** of per-capita consumption, and Ms. D invited students to propose **evidence-based claims [SEP-7]**. Some students noticed a **pattern [CCC-1]** that some small countries, particularly in the Middle East, had the highest levels of per-capita emission. For example, Kuwait had a per-capita emission rate of 37 tons of CO_2 per person per year. They made a claim that this extremely high rate resulted from Kuwait's large role as a producer, refiner and exporter of fossil fuel resources, and cited as **evidence [SEP-7]** correlations with other countries that produce and export large amounts of fossil fuels.

Throughout the year, Ms. D had posters along her wall with illustrations of California's Environmental Principles and Concepts and she asked students to refer to them now. She asked her students which EP&Cs might apply to the data set they analyzed. One student suggested EP&C II (*The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies*). She facilitated a brief class discussion about the concepts associated with that principle. Several students observed that their data seemed to support the idea that the growth of human populations is directly related to the amount of resources humans consume (EP&C II, concept a).

Day 2: Introducing Capstone Projects

Motivated by these observations about human consumption and questions about the possible impacts this consumption has on the rest of Earth systems, Ms. D introduced student group projects that concluded their immersion in the middle grades science. Student teams chose a specific human activity that has an environmental impact and explored it using all three dimensions of the CA NGSS as they experienced them throughout all three middle grades. She organized her expectations around the SEPs:

- **obtain and evaluate information [SEP-8]** about a specific phenomenon in which human activities are impacting one or more Earth systems;
- **analyze data [SEP-4]** related to the impacts on Earth systems, and identify how they demonstrate the California EP&Cs;
- **construct explanations and design solutions [SEP-6]** related to those human activities and impacts;
- **analyze design solutions [SEP-4]** with respect to their criteria and constraints associated with successful implementation;
- **model [SEP-2]** how digital technologies can assist with gathering data, implementing solutions, and/or communicating results;
- **argue using evidence [SEP-7]** to evaluate and refine their solutions; and
- **communicate the scientific and/or technical information [SEP-8]** related to their project and their proposed solution.

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To help establish a shared background within and across the student groups, Ms. D provided five different illustrated readings that she had made based on the *Living Planet Report 2014* from the World Wildlife Fund (World Wildlife Fund 2014). Students worked in teams of two to initially process the information in one of the readings and then combined into larger groups focused on that reading. These groups then made presentations to the whole class, followed by discussions about the individual topics and how those topics connected with each other around the theme of human impacts on Earth systems. The five readings focused on **cause and effect [CCC-2]** and **stability and change [CCC-7]** as they related to

- an overall decline in biodiversity of 52 percent between 1970 and 2010 resulting from habitat modification, over-exploitation, pollution, and invasive species;
- the ways that climate change can magnify the negative impacts on biodiversity;
- how humans are currently converting more nitrogen from the atmosphere into "reactive forms" than all terrestrial processes combined;
- the claim that humanity's demand for natural resources currently exceeds the capacity of land and sea areas to regenerate those resources; and
- **analyzing data [SEP-4]** comparing the "ecological footprints" of high-income countries and low-income countries.

Day 3: Focus on Solutions

Ms. D transitioned to a focus on solutions by sharing seven brief readings from the *Living Planet Report 2014*. Each reading described positive strategies that a specific community had implemented to preserve natural resources, have more efficient production, and consume more wisely. While they **evaluated information [SEP-8]** in these readings in teams and as a whole class, students began brainstorming potential solutions related to the impacts in the first set of readings. Student facilitators helped summarize and display notes on these potential solutions.

Students then started meeting in groups to develop projects. Groups shared their initial ideas with each other and with the teacher. These ideas and the partnering of students were in flux for a while until they solidified into specific project teams. Four teams focused on climate change but with different geographical contexts (the Arctic, Pacific Atolls, and two in California). Another team focused on protecting the California freshwater shrimp, an endangered species living in a stream near the school, while another team focused on reducing the school's energy consumption. After Ms. D approved the request of students to broaden the topics to include other concepts they had covered in grade eight, two groups chose asteroid-impact deflection to protect the planet, and a third group chose genetic engineering as a general way to increase food supplies.

Days 4–8: Collaborative Work Sessions

The schedule for the work on student projects included designated dates when groups shared their current status with each other. This sharing greatly broadened the learning from the projects about the topics and expanded the feedback to the student groups. During these

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sessions, each group focused on reporting about their project through the lens of one or two CCCs. The CCCs helped guide student thinking and lead them to ask specific types of questions (see chapter 1 of this framework for examples).

Day 9: Poster Presentations

At the end of the projects, student groups across the different grade eight classes presented posters of their projects at a school science evening program.

Some highlights from the projects included public outreach and monitoring water quality in a local stream to help protect the California freshwater shrimp. Students shared that this organism was an example of the four main HIPPO (**H**abitat loss, **I**nvasive species, **P**ollution, **P**opulation growth, **O**verexploitation) categories of activities that threaten biodiversity. People have altered its habitat by building dams, and also overharvesting timber and gravel along the stream banks. In addition, people have stocked streams with invasive nonnative fish species and polluted the water. The students proposed plans to increase public awareness related to stream overharvesting and pollution practices, and identified constraints that need to be addressed to reduce these practices. (EP&C II; See the EEI unit "Extinction: Past and Present" http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link39 for more information and a lesson on HIPPO.)

The genetic engineering group made an analogy between genetic code and the encoding involved in digital files. They claimed that genetic code is neither analog nor digital, but instead is uniquely biological and provides the evidence that the language of DNA includes four "digits" instead of just the two options in the binary codes of digital communication. In addition, they provided **evidence for claims [SEP-7]** that genetic engineering of food crops does not significantly endanger personal health (e.g., cancer) but a key design constraint in genetic engineering is that solutions must not endanger the health of ecosystems (EP&C V).

The school energy group visited a school in a different district that had been recognized as a green school. They **analyzed and compared energy consumption data [SEP-4]** from their school and the green school, and made recommendations based on those analyses. In addition, they **shared information [SEP-8]** about digital tools that schools use to monitor and reduce energy consumption by improving the efficiency of lighting and heating. The team identified specific reduction goals as their criteria for success as well as detailed plans to achieve those goals. They identified a constraint that energy budgets and decisions are made at the district level rather than the school level (EP&C V).

One of the asteroid-impact teams changed projects. They remembered that the HHMI BioInteractive Web site about the impact crater included remote digital data that originally identified the crater in the Yucatan. While checking other links, they discovered that the HHMI BioInteractive Web site included conservation efforts at the Gorongosa National Park in Mozambique (http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link40). The students explained that this park provided a case study in ecology and conservation science. They were particularly excited when they learned that park scientists used GPS satellite collars and motion-sensitive cameras to gather data about the recovery of the park's lion population. In addition to sharing pictures

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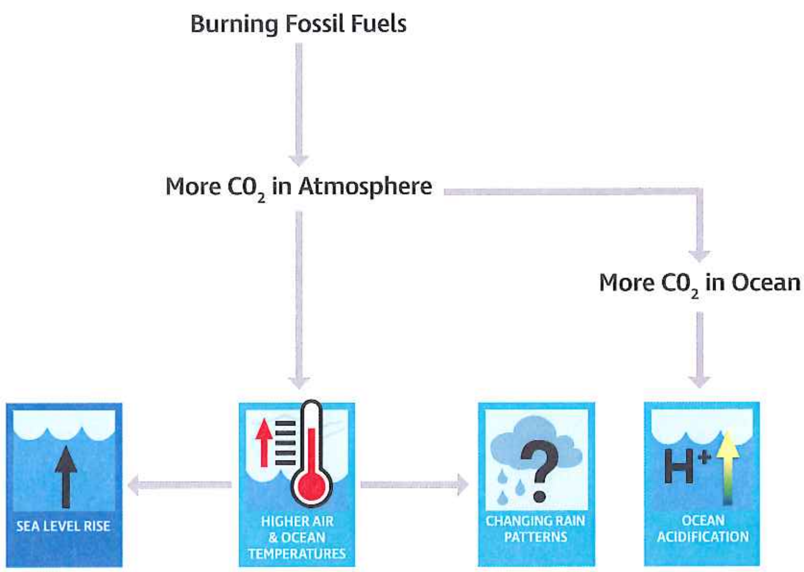
and video, the students used educational resources from the Web site to **explain [SEP-6]** factors that influenced the park ecology, the conservation recovery plans, and significant constraints that need to be addressed to promote successful restoration (EP&C V).

The different student groups working on climate change issues jointly identified as a constraint that many people were confused about global warming and climate change. They consulted with their grade six science teacher who had taught them that global warming is the increase in air and ocean temperatures due to the increased greenhouse effect (MS-ESS3-5). She referred them to a PBS LearningMedia Web site (http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link41) that has a computer interactive explaining four main impacts of climate change (figure 5.59). Higher concentrations of atmospheric CO_2 directly result in global warming and ocean acidification. The increased thermal energy trapped in the Earth system **causes [CCC-2]** other changes such as sea-level rise and changing precipitation patterns (EP&C IV).

Figure 5.59. Effects of Burning Fossil Fuels



Increased emissions of carbon dioxide cause global warming (higher air and ocean temperatures) and three other climate change impacts. *Sources:* Illustration by Dr. Art Sussman, WestEd, and Lisa Rosenthal, WGBH.

Since their school is located relatively near the major Lake County 2015 Valley Fire that burned 76,000 acres and destroyed almost 2,000 structures, several student groups researched predictions related to climate change and wildfires. They learned that average temperatures in California are projected to generally keep increasing throughout this century (figure 5.60). They noted that reductions in emissions of greenhouse gases could reduce the amount of heating. They also learned that communities could engage in individual and collective actions that would increase the fire safety of homes.

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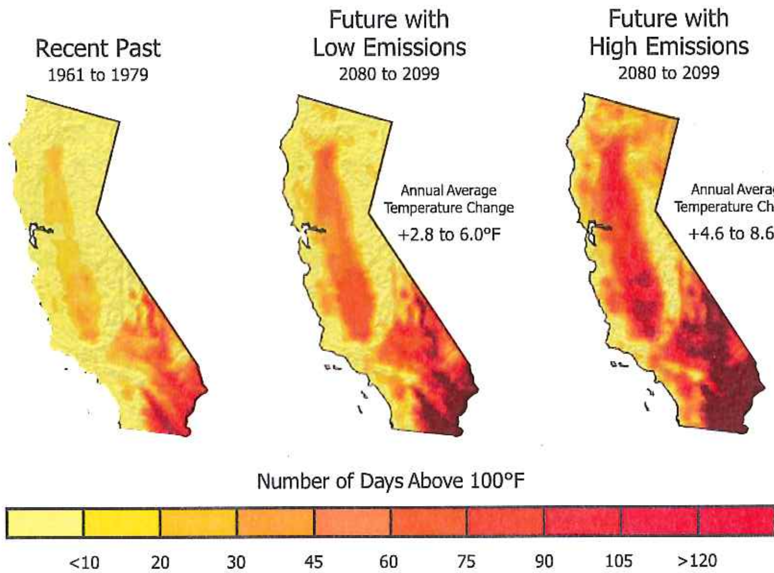
Figure 5.60. Projected Changes to California's Average Temperature



Projected increases in statewide annual temperatures during this century. *Source:* M. d'Alessio with images from U.S. Global Change Research Program 2009 and data from Moser, Ekstrom, and Franco 2012.

The Pacific Atoll climate change group reported about the Marshall Islands, which had been a territory of the United States. They shared information about its geography and used digital tools to video conference with a school on the island of Majuro. The group explained that the approximately 60,000 Marshall Islanders were severely threatened by sea-level rise. The highest natural points on the islands are generally just 3 meters (10 feet) above sea level. During the period the schools communicated with each other, a King Tide caused serious flooding in the area of the Majuro School. The group presentation included **explanations [SEP-6]** of how climate change **caused [CCC-2]** sea levels to rise, and how scientists remotely measure sea level around the globe via satellites equipped with digital tools. Their engineering design challenge focused on ways communities can protect beaches and homes from rising sea levels. Like the other student groups, they wanted to learn more about ways to reduce the amount of climate change caused by human activities. (EEI Curriculum unit *The Greenhouse Effect on Natural Systems* http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link42 provide additional resource materials on climate change and greenhouse gases.)

Day 10: Synthesis

In each of the three middle grades, students learned about the EP&Cs that were approved by the California State Board of Education. For the final lesson related to the student projects, students formed groups that consisted of students who had worked on at least three of the different projects. Each of these new groups then discussed what they had done or heard

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about that related to each of the EP&Cs. Students then shared their ideas in a whole-class discussion. They were surprised how many of them identified Principle V as something they had seen but not really understood until they had to think about engineering criteria and constraints related to reducing their specific environmental impact. They concluded that decisions affecting resources and natural systems are definitely based on a wide range of considerations and decision-making processes.

Vignette Debrief

This vignette illustrated the CA NGSS vision of blending SEPs, DCIs, and CCCs. While the lesson description described this blend, the sections below focus on relevant aspects of each dimension in isolation, along with ties CA CCSS and the EP&Cs.

SEPs. Scientists typically use all SEPs to fully understand new phenomenon, though they may focus on one practice at a time during the course of a project. Typical educational settings mirror this focus by isolating certain tasks to focus on building specific skills. In a capstone project where students confront an entirely new phenomenon and have the time to fully pursue it, students should fully employ all SEPs. For this reason, Ms. D explicitly organized her project criteria around all the SEPs.

CCCs. The CCC's are a series of big, overarching issues that scientists consider when they approach a new phenomenon. Since the students were engaging in a big science and engineering problem that was new to them, the CCCs provide a critical scaffold. Presentations during the collaborative work sessions on days 4–8 focused on viewing the projects through individual CCCs.

DCIs. The vignette integrated major concepts in Earth science (human impacts and Earth systems), physical science (information technologies and instrumentation), life science (natural selection), and engineering technology and applications of science (engineering design: defining and delimiting engineering problems). Different project groups focused on problems that were more closely related to DCIs in one or two domains, though the project criteria required that students consider human impacts (ESS3) and include digital technology (PS4.C) and engineering design (ETS).

CA CCSS Connections to English Language Arts and Mathematics. The capstone projects and surrounding structure in the vignette were heavily focused on gathering and synthesizing information from informational texts about environmental problems (RST.6–8.1, 2, 7, 9; RI.8.3). Student groups analyzed data, calculating the per-capita consumption as the ratio of the emissions and population. They looked for patterns in the data and made evidence-based claims about what they observed (8.SP.2, 4). The entire project was structured to promote student discourse in small groups and in formal presentations (SL.8.1, 4, 6). Students then created written and visual communications products that summarized their process and findings (WHST.6–8.2, 7-9).

EP&Cs. By the end of grade eight, students are able to focus on much broader issues than they did back in kindergarten. The entire capstone project was designed to draw together all of the EP&Cs. Even though this framing was intentional, Ms. D still devoted specific time on day 1 and again on day 10 to identifying which EP&Cs apply to the situations.