Shark Encounters

8.1

Image courtesy of CSULB Shark Lab [Reproduced with permission]

Anchoring Phenomenon

Numerous reports suggest an increase in white shark encounters* in the United States in recent years, and the public is worried.

Lesson Concept

Begin to construct an explanation supported by evidence to determine the possible causes of recent increases in white shark encounters and whether past records like the fossil record may provide us with reliable information to give context.

Investigative Phenomenon

This part of the lesson sequence introduces students to the anchoring phenomenon and then uses news reports of sharks as an investigative phenomenon: shark encounters have happened recently and seem to be increasing.

Standards

Refer to Appendix 8.1 for NGSS, CCSS (ELA and Math), California ELD, and EP&C standards.

*Encounters include sightings and census estimates, as well as physical interactions between humans and sharks.

Storyline Link

This learning sequence is positioned at the beginning of the last instructional segment identified for California Middle School Integrated, grade 8, in the California Science Framework (essentially, the end of middle school). Important Disciplinary Core Idea (DCI) prior knowledge that students should bring to this learning sequence from grades 6–8 includes history of planet Earth (rock strata and the fossil record can be used as evidence to organize the relative occurrence of major historical events in Earth's history, ESS1.C), growth and development (animals engage in behaviors that increase the odds of reproduction, LS1.B), information processing (each sense receptor responds to different inputs, transmitting them as signals that travel along nerve cells to the brain; the signals are then processed in the brain, resulting in immediate behavior or memories, MS-LS1-8), interdependent relationships in ecosystems (organisms and populations are dependent on their environmental interactions both with other living things and nonliving factors, LS2.A), ecosystems dynamics (ecosystem characteristics vary over time. Disruptions to any part of an ecosystem can lead to shifts in all of its populations. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health, LS2.C), natural selection (both natural and artificial selection result from certain traits giving some individuals an advantage in surviving and reproducing, leading to predominance of certain traits in a population, LS4.B), adaptation (species can change over time in response to changes in environmental conditions through adaptation by natural selection acting over generations. Traits that support successful survival and reproduction in the new environment become more common, LS4.C) and wave properties. As this is at the end of middle school, students should also bring a full breadth of understanding of the 6–8 grade band progressions for the Science and Engineering Practices (SEPs) and Crosscutting Concepts (CCCs).

This learning sequence primarily serves to help students to extend understanding of wave properties, deepen understanding of waves and information technologies, and begin to build an understanding of magnetic and electric fields (students will receive much more detailed instruction later in the instructional segment) with a subtle nature of science storyline focusing on the value of interpretation of data in science and its role in framing knowledge (science is a way of knowing, scientific knowledge is based on empirical evidence, scientific knowledge is open to revision in light of new evidence). Set in the context of tracking sharks, integration of life science (how we learn information from the fossil record) and Earth science (human impacts) helps students begin to build an understanding of the phenomenon of the possible increase in encounters with white sharks and subsequent public concern. It is recommended that students have prior instruction on wave properties (just wavelength, amplitude, and frequency) when they study astronomy-related DCIs earlier in the year, as this sequence will provide students the opportunity to see those properties play out with tracking devices. (It's possible for this to be addressed in this sequence, but the authors felt that to do so in a way that fosters adequate student sensemaking would take even more time in an already long sequence and deviate too far from the anchoring phenomenon.)

As this is the end of middle school, students should be at middle school level proficiency for SEPs and CCCs, although this sequence will reinforce a few. Throughout the sequence, students will be prominently using many elements of Asking Questions and Defining Problems, Developing and Using Models, Analyzing and Interpreting Data, and an intentional scaffolding of Constructing Explanations and Designing Solutions throughout, which will ultimately lead to students Engaging in Argument from

Evidence as they decide how to influence public perception of white sharks. Cause and Effect is the strongest CCC at play where all elements are used by students (with some elements of Patterns and Structure and Function).

This Engage lesson introduces students to the anchoring phenomenon of the learning sequence (Numerous reports suggest an increase in white shark encounters in the United States in recent years, and the public is worried.) and a real-world investigative phenomenon (Shark encounters have happened recently and seem to be increasing.) that they can investigate. Students use their prior knowledge to share their own ideas about sharks and deepen their ability to ask questions based on observations from text to consider how they can distinguish fact from fiction. Students build on their abilities to analyze and interpret data to provide evidence for a phenomenon by questioning the sufficiency of the data they find. They use patterns to identify cause and effect relationships that are used to begin constructing an explanation about whether or not there are really more shark encounters now than in the past, relying on cause and effect to help them identify that the phenomenon likely has more than one cause. Following this lesson, students will have an opportunity to answer their questions about whether or not the amount of shark encounters in recent history is different from the past and what historical data suggests by analyzing fossil evidence and fishers logs on white sharks.

This lesson is part of a series in the learning sequence that will culminate in students revising an idea over time, leading to engaging in argument from evidence about the causes of recent increases in the white shark population, with the goal of building public understanding and alleviating concerns.

Overview

STEP	RATIONALE
Introducing an Article	Students learn about the investigative phenomenon and are provided an opportunity to build excitement in the room and bring opinion out into the open.
Refining Ideas	Students begin to move away from opinion and consider the need for evidence to address key questions. (Key questions have been pre-planned by the teacher in anticipation of what students will bring up in conversation.)
Identifying Needed Data	Students consider types of evidence needed to address the key questions.
Gathering More Information	Students use another source of information and attempt to identify a cause for patterns observed.
Beginning Explanation	Students make a first attempt at an explanation for what we know about white shark life history over time by evaluating three claims.
Providing a Context for More Information	Students recognize that their explanation is weak without context and that historical information is necessary to strengthen the explanation.
Documenting Current Thinking	Students complete a task to support metacognition that asks them to consider previous ideas, current thinking, and where they need to go next.

8.1 Shark Encounters

Following this lesson, students will have an opportunity to answer their questions about whether or not the amount of shark encounters in recent history is different from the past and what historical data suggests by analyzing fossil evidence and fishers logs on white sharks.

Throughout the lesson, a flag (▶) denotes formative assessment opportunities where instruction may change in response to students' level of understanding and making sense of phenomena.

Time

90 minutes

90 minutes   Engage

Materials

Whole Class

- ❑ Devices with internet access
- ❑ Access to sticky notes (for adding extra information into their Science Notebook)
- ❑ 8.1.C1: Shark Encounter Claim Chart
- ❑ Video *Shark Sightings Force Closure of Stretch of Sunset Beach*, https://www.youtube.com/watch?v=rVQcRCcL-R4

Per Group of 4

- ❑ Chart paper (not a whiteboard)
- ❑ Markers

Individual

- ❑ Science Notebook (personal student Science Notebook)
- ❑ 8.1.H1: CSULB Shark Lab Reports Record Breaking White Shark Sightings
- ❑ 8.1.H2: Scientist Communication Survival Kit (a good resource to keep in their Science Notebook)
- ❑ 8.1.H3: My Shark Encounter Claim Chart
- ❑ 8.1.H4: Crosscutting Concepts for Middle School Students (to become a permanent Science Notebook resource)
- ❑ 8.1.H5: Science and Engineering Practices (SEP) Progressions (to become a permanent Science Notebook resource)

Teacher

None

Advance Preparation

1. Create **8.1.C1: Shark Encounter Claim Chart** as a classroom chart to post or display. This chart will be added to and used as a reference in several lessons. (Step 6 of Procedure)
2. Students should be seated in groups of four for the duration of the learning sequence to foster collaboration.
3. Duplicate **8.1.H1: CSULB Shark Lab Reports Record Breaking White Shark Sightings** for each student. (Step 1 of Procedure)
4. Duplicate **8.1.H2: Scientist Communication Survival Kit** for each student.
5. Duplicate **8.1.H3: My Shark Encounter Claim Chart** for each student.
6. Duplicate **8.1.H4: Crosscutting Concepts for Middle School Students** for each student.
7. Duplicate **8.1.H5: Science and Engineering Practices (SEP) Progressions** for each student. This is a resource that can be referenced as needed when students engage with science and engineering practices.
8. Preview the video *Shark Sightings Force Closure of Stretch of Sunset Beach*.

Procedure

Engage (90 minutes)

Ask questions about data supported by evidence to determine the possible causes of recent increases in white shark encounters and whether past records like the fossil record may provide us with reliable information to give context.

TEACHER NOTE

Throughout the entire learning sequence, articles, videos, and websites have been carefully chosen so as not to reveal information students will later discover, allowing them to develop ideas over time. This first lesson, especially, is designed to have references that provide incomplete information so students can better engage in SEPs and CCCs. If other references are preferred, review the entire learning sequence to get a sense of what students will be discovering over time before replacing.

1. Setting the Stage

   To start the lesson, give students the CSULB Shark Lab press release, **8.1.H1: CSULB Shark Lab Reports Record Breaking White Shark Sightings**. This article sets the stage for the investigative phenomenon: shark encounters have happened recently and seem to be increasing. For classes with little prior knowledge on white sharks, see the shark sighting video to set the context without revealing information students will learn later in the learning sequence. (Sunset Beach is near Seal Beach.)

2. Introducing an Article

   Ask students to read the press release and record the following in their Science Notebook:

   - any detail from the press release that seems important or interesting
   - questions they have about the information in the press release
   - their own personal experiences with sharks (or experiences of someone they know)

   To move students deeper into the SEP, as they record questions facilitate them by asking groups and individual students the following questions:

   - What questions do you have about white sharks?
   - What was unexpected?
   - What do you want clarified?
   - What do you want more information on?

After time for individual processing, invite students to share with their group a detail they thought was important or interesting; a question they have or something they want clarified or more information on; and a personal experience. Give time to let some excitement in the room build. Remind students to use **8.1.H2: Scientist Communication Survival Kit** to facilitate group conversations. (Use of this tool is a differentiation strategy and a strategy to promote more equal talk among students.)

3. Refining Ideas

   a. Ask each group to share one detail with the class and chart. Begin to redirect the conversation away from hype.

   b. Point out that communities where white shark encounters occur need to make decisions about how to respond to public concerns. Responsible leaders must be careful how they communicate with the public. Students' ultimate goal in this learning sequence is to think about such communication. (They will be making a public service announcement in a few weeks.) Ask for input from students on the types of questions a leader should be asking and chart.

   c. Start guiding the conversation with students. Be sure to specifically ask and chart the following if students don't generate these questions:

      - How can we distinguish accurate information on sharks from the fantastical stories friends and families share?
      - How can we tell if the frequency of encounters with white sharks in recent years is different than in the past? (Are they increasing, decreasing, or staying the same?)
      - If there is a difference in the frequency of encounters? What are the possible causes? (Students might initially mention there is a difference. They should identify multiple reasons for the difference; acknowledging the plausibility of multiple causes is a necessary discussion. Ideas may include that the size of the shark population is changing, the number of people has increased, and therefore, the number of people visiting the beach is changing, etc.)
      - What evidence will we need to reassure or convince the public? (▶ Probe for student understanding of what is considered quality evidence and ask students to recall the importance of empirical evidence in supporting or refuting an explanation for a phenomenon. Adjust instruction if students do not understand. This will be addressed more specifically in Step 7.)

4. Identifying Needed Data

   a. Ask students:

      - What other information would be useful to help answer these questions?

- What information is the article missing that you wish was included?
- Remind me what you know about patterns. (Solicit ideas until students begin to describe that we use patterns to help us organize the things we observe so we can later understand relationships and identify underlying causes.) How do you think patterns might help you answer your questions? What are some patterns you might look for?

b. Encourage students to discuss with their group and record ideas in their Science Notebook. Have each group share an idea and chart. Student ideas should identify things such as wanting more than one news article, a quote from a reliable source and actual data/statistics, etc. ▶ For students that are struggling, possible questions to facilitate their thinking include:

- Are there any patterns to what is being observed?
- Is there a cause to this pattern?
- Why might reports from the public claim that sharks are up to 10 feet in length, but the team has only been able to verify sharks of 5–7 feet?
- Would you be confident in saying that white sharks are doing something different than normal from one news article?
- So, if several news articles are reporting the same information, where are they getting their information from?
- Who collects this data?

5. Gathering More Information

Students use other sources of information in an attempt to identify a cause for patterns observed. Divide each group in half to focus research in two different areas.

a. News reports can provide us with information, while the most compelling type of evidence in science comes from data. Once students have identified the need for more information, specifically data, have some students in each group explore the following:

Question: What data do we have on white shark encounters?

A possible source for this is "Shark Attacks Hit All-Time High in 2015" (Clark 2016).

1. Ask students to consider what information this source (and its links) provides us on white sharks and record evidence in their Science Notebook. Remind students to cite their sources as they record information.

2. Ask students to note any patterns observed and describe how the patterns provide evidence of possible causes.

b. In order to inform the public and to differentiate hype and inaccurate information from accurate information, students should understand basic information about sharks. Have students in each group explore the following:

Question: What do we know about white shark life history over time?

Ask students to record the question in their Science Notebook and record what they are able to find out about shark life history.

Possible sources:

"The Great White Shark" (Long 2017) University of California Museum of Paleontology. Retrieved from https://ucmp.berkeley.edu/vertebrates/Doug/shark.html

"Carcharodon carcharias" (Martins and Knickle 2017) Florida Museum of Natural History, University of Florida. Retrieved from https://www.floridamuseum.ufl.edu/fish/discover/species-profiles/carcharodon-carcharias/

"White Shark" Monterey Bay Aquarium (2017) Retrieved from https://www.montereybayaquarium.org/animal-guide/fishes/white-shark

"White Shark Information" (Wilson and Patyten 2015), California Department of Fish and Wildlife. Retrieved from https://www.wildlife.ca.gov/Conservation/Marine/White-Shark#facts

Students working on this question can be put into smaller groups to peruse each resource, and then share what they learn with those that read a different source. Students may need clarification on what is meant by life history. Ask them for ideas of what they think life history means. Confirm and add onto student ideas to help build a class definition. You may find a definition in your curricular resources that would be useful to students. In the absence of that, the characteristics of a species' life history are often considered to include the following:

- Reproductive behavior
- Feeding behavior and interaction with resources
- Response to change in environment
- Other social behaviors
- Lifespan and aging process

1. Ask students to consider what information this source provides about white sharks' life history and to record the information in their Science Notebook. Remind students to cite their sources.

2. Ask students to note any patterns observed that might help us understand shark encounters.

> **TEACHER NOTE**
>
> One way to differentiate instruction for students is to suggest topics for investigation of shark life history. For the highly engaged student, the topics of "response to change in environment" and "other social behaviors" will provide a more challenging exploration and synthesis of information. Consider providing additional guidance in navigating resources for students that struggle to identify relevant information and/or suggest using a graphic organizer to help with focusing on important information. This can include sentence frames for students needing language support.

c. Facilitate a whole class discussion of what students learned about data on white shark encounters and shark life history. Encourage students to track any information in their Science Notebook that they think might be useful moving forward (anything that would help them address ideas on the class chart built in Step 3, Refining ideas. Following the discussion, direct students to identify/code/highlight information that could be used to establish a pattern. Ask students to note any patterns observed and describe how the patterns provide evidence of possible causes. ▶ Students will likely focus on simple patterns (such as how lightning has killed more people than sharks have) so expect to redirect the conversation to keep the focus on "encounters" between sharks and people (there are more people than ever before, there are more beachgoers than ever before, there is an increase in the number of sharks spotted, the number of attacks has increased slightly, etc.) as this will provide useful information for part 6 and better help with making sense of the phenomena later.

6. Beginning Explanation

Students consider possibilities to explain the following question:

Question: Are there really more shark encounters now than in the past?

Have students work in groups of four, creating the table below, **8.1.C1: Shark Encounter Claim Chart** on chart paper. (Chart paper is recommended, as it can be added to over time throughout the learning sequence and allows groups to work collaboratively.) Students can go back to the resources used in Step 5, Gathering More Information, to look for evidence for the three claims below. Have students code information in the chart that reveals any pattern among the sources and possible causes for that pattern. Patterns could be interactions with humans or other species (like seals), reporting of encounters, fishing, etc.

▶ Some students may need clarification for the components of an explanation:

- **Evidence**: Scientific data (records, observations, etc.) about the frequency of white shark encounters over time that support the claim.

- **Reasoning**: Learnings about white sharks' life history that provide a logical connection between the evidence and the claim and explains why the evidence supports the claim.

Students are considering three plausible claims for an explanation at this time in the sequence as a mechanism to see which has the strongest evidence and reasoning over time. As a result, it's likely that students will be engaging in argument from evidence as ideas are refined over time.

Claim #1	Claim #2	Claim #3
There are more white shark encounters now than in the past.	There are fewer white shark encounters now than in the past.	The number of white shark encounters today is the same as in the past.
Evidence for Claim #1	**Evidence for Claim #2**	**Evidence for Claim #3**
Reasoning	**Reasoning**	**Reasoning**

Facilitating group discussion by circulating the room and asking guiding questions can support students in this task. Examples of guiding questions include: "How does this help answer our question?" "What other evidence should you consider to support this explanation?" and "Is there another explanation that can account for this evidence?"

Once groups have worked collaboratively, ask students to attach **8.1.H3: My Shark Encounter Claim Chart** in their Science Notebook to help keep a personal account of information. (Students will be adding information to this chart throughout the duration of the sequence.) Remind students to code any information revealing patterns and possible causes of patterns.

TEACHER NOTE

Some students may ask for clarification as to what is meant by "the past." In the context of this lesson and beginning **8.1.C1: Shark Encounter Claim Chart**, it's probably useful to think of "the past" as the overall history we have established for sharks throughout time (geologic time, evolutionary history). In subsequent lessons (by Lesson 8.3: Fisher Logs), some students may choose to use the lens of more recent history ("the past" being the last 100 or 200 years), which is fine. "Time" is a construct and should be agreed upon by the students in the class and may change depending upon usefulness.

There is likely not enough space in **8.1.H3: My Shark Encounter Claim Chart** for students to record the breadth of information they will need to record in the sequence. Offer sticky notes as a way to "extend the notebook space."

7. Providing a Context for More Information

   Remind students that their overall objective will be to communicate with the public about white sharks in a way that addresses concerns and helps communities make informed decisions.

   Challenge each group to think about additional information needed to address the question, "Are there really more white shark encounters now than in the past?" This starts with examining the quality of their current explanation.

   a. Ask students to evaluate the quality of information they have recorded. (▶ If students code evidence and reasoning that isn't strong, have a class discussion about what makes for strong/quality evidence and reasoning.)

      Code evidence according to its strength:

      - underline/highlight appropriate evidence (scientifically relevant) in color #1
      - underline/highlight sufficient evidence (multiple pieces) in color #2

      Code reasoning according to its adequacy:

      - underline/highlight reasoning that explains why the evidence supports the claim in color #3
      - underline/highlight reasoning that includes science ideas in color #4

   Once this coding is completed, asking groups to brainstorm how they could strengthen each explanation (hint: look for missing colors) by expanding their chart to include a fourth component: information needed to strengthen this explanation.

Claim #1	**Claim #2**	**Claim #3**
There are more white shark encounters now than in the past.	There are fewer white shark encounters now than in the past.	The number of white shark encounters today is the same as in the past.
Evidence for Claim #1	**Evidence for Claim #1**	**Evidence for Claim #1**
Reasoning	**Reasoning**	**Reasoning**
Information Needed to Strengthen this Explanation	**Information Needed to Strengthen this Explanation**	**Information Needed to Strengthen this Explanation**

b. Ask students to make another evaluation of information to strengthen their explanation by considering two crosscutting concepts: Patterns, and Stability and Change. (Depending on time, this can be a class discussion or group discussion with teacher monitoring and facilitating.) Ask students to briefly recall what they understand about Pattern and Stability and Change. (Students have learned these concepts in middle school.) After recalling, encourage students to use **8.1.H4: Crosscutting Concepts for Middle School Students** in their Science Notebook to help with their discussion.

- ▶ Begin by letting students share what they understand about patterns, then directing students to ask their own questions using elements of their respective CCC. Model the use of this first, then let students work independently.

Example of modeling use:

Teacher: Let's look at what is written in the green box and record ideas you have about how scientists use patterns in your Science Notebook. Think of a specific way you have used patterns before. (Wait a couple of minutes.) Take a moment to discuss with your group one thing you can share with the whole class about how you understand patterns and how you have used what you have learned. (Wait a couple of minutes.) Someone from Group A, please share what your group discussed.

Student: We said that patterns can help us find a cause for something. She shared that we used this last week when we were trying to make sense of the finch data and we looked for a pattern that could help us decide what two variables we could compare.

Teacher: Tell me more about the pattern you found and how it helped you find a cause.

Student: Well, we noticed that a lot of finches died during a certain time—that's a pattern—and we noticed that all of the birds that survived that time had bigger beak depths; that's another pattern.

Teacher: How did that help you find a cause?

Student: We remembered what we learned about beaks being able to only get some food types, so we thought that the cause of death of the birds with smaller beak depths could be that only some type of food might be available.

Teacher: Thanks for sharing. How about another group, can you please share what your group discussed?

(additional discussion)

Teacher: Ok, so we all have some experience working with the concept of Pattern. Let's look at the questions on this page now. Thinking about what you just said, which of these questions seems to "fit" here—which one might help us with our thinking about strengthening an explanation?

Student: Under Increasing Sophistication, bullet 5 helps: "What patterns provide evidence for your explanation?"

Teacher: Tell me more.

Student: Well, my group noticed that a source from Florida and California said shark populations around the world are declining, so that's a pattern in evidence.

Teacher: What else can you add? How does that pattern strengthen your explanation?

Student: Um, maybe with sufficiency in evidence.

Teacher: How so?

Student: Well, it's more than one source saying the same thing, so that's multiple pieces.

Teacher: Thanks for sharing your thinking. You provided a useful example of how to use the resource. Ok, let's try another, but this time I'm going to throw down a challenge. Can you use something from "On-Target"? It's our goal to work from there.

dead silence

Teacher: This is more challenging, isn't it? What do you think is meant by "macroscopic patterns" in the first bullet? (Continue the conversation and ask students to clarify meaning. Encourage students to write on their page, adding personal notes about how they interpret each element/bullet.)

Teacher: Let's try again. Do any of these help give us a way to think about strengthening your explanation? Discuss with your group; I'll check back in with you in a couple of minutes.

Teacher: Ok, what did you discuss?

Student: My group thought the last bullet, "What cause and effect relationship(s) can you identify from the pattern" would work.

Teacher: Tell me more.

Student: Well, we had reports showing a pattern that shark populations around the world are declining, and we also noticed that there were reports showing a pattern that the rate of sharks being captured by humans is alarmingly high, so maybe a pattern of humans capturing sharks is causing their decline.

Teacher: So you have a pattern that helped you identify a cause and effect relationship. How does that help strengthen your explanation?

Student: Um, well, we are confused because we see it in two places. It strengthens evidence for the claim that there are more encounters because we capture a lot, but we wrote that the populations are declining in the fewer column.

Teacher: So, it sounds like your group needs to continue discussing this and make a decision about where this best fits or if we need it in both places for now until we can get more information. I'll check on your group in a few minutes.

Teacher: What questions can I answer about how to use this resource?

After a few moments, encourage the students to use the resource independently, checking on groups as they start working.

TEACHER NOTE

For future use of **8.1.H4: Crosscutting Concepts for Middle School Students**, each time students use a new crosscutting concept on the handout, use a similar discussion pattern—asking students to share what they understand about the crosscutting concept, how they have used it in the past, what questions they feel would help facilitate their thinking, and share examples of how to move over to the On-Target category to ensure students are engaging at the 6–8 level.

This resource can also be used as a rubric for assessing where students are on a continuum of understanding of the crosscutting concepts. Consider replacing column headers with 1-2-3. Students who are routinely using questions from Entry Level are a 1, those routinely using Increasing Sophistication are a 2, and those routinely using On-Target are a 3.

- As groups work independently, ask additional questions to probe student thinking.

  When researching white shark encounters and life history over time in an attempt to answer the question, "Are there really more shark encounters today than in the past":

  - What pattern emerged?
  - Is the pattern clear? Are there other patterns?

  - What other information would we need to determine that the pattern identifies a cause and effect relationship?
  - If we want to know if encounters are increasing, decreasing, or remaining the same, do we have information that can tell us what is happening over time?
  - Are things changing quickly? Slowly? How do we know or how can we find out?
  - Sharks have a long history on Earth; is the time scale of the information we are looking at adequate to make a conclusion?
  - If 2015 was a record year, is that "normal"? Have there been other record years? How can we get some baseline data for the white shark population over a longer time period?
- The goal is for students to think of establishing a pattern of population size, encounters, etc. They cannot support the claim that encounters have increased or decreased without information from the past.

Students should realize that they need a context larger than the years identified in the websites visited. Encourage groups to discuss how they can build an accurate record of information on white sharks that have visited the coast of California in the past. Have students keep a record of their conversation in their Science Notebook. We cannot establish if the population we are seeing today is normal, increasing, or decreasing without a context for what the population has done over time (or compared to the past).

▶ For groups that seem stuck, ask:

  - How do we find out information about things that happened in the past? What about the deep past?
  - Can you think of anyone or any type of person who might have had consistent access to the coast and might have documented information on sharks?

When some groups appear to be on-target (ideas emerge about looking for fossils and/or asking lifeguards, fisherman, scientists), bring the conversation back to the whole class, and lead a discussion that reveals the fossil record and fisher logbooks as plausible sources of information. (Both will be future lessons in the learning sequence.)

- Ask groups to return to their explanation chart and add ideas to "information needed to strengthen this explanation."

8. Documenting Current Thinking

   Build a class chart where each group contributes at least three things:

   - At the beginning of class yesterday, what were some things you heard people say about white sharks?
   - What questions did you hear about white sharks?
   - What information have you gathered so far about white sharks?
   - What questions do you have now?
   - What information do you need to be able to answer those questions and build a strong scientific explanation?

Accommodations

Ask students who need help with reading tasks to skim the article first, and identify any words for which they want clarification. Clarify the directions, then ask students to do a "group read" (have one person in the group read the article out loud), but encourage students to withhold group discussions until everyone has had a chance to do their own thinking and make notes in their Science Notebook first, then discuss with their group, and revise Science Notebook work accordingly.

By seating students in groups (groups of 4 work well) and encouraging regular conversation, students have time to interact more with content and naturally help those that need more support. Use of **8.1.H2: Scientist Communication Survival Kit**, helps to make sure that students who don't feel comfortable sharing (often because of language, literacy level, uncertainty of content knowledge, etc.) are prompted to do so in a supportive way.

Use of a sense-making Science Notebook supports student language development, conceptual development, and metacognition. Students should be prompted to use their Science Notebook for

- prior knowledge of phenomena,
- exploration of phenomena and data collection,
- making sense of phenomena, and
- metacognition.

Consider providing sentence frames for low literacy and second language learners. The use of graphic organizers can help struggling students manage Science Notebook work. To support students learning English, allow conversations and Science Notebook work to happen in the language that the student is most comfortable expressing understanding, and then encourage expression using simple English phrases (or more complex for students with increasing proficiency).

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Toolbox Table of Contents

* to become a permanent Science Notebook resource

Shark Encounter Claim Chart

Create a chart to post or display in the classroom.

My Shark Encounter Claim Chart

Question: Are there really more shark encounters now than in the past?

Claim #1	Claim #2	Claim #3
There are more white shark encounters now than in the past.	There are fewer white shark encounters now than in the past.	The number of white shark encounters today is the same as in the past.
Evidence for Claim #1	**Evidence for Claim #2**	**Evidence for Claim #3**
Reasoning	**Reasoning**	**Reasoning**
Information Needed to Strengthen this Explanation	**Information Needed to Strengthen this Explanation**	**Information Needed to Strengthen this Explanation**

- ❑ **Evidence**: Scientific data (records, observations, etc.) about the frequency of white shark encounters over time that support the claim.
- ❑ **Reasoning**: Learnings about white sharks' life history that provides a logical connection between the evidence and the claim and explains why the evidence supports the claim.

CSULB Shark Lab Reports Record Breaking White Shark Sightings

23 September 2015

CSULB Shark Lab Reports Record Breaking White Shark Sightings

Scientists from the Shark Lab at California State University, Long Beach have been busy this summer with reports of white sharks swimming off public beaches along the coast of Southern California from Seal Beach to as far south as San Onofre.

Police, lifeguards, and members of the public have reported as many as 13 white sharks at any given time with some swimming near paddleboarders and surfers. Although some public reports claim the sharks are up to10 feet in length, the team has only verified individuals at 5–7 feet in length.

Between the months of April and August, the Shark Lab team monitored over 80 white shark sightings between these two locations. The team continues to work closely with lifeguards and responds to as many calls as possible so they can monitor the sharks and determine why the sharks are swimming closer to shore and remaining in the area. No beaches have been closed, but lifeguards and the Shark Lab team are warning beachgoers to be cautious.

# # #

Media contacts: Dr. Chris Lowe, sharklab@csulb.edu

CSULB Shark Lab. (2016). Long Beach, CA. [Reproduced with permission.]

Scientist Communication Survival Kit

Scientist Communication Survival Kit

SCIENTISTS SHARE THINKING	SCIENTISTS RESPECTFULLY CHALLENGE IDEAS
I observed _______.	I hear you saying _______, but would argue that _______.
Based on my observations, I think _______ because _______.	Interesting idea, but I am wondering _______.
For example, _______.	My data suggest something else_______.
Here's something we might try _______.	Can you help me understand _______.
I found out from _______ that _______.	I hadn't thought of that. Another idea is_______.
I would like to suggest _______.	I see it another way, _______.
SCIENTISTS ACKNOWLEDGE & BUILD ON IDEAS	**SCIENTISTS ENCOURAGE OTHERS**
We agree on _______ so what if _______.	_______ why don't you share first?
My idea is similar to _______ idea that _______.	What do you think _______?
What _______ said about _______ makes me wonder _______.	We haven't heard from you yet…
I agree with _______ and can add _______.	_______ tell me what you are thinking.
I'm going to add what you said about _______ to my own notebook.	Do you have anything to add _______?
WHEN INTERRUPTED	
deep calm breath… As I was saying _______.	_______ what were you trying to say?
I appreciate your excitement ☺, but I was trying to say _______.	Thanks, but I think _______ also had something to say.

CA NGSS Roll Out #4: Middle School Integrated Learning Sequence. https://cascience.org/ngss/ngss-collaborative [Reproduced with Permission]

My Shark Encounter Claim Chart

Question: Are there really more shark encounters now than in the past?

Claim #1	Claim #2	Claim #3
There are more white shark encounters now than in the past.	There are fewer white shark encounters now than in the past.	The number of white shark encounters today is the same as in the past.
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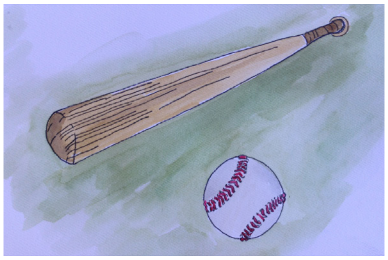
- ❑ **Reasoning**: Learnings about white sharks' life history that provides a logical connection between the evidence and the claim and explains why the evidence supports the claim.

Crosscutting Concepts for Middle School Students



Crosscutting Concepts

Cause and Effect

Identifying the cause of an event (whether there is one cause or many) helps us decide if there is a relationship that can be explained, and, in some cases, it might inform a solution to a problem.

I can use evidence to identify and analyze causes of events and design tests that gather more evidence.	**I can identify cause and effect relationships to help explain change and the reasons for the change.**	**I can use evidence of cause(s) and effect(s) to decide the type of relationship between them and to predict future change.**
› What is the cause of this event? › How do you know? › How does this cause help you identify a pattern? › How can you design a test to gather evidence (or refute ideas) about a possible cause?	› What cause and effect relationship(s) can you identify? How did this change happen? Why did this change happen? › What conditions were needed for an event to happen? › What did you learn when you tested a cause and effect relationship? Do the results of this test help you explain change? If so, how? › If your observations/data show that two things happen together regularly—does it mean that one caused the other? How do you explain this? › What evidence do you have that one event caused (or didn't cause) another when the two things happen together regularly?	› Is the relationship you are seeing describing a cause that directly leads to an effect? Or, is the relationship describing two (or more) events that occur together, where one may not cause the other? › What predictions can you make about phenomena, with confidence, based on this cause and effect relationship? What is your evidence for this? › How confident/sure are you? What else do you need to be more confident/sure? › What other causes might help you explain these phenomena? › How can a pattern in the effect, predicted by the cause, help describe phenomena? › How likely is it that this effect is going to happen? Why is this more or less likely?

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Crosscutting Concepts for Middle School Students (continued)

Crosscutting Concepts

Energy and Matter

In any system, there are amounts of energy and matter that can change, but are conserved. Tracking how these flow/cycle into, within, and out of a system help us understand how a system works.

I can identify and describe the change in objects.	I can identify and describe matter moving into, within, and out of a system and the parts it's made of. I can describe energy moving from one object to another.	I can identify and describe how matter and energy are conserved, how they can change, and the relationship between the two.
› How can the object be broken down into smaller parts? › How can smaller parts make a larger structure? › How can the object change shape? › How can the objects be broken down and put back together?	› How can you show/describe what this matter is made of? › What evidence do you have that matter moved—into, within, or out of—a system? › Where did the energy come from? Where is the energy going? › How does the energy change? Can it change in another way? › How can you show/describe what is happening to energy?	› What evidence do you have for changes in matter during this physical process? › What evidence do you have for changes in matter during this chemical process? › What happened to the amount(s) of matter as a result of these changes? › How is matter changed, yet still conserved? › What evidence do you have of atom rearrangement in a chemical process? › What are the different forms of energy you can identify? Do they change? Do they move? What is your evidence? › How can you describe/show the different forms of energy? › How can you describe/show the path of energy flowing through a system?

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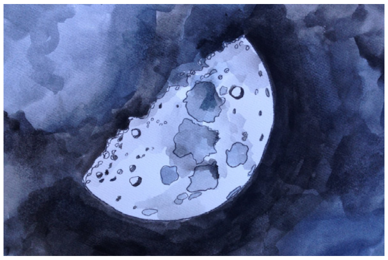
Crosscutting Concepts for Middle School Students (continued)



Crosscutting Concepts

Patterns

Patterns are used to help organize and classify observed phenomena, and ask questions about relationships and their underlying causes.

I can make observations, find patterns, and describe them.	**I can see similarities and differences in patterns and use them to predict and explain.**	**I can identify and infer patterns in things not easily seen.**
› What patterns can be you identify based on your observations? › How can the patterns you identified be used to describe phenomena? › How can the patterns you identified be used as a way to provide evidence about phenomena?	› When you compare patterns, what about them is similar? What about them is different? › How can you use similarities and differences to sort, classify, and help communicate understanding? › What is a rate of change between patterns you have observed? › What do you predict will happen in the future? How does a pattern showing change help you predict what will happen in the future? › What patterns provide evidence for your explanation?	› What are macroscopic patterns you are observing? › What patterns can you identify from structure(s) that are microscopic? › How can you describe a large pattern based on all the components of smaller patterns? › How do your observations of large patterns help you understand smaller patterns and patterns in things not directly observable? › What information do patterns in rates of change provide? › What patterns in the organized data (graph, chart, figure, or image) can you identify? › What cause and effect relationship(s) can you identify from the pattern?

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Crosscutting Concepts for Middle School Students (continued)

Crosscutting Concepts

Scale, Proportion and Quantity

Recognizing that systems and processes can be different in size, time, and in the amount of energy flowing through them helps us understand that the way things work will change with scale (like things too small or fast to observe, or those that are too large or slow making them hard to understand) and that there will be differences in rates of changes between things because of scale, and changes in scale can also change the relationship between things.

I can describe and compare the differences in scale in objects, space, and time, and I can measure length.	**I can estimate scale as I make sense of data. I can measure, compare, and organize quantities of weight, time, temperature, and other variables.**	**I can use models showing different scales to help me understand phenomena, including time, space, and energy. I have a sense of how relationships change with changes in scale. I can recognize, use, and interpret mathematical representations.**
› How can you describe differences between two objects or events? (Which is bigger/ smaller? Which is hotter/cooler? Which is faster/slower?) › How can you measure the length of an object (using m, cm, or mm)?	› How can you describe and estimate the size of something very small? Very large? Very short? Very long? › Does your description sound reasonable? › How can you measure the weight of an object (using g, kg)? › How can you measure the time involved (using seconds, minutes, hours, years, etc.)? › How can you measure the temperature (using C)? › How can you measure the volume (using mL, L)? › What is another way you can measure this? › How can you use the measurements of something to compare and organize objects?	› How is this model used to represent very long/ short periods of time (or things that are very large/ small)? What does it help you understand? › How can you develop a model to represent very long/short periods of time (or things that are very large/small)? What are important considerations for this model for the scale to be understandable? › How can the model be adjusted to improve understanding of the scale of the phenomena to you or another person? › If the scale of this changes, how will the function change? › Is there a proportional relationship in the types of quantities? Can you use this to describe a property or process at larger and smaller scales? › How does this equation represent a relationship between aspects of the phenomenon? › What equation could you write to show the relationship between parts of this phenomenon? › If you change the scale, would you still be able to observe this? How would the relationships change?

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Crosscutting Concepts for Middle School Students (continued)

Crosscutting Concepts

Stability and Change

To help make sense of our world, we try to understand how change occurs how some parts of the system can change but the overall system stays stable.

I can describe and explain things that don't appear to change (remain stable) and things that change.	I can describe and measure change, and differences in change.	I can explain aspects of change including understanding of substructures, interactions between parts, and the need for feedback to maintain stability.
› What things are staying the same? How do you know? › What things are changing? How do you know? › How quickly or slowly is change happening? › What is affecting the speed of change?	› How do you know a change happened? How do you measure it? › How do you know something is stable? How do you measure it? › How do you determine if the change is consistent or if it fluctuates? › When did the change occur? › When did things become stable? › How can you suggest a better way to measure change and stability? › Would you describe the change as great or small? Why? › What happens to the change over short periods of time? › What happens to the change over long periods of time?	› What evidence do you have for when and why the change occurred? › What evidence do you have for when and why things became stable? › How can you explain the changes over time? What is your evidence? › How can you explain the disruption in stability? What is your evidence? › How do forces at different scales influence change? › How does change in one part of the system lead to change in another part? › How could a sudden event affect stability? › How do gradual changes over long periods of time influence overall stability? › What leads to stability? › How does information about subsystems inform the overall system? › How does one part of the system respond to changes in other parts of the system? › How can parts of the system respond to changes in another part to create an overall stable system?

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Crosscutting Concepts for Middle School Students (continued)

Crosscutting Concepts

Structure and Function

Understanding how an object is shaped and how it is structured helps us understand its properties and function.

I can identify the relationship between shape, stability, and the function of an object.	I can relate the structure of sub-systems and the shapes of their parts to their function.	I can visualize and model the structure and function of objects, sub-systems, and processes.
› How does the shape of the structure affect its function? › How does the shape of the structure affect its stability? › What is the relationship between stability and function of the structure?	› What evidence do you have for the type of material a substructure is made of? › How do the shapes and parts of substructures impact their function?	› What variables influence the properties of this structure? (Variables include shape, composition, relationship among its parts, etc.) › How can this system or structure (whether complex or microscopic) and the influence of its variables be visualized, modeled, and/or used to describe how variables impact its function? › What function does this object, sub-system or process need to do? What variables need to be taken into account when designing a structure for this particular function?

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Crosscutting Concepts for Middle School Students (continued)

Crosscutting Concepts

Systems and System Models

Sometimes things we want to understand are so big and complicated they can be hard to make sense of. Applying systems thinking, we can consider a small part, with pretend boundaries, to build smaller understanding first. All of the small parts we consider add up to the whole part and can give us bigger understanding.

I can describe (through words and drawings) everything in the world as made up of smaller parts that work together.	**I can describe a system based on its smaller parts and the jobs they do. The small parts have a relationship with each other and also work together to help the whole system function.**	**I can describe a system and the smaller sub-systems that create the larger system. I can use models to represent the system, its sub-systems and how these sub-systems interact together and I can identify the limitations of those models.**
› What are the parts that make up this object/organism? › How can you show/describe the parts of the system? › How do the parts of this object/organism work together as a system? › How can you show how the parts of this object/organism work together as a system? › What changes can you make to your plan or model of parts and how they work together so someone else can understand it?	› What are the parts within this system? › What are the functions of these parts of this system or this system as a whole? › How can this system be described? › How does your model show things you can't see, but have indirect evidence for? › What do the parts do together that no single part can do alone?	› How does one system interact with another system? › Is your system really a sub-system of a larger, more complex system? How do you know? › What model could you use to represent the whole system? The sub-systems? › What part of the system does the model represent? How is that shown? › What interactions between parts are represented in the model? How are they shown? › How does energy flow into, within, and out of the system? › How does matter cycle into, within, and out of the system? › How does information flow into, within, and out of the system? › What is the model unable to show? › What do you have to assume is true for this model to work? › How confident are you that this model fairly represents the system? Why? Are there any changes you can make to increase confidence?

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Science and Engineering Practices (SEP) Progressions

Science & Engineering Practices in *Next Generation Science Standards*

NGSS@NSTA STEM STARTS HERE

Asking Questions and Defining Problems: A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world(s) works and which can be empirically tested. Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify ideas.

K–2 Condensed Practices	3–5 Condensed Practices	6–8 Condensed Practices	9–12 Condensed Practices
Asking questions and defining problems in K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.	Asking questions and defining problems in 3–5 builds on K–2 experiences and progresses to specifying qualitative relationships.	Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, clarify arguments and models.	Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.
• Ask questions based on observations to find more information about the natural and/or designed world(s).	• Ask questions about what would happen if a variable is changed.	• Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. • Ask questions to identify and/or clarify evidence and/or the premise(s) of an argument. • Ask questions to determine relationships between independent and dependent variables and relationships in models. • Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.	• Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. • Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. • Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables. • Ask questions to clarify and refine a model, an explanation, or an engineering problem.
• Ask and/or identify questions that can be answered by an investigation.	• Identify scientific (testable) and non-scientific (non-testable) questions. • Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.	• Ask questions that require sufficient and appropriate empirical evidence to answer. • Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.	• Evaluate a question to determine if it is testable and relevant. • Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.
		• Ask questions that challenge the premise(s) of an argument or the interpretation of a data set.	• Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of the design.
• Define a simple problem that can be solved through the development of a new or improved object or tool.	• Use prior knowledge to describe problems that can be solved. • Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.	• Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	• Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations.

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National Science Teachers Association (2014). Science and Engineering Practices. Retrieved from http://ngss.nsta.org/PracticesFull.aspx

Science and Engineering Practices (SEP) Progressions (continued)

Science and Engineering Practices

Developing and Using Models: A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.

K–2 Condensed Practices	3–5 Condensed Practices	6–8 Condensed Practices	9–12 Condensed Practices
Modeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.	Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.	Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.	Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).
• Distinguish between a model and the actual object, process, and/or events the model represents. • Compare models to identify common features and differences.	• Identify limitations of models.	• Evaluate limitations of a model for a proposed object or tool.	• Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. • Design a test of a model to ascertain its reliability.
• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).	• Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena.	• Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed. • Use and/or develop a model of simple systems with uncertain and less predictable factors. • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.	• Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.
• Develop a simple model based on evidence to represent a proposed object or tool.	• Develop a diagram or simple physical prototype to convey a proposed object, tool, or process. • Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.	• Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.	• Develop a complex model that allows for manipulation and testing of a proposed process or system. • Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

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Science and Engineering Practices (SEP) Progressions (continued)

Science and Engineering Practices

Planning and Carrying Out Investigations: Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions.

K–2 Condensed Practices	3–5 Condensed Practices	6–8 Condensed Practices	9–12 Condensed Practices
Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.	Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.	Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.	Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.
• With guidance, plan and conduct an investigation in collaboration with peers (for K). • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question.	• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.	• Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.	• Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible variables or effects and evaluate the confounding investigation's design to ensure variables are controlled. • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. • Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.
• Evaluate different ways of observing and/or measuring a phenomenon to determine which way can answer a question.	• Evaluate appropriate methods and/or tools for collecting data.	• Evaluate the accuracy of various methods for collecting data.	• Select appropriate tools to collect, record, analyze, and evaluate data.
• Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons. • Make observations (firsthand or from media) and/or measurements of a proposed object or tool or solution to determine if it solves a problem or meets a goal. • Make predictions based on prior experiences.	• Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. • Make predictions about what would happen if a variable changes. • Test two different models of the same proposed object, tool, or process to determine which better meets criteria for success.	• Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. • Collect data about the performance of a proposed object, tool, process, or system under a range of conditions.	• Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. • Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.

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Science and Engineering Practices (SEP) Progressions (continued)

Science and Engineering Practices

Analyzing and Interpreting Data: Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis. Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.

K–2 Condensed Practices	3–5 Condensed Practices	6–8 Condensed Practices	9–12 Condensed Practices
Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.	Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used.	Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.	Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
• Record information (observations, thoughts, and ideas). • Use and share pictures, drawings, and/or writings of observations. • Use observations (firsthand or from media) to describe patterns and/or relationships in the natural and designed world(s) in order to answer scientific questions and solve problems. • Compare predictions (based on prior experiences) to what occurred (observable events).	• Represent data in tables and/or various graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships.	• Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. • Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships. • Distinguish between causal and correlational relationships in data. • Analyze and interpret data to provide evidence for phenomena.	• Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
	• Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.	• Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.	• Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
		• Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).	• Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.
	• Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.	• Analyze and interpret data to determine similarities and differences in findings.	• Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.
• Analyze data from tests of an object or tool to determine if it works as intended.	• Analyze data to refine a problem statement or the design of a proposed object, tool, or process. • Use data to evaluate and refine design solutions.	• Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.	• Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. • Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.

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Science and Engineering Practices (SEP) Progressions (continued)

Science and Engineering Practices

Using Mathematics and Computational Thinking: In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions.

K–2 Condensed Practices	3–5 Condensed Practices	6–8 Condensed Practices	9–12 Condensed Practices
Mathematical and computational thinking in K–2 builds on prior experience and progresses to recognizing that mathematics can be used to describe the natural and designed world(s).	Mathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions.	Mathematical and computational thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.	Mathematical and computational thinking in 9-12 builds on K-8 and experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
		• Decide when to use qualitative vs. quantitative data.	• Decide if qualitative or quantitative data are best to determine whether a proposed object or tool meets criteria for success.
• Use counting and numbers to identify and describe patterns in the natural and designed world(s).	• Organize simple data sets to reveal patterns that suggest relationships.	• Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.	• Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.
• Describe, measure, and/or compare quantitative attributes of different objects and display the data using simple graphs.	• Describe, measure, estimate, and/or graph quantities such as area, volume, weight, and time to address scientific and engineering questions and problems.	• Use mathematical representations to describe and/or support scientific conclusions and design solutions.	• Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.
• Use quantitative data to compare two alternative solutions to a problem.	• Create and/or use graphs and/or charts generated from simple algorithms to compare alternative solutions to an engineering problem.	• Create algorithms (a series of ordered steps) to solve a problem. • Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems. • Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem.	• Apply techniques of algebra and functions to represent and solve scientific and engineering problems. • Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. • Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).

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Science and Engineering Practices (SEP) Progressions (continued)

Science and Engineering Practices

Constructing Explanations and Designing Solutions: The end-products of science are explanations and the end-products of engineering are solutions. The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.

K–2 Condensed Practices	3–5 Condensed Practices	6–8 Condensed Practices	9–12 Condensed Practices
Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions.	Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.	Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.	Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
• Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena.	• Construct an explanation of observed relationships (e.g., the distribution of plants in the back yard).	• Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena. • Construct an explanation using models or representations.	• Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.
	• Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.	• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. • Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.	• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.
	• Identify the evidence that supports particular points in an explanation.	• Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.	• Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
• Use tools and/or materials to design and/or build a device that solves a specific problem or a solution to a specific problem. • Generate and/or compare multiple solutions to a problem.	• Apply scientific ideas to solve design problems. • Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.	• Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system. • Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. • Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.	• Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

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Science and Engineering Practices (SEP) Progressions (continued)

Science and Engineering Practices

Engaging in Argument from Evidence: Argumentation is the process by which evidence-based conclusions and solutions are reached. In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to evaluate claims.

K–2 Condensed Practices	3–5 Condensed Practices	6–8 Condensed Practices	9–12 Condensed Practices
Engaging in argument from evidence in K–2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world(s).	Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).	Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s).	Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.
• Identify arguments that are supported by evidence. • Distinguish between explanations that account for all gathered evidence and those that do not. • Analyze why some evidence is relevant to a scientific question and some is not. • Distinguish between opinions and evidence in one's own explanations.	• Compare and refine arguments based on an evaluation of the evidence presented. • Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation.	• Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts.	• Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
• Listen actively to arguments to indicate agreement or disagreement based on evidence, and/or to retell the main points of the argument.	• Respectfully provide and receive critiques from peers about a proposed procedure, explanation or model.by citing relevant evidence and posing specific questions.	• Respectfully provide and receive critiques about one's explanations, procedures, models and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.	• Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions.
• Construct an argument with evidence to support a claim.	• Construct and/or support an argument with evidence, data, and/or a model. • Use data to evaluate claims about cause and effect.	• 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.	• Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.
• Make a claim about the effectiveness of an object, tool, or solution that is supported by relevant evidence.	• Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.	• Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system, based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints. • Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	• Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence. • Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

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Science and Engineering Practices (SEP) Progressions (continued)

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information: Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to obtain information that is used to evaluate the merit and validity of claims, methods, and designs.

K–2 Condensed Practices	3–5 Condensed Practices	6–8 Condensed Practices	9–12 Condensed Practices
Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.	Obtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluating the merit and accuracy of ideas and methods.	Obtaining, evaluating, and communicating information in 6–8 builds on K–5 experiences and progresses to evaluating the merit and validity of ideas and methods.	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.
• Read grade-appropriate texts and/or use media to obtain scientific and/or technical information to determine patterns in and/or evidence about the natural and designed world(s).	• Read and comprehend grade-appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence. • Compare and/or combine across complex texts and/or other reliable media to support the engagement in other scientific and/or engineering practices.	• Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).	• Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
• Describe how specific images (e.g., a diagram showing how a machine works) support a scientific or engineering idea.	• Combine information in written text with that contained in corresponding tables, diagrams, and/or charts to support the engagement in other scientific and/or engineering practices.	• Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings.	• Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
• Obtain information using various texts, text features (e.g., headings, tables of contents, glossaries, electronic menus, icons), and other media that will be useful in answering a scientific question and/or supporting a scientific claim.	• Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.	• Gather, read, 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. • Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts.	• Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. • Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
• Communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers that provide detail about scientific ideas, practices, and/or design ideas.	• Communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts.	• • ▯ Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.	• Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

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Next Generation Science Standards (NGSS)

As this is the Engage lesson of the learning sequence, students are only broadly introduced to ideas that touch on these Performance Expectations and will not begin building deeper understanding until later in the learning sequence.

This lesson is building toward:

PERFORMANCE EXPECTATION (PE)	
MS-LS4-1	Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past. [Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.]
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.]

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)
Asking Questions and Defining Problems
• Ask questions that arise from careful observation of phenomena, ~~models, or unexpected results~~, to clarify and/or seek additional information.
Constructing Explanations and Designing Solutions
• Apply scientific reasoning to show why the data or evidence is adequate for the explanation ~~or conclusion~~.
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~~.
Obtaining, Evaluating, and Communicating Information
• Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural ~~and designed~~ world~~(s)~~.

Appendix 8.1

DISCIPLINARY CORE IDEAS (DCI)
(This is the Engage part of the learning sequence; students do not build understanding of this, but this sets the stage for future learning.)
LS4.A: Evidence of Common Ancestry and Diversity
• The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth. (MS-LS4-1)
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. (MS-ESS3-4)

CROSSCUTTING CONCEPTS
Patterns
• Patterns can be used to identify cause and effect relationships. • ~~Graphs~~, charts, ~~and images~~ can be used to identify patterns in data.
Cause and Effect
• [Some] 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~~.
Scale, Proportion, and Quantity
• Phenomena that can be observed at one scale may not be observable at another scale.

Common Core State Standards (CCSS)

CCSS ELA SPEAKING & LISTENING
CCSS.ELA-LITERACY.SL.8.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
CCSS ELA WRITING
CCSS.ELA-LITERACY.WHST.6-8.9
Draw evidence from informational texts to support analysis, reflection, and research.

Appendix 8.1

CCSS MATH FUNCTIONS
CCSS.MATH.CONTENT.8.F.B.5
Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). ~~Sketch a graph that exhibits the qualitative features of a function that has been described verbally.~~

California English Language Development (ELD) Standards

CA ELD		
Part 1.2 Interacting with others in written English in various communicative forms (print, communicative technology, and multimedia)		
EMERGING	**EXPANDING**	**BRIDGING**
P1.8.2 Engage in short written exchanges with peers and collaborate on simple written texts on familiar topics, using technology when appropriate.	**P1.8.2** Engage in longer written exchanges with peers and collaborate on more detailed written texts on a variety of topics, using technology when appropriate.	**P1.8.2** Engage in extended written exchanges with peers and collaborate on complex written texts on a variety of topics, using technology when appropriate.
In addition to the standard above, you may find that you touch on the following standards in this lesson as well: **1.8.1:** Exchanging information and ideas with others through oral collaborative discussions on a range of social and academic topics **1.8.3:** Offering and justifying opinions, negotiating with and persuading others in communicative exchanges **1.8.6:** Reading closely literary and informational texts and viewing multimedia to determine how meaning is conveyed explicitly and implicitly through language **1.8.11:** Justifying own arguments and evaluating others' arguments in writing **2.8.5:** Modifying to add details		

California's Environmental Principles and Concepts (EP&Cs)

EP&C		
	Principle 2 People Influence Natural Systems	The long-term functioning and health of terrestrial, freshwater, coastal, and marine ecosystems are influenced by their relationships with human societies.
	Principle 3 Natural Systems Change in Ways that People Benefit From and Can Influence	Natural systems proceed through cycles that humans depend upon, benefit from, and can alter.

California Education and the Environment Initiative. 2016. California's Environmental Principles and Concepts. https://californiaeei.org/epc/