Grade 8 **Instructional Segment 4**

Teacher Background and Instructional Suggestions

This Instructional Segment features a very important concept related to the NGSS Earth and Space Science strand: “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 re-visit life science concepts that they explored in the previous Instructional Segment: 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. As described in the vignette closing this chapter, student teams engage in projects that illustrate and apply these concepts across the three science disciplines and engineering design.

These student projects help serve as a capstone for Integrated Grade 8 and also for many concepts and practices in Integrated Grades 6 and 7. With respect to “Earth and Human Activity,” students in Integrated Grade 6 designed methods to monitor and minimize a human impact on the environment (MS-ESS3-3), and they interpreted evidence related to global warming (MS-ESS3-5). Also in Integrated Grade 6 students used models related to unequal heating of the planet (MS-ESS2-6). Here in Grade 8 they build upon their earlier spatial modeling to show how a **model** of the Earth-Sun system ***helps explain*** the regional differences in seasons (MS-ESS1-1).

To better understand seasons and Earth’s global and regional climates, students investigate the wave nature of electromagnetic radiation such as sunlight and infrared radiation. These explorations are part of a more general understanding of the nature of waves (MS-PS4-1 and MS-PS4-2) that helps tie together ***flows of energy*** concepts that have been progressively building in depth in the integrated middle school grade span.

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** with real-world objects can be complemented with technology. Computer or smartphone apps provide interactive simulations of simple waves[1], ripple tanks[2] 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*** 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, transmission of a wave past a row of posts, and even addition of multiple waves to make complex waveforms. Placing floating objects at the surface and drops of colored dye below the surface allow students to track the motion of particles within the tank. These observations of phenomena should provoke students to ***ask questions*** 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*** 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** of a typical wave and compare the ones they developed with the

[1] http://phet.colorado.edu/en/simulations/category/physics/sound-and-waves

[2] Falstad, P. Virtual Ripple tank: http://www.falstad.com/ripple/

standard diagrammatic representation of wave shape as a regularly spaced series of peaks and valleys (Figure 21). 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.

Model of a Typical Wave

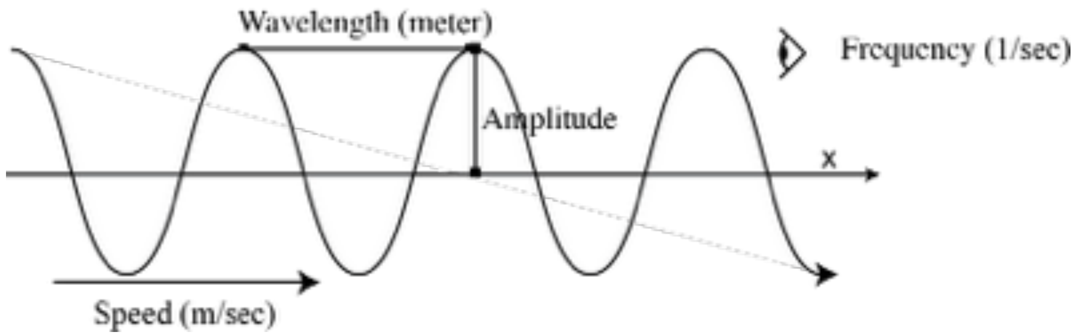

Figure 21: Some properties that distinguish waves from each other include wavelength, amplitude, frequency, and speed of wave movement.

Having become familiar with the properties of waves and 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***. 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 in 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 make this representation quantitative 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** of wave motion, amplitude, and ***energy*** can help them **explain** 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 explore 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. Waves breaking at a beach are not a travelling wave pattern, but rather the result of the shallowness of the sea-floor disrupting a travelling wave pattern that was established in deeper water. Students can cite floating corks in a ripple tank as strong **evidence supporting a claim** that the water goes mostly up and down while the wave moves across the tank.

Sound Waves

Sound waves introduce a different kind of wave that students can investigate. 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** of sound traveling as the back and forth motion within a solid material. Students can then readily **generalize this model to explain** how sound travels through a gas, where the movement of air must be happening but cannot be seen.

Model of a Sound Wave in Air

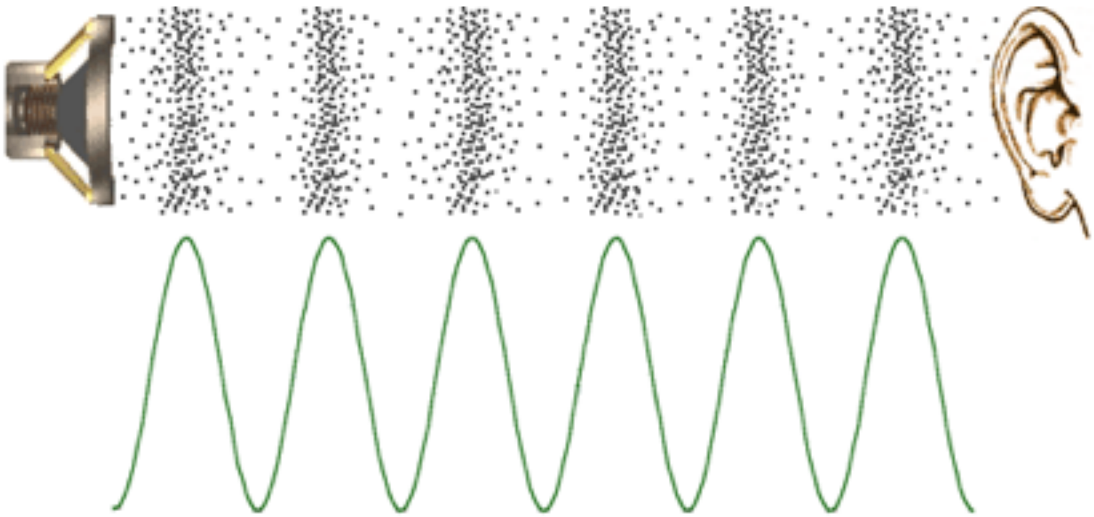

Figure 22: Two representations of how sound travels as a wave in air. Accessed at http://www.mediacollege.com/audio/01/sound-waves.html

We can think of sound as a traveling wave of pressure differences in the air. The black dots in Figure 22 represent air molecules packed together very tightly or less tightly. ***Because of*** the vibrations in the speaker, the air varies in density in a ***wave-like pattern*****.** The dots and the wave-line provide two complementary ways to **model** 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*** our conscious perception of sound (Integrated Grade 6 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 that both of these wave patterns transfer energy through a medium across a distance, 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 sound wave, the particles move parallel to the wave direction.

A surprising phenomenon related to the transmission of ***energy*** by sound waves is the event in which a singer is able to break a glass using the sound of his voice. In order to

explain how the glass breaks, students will **model** 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, students' model will represent the transfer of energy from the vibrating air molecules to the molecules in the glass.

Electromagnetic 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*** 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. For grade 8, visible light serves as a familiar form of energy that illustrates how electromagnetic radiation can transfer energy very quickly across huge distances.

Students in Integrated Grade 6 encountered the concept that sunlight is a form of electromagnetic radiation that transfers energy from the Sun to Earth. In explaining global warming due to human emissions, they referred to the electromagnetic spectrum to contrast sunlight bringing energy into the Earth system and infrared radiation carrying energy out of the Earth system. Having measured electromagnetic fields in Instructional Segment 1, grade 8 students are better prepared to discuss the concept of electromagnetic radiation as a way that electricity and magnetism work together to ***transmit energy*** across space.

Earth's Annual Orbit Around the Sun

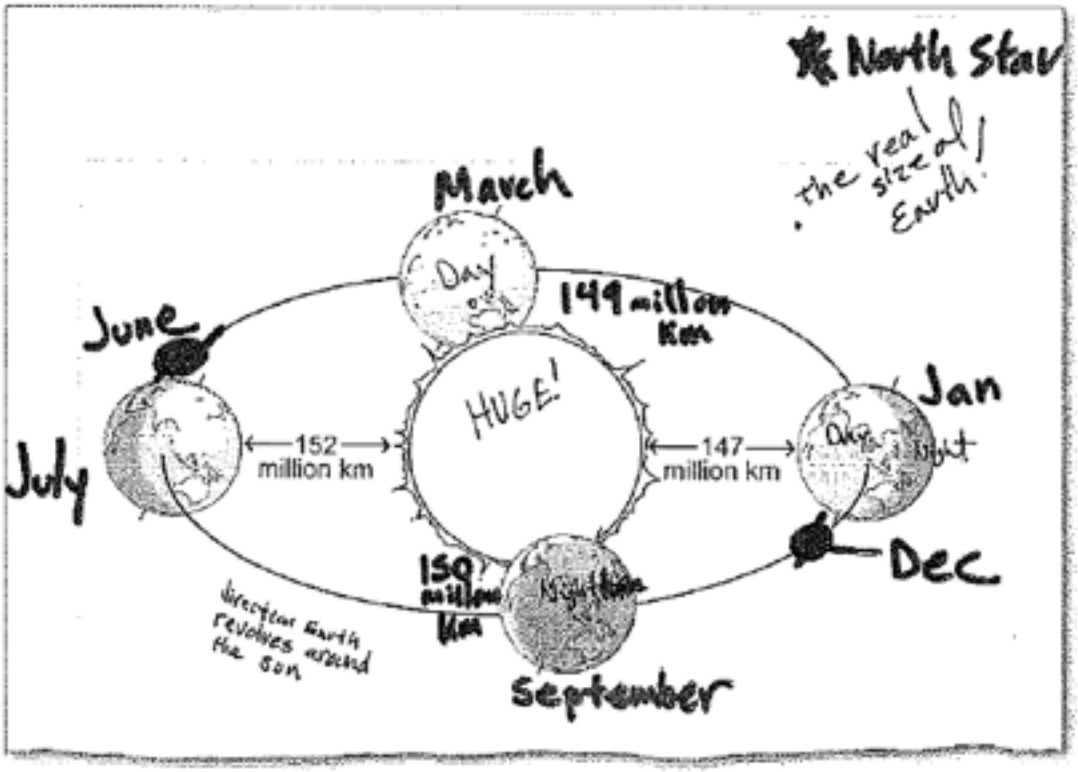

Figure 23: The trip Earth makes around the Sun each year. Note the dot showing the more correctly scaled size of Earth. (Illustration from Making Sense of Science *Weather and Climate* course, courtesy of WestEd)

This Instructional Segment includes the concept of seasons, wherein students revisit **models of spatial relationships and motions** in the solar system (MS-ESS1-1). In particular, understanding seasons involves researching and modeling the ***changes in the absorption of sunlight*** at different latitudes during Earth's annual orbit (Figure 23). Earth's tilt on its axis relative to the plane of its orbit causes the Northern Hemisphere to receive more direct sunlight in June through mid-September (North America summer/ South America winter) and the Southern Hemisphere to receive more direct sunlight in December through mid-March (South America summer/North America winter).

The University of Nebraska-Lincoln Astronomy Education website has excellent simulations that **model** and **explain** seasonal and latitudinal changes in sunlight and temperature over the course of a year.[3] Similar to the lunar phase models in Instructional Segment 2, these simulations provide space-view perspectives and Earth-view perspectives. Students can change the planetary location and the date of the year to **investigate** how these variations affect the intensity of sunlight and ***cause*** seasonal variations in temperature and the sun's position in the sky.

Waves Can Encode and Transmit Information

After having researched water waves, sound, light and electromagnetic radiations (EM), students can be challenged to summarize the characteristics of each of these with respect to:

- wavelength/frequency;
- amplitude; and
- wave speed.

The students can 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 9 illustrates one kind of summary.

TABLE 9: Characteristics of Waves

Type of Wave	Wavelength/Frequency Associated With	Amplitude Associated With	Wave Speed
Water wave	Physical distance between top of water waves	Height of the physical wave	Depends mainly on winds
Sound wave	Pitch of the sound	Loudness of the sound	1,235 km/hour in dry air at 20
Light wave	Color of the light	Brightness of the light	108,000,000 km/hour in vacuum
All EM Waves	Type of EM wave (x-ray, UV, light, IR, microwave)	Intensity of that EM wave	108,000,000 km/hour in vacuum

[3] "Motions of the Sun Simulator" at http://astro.unl.edu/naap/motion3/animations/sunmotions.html
"Seasons and Ecliptic Simulator" at: http://astro.unl.edu/naap/motion1/animations/seasons_ecliptic.html

(Table developed 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*** 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** 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 comes 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 very mechanical ways. For examples, clocks had an inside pendulum whose movements resulted in the hour and minute hands going round and round. 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 an AM and an FM radio signal may provide an interesting activity. Students should be able to **model** 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 a person hearing the song in the comfort of her 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).

Digitizing a Screen Picture

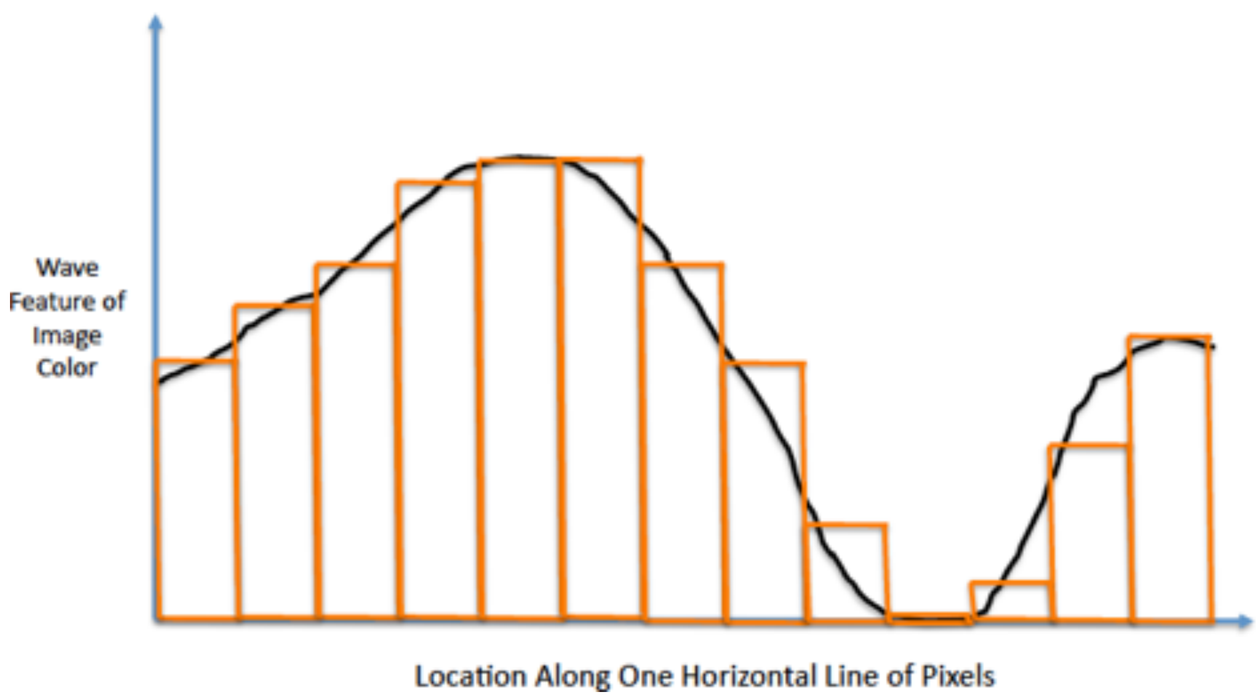

Figure 24: The features of an electromagnetic wave can be converted into numbers that change over a spatial location. These numbers can then be converted into computer-friendly digital formats so a very clear image can be displayed on a screen. (Illustration by Dr. Art Sussman, courtesy of WestEd)

Figure 24 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 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 thirteen different locations, and summarize the color at each of those thirteen locations as a number. Specifying the color of only 13 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.

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. This Instructional Segment includes students evaluating the claim that digitized signals offer significant advantages with respect to encoding and transmitting information (MS-PS4-3). In the vignette that concludes this narrative, student groups engage with a design challenge focused on sustaining Earth’s systems in which they use and evaluate at least one digital technology in researching their challenge and/or designing their solution.

Vignette: Grade 8 Instructional Segment 4

Student Capstone Projects

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

It is important to note that the vignette focuses on only a limited number of performance expectations (PE's). It should not be viewed as showing all instruction necessary to prepare students to fully achieve these PE's or complete the Instructional Segment. Neither does it indicate that the PE's should be taught one at a time, nor that this is the only way or the best way in which students are able to achieve the indicated PE's.

Introduction

Students in groups and as a whole class shared what they know or estimate about human population numbers. 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 helped chart that information, and then guided the discussion towards estimates of consumption patterns. After a while, students concluded that for each country or continental area, they should probably get data about total consumption and per-capita consumption.

Having established that background, Ms. D provided each group of students with information about world populations[4] and about consumption of natural resources in the year 2012. In both cases, the datasets include information at the country level (e.g., Brazil) and at a regional level (e.g., South America). The data for consumption was provided as the number of millions of metric tons of carbon dioxide emitted from the

[4] Data from the Population Reference Bureau report accessed at http://www.prb.org/Publications/Datasheets/2012/world-population-data-sheet.aspx

consumption of energy resources.[5] Since the total amount of data from the sources was somewhat overwhelming and also not 100% 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** that Ms. D had provided, **calculated** per-capita consumption based on emitted carbon dioxide from energy resources, and created model representations of the data. Some student groups used the **model** of 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 that included both total consumption and per-capita consumption in comparing regions and highlighted countries (Table 10).

TABLE 10: Energy Consumption Patterns Based on Carbon Dioxide Emissions in 2012			
Region or Country	**Population in 2012 (number of people)**	**Total CO Emitted in 2012 (tons)**	**Per-Capita Emission of CO (tons/person/year)**
Africa (Nigeria)	1,100 million (170 million)	1,200 million (83 million)	1.1 (0.5)
Asia (China)	4,300 million (1,400 million)	14,000 million (8,100 million)	3.3 (5.8)
East Europe (Russia)	300 million (1400 million)	2,700 million (1,800 million)	9.0 (13)
West Europe (Germany)	190 million (82 million)	1,700 million (790 million)	8.9 (9.7)
South America (Brazil)	400 million (200 million)	1,200 million (500 million)	3.0 (2.5)
Middle East (Saudi Arabia)	230 million (79 million)	2,000 million (590 million)	8.7 (7.5)

[5] Data from the U.S. Energy Information Administration accessed at http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8

North America (USA)	350 million (310 million)	5,800 million (5,300 million)	17 (17)

(Table developed by Dr. Art Sussman, courtesy of WestEd)

Each student group posted its representation on a big chart. The whole class then did a gallery walk where they examined each of the charts and listened to the group's presentation about their chart. Students asked questions, and wrote down notes to inform later discussions. After the gallery walk and while the charts were still visible, the whole class discussed the ***benefits and disadvantages of the different representational models***, the most important ***patterns*** of per-capita consumption, and any **evidence-based claims** that they might want to make.

Some students had noticed a ***pattern*** 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 hypothesized 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** correlations with other countries that produce and export large amounts of fossil fuels.

Ms. D recognized many connections to ***California's Environmental Principles*** in this instructional segment and so posted them on her classroom wall. One of the students asked if the data they had analyzed was an example of California Environmental Principle 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. (Principle II, concept a)

Capstone Projects

Ms. D then led a class discussion about the student group projects that would conclude their immersion in middle school science. Most of the student projects should focus on higher levels of impacts to Earth's systems due to increasing human populations and increasing consumption of natural resources (MS-ESS3-4). Student teams would refer to and use concepts and practices that they had learned in grade 8 but also in earlier integrated middle school science grades to:

• **obtain and evaluate information** about a specific phenomenon in which human activities are impacting one or more Earth systems;

• **analyze data** related to the impacts on Earth systems, and identify how they demonstrate the California Environmental Principles and Concepts;

• **construct explanations and design solutions** related to those human activities and impacts;

• **analyze design solutions** with respect to their **criteria and constraints** associated with successful implementation;

• **model** how digital technologies can assist with gathering data, implementing solutions, and/or communicating results;

•**argue using evidence** to evaluate and refine their solutions; and

• **communicate the scientific and/or technical information** related to their project and their proposed solution.

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.[6] 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 the two crosscutting concepts of ***Cause and Effect*** and ***Stability and Change*** as they relate to:

• an overall decline in biodiversity of 52% 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;

[6] Report can be downloaded at no cost at http://www.worldwildlife.org/publications/living-planet-report-2014

• how humans 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** comparing the “Ecological Footprints” of high-income countries and low-income countries.

Ms. D helped transition 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, produce better, and consume more wisely. While they were processing these readings in teams and as a whole class, students began brainstorming potential solutions related to the impacts that had been raised by the first set of readings. Student facilitators helped s**ummarize 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 changed and stabilized around a variety of projects. Four teams focused on climate change but had 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, as well as a 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 8, 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.

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 as well as expanding the feedback to the student groups. At the end of the projects, student groups across the different Grade 8 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 had 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 **h**abitat by building dams, and also **o**verharvesting timber and gravel along the stream banks. In addition, people have stocked streams with **i**nvasive nonnative fish species and **p**olluted the water. The students proposed plans to increase public awareness related to stream overharvesting and pollutions practices, and identified constraints that needed to be addressed in reducing these practices. (California Environmental Principle II) (See the EEI 7th grade unit “Extinction: Past and Present” for more information and a lesson on HIPPO)

The genetic engineering group had become interested in comparing the genetic code with the encoding involved in digital files. They provided **evidence for their claim** that the genetic code was neither analog nor digital, but instead was uniquely biological. They **explained** that the genetic code resembles a digital coding in some ways, but consists of four “digits” (the letters of the DNA “language”) instead of just two. In addition, they provided **evidence for claims** that genetic engineering of food crops did not significantly endanger personal health (e.g., cancer) but that genetic engineering had a significant constraint with respect to potentially endangering the health of ecosystems. (California Environmental Principle 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** from their school and the Green School, and made recommendations based on those analyses. In addition, they **shared information** about digital tools that schools can use to collect and analyze that kind of data as well as to 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 were made at the district level rather than the school level. (California Environmental Principle V)

One of the asteroid impact teams had changed projects. They had remembered that the HHMI BioInteractive website about the impact crater had included remote digital data that had originally identified the crater in the Yucatan. While checking other links, they discovered that the HHMI BioInteractive website included conservation efforts at the Gorongosa National Park in Mozambique.[7] The students explained that this park provided a case study in ecology and conservation science. They had gotten particularly excited when they learned that park scientists use GPS satellite collars and motion-sensitive cameras to gather data about the recovery of the park's lion population. In addition to sharing pictures and video, the students used educational resources from the website to **explain** the park ecology, the conservation recovery plans and significant constraints that needed to be addressed to promote successful restoration. (California Environmental Principle V)

Global Warming and Climate Change

[7] http://www.hhmi.org/biointeractive/gorongosa-national-park

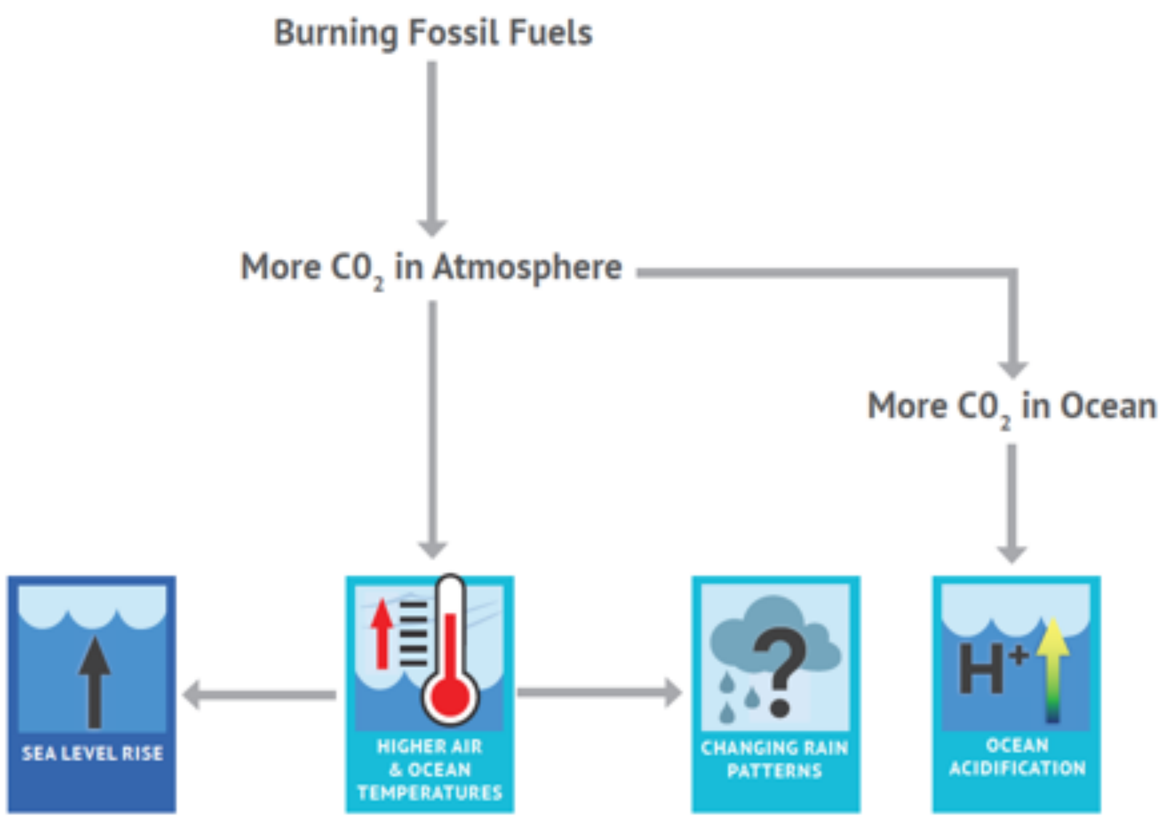

Figure 25: Increased emissions of carbon dioxide cause global warming (higher air and ocean temperatures) and three other climate change impacts. (Illustration by Dr. Art Sussman and Lisa Rosenthal, courtesy respectively of WestEd and WGBH)

The different student groups working on climate change issues jointly identified as a constraint that people had a lot of confusion about global warming and climate change. They consulted with their Grade 6 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 website that has a computer interactive explaining four main impacts of climate change (Figure 25).[8] Higher concentrations of atmospheric CO_2 directly result in global warming and ocean acidification. The increased thermal energy trapped in the Earth system ***causes*** other changes such as sea level rise and changing precipitation patterns. (California Environmental Principle IV)

[8] http://www.pbslearningmedia.org/resource/pcep15-sci-ess-impacts/impacts-climate-change-pacific-region/

Projected Average Temperatures in California

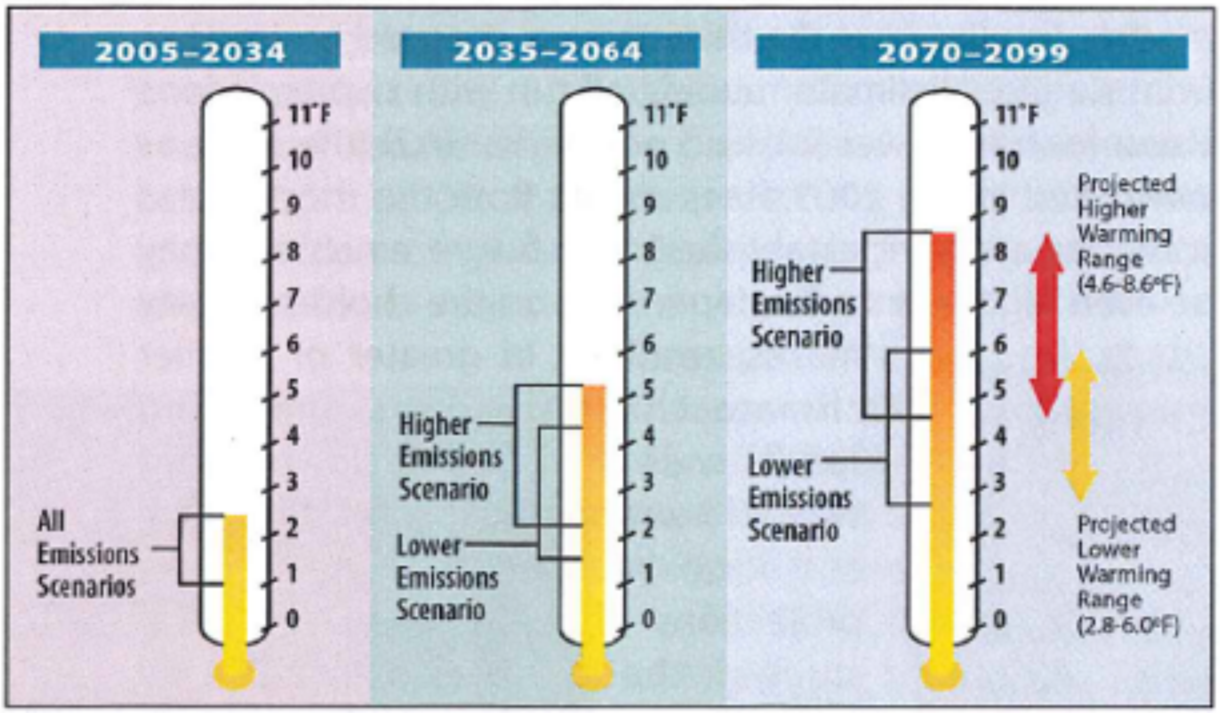

Figure 26: Projected increases in statewide annual temperatures during this century. From *Our Changing Climate 2012*, a Summary Report on the Third Assessment from the California Climate Change Center.[9]

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. They noted that reductions in emissions of greenhouse gases could reduce the amount of heating (Figure 26). They also learned that communities could engage in individual and collective actions that increase the fire safety of homes.

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 had been using digital tools to communicate with a school on the island of Majuro. The group explained that the approximately 60,000 Marshall Islanders were severely

[9] http://www.climatechange.ca.gov/climate_action_team/reports/third_assessment/index.html

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 had been communicating with each other, a King Tide caused serious flooding in the area of the Majuro school. The group presentation included **explanation** of how climate change ***causes 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 units "The Greenhouse Effect on Natural Systems" provide additional resource materials on climate change and greenhouse gases.)

In each of the three middle school grades, students had learned about the Environmental Principles and Concepts that had been adopted 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 about that related to any of the five Environmental Principles. Students then shared their ideas in a whole class discussion. They were surprised how many of them had 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.

NGSS Connections and Three-Dimensional Learning

Performance Expectations

MS-ESS3-4 Earth and Human Activity
Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

MS-PS4-3 Waves and Their Applications in Technologies for Information Transfer
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.

MS-LS4-4 Biological Evolution: Unity and Diversity
Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

MS-ETS1-1 Engineering Design
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 Engineering Design
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of a problem.

Science and engineering practices	Disciplinary core ideas	Crosscutting concepts

Obtaining, Evaluating, and Communicating Information *Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.* **Constructing Explanations and Designing Solutions** *Undertake a design project, engaging in the design cycle, to construct and/or test a design of an object, tool, process, or system.* **Engaging in Argument from Evidence** *Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.*	**ESS3.C Human Impacts on Earth Systems** *Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, unless the activities and technologies involved are engineered otherwise.* **PS4.C Information Technologies and Instrumentation** *Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.* **LS4.B Natural Selection** *Natural selection leads to the predominance of certain traits in a population and the suppression of others.* **ETS1.A Defining and Delimiting Engineering Problems** *The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge likely to limit possible solutions.*	**Patterns** *Patterns can be used to identify cause-and-effect relationships* **Cause and Effect: Mechanism and Prediction** *Phenomena may have more than one cause, and some cause-and-effect relationships in systems can only be described using probability.* **Stability and Change** *Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.*

Connections to the CA Environmental Principles and Concepts:

Principle I: The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.

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

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

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

Principle V: Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.

Connections to the CA CCSSM: 8.EE.4–6, 8.F.1–5, 8.SP.1–4

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

Connection to CA ELD Standards: ELD.PI.6-8.1, 9

Vignette Debrief

The *CA NGSS* require that students engage in science and engineering practices to develop deeper understanding of the disciplinary core ideas and crosscutting concepts. The lessons give students multiple opportunities to engage with core ideas in space science (Moon phases and the solar system), helping them to move towards mastery of the three dimensions described in the *CA NGSS* performance expectations (PE's).
In this vignette, the teacher selected performance expectations across the three science disciplines and engineering. In the lessons described above she engaged students only in selected portions of these PE's. Full mastery of the PE's will be achieved throughout this Instructional Segment. 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 Design (Defining and Delimiting Engineering Problems).

After students analyzed data related to impacts on Earth systems caused by increasing populations and per-capita consumption, they formed groups to deeply engage with a specific project that involved key concepts in Instructional Segment 4. They also considered other concepts and practices from the entire year, and were encouraged to connect their projects with concepts and practices from Integrated Grades 6 and 7. Over the course of their projects, students interacted within and across groups as well as with the teacher. During their project development and final presentations, students also taught each other and reinforced middle school learning experiences that deepened their understanding of California’s Environmental Principles and Concepts.