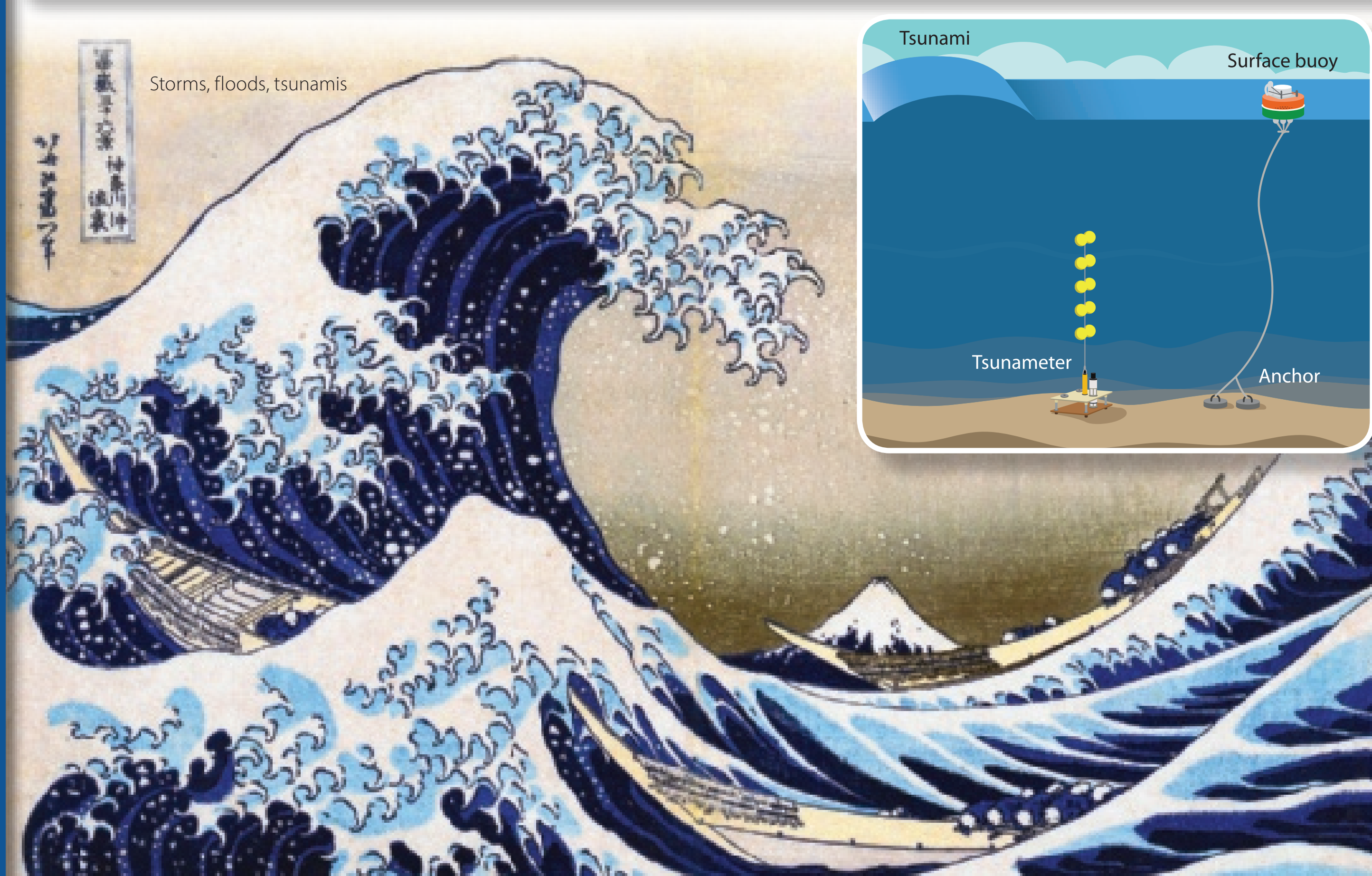
Natural Hazards:

Where do natural hazards happen, and how do we prepare for them?

Science Literacy

Teacher Guide

Storms, floods, tsunamis



GRADE 6 Core Knowledge Science®

Core Knowledge®

Natural Hazards:

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Teacher Guide

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BEFORE YOU BEGIN

Before introducing the unit, please become fully acquainted with the program instructional model and classroom routines by reading the online resource **Teacher Handbook: Overview of the Core Knowledge Middle School Science Program**.

Online Resources

Use this link to download the **CKSci Online Resources Guide** for this unit, which includes specific links to:

- the unit's comprehensive materials list
- a full unit pacing snapshot
- lesson guidance slides
- all other recommended resources.

www.coreknowledge.org/cksci-online-resources

Student Work Pages

All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources.

Student Books

All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources. Students also will use the Student Procedure Guide and the Science Literacy Student Reader throughout the unit.

UNIT OVERVIEW

Where do natural hazards happen and how do we prepare for them?

This unit begins with students experiencing, through text and video, a devastating natural event that caused major flooding in coastal towns of Japan. This event was the 2011 Great Sendai or Tōhoku earthquake and subsequent tsunami that caused major loss of life and property in Japan. Through this anchoring phenomenon, students think about ways to detect tsunamis, warn people, and reduce damage from the wave. As students design solutions to solve this problem, they begin to wonder about the natural hazard itself: what causes it, where it happens, and how it causes damage.

The first part of the unit focuses on identifying where tsunamis occur, how they form, how they move across the ocean, and what happens as they approach shore. Students investigate these ideas using maps, graphs, physical models, videos, and simulations. They use these science ideas to forecast which communities are most at risk for a tsunami and why.

The second part of the unit transitions students to consider combinations of engineering design solutions and technologies to mitigate the effects of tsunamis. Students evaluate different design solutions and technologies by identifying criteria and constraints and using a systematic process to rate the solutions and identify trade-offs. Realizing that design solutions can sometimes fail, as they did during the 2011 earthquake, students recognize the need to prepare for these events. As such, students consider communication and education systems that prepare community stakeholders so that they can respond appropriately when the tsunami approaches.

Finally, students apply these science ideas to consider how to communicate about another natural hazard to stakeholders in a community. In this unit, students develop an understanding of the following science ideas:

- Data about where hazards have occurred in the past can determine where hazards may happen in the future and which communities are at risk.
- Impacts of natural hazards can be mitigated by knowing how quickly a hazard develops and moves, and how large and intense it can become.
- Engineering design solutions include structural solutions and technologies to detect hazards, warn people, and reduce damage.
- Design solutions and technologies can be evaluated using a systematic process that accounts for an understanding of the science of the hazard and the needs of the people at risk.
- Communication strategies include educating the community before a natural hazard happens and alerting people when the hazard is happening.
- Knowledge about hazards (the causes of the hazard, locations at risk, how to design solutions, and how to respond when it happens) can empower us and others to design safer communities and save lives.

Focal Disciplinary Core Ideas (DCIs): ESS3.B, ETS1.A, ETS1.B

Focal Science and Engineering Practices (SEPs): Analyzing and Interpreting Data; Using Mathematics and Computational Thinking; Constructing Explanations and Designing Solutions; Engaging in Argument from Evidence; and Obtaining, Evaluating, and Communicating Information

Focal Crosscutting Concepts (CCCs): Cause and Effect; Systems and System Models; Stability and Change

Building Toward NGSS Performance Expectations

MS-ESS3-2: Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

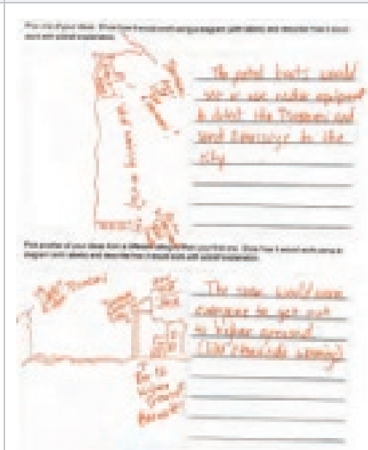
MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

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

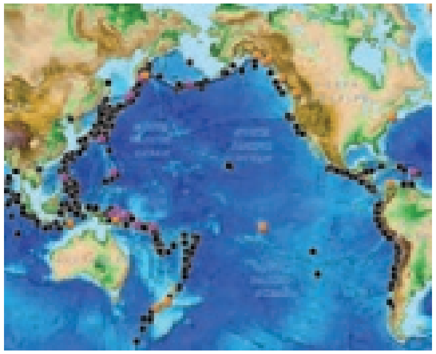
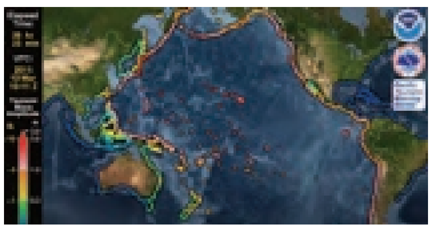
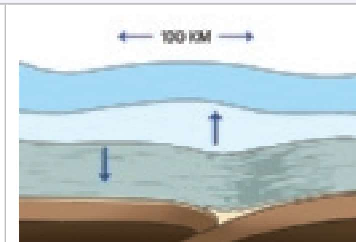
How students will engage with each of the phenomena

HANDS-ON/ LAB ACTIVITIES	VIDEOS OR IMAGES	DATA SETS	READINGS	COMPUTER INTERACTIVES

Where do natural hazards happen, and how do we prepare for them?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 1 **3 days** **What happens to a community when a tsunami occurs?** Anchoring Phenomenon	 *Triggered by a strong earthquake in the Pacific Ocean in 2011, a massive tsunami caused loss of life and damage to structures along Japan's entire east coast.*	We read about and watch the 2011 tsunami triggered by an earthquake off the eastern coast of Japan, causing devastating loss of life and structural damage. We develop initial engineering ideas intended to detect tsunamis, provide warning of their approach, and reduce their impact. We think about what makes some engineering ideas more promising or challenging than others. We brainstorm related natural hazards and ask questions to generate a list of data and information we need to better understand where these hazards occur and how we can prepare for them. We figure out: • A tsunami is a large wave that results from movement of the ocean floor. • Tsunamis cause major flooding that damages homes and property and harms people in the community. • Proposed solutions include a system of detection sensors, warning plans, and design solutions to reduce damage.	

⇩ **Navigation to Next Lesson:** We are wondering where tsunamis happen in the world, because knowing this can help us understand how those communities can prepare for them.

<table>
<tr><th>Lesson Question</th><th>Phenomena or Design Problem</th><th>What we do and figure out</th><th>How we represent it</th></tr>
<tr><td>LESSON 2
2 days
Where do tsunamis happen and what causes them?
Investigation</td><td>
Data reveal patterns in the locations and causes of tsunamis.</td><td>We investigate historical tsunami data and figure out spatial patterns for where tsunamis occur and that most are caused by earthquakes. We use digital tools, analyze maps and graphs, and notice that only certain types of earthquakes cause tsunamis. We establish a cause-and-effect relationship between types of earthquakes and tsunami formation. We use this relationship to forecast the locations that may be at risk for future tsunamis. We figure out these things:
• Tsunamis form as a result of earthquakes, volcanic eruptions, and landslides.
• Stronger, shallow earthquakes tend to be most related to tsunami formation.
• Almost all tsunamis occur along plate boundaries where the plates are colliding.
• Data about where tsunamis have occurred in the past help to forecast where they might happen in the future.</td><td>Tsunami Predictions
</td></tr>
<tr><td colspan="4">Navigation to Next Lesson: We figured out that most tsunamis form because of strong, shallow earthquakes along colliding plate boundaries, but we wonder how these types of earthquakes form a tsunami.</td></tr>
<tr><td>LESSON 3
3 days
What causes a tsunami to form and move?
Investigation</td><td>
Analyze and evaluate different wave models.</td><td>We analyze three wave models to make sense of how an earthquake-driven tsunami forms and moves to shore. We use different perspectives to understand various aspects of the phenomena, and then we identify benefits and limitations of each model. We figure out these things:
• Physical waves form from a single point of movement, and then move outward in a circular pattern.
• The bigger the movement of the ocean floor, the greater the movement of the water above it.
• When a wave approaches shore, it gets taller until it reaches the shore, where it collapses and flows, or runs up onto the shore.
• The bigger the wave is when it reaches shore, the farther onto the land the water will flow.
• As waves move and interact with surrounding land at the shore and in the ocean, they transfer energy to the land and reflect off its surface. As this continues, the waves get smaller and smaller due to losing energy that has been transferred to their surroundings.</td><td>
</td></tr>
<tr><td colspan="4">Navigation to Next Lesson: We want to know what happens to communities as a tsunami meets the shore so we can find ways to protect them.</td></tr>
</table>

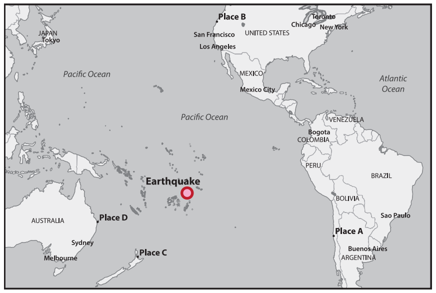
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 4

1 day

How can we forecast where and when tsunamis will happen and which communities are at risk?

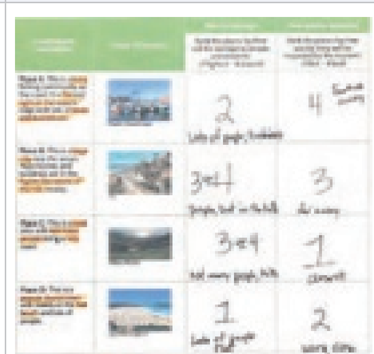
Putting Pieces Together



An earthquake occurs that could affect communities around the Pacific Ocean.

Using the Tsunami Chain of Events poster as evidence from previous lessons, we construct an explanation that describes the geologic changes that cause a tsunami. Then we use what we know about tsunamis—where they happen and what causes them—to consider how to protect people and property from their effects. We revisit the DQB to determine which questions we are now able to answer and document responses for each question. We figure out these things:

- Places with more people, closer to water, or at low elevations have greater risk for a tsunami to cause damage.
- We can use science ideas to forecast tsunamis and predict which areas will experience damage to people and property.



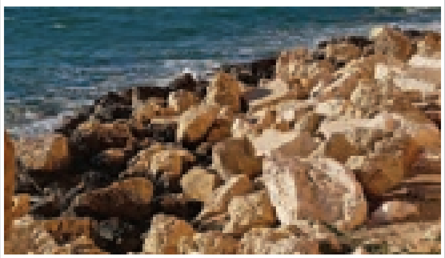
⇩ **Navigation to Next Lesson:** Now that we understand what causes tsunamis, where they happen, how they move, and how they impact coastal communities, we are wondering about solutions to protect communities.

LESSON 5

3 days

How can we reduce damage from a tsunami wave?

Investigation

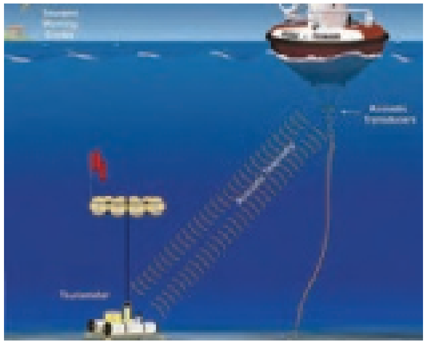


Many design solutions exist to reduce the damage from tsunami waves.

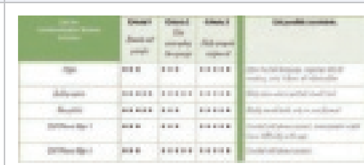
We revisit the coastal communities of Japan that were affected by the 2011 tsunami to evaluate existing solutions. We define our problem, identify criteria and constraints, and evaluate each solution using a systematic process. We consider what it means for a solution to be promising for one community versus another. We figure out:

- Engineers account for relevant scientific principles and potential impacts on people and the natural environment when designing and evaluating solutions.
- Clearly identifying the design problem, criteria, and constraints allows for the evaluation of solutions and increases the likelihood that a solution will meet the needs of communities at risk.
- Effective solutions to reduce damage from tsunamis need to not only dissipate the energy of the wave and deflect the water, but also meet the needs of communities at risk.

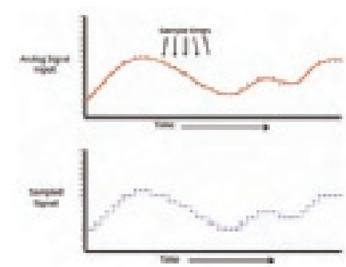
⇩ **Navigation to Next Lesson:** Sometimes tsunami solutions fail, so we are wondering what else we can do to protect communities when a tsunami happens.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 6 **1 day** **How are tsunamis detected and warning signals sent?** Investigation	 *A complex system exists to detect and warn people of tsunamis.* NOAA	We read about how tsunamis are detected using a complex system of instruments set up on land (seismometers), on the ocean surface (surface buoys), on the ocean floor (tsunameters), and in space (satellites). We read that tsunami warnings are sent only when specific sets of criteria are met, first regarding the location, strength, and depth of the earthquake that is detected, and then regarding whether the tsunami is expected to reach land. We figure out these things: • Tsunamis happen suddenly and can travel at high speeds over great distances. Depending on where the tsunami forms, communities have more or less time to respond. • To help prevent or reduce loss of life, we need to detect a tsunami quickly and accurately in order to provide timely information to an at-risk community. • Criteria and constraints for a tsunami detection system must consider the available scientific information (earthquake data) and design limitations (signal transmission through air and water).	*A complex system with many parts (some on land, some in space, and some on the ocean surface and ocean floor) is designed to detect tsunamis, predict whether they will reach land, and then send a warning*.

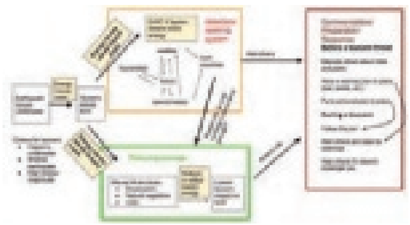
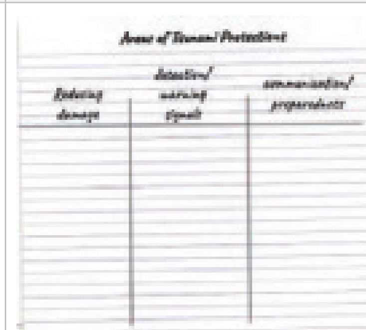
⇩ **Navigation to Next Lesson:** We are wondering what people do when a tsunami is detected and the warning signal is sent. How do they respond?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 7 **2 days** **What are ways we can communicate with people before and during a tsunami?** Investigation	 *Communication systems warn people to respond when a tsunami approaches.*	We listen to a tsunami warning signal and read accounts of tsunami survivors from Japan. We identify stakeholders who the warning signal must work for, and then develop criteria and constraints for tsunami communication. We evaluate different communication options based on stakeholder needs. From this we learn that there are many ways to communicate with different stakeholders before and during a tsunami event. We figure out the following: • Groups of people can be affected by hazards in different ways. People particularly at-risk during a hazard are older people, children, people who speak a different language, and those who are sick or need assistance. • Effective plans account for the people living in a place and the resources communities have to respond. • A variety of communication strategies and modalities are necessary to ensure that all people at risk receive the warning. • Communication strategies include educating the community before a natural hazard happens.	

⇩ **Navigation to Next Lesson:** All the coastal towns in Japan had different systems in place. We are wondering how they all work together to protect communities.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 8 **1 day** **Which emergency communication systems are the most reliable in a hazard?** Investigation	 *Different communication systems and signals have advantages and disadvantages in how they alert people.*	We consider the ways in which people are alerted during a hazard and what would make a warning system reliable. We read about analog and digital signals and discuss what forms of communication best meet the needs and are most reliable for multiple stakeholder groups. We figure out: • Communication technologies use different equipment and signals to transmit and receive information during a hazard. • Digital signals use technology that makes them more reliable means of communication than analog signals. • A combination of communication technologies are important to use during a hazard to ensure as many people receive the warning messages as possible.	

⇩ **Navigation to Next Lesson:** We figured out that we need a combination of communication technologies to warn people during a hazard, but how does this system of communication work within the larger hazard response system?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 9 **1 day** **How can we model the systems put into place to protect communities?** Putting Pieces Together	 *Tsunami systems consist of many subsystems working together to meet the overall criteria of the community.*	We develop a tsunami system model. We analyze the model to determine the importance and interactions of the various subsystems. We develop a process engineers use to solve problems and determine we can use our ideas to prepare for a hazard that is important to us. We figure out the following: • Engineers can design a system for responding to hazards that includes design solutions to forecast, detect, warn and communicate with people, and reduce damage. • Each part of the system is dependent on another part of the system; subsystems work together to meet the criteria for the overall system. • Engineers engage in a generalized process to define problems, develop solutions, and optimize those solutions.	

⇩ **Navigation to Next Lesson:** We have learned about systems in place to protect against tsunamis. Can we use this same approach to prepare for a natural hazard important to us?

LESSON 10 **2 days** **How can we effectively prepare our communities for a natural hazard?** Putting Pieces Together	 *Local communities are at risk of other types of natural hazards.*	We investigate the general patterns of risk of other natural hazards in the United States and determine our local level of risk for each hazard. We choose a natural hazard, gather information, and plan for communication to an identified stakeholder community at risk for the hazard. We evaluate our final plans and products using constraints and criteria for effective communication with our stakeholder groups. We figure out: • All communities are impacted by natural hazards with different levels of risk, and these hazards often require different ways to detect risk, warn people, and reduce damage. • Knowledge about hazards (the causes of the hazard, locations at greater or lesser risk, how to design solutions, and how to respond when it happens) can empower us and others to design solutions to save lives. • Effective communication and response plans account for the needs of people living in a place and the available resources to respond. • Communication strategies include educating the community before a natural hazard happens and alerting people when the hazard is happening.	

LESSONS 1–10
19 days total

TEACHER BACKGROUND KNOWLEDGE

Lab Safety Requirements for Science Investigations

It is important to adopt and follow appropriate safety practices within the context of hands-on investigations and demonstration, whether this is in a traditional science laboratory or in the field. In this way, teachers need to be aware of any school or district safety policies, legal safety standards, and better professional practices that are applicable to hands-on science activities being undertaken.

Science safety practices in laboratories or classrooms require engineering controls and personal protective equipment (e.g. wearing safety goggles, non latex aprons and gloves, eyewash/shower station, fume hood, and fire extinguishers). Science investigations should always be directly supervised by qualified adults and safety procedures should be reviewed annually prior to initiating any hands-on activities or demonstration. Prior to each investigation, students should also be reminded specifically of the safety procedures that need to be followed. Each of the lessons within the units includes teacher guidelines for applicable safety procedures for setting up and running an investigation, as well as taking down, disposing of, and storing materials.

Prior to the first science investigation of the year, a safety acknowledgement form for students and parents or guardians should be provided and signed. You can access a model safety acknowledgement form for middle school activities online. (see the **Online Resources Guide** for a link to this item)

Disclaimer: The safety precautions of each activity are based in part on use of the specifically recommended materials and instructions, legal safety standards, and better professional safety practices. Be aware that the selection of alternative materials or procedures for these activities may jeopardize the level of safety and therefore is at the user's own risk.

Please follow these lab safety recommendations for any lesson with an investigation:

1. Wear safety goggles (specifically, indirectly vented chemical splash goggles), a non latex apron, and non latex gloves during the set-up, hands-on investigation, and take down segments of the activity.
2. Immediately wipe up any spilled water and/or granules on the floor, as this is a slip and fall hazard.
3. Follow your *Teacher Guide* for instructions on disposing of waste materials and/or storage of materials.
4. Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
5. Wash your hands with soap and water immediately after completing this activity.
6. Never eat any food items used in a lab activity.
7. Never taste any substance or chemical in the lab.

Specific safety precautions are called out within the lesson using this icon and a callout box.

What is the anchoring phenomenon and why was it chosen?

For the anchoring phenomenon, students read text and watch videos of the 2011 Great Sendai or Tōhoku earthquake and tsunami that occurred off the east coast of Japan. This natural hazard caused great devastation to Japan's coastal communities despite the occurrence of tsunamis in this area throughout Japan's history and the engineering preparation that had been done in the area to protect communities. It provides a rich context in which to investigate our abilities to forecast hazards and use engineering design solutions and technologies to mitigate the effects of hazards. Importantly, this phenomenon also highlights the importance of education and communication with people for how to prepare and respond during a natural hazard.

Each unit's anchoring phenomenon is chosen from a group of possible phenomena after analyzing student interest survey results and consulting with several external advisory panels. The tsunami hazard for this unit was chosen for three reasons:

- Tsunami hazards build directly upon Disciplinary Core Ideas (DCIs) from 4th grade in which students learned about physical waves. It advances their understanding of mechanical waves by providing a much larger scale phenomenon to investigate.
- Tsunami hazards also directly build upon Disciplinary Core Ideas from grades 6-8 regarding geologic processes and changes in Earth's surface in Unit 6.4: *What causes Earth's surface to change? (Everest Unit)*, which comes

just prior to this unit in the Scope and Sequence. Students leverage their ideas about movement of Earth's plates to develop a causal mechanism for how tsunamis form.

- Tsunamis have not had a direct impact on US communities in recent years and students in the US have likely not experienced one directly. This is an important consideration in choosing a natural hazard for in depth investigation since a distal hazard is least likely to elicit direct emotional response from students who may have experienced direct devastation from other types of hazards, such as floodings, tornadoes, earthquakes, and/or hurricanes.

What are the NGSS Dimensions developed in this context?

The anchoring lesson introduces students to the idea that there are ways to mitigate the effects of natural hazards by detecting when they are happening, warning people, and designing solutions to reduce damage. Students develop initial design solutions, but realize they need to know more about where, when, and why tsunamis happen in order to evaluate design solutions and choose the best ones for the communities at risk.

First, students use maps, graphs, physical models, videos, and simulations to identify the causal mechanism for where and how tsunamis form, how they move across the ocean, and what happens as they approach shore. Students then use these science ideas to forecast which communities are most likely at future risk of a tsunami hazard and why.

Students then work to identify criteria and constraints across different aspects of a hazard response system: (1) structural design solutions to reduce damage, (2) technologies to detect and send warning signals and communication, and (3) communication and education plans that target stakeholders in the communities that will be impacted by a natural hazard. They also use a systematic process to evaluate different design solutions, technologies, and communication options. Finally, students develop a representation of how all these components of subsystems work together in a more complex hazard response system to protect communities, and they also reflect on the engineering design process they used to evaluate those subsystems. In the final assessment, students apply these ideas and principles to develop a communication plan and final product for a natural hazard of interest to them.

This unit builds toward these performance expectations:		
MS-ESS3-2: Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.		
Focal DCIs*	**Focal Science and Engineering Practices**	**Focal Crosscutting Concepts**
ESS3.B: Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. Students use historical tsunami data, videos, simulations, and physical models to investigate where and why tsunamis form, how they move across the ocean, and what happens as the wave approaches shore. They also use historical data for nine other natural hazards to determine general patterns of risk and their own local level of risk for each hazard.	**Analyzing and Interpreting Data:** Students construct and/or use multiple graphical displays (e.g., maps, scatter plots) of large data sets to identify linear relationship and distinguish between correlation and causation. **Mathematics and Computation Thinking:** This is the first time in 6th grade that students use digital tools to build their own scatter plots with large data sets and look for patterns and trends between multiple variables. **Constructing Explanations and Designing Solutions:** Students construct written explanations during the mid-point (Lesson 4) and summative (Lesson 9) assessments to apply science ideas and evidence to identify areas of risk and why, and to use relationships between variables to support a prediction of risk for tsunami and local natural hazards.	**Cause and Effect:** Students will build a Tsunami Chain of Events diagram that links together cause-and-effect relationships across science and engineering ideas from the unit. These science and engineering ideas are developed in Lessons 2-7.

Focal DCIs*	Focal Science and Engineering Practices	Focal Crosscutting Concepts
ETS1.A: The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. Students use criteria and constraints, based on the science and engineering ideas developed in the unit, to evaluate design solutions and technologies that work together to mitigate the effects of natural hazards. **ETS1.B: There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.** Students systematically evaluate structure design solutions and technologies to determine how well they meet criteria and constraints for communities and stakeholder groups.	**Engaging in Argument from Evidence:** For the first time in 6th grade students are evaluating competing design solutions based on jointly developed and agreed-upon design criteria. Initial students are given some criteria for the tsunami design solutions, but later in the unit, they develop their own jointly agreed-upon criteria for natural hazards communication systems. This scaffolding allows students to practice developing criteria and constraints as a class and then apply them to design solutions. **Obtaining, Evaluating, and Communicating Information:** Throughout the unit students are gathering, reading, synthesizing and evaluating information from multiple sources (e.g., text, data, maps, graphs, images). The scaffolding around this practice lessens so that by the final project in Lesson 9, students are gathering, evaluating, and communicating information independently with a guiding framework for the kinds of information they need, but flexibility to allow them to determine the sources of some of the information and how they will communicate it. Asking Questions and Defining Problems and Developing and Using Models occur in this unit; however, no new elements are being developed. This unit does not provide opportunities to practice Planning and Carrying Out Investigations.	**System and System Models:** Integrated with the Tsunami Chain of Events is a Hazard System Model that links components of subsystems with those science and engineering ideas about tsunamis. These components and subsystems are developed in Lessons 5-7 and integrated in Lesson 9. **Stability and Change:** Throughout the unit, students often consider the rate of onset of hazards and how quickly a "sudden event" can disrupt the stability of a system. This aspect of the crosscutting concept is used to consider how people will need to respond in such an event. The unit also includes opportunities to practice using Patterns; Scale, Proportion, & Quantity; Energy and Matter; and Structure and Function.

"Disciplinary Core Ideas" are reproduced verbatim from A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). National Research Council; Division of Behavioral and Social Sciences and Education; Board on Science Education; Committee on a Conceptual Framework for New K-12 Science Education Standards. National Academies Press, Washington, DC. This material may be reproduced and used by other parties with this attribution. If the original material is altered in any way, the attribution must state that the material is adapted from the original.

How is the unit structured?

The unit is organized into two main lesson sets, each of which help make progress on a sub-question related to the driving question for the entire unit. Lessons 1-4 focus on developing science ideas about tsunamis, and in particular focuses on developing key aspects of science ideas related to where, when, and why tsunamis happen and how they pose risk to certain communities more so than others. Lessons 5-9 transition to focusing on engineering design solutions (structural, technological, and communication & education based systems) to mitigate the effects of tsunamis. Students apply these ideas in a culminating project on another natural hazard event in Lesson 10.

Driving question: Where do natural hazards happen and how do we prepare for them?

Lesson Set 1: ***What causes tsunamis and other natural hazards to form, and how can we predict which communities are at risk?***

Lesson 1

Students watch, read, and discuss the 2011 Japan tsunami and brainstorm ways to protect people and property.

Lessons 2-4

Students investigate where tsunamis happen, how they form, how they move, and who is at risk.

Problematize

Now that we know who is at risk, what can we do to mitigate the effects of tsunamis?

Lesson Set 2: ***How can we design systems to detect, warn communities, and reduce damage from tsunamis and other natural hazards?***

Lessons 5-8

Students investigate structural, technological, and communication systems designed to protect communities.

Lesson 9

Students apply science and engineering ideas in a culminating project on another hazard.

Where does this unit fall within the Scope and Sequence?

This unit is designed to be taught just after *Everest Unit* in the Scope and Sequence. As such, it can leverage ideas about earth system processes that cause motion in Earth's crust and thus generate the release of energy to form a tsunami wave. The focal DCI for this unit pulls together ideas about where natural hazards are likely to occur based on "related geologic processes," which is the focus of the *Everest Unit*.

Additionally, another prior unit, Unit 6.3: *Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)*, can provide science ideas for students as they investigate other natural hazards in Lesson 9. Many of the hazards that affect US communities are meteorologically-driven hazards, such as hurricanes, flooding, storms, hail, droughts, and tornadoes. Students can bring forward ideas about air temperatures and precipitation patterns from Storms Unit to bolster their final projects for the unit.

Finally, this unit is also designed to be taught after Unit 6.2: *How can containers keep stuff from warming up or cooling down? (Cup Design Unit)*, which means ideas about energy and energy transfer developed in that unit can be leveraged in Lessons 3 and 5 of this unit. Lesson 2 of this unit also leverages prior ideas about causation and correlation that are developed in the *Everest Unit*.

What additional ideas will my students have or know from earlier grades or units?

In planning this unit, it builds upon ideas from earlier grades and units while also preparing students for ideas they will encounter in high school. As stated previously, the tsunami hazard was purposefully chosen for this unit to leverage ideas from grades 3-5 and the previous Everest Unit.

Previous grade or unit DCIs	How it is leveraged in this unit
Building upon Waves. Tsunami hazards build directly upon Disciplinary Core Ideas from 4th grade in which students learned about physical waves: • PS4.A: Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach. • PS4.A: Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between the wave peaks).	Students will directly apply these DCIs to the tsunami hazard in Lessons 3-5 as they explain how the waves form and move across the ocean floor, what happens as they approach shore, and what engineering design solutions need to do to protect communities. Note: This unit does not build upon any new grade 6-8 DCIs for Waves and Wave Properties. Those DCIs are developed in *Unit 8.2: How can a sound make something move? (Sound Unit)*.
Building upon the distribution and impact of natural hazards. Tsunami hazards build directly upon the grades 3-5 Disciplinary Core Ideas regarding the present and impact of natural hazards: • ESS3.B: A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards, but can take steps to reduce their impacts.	Students will use these DCIs to build a more sophisticated understanding of where natural hazards occur and why in those places versus other places. This allows them to forecast future risk of hazards for specific communities. Students also investigate a large system of engineering design solutions, technologies, communication systems, and education programs that work together to mitigate the effects of natural hazards on communities.
Building upon Defining Problems and Developing Solutions. This unit builds upon ideas from the 3-5 grade band for Engineering Design, but most specifically: • ETS1.A: Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.	Students use this DCI from earlier grades but will build in sophistication by developing a systematic evaluation process to compare designs to one another. They will also develop new ideas that criteria and constraints are often influenced by those affected by the design solution (i.e., stakeholders), and that evaluating design solutions against stakeholder needs is an important aspect of the process.
Building upon geologic processes. Tsunami hazards also directly build upon Disciplinary Core Ideas from grades 6-8 regarding geologic processes and changes in Earth's surface: • ESS1.C: Tectonic processes continually generate new ocean sea floor at ridges and destroy old seafloor at trenches. • ESS2.B: Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.	Students will use ideas about motion in the ocean flood along colliding plate boundaries as the primary causal mechanism for the tsunami hazard. While specific earthquake events cannot be predicted, we can use historical data of earthquake activity to narrow our forecast to which places in the world are most at risk for the tsunami hazard based on these DCIs.

In addition to these specific DCIs, students will likely have ideas about the kinds of natural hazards that might impact their community, but may not bring with them ideas about the magnitude, intensity, seasonality, or causal mechanisms (i.e., related geologic or meteorological processes) for why and how these natural hazards occur where and when they do. They will likely know of natural hazards that can get "really bad" or "really strong" or "really big"—these incoming student ideas will be useful in helping students develop ideas about the magnitude, intensity, and size of natural hazards. Students will also likely bring with them ideas about natural hazards happening "really fast" (e.g., an earthquake or tornado), but some that are not as fast, like an approaching hurricane. This idea can be leveraged to help students build an understanding that some natural hazards give people more or less time to respond when they are happening.

How will I need to modify the unit if taught out of sequence?

This is the fifth unit in 6th grade in the Scope and Sequence, and it is intentionally planned to come just after the *Everest Unit*. Given this placement, several modifications would need to be made if teaching this unit earlier or later in the middle school curriculum. These include:

- If this unit is not taught after *Everest Unit*, then students will need to develop some ideas around geologic processes related to plate movements and the release of energy that we feel as earthquakes. This is the main causal mechanism for tsunami formation and are prerequisite ideas for Lessons 2 and 3 in this unit, and also an important idea if students investigate earthquakes as a hazard in Lesson 10.
- If this unit is taught before *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)*, more support will need to be included for helping students identify a design problem and defining criteria and constraints. The current unit assumes students have already done some initial work in this area during the *Cup Design Unit*.
- If this unit is taught before *Cup Design Unit* or *Storms Unit*, additional support may be needed in Lesson 3 in developing ideas about energy and energy transfer as the tsunami forms, moves, and interacts with the shore and/or structural design solutions.
- If this unit is taught before *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)*, support will need to be provided for developing science classroom norms and formulating investigable questions.
- Finally, developing a model with multiple subsystems is highly scaffolded across the sixth grade units, so less support is provided in this unit as it is the fifth unit in sixth grade. If taught earlier in the Scope and Sequence, more support for modeling in Lessons 3 and 9 will be needed.

How do I shorten or condense the unit if needed? How can I extend the unit if needed?

The following are example options to shorten or condense parts of the unit without eliminating important sensemaking for students:

- **Lesson 2:** Conduct mapping and graphing exercises as a whole class. Project maps and graphs onto a whiteboard and ask students to volunteer to annotate a shared class map or graph using a dry erase marker.
- **Lesson 2 & 3:** Wait to build Tsunami Chain of Events in one pass at the end of Lesson 3 or beginning of Lesson 4.
- **Lesson 5:** Use the prefilled design matrix with the rankings already provided instead of having students make one from scratch.
- **Lesson 10:** Exchange communication project to a individual written explanation that includes information about the hazard (what it is, where it happens, what time of year does it happen, why it happens), information about the community and stakeholders at risk, and at least three design solutions or technologies that can be used to help protect and prepare communities.

To extend or enhance the unit, consider the following:

- **Lesson 3:** If the unit is taught after *Sound Unit*, consider bringing in middle school level DCIs on waves (MS-PS4.A) and model the wavelength, amplitude, and frequency of tsunamis based on stronger or weaker precipitating events (e.g., earthquakes).
- **Lesson 5:** Have students jigsaw the different design solutions and research more about them and how they are used in Japan.
- **Lesson 10:** Have students present their projects to community members for feedback and revision prior to releasing the final product to the community.
- All lessons: Remove scaffolds provided with Science and Engineering Practices as a way to give students more independent work with the elements of these practices.

What mathematics is required to fully access the unit's learning experiences?

This unit requires students to triangulate data across different units of measurement and symbology as they work with a series of maps and graphs in Lesson 2. It also references units of measurement throughout the unit, such as magnitude or wave height. There are no required math concepts for this unit. However, prerequisite math concepts that may be helpful include:

- CCSS.Math.Content.4.MD.A.1 Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit. Record measurement equivalents in a two-column table.
- CCSS.Math.Content.5.NBT.A.3 Read, write, and compare decimals to thousandths.
- CCSS.Math.Content.5.NBT.A.4 Use place value understanding to round decimals to any place.

It is important to note that this unit is reinforcing some elementary mathematics standards in a new context and at scales which students may have not considered before; thus, we anticipate that while some of the mathematics in this unit is aligned to upper elementary, it may be a new challenging context for students to apply these mathematics ideas.

What additional strategies are available to support equitable science learning in this unit?

Units are designed to promote equitable access to high-quality science learning experiences for all students. Each unit includes strategies which are integrated throughout the routines and are intended to increase relevance and provide access to science learning for all students. Units support these equity goals through several specific strategies such as: 1) integrating Universal Design for Learning (UDL) Principles during the unit design process to reduce potential barriers and provide more accessible ways in which students can engage in learning experiences; 2) developing and supporting classroom norms that provide a safe learning culture, 3) supporting classroom discourse to promote students in developing, sharing, and revising their ideas, and 4) specific strategies to supporting emerging multilingual students in science classrooms.

Many of these strategies are discussed in the teacher guides in sidebar callout boxes titled "Attending to Equity" and subheadings such as "Supporting Emerging Multilingual Learners" or "Supporting Universal Design for Learning." Other callout boxes with strategies are found as "Additional Guidance", "Alternate Activity," and "Key Ideas" and various discussion callouts. Finally, each unit includes the development of a Word Wall as part of students' routines to "earning" or "encountering" scientific language.

For more information about each of these different strategies with example artifacts, please see the Teacher Handbook.

Supporting Empathy and Emotions

This unit has an intentional effort to support students' empathy and emotional responses as they relate to natural hazards. Many students may have directly experienced a natural hazard in their lifetime, and in some cases, these students may have been scared or lost valuable property, their homes, or even a loved one. For other students, they may not have experienced a natural hazard directly, but they will feel empathy for the people who experienced the 2011 tsunami in Japan. They may have some level of anxiety or sadness associated with knowing the tsunami hurt and killed people, and destroyed homes and even entire towns.

It is important to recognize for students that this is a very natural and normal response. No one wants to see others hurt during a natural hazard. Equally important is to emphasize for students that learning about natural hazards and how to protect communities can help save lives in the future. Indeed, this is the desire that drives engineers who focus on hazard mitigation; these individuals use their knowledge about natural hazards to design systems that can protect communities from future loss. The goal of this unit is to help students use science and engineering ideas and practices to empower them to prepare for and respond during a natural hazard that may impact them and their community.

In particular, be prepared to support students in the following lessons:

- **Lesson 1:** The videos and text of the anchoring phenomenon are likely to elicit an emotional or empathetic response from students as they view the destruction of the 2011 tsunami. The text and videos were purposely edited to avoid any viewing of people struggling in the tsunami or any audio of scared people. There are many videos of tsunamis and other natural hazards online, and the majority include people screaming, running, or being injured by the hazard. We recommend avoiding these videos as they will not add to the goal of the unit and can unnecessarily raise anxiety in students.

- **Lesson 7:** Students will hear an audio clip with tsunami alarm systems. This will raise anxiety in students as they listen to the sounds. This lesson purposely introduces the sounds to help students understand what it is like when a community member receives a natural hazard warning signal. They are intended to alert people to action. Prepare students prior to playing the clips, and do not play the clip if you have students who could be affected by loud, alarming noises.
- **Lesson 10:** Students will investigate a local hazard and develop a communication plan for stakeholders in their community. At this point, students are assessing their own risk of a natural hazard and planning for how they and their loved ones might respond. Emphasize for students that while it is scary to plan for a natural hazard that might impact their community, it is important to be prepared and respond appropriately if it does happen.

If you have students who have traumatic experiences from natural hazards, a recommended source to read is: the CDC's Caring for Children in a Disaster website. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

GUIDANCE FOR DEVELOPING YOUR WORD WALL

This unit refers to two categories of academic language (i.e., vocabulary). Most often in this unit, students will have experiences with and discussions about science ideas before they know the specific vocabulary word that names that idea. After students have developed a deep understanding of a science idea through these experiences, and sometimes because they are looking for a more efficient way to express that idea, they have "earned" that word and can add the specific term to the class Word Wall. These "words we earn" should be recorded on the Word Wall using the students' own definition whenever possible. On the other hand, "words we encounter" are "given" to students in the course of a reading, video, or other activity, often with a definition clearly stated in the text. Sometimes, words we encounter are helpful just in that lesson and need not be recorded on the Word Wall. However, if a word we encounter will be frequently referred to throughout the unit, it should be added to the Word Wall. As such, the Word Wall becomes an ongoing collection of words we will continue to use, including all the words we earn in the unit and possibly a few key words we encounter.

It is best for students if you create cards for the Word Wall in the moment, using definitions and pictorial representations that the class develops together as they discuss their experiences in the lesson. When they co-create the posted meaning of the word, students "own" the word—it honors their use of language and connects their specific experiences to the vocabulary of science beyond their classroom. It is especially important for emergent multilingual students to have a reference for this important vocabulary, which includes an accessible definition and visual support.

Sometimes creating Word Wall cards in the moment is a challenge. The teacher guide provides a suggested definition for each term to support you in helping your class develop a student-friendly definition that is also scientifically accurate. If you keep one Word Wall in your classroom for several sections of students, you might choose to record each class's definition separately, and then propose an "official" definition to post the next day that captures the collected meaning.

The words we earn and words we encounter in this unit are listed in this document and in each lesson to help prepare and to avoid introducing a word before students have earned it. They are not intended as a vocabulary list for students to study before a lesson, as that would undermine the authentic and lasting connection students can make with these words when they are allowed to experience them first as ideas they're trying to figure out.

Lesson	Words we earn	Words we encounter	Words from previous unit
L1		Varies; these will emerge from the text and be different for various classes.	
L2			magnitude, correlation, causation
L3	amplitude		epicenter
L4			
L5	primary criteria, secondary criteria, trade-offs		criteria, constraints
L6		seismometer, tsunameter, buoy, satellite, sonar	
L7	stakeholders, systems		
L8		reliability, transmitter, digital, analog, many additional words in the reading	
L9	subsystem		
L10		Varies; depends on the natural hazard and the text and media that students consult.	

TEACHING SCIENCE LITERACY

How does the Core Knowledge Science Literacy routine integrate with the unit investigations?

The Core Knowledge Science Literacy Student Reader and the weekly Science Literacy routine layer varied reading opportunities into the science unit. In their lives after graduating from high school, most students will not become scientists. They will no longer routinely participate in guided investigations to figure out how phenomena work. They will, however, read text about science and scientific claims, day in and day out. The ability to learn and think about science through reading is a skill unto itself and is important in tandem with investigative learning. It is natural to primarily associate emerging literacy with reading and writing instruction at the elementary level, but middle school is an important time to hone literacy skills—specifically in science in the era of politicization of science topics, polarization among adults, and proliferation of misinformation on social media. Detection and construction of well-reasoned explanations are important not just in science, but throughout everyday life. Using claims and evidence in reasoning is the way that thoughtful people think about things, and writing is thinking in print. Students become voters as they emerge from high school, so it is important that they acquire skills for detection of faulty information and practice legitimate communication about scientific issues in the years leading up to that civic benchmark.

Throughout the course of the unit's investigative lessons, students write in their science notebooks in some fashion almost daily, and significant emphasis is placed on the speaking and listening communication threads of the CCSS. The instructional design of the investigations is deliberately light on having students access disciplinary core content through text. NGSS emphasis is on students investigating phenomena along the storyline, so students' interaction with text within lessons is minimal and in service to the unit's storyline. The Science Literacy routine is integrated to exercise students' ability to interact with text about science topics. The routine presents students with short reading selections in a variety of styles, all related to the unit in which students are engaged. Each reading selection is accompanied by a brief but thoughtful writing exercise.

The subject matter of the reading selections ties back to the unit, but the timing for the assigned readings is such that students do not read about specific facets of the subject before they have completed the lessons to investigate that content. In other words, the reading enhances and reinforces the knowledge that students have built in previous lessons; the reading does not reveal beforehand the key takeaways that students are intended to learn through lesson interactions.

When is it done within a unit?

The Core Knowledge Science Literacy Student Reader includes one reading collection per week for every week of the unit. A week's reading collection relates to the lessons completed in the previous week. The reading is assigned at the beginning of the week with the accompanying writing exercise due at the end of the week.

The reading and writing exercises are designed to be completed by students independently, with brief, supporting, teacher-facilitated discussions at the beginning, midpoint, and end of the week.

How do students typically represent their thinking as part of the routine?

Students generate a written product associated with each reading selection. The products are varied in form, and include graphic organizers, concept maps, cartoons, memes, infographics, storyboards, outlines, and paragraphs. The complexity of the products increases from week to week, with the final product for the unit being a single, thoughtfully reasoned, and well-constructed paragraph.

Put Yourself in This Scene

Literacy Objectives

✓ Initiate thinking about the need to evaluate information in text and images.

Literacy Activities

- Read a brief scenario to pique interest, launch discussion, and begin to frame expectations.

Instructional Resources

Student Reader

Preface

Science Literacy Student Reader, Preface
"Put Yourself in This Scene"

No Prerequisite Investigations

The reading of the Preface is appropriate during the first week of unit instruction. The reading does not preemptively tell students facts about the topic that they are intended to learn throughout the course of their investigations.

Standards and Dimensions

NGSS

Disciplinary Core Ideas ESS3.B: Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.

ETS1.B: There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

Science and Engineering Practice: Asking Questions and Defining Problems

Crosscutting Concept: Stability and Change

CCSS

English Language Arts
RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. No Core Vocabulary terms are highlighted in the Preface.

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

natural hazards
science literacy
sea level rise
social media
tropical storm
wildfire

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the Science Literacy Student Reader.
- Friday: Set aside time at the end of the week to facilitate a brief discussion about the reading.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (MONDAY)

- Let students know that for the Science Literacy routine, they will read independently and then complete short writing assignments. The reading selections relate to topics they will be exploring in their Natural Hazards unit science investigations.
- The reading and writing will typically be completed outside of class (unless you have available class time to allocate).
- The first week's reading is a short introductory segment in the book, and there is no accompanying writing exercise as the unit is getting started.
- The class will discuss the reading together at the end of the week.

SUPPORT—The Preface with a scenario about a family deciding which of two cities to move to is written at approximately Lexile 1100–1200, which leans toward the high end of the expected text complexity band for middle school. You may wish to introduce a word identification and comprehension convention into your routine to support struggling readers. Hang an envelope near the door with the label, "When we talk about the next reading selection, I could use a little more help understanding the word(s). . . " Encourage students, as they are reading, to jot words, phrases, or sentences that they are unclear about onto small scraps of paper and tuck them into the envelope at any time preceding the discussion of the reading. Whenever you facilitate class discussion about a reading selection, check the envelope first, and layer in added examples and repeat definitions to help students build comprehension and fluency for terms or complex sentences about which they have revealed they are uncertain.

3. Facilitate discussion.

Facilitate a brief class discussion about the Science Literacy Student Reader Preface, entitled "Put Yourself in This Scene."

Pages 2–3 **Suggested prompts**	**Sample student responses**
How would you summarize the "scene" referred to in the title?	*There is a family of four considering natural hazards and other factors when deciding where to relocate.* *A family lives in Chicago now and is discussing what factors should influence a decision to move to Portland, OR, or Charleston, SC.*
Restate the situation as an engineering problem to solve. This means, reword it as a question.	*Which city is best for a family to move to, Portland, OR, or Charleston, SC?*
What criteria did the family use to make their decision?	*winter climate* *food* *risk to humans from natural hazards* *pro sports teams*
How could a U.S. map showing risk levels of several natural hazards by county help the family make their decision?	*If they can find Portland, OR, and Charleston, SC, on the map, they can compare the risk data for each kind of hazard. They could use these data to decide which city has fewer risks.*
Dan and Emma mention "sea level rise." How is it related to climate change?	*Sea level is rising because Earth's climate is warming. Warmer air means ice on land is melting and flowing into the ocean.* *Also, warmer water takes up more space than colder water.*
Is sea level rise a sudden event or gradual change? What could be the risks to people?	*Both. It is a slow or gradual change due to warming, but when there is a very high tide or a tropical storm, that is a sudden change.* *Flooding affects homes and people's ability to use roadways.*
What other questions do you have about this scenario?	*Are there other natural hazards that the family has not thought of?* *Are there differences in risk depending on where in each city they find a place to live?* *Are there differences in risk depending on the type of structure they move into?* *What are the natural hazard risks in Chicago, where they live now, compared to the other two cities?*

Student Reader

Preface

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Pages 2–3 **Suggested prompts**	**Sample student responses**
When they move, this family will need a new apartment or house and will likely check real estate websites. How reliable would real estate sites be for learning about natural hazards in a particular neighborhood or for a particular type of home?	*not very reliable, because the purpose of real estate websites is to sell you homes, not warn you of the risks of certain neighborhoods or types of homes*
How could this family research how a city prepares for natural hazards such as wildfires or tropical storms?	*They could read the city government websites.* *They could ask people who live there how well the city was prepared during the last hazardous event.* *They could contact a local university to ask a professor who studies natural hazards.*
In general, why is understanding how a search engine lists search results important to scientific literacy?	*because many people just read the top result without knowing how it made it to the top spot* *because sometimes the top results are ads* *Just because a website is popular does not mean it is scientifically accurate,*
Think about evaluating social media sources. When might they be useful for gathering scientific data about natural hazards?	*If you follow the social media of people who are scientists or governments that prepare for natural disasters, they could be useful.*

KEY IDEA—Point out that, without a thorough analysis of scientific data from reputable sources on the likelihood of natural hazards and learning how a community prepares for them, there isn't really a way for this family to make an informed decision about which of two cities will be the best one to relocate to. Both the investigations and the reading selections in the unit ahead will help students advance to a place where they have more knowledge to apply to the scenario, and they will circle back to the topic of how to make decisions about risks associated with natural hazards at the end of the unit.

What happens to a community when a tsunami occurs?

Previous Lesson

There is no previous lesson.

This Lesson

Anchoring Phenomenon

3 DAYS

A tsunami just reaching Miyako, Japan.

In this lesson, we read about an earthquake in 2011 that occurred off the eastern coast of Japan and triggered a tsunami. From the reading and photographs, we learn that when a tsunami reaches land, it may result in catastrophic loss of life and property. Two video clips help us further explore how this phenomenon impacts people and structures. We brainstorm and develop several engineering ideas to help detect tsunamis, provide advance warning of their approach, and reduce their impact. While evaluating our initial ideas, we notice patterns about what makes some engineering solutions more promising or challenging than others. Finally, we brainstorm related phenomena (local natural hazards) and ask questions to generate a list of data and information we need to better understand where natural hazards occur and how we can prepare for them.

Next Lesson

We will investigate patterns in historical tsunami data and figure out that most tsunamis are caused by strong, shallow earthquakes on colliding plate boundaries. We will establish a cause-and-effect relationship and use it to forecast locations at risk for future tsunamis.

Building Toward NGSS

MS-ESS3-2, MS-ETS1-1, MS-ETS1-2

What Students Will Do

1.A Ask questions that arise from careful observations of a sudden natural event that causes damage to communities.

1.B Apply scientific ideas to design an object, tool, process, or system that detects a tsunami when it starts (cause) and warns people or reduces damage to communities (effect).

What Students Will Figure Out

We will figure out these ideas about tsunamis:

- A tsunami is a large wave or surge of water that results from the movement of the ocean floor (e.g., an earthquake).
- Tsunamis cause damage to communities through major flooding of low-lying areas, impacting homes and property and making it hard for people to live there.

We will figure out these ideas about designing engineering solutions:

- Proposed engineering solutions for tsunami response include a system of detection sensors, warning plans, and solutions for reducing damage.
- Though communities may be impacted by different kinds of natural hazards, a response to most hazards often requires engineers to design technologies that can detect, warn people, and reduce damage.

Lesson 1 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	7 min	**INTRODUCE THE TSUNAMI PHENOMENON** Introduce the tsunami phenomenon through a brief reading and a series of photographs. Record noticings and wonderings.	A-B	*Tsunami: Japan 2011*, World Map (from *Everest Unit*)
2	8 min	**WATCH TSUNAMI VIDEO** Watch short video clips about the anchor phenomenon: a tsunami that impacted the eastern coast of Japan in 2011. Record noticings and wonderings.	C	computer, projector, 6.5 - Lesson 1 Japan Coast Guard Tsunami Footage (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
3	10 min	**SHARE NOTICINGS AND WONDERINGS** The class shares noticings and wonderings from the reading, photographs, and video clips.	D	Notice and Wonder poster, markers
4	10 min	**INITIAL ENGINEERING IDEAS** Brainstorm ideas around technologies for detecting tsunamis, warning people, and reducing damage due to tsunamis.	E-F	*Tsunami: Japan 2011*
5	15 min	**SHARE INITIAL IDEAS AND NAVIGATION** Through a series of paired Initial Ideas Discussions, students each share one developed engineering idea to detect tsunamis, warn people, or reduce the damage caused.	G-I	*Tsunami: Japan 2011*
				End of day 1
6	1 min	**NAVIGATION** Gather in a Scientists Circle to share initial ideas for detecting tsunamis, warning people, or reducing damage.	J	*Tsunami: Japan 2011*
7	10 min	**SHARE INITIAL ENGINEERING IDEAS** Share and record students' initial engineering ideas, classifying them as designs intended to detect tsunamis, warn people about their approach, or reduce the damage they cause.	J	*Tsunami: Japan 2011*, Detect Tsunamis poster, Warn People poster, Reduce Damage poster, markers

Part	Duration	Summary	Slide	Materials
8	20 min	**EVALUATE INITIAL ENGINEERING IDEAS** Individually and in class discussion, identify engineering ideas that show promise or may be challenging to implement.	K	*Tsunami: Japan 2011*, Detect Tsunamis poster, Warn People poster, Reduce Damage poster, markers, optional: small stickers, sticky notes
9	8 min	**NAVIGATE TO RELATED PHENOMENA** Consider related phenomena and connect the anchoring phenomenon to local natural hazards. Begin thinking about how we might design and evaluate engineering solutions for natural hazards in general.	L	*Tsunami: Japan 2011*, World Map (from *Everest Unit*)
10	10 min	**DISCUSS RELATED PHENOMENA** Share examples of local natural hazards and discuss examples of technologies used to detect, warn people, or reduce the damage of those hazards.	M-N	*Tsunami: Japan 2011*, Local Hazards poster, Technologies or Related Solutions poster, markers
11	2 min	**ASSIGN HOME LEARNING** Assign students to learn more about their family's experience and knowledge around natural hazards.	O	
				End of day 2
12	5 min	**NAVIGATION TO STUDYING NATURAL HAZARDS** Briefly review the home learning in partners and as a class to preface a discussion of how we study natural hazards and design solutions.	P	*Tsunami: Japan 2011*, Local Hazards poster, Technologies or Related Solutions poster, markers
13	10 min	**CONNECT STUDYING NATURAL HAZARDS TO DESIGNING SOLUTIONS** Revisit related phenomena to generate ideas for how we might study natural hazards and design solutions.	Q	*Tsunami: Japan 2011*, Local Hazards poster, Technologies or Related Solutions poster, markers
14	8 min	**DEVELOP QUESTIONS FOR THE DRIVING QUESTION BOARD** Develop questions for the DQB about the 2011 Japan tsunami, related phenomena, and ways to reduce the impacts of these natural hazards.	R	2-3 sticky notes, markers, *Tsunami: Japan 2011*, Detect Tsunamis poster, Warn People poster, Reduce Damage poster, Local Hazards poster, Technologies or Related Solutions poster
15	25 min	**DEVELOP THE DRIVING QUESTION BOARD** Convene a Scientists Circle to construct the DQB around students' questions, organized into categories. Develop the unit question through class discussion.	S-T	questions written on sticky notes, *Tsunami: Japan 2011*, Detect Tsunamis poster, Warn People poster, Reduce Damage poster, Local Hazards poster, Technologies or Related Solutions poster, DQB, markers
16	10 min	**BRAINSTORM IDEAS FOR INVESTIGATION AND INFORMATION WE NEED** As a class, create an Ideas for Investigation and Information We Need poster and record thoughts on how to figure out the answers to our initial questions as we move forward.	U	Ideas for Investigation and Information We Need poster, DQB, markers

Part	Duration	Summary	Slide	Materials
17	2 min	**NAVIGATION** As students reflect on the DQB, offer a suggestion for the next step.		DQB

End of day 3

Lesson 1 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• *Tsunami: Japan 2011* • science notebook • 2-3 sticky notes • markers • questions written on sticky notes		• World Map (from *Everest Unit*) • computer • projector • 6.5 - Lesson 1 Japan Coast Guard Tsunami Footage. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • Notice and Wonder poster • markers • Detect Tsunamis poster • Warn People poster • Reduce Damage poster • optional: small stickers • sticky notes • Local Hazards poster • Technologies or Related Solutions poster • DQB • Ideas for Investigation and Information We Need poster

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test the Japan Coast Guard Tsunami Footage video. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Online Resources

Prepare a space for your Word Wall to include “words we encounter,” “words we earn,” and “words from previous units.” Not every vocabulary word should be placed on the Word Wall. A helpful distinction is whether the term is earned or encountered. A word we earn is one we work together to understand through investigation and collaborative sensemaking, thus we celebrate our growing understanding by adding it to the wall. A word we encounter may be introduced through text or other media and is often defined for us. If our understanding of this word grows during the lesson or unit, we can then consider it to be a word that we earn. During day 1, add words we encounter from the reading. This unit will also include words from previous units as students revisit some words from the *Unit 6.4: What causes Earth’s surface to change? (Everest Unit)*, which might be helpful to put back on the Word Wall so students can apply them in another context.

Prepare all posters using chart paper and markers:

- day 1 - Notice and Wonder poster
- day 2 - Detect Tsunamis poster, Warn People poster, Reduce Damage poster, Local Hazards poster, Technologies and Related Solutions poster
- day 3 - Driving Question Board (DQB) poster(s), Ideas for Investigation and Information We Need poster

Poster guidance: Determine where to set up the DQB prior to day 3. Also, several posters can be combined into one to save space if necessary; for example, on day 2, the Detect Tsunamis, Warn People, and Reduce Damage posters could be combined.

Optional: For day 1, position the World Map from the *Everest Unit* where everyone can view it. This is used before the reading to locate Japan, Indonesia, and the Indian Ocean. The map serves not only as a way to locate natural hazards around the world but also to help connect the occurrence of certain natural hazards (i.e., tsunamis) with Earth’s geologic processes explored in the *Everest Unit*. Alternatively, you can project a world map without any reference to other geologic processes (e.g., earthquakes). Students will have an opportunity to observe the connections between earthquakes and tsunamis using maps during Lesson 2.

To encourage productive discussions throughout this unit, display the Communicating in Scientific Ways poster in a place where students can reference it.

Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

Students engage with the anchor phenomenon through a brief informational reading, several photographs, and two video clips showing a rapid surge of water, triggered by an earthquake, overtaking the eastern coast of Japan. They are then motivated to brainstorm and develop several engineering ideas to help detect tsunamis, provide advance warning of their approach, and reduce their impact. The purpose of the anchor is to probe students’ understanding of how Earth’s natural processes are related to specific natural hazards. It leverages their ideas about geologic processes (i.e., earthquakes) and other natural hazards (i.e., floods, wildfires). The anchor then encourages students to use their observations to develop engineering solutions to reduce a tsunami’s impact. As they think more deeply about their proposed solutions, they notice patterns in what makes some more promising or challenging than others. Finally, as students consider related phenomena, the anchor motivates them to think more broadly about how scientists forecast which areas are most at risk for natural hazards and how engineers evaluate proposed solutions to reduce their impact.

Where We Are NOT Going

As students share their ideas, they may mention what they already know about earthquakes, tsunamis, tidal waves, and tsunami barriers. In terms of geologic forces, specifically earthquakes, encourage them to use their knowledge from the *Everest Unit*. Similarly, when discussing related phenomena, encourage students to discuss any personal experiences with other natural hazards. In both cases, however, avoid giving too much away at this point in the unit (for example, do not discuss in detail the connection between earthquakes and tsunamis as these ideas will emerge in subsequent lessons).

Lessons 2-5 will draw upon these particular areas of students' prior knowledge:

- Earthquakes that occur along specific plate boundaries often cause the ocean floor to shift, triggering tsunamis.
- The energy of a tsunami can be described in terms of wave speed and wave height. Many tsunami-specific engineering solutions involve dissipating the energy of the wave.
- As engineers decide upon criteria and constraints in their design process, they consider factors such as what knowledge is available, what technology is available, and what the affected communities need and value.

1. Introduce the tsunami phenomenon.

7 MIN

Materials: *Tsunami: Japan 2011,* science notebook, World Map (from *Everest Unit)*

Introduce the phenomenon. Say something like, *I want to share some information with you about a phenomenon that impacts places where many people live. When it happens, structures can be damaged and people can be hurt, or even die, as a result. This phenomenon is called a tsunami. Has anyone heard of this before?*

Let students share a few initial ideas with the class.

Introduce the reading and photographs. Project **slide A**. Tell students that the slide shows a tsunami wave reaching the eastern coast of Japan in 2011. Say, *We have a reading that talks about events that occurred in Japan and Indonesia. It might be helpful to know where these places are. Can someone show us Japan and Indonesia on the map?*

Have a volunteer point out the approximate locations of Japan and Indonesia on the World Map. Use sticky notes or some other method to mark them for reference throughout the unit (see reference map with arrows showing Japanese and Indonesian islands).

Distribute a copy of *Tsunami: Japan 2011* to each student.

Additional Guidance

Supporting empathy and emotions: A unit on natural hazards is likely to elicit emotional stress from some students, whether from their empathy for those affected or from experiencing a natural hazard directly or through the experiences of family and friends.

Emotional stress from a disaster can often be great in students who feel they do not understand the situation or have no control over it. Although natural hazards often bring impacts that students cannot control, the aim of this unit is to help students consider what is happening before, during, and after such events, and to empower them to use what they learn to respond in ways that can keep them and their loved ones safe in the event of a disaster.

If you have students who have traumatic experiences from natural hazards, a recommended source is the CDC's Caring for Children in a Disaster website. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Read text and examine photos. Give students 5 minutes to complete Part 1 of their handout individually by reading the text, examining the photographs, and marking things they notice or wonder about.*

***Attending to Equity**

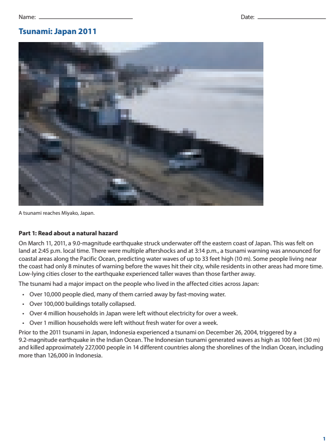
Supporting Universal Design for Learning: In this unit, Constructing Explanations and Designing Solutions is a focal SEP. Therefore, numerous scaffolds exist to support students in this practice in the context of natural hazards. If you believe your students are ready to proceed with less support, we recommend first removing scaffolding related to practices that are not focal in this unit. For example, though modeling is used in many activities, it is likely a familiar practice, as students have engaged with it in previous units. Therefore, consider asking students to generate their own models without offering them supplemental image starters or handouts (often provided throughout this unit). However, take caution when removing scaffolding, as it is designed to ensure greater access and to help remove barriers to understanding complex phenomena.

For the reading, ask students to mark the text using your typical classroom annotation protocol, such as underlining or circling. Remind them to take notes or write questions about any unfamiliar words on their handout.*

For the photos, ask students to circle or use arrows to point out parts of the images that attract their attention. At this point, let them select things they find interesting without guiding them to compare or look for certain details. Some details may be obscure as the images are taken from video footage, but the interaction between land and water should be clear.

Set up a Notice and Wonder chart. Present **slide B.** Have students find a blank page on the left side of their science notebooks and title the page, "Tsunami Phenomenon." Then, have them make a two-column chart to record their noticings (left column) and wonderings (right column) from the reading and photographs.

Give students 1-2 minutes to record in this chart what they noticed and wondered about from the reading and photographs. Tell them we will share noticings and wonderings later, after we view video footage from this event.


Name: ______ Date: ______

Tsunami: Japan 2011

A tsunami reaches Miyako, Japan.

Part 1: Read about a natural hazard

On March 11, 2011, a 9.0-magnitude earthquake struck underwater off the eastern coast of Japan. This was felt on land at 2:45 p.m. local time. There were multiple aftershocks and at 3:14 p.m., a tsunami warning was announced for coastal areas along the Pacific Ocean, predicting water waves of up to 33 feet high (10 m). Some people living near the coast had only 8 minutes of warning before the waves hit their city, while residents in other areas had more time. Low-lying cities closer to the earthquake experienced taller waves than those farther away.

The tsunami had a major impact on the people who lived in the affected cities across Japan:

- Over 10,000 people died, many of them carried away by fast-moving water.
- Over 100,000 buildings totally collapsed.
- Over 4 million households in Japan were left without electricity for over a week.
- Over 1 million households were left without fresh water for over a week.

Prior to the 2011 tsunami in Japan, Indonesia experienced a tsunami on December 26, 2004, triggered by a 9.2-magnitude earthquake in the Indian Ocean. The Indonesian tsunami generated waves as high as 100 feet (30 m) and killed approximately 227,000 people in 14 different countries along the shorelines of the Indian Ocean, including more than 126,000 in Indonesia.

1

***Attending to Equity**

Supporting Universal Design for Learning: Previewing or pausing to discuss technical terms in the text can be particularly helpful for emergent multilingual learners, students with dyslexia, and students who read below grade level. These words include: *magnitude, aftershocks*, and *tsunami*. At this point, the term *magnitude* should be included on the Word Wall as a "word from a previous unit."

Additional Guidance

The reading contains technical words that you may want to discuss with your students before they begin reading, or pause to discuss as they encounter them in the text. A word we earn is one we work together to understand through investigation and collaborative sensemaking, thus we celebrate our growing understanding by adding it to the wall. A word we encounter may be introduced through text or other media and is often defined for us. If our understanding of this word grows during the lesson or unit, we can then consider that word one that we earn. This unit will also include words from previous units as students revisit some words from the *Everest Unit,* which might be helpful to put back on the Word Wall so students can apply them in another context.

Science Notebook

This is the unit's first use of the science notebook. Students may need time to organize a new section. The setup will vary depending on how you've structured the notebook's components. It is recommended to have students do the following:

- Reserve a blank page at the start of the unit, to be titled with the unit question on day 3 of this lesson.
- After the title page, reserve 2 pages (4 pages front-to-back) for the table of contents (unless all tables of contents are at the front of the notebook).
- Reserve 10 pages (20 pages front-to-back) for the Progress Tracker. (This is optional for this unit.)
- Number the pages so everyone begins the unit on the same page number.

Remind students that the notebook is their tool for recording their observations, evidence, and ideas to share with the classroom community. They should see it as a space to brainstorm and record their thinking, as well as a place to show how their thinking changes as they learn more.

2. Watch tsunami video.

8 MIN

Materials: science notebook, computer, projector, 6.5 - Lesson 1 Japan Coast Guard Tsunami Footage (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Additional Guidance

Supporting empathy and emotions: We have elected to present information and photos from the 2011 Japan tsunami before showing actual video footage as a way to prepare students for viewing a potentially disturbing natural event. Though many people were killed during this event, we have taken care to select footage that does not show any people suffering or in visible distress. We do not feel it is necessary to show sensitive footage of human death and suffering for students to engage with the unit's goals.

However, some students may have experienced this type of hazard firsthand or have a relative or friend who has experienced a tsunami. The videos might also elicit negative emotions from students who have experienced loss from other natural hazards. If students would prefer not to watch the videos, it will not take away from their learning experience. It might also be helpful to encourage students by pointing out that we can improve how well we protect people by learning more about how these events happen.

Prepare students to see tsunami videos. Project **slide C**. Before presenting the tsunami videos, prepare your students by reminding them of the information in their prior reading about how this event caused devastating loss of life and physical damage.

Although your students may not have experienced a tsunami, point out that some of them may have experienced other natural hazards or have close family or friends who have been affected by such events. Explain that, though we may not be able to stop these events, we can use science to understand them better, predict when they may occur, and make more informed decisions about what to do when they happen.

For further guidance on what to say to your students before viewing this phenomenon, please refer to the Guidance callout; for guidance on supporting student reactions and experiences with natural hazards, see the Guidance callout.

Additional Guidance

Supporting empathy and emotions: Viewing natural hazard events may cause anxiety for some students, as they feel helpless in the face of devastating natural events. To help prepare your students to view natural hazards, such as the tsunami, consider how you may use aspects of the following script:

In previous units we've thought a lot about natural processes that occur on Earth. By looking at data, we've been able to better understand why certain events occur and even predict, to some degree, when and how they will happen in the future. However, because our models are not perfect, they cannot yet account for every natural event. Sometimes, unforeseen events are devastating for those who live through them, as they may lose loved ones and experience dramatic changes in their daily lives. It's also important to realize that for some, just watching or reading about these events can be equally difficult. Even without experiencing a natural hazard, we can imagine what it might feel like to live through something so powerful and seemingly unpredictable, or to lose someone close. It's easy to feel scared or worried.

One thing we can do as scientists in this class is to understand our world a little better by uncovering more information, examining more data, and thinking of new ideas or ways to solve problems. With every natural event that occurs, we gain valuable new information that allows us to revise our models and make them more accurate. So, although we cannot control whether these events occur, we can get better at knowing what happens before, during, and afterward. We can then use our new knowledge to make better decisions so we can keep our communities safer and be more prepared for future hazards.

Watch the video. Explain to students that you will play the video twice, and recommend that they simply watch during the first playthrough. Play the video 6.5 - Lesson 1 Japan Coast Guard Tsunami Footage. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Consider pausing on video transitions so students can orient themselves to the map locations of where the video was taken.

Before playing the video a second time, instruct students to draw a line in their notebook beneath their noticings and wonderings from the reading and photographs, and to record their noticings and wonderings from the videos below this line during the second playthrough.

Additional Guidance

The video clips document the 2011 Japan tsunami. We want students to understand how a particular event affected specific locations. We also want students to notice that a tsunami involves not only a large wave, but more importantly, a dramatic increase in water flow, resulting in flooding. Finally, we want students to consider how the event could be predicted or damage be reduced.

There are many other video clips of global tsunamis available. You may consider whether to show other tsunami events at a later date should students have questions about how tsunamis behave more generally and need to explore further evidence. However, we recommend selecting video clips that highlight the tsunami event itself without showing people suffering bodily harm.

Give students 1-2 minutes to make notes in their Notice and Wonder chart. For 1 minute, have students turn and talk with a partner about their noticings and wonderings from the videos.

3. Share noticings and wonderings.

10 MIN

Materials: science notebook, Notice and Wonder poster, markers

Share noticings and wonderings as a class. Show **slide D.** For 10 minutes, facilitate a whole-class discussion by calling on student volunteers to share their noticings and wonderings from the reading, photos, and videos. Be sure to record what is shared on the class Notice and Wonder poster. After 5 minutes, ask students whether they notice any commonalities in what was shared, and ask them to name the categories or themes. For example, observations or questions regarding what happens as the tsunami contacts structures on land could be categorized as "tsunami and structures", while those about how it impacts people could be grouped together under "tsunami and people".

Keep this Notice and Wonder poster visible to reference as you transition into an Initial Ideas Discussion. Tell the class we will revisit it during the lesson so more students can share their observations and questions.

Assessment Opportunity

Building towards: 1.A Ask questions that arise from careful observations of a sudden natural event that causes damage to communities.

This is the first point in this lesson that you can assess students on this lesson-level performance expectation. You can also assess students' initial questions on day 2 as the class constructs the Local Hazards poster and the Technologies or Related Solutions poster, or on day 3 as the class constructs the DQB.

What to look for/listen for: Observations or questions about (1) size or speed of tsunamis or type of damage to communities, (2) disagreement or uncertainty about what causes tsunamis, (3) disagreement or uncertainty about why a tsunami possesses such destructive power, and (4) how communities could be protected from tsunamis.

What to do: Encourage students to share their observations and related questions from the reading and videos. Prompt them by asking *Where did you see that happen?* and *What kinds of questions do you have about ____?*

4. Initial Engineering Ideas

10 MIN

Materials: *Tsunami: Japan 2011*, science notebook

Brainstorm initial ideas individually. Explain to students that because natural hazards like tsunamis affect people and communities frequently, scientists and engineers want to come up with solutions to help protect them. Say, *We saw that this natural event can do a lot of damage to land, buildings, other property, and sometimes even human lives. Devastating events like tsunamis motivate people to study why they occur, how they work, and also how to reduce their effects. As scientists understand these events better, engineers can use that knowledge to help design solutions to protect or warn us. Therefore, in this unit, we will think like both scientists and engineers.*

Display **slide E**. Explain that we will now think about the tsunami again, but from an engineering perspective. Prompt students to come up with ideas to detect tsunamis, warn people of their approach, and reduce the damage they cause.

Say, *You've all noticed some interesting things from the reading, photos, and videos. As you brainstorm engineering ideas, use what you already recorded in your notebook about what you noticed during the tsunami to help you think about how people and communities could be protected and warned in the future.* Give students 5 minutes to brainstorm and record their ideas in Part 2 of their handout. Encourage them to think of at least one idea for each column.

Develop initial ideas. Display **slide F**. Ask students to pick one idea from their initial brainstorm to model and explain more thoroughly in their handout. Say, *Pick one of your ideas. Show how it would work using a diagram and then write a short explanation. Remember to label your diagram so someone else could understand how your design works.*

After 5 minutes, ask students to pick an idea from a different category to model and explain more thoroughly. Give students 5 minutes to model and explain their second idea in greater detail. Tell them to be prepared to share their ideas with a partner.

5. Share initial ideas and navigation. 15 MIN

Materials: *Tsunami: Japan 2011*

Promote collaboration. Display **slide G**. Transition to initial ideas discussion by reminding students of classroom norms.

Explain to students that it's important to look at each other's ideas so we can see things from other perspectives. Say, *Just as scientists do not work in isolation, engineers often collaborate. How might this help engineers and scientists when they are trying to figure out how things work and then how to design solutions?* Have a few students share their ideas for why collaboration is important in science.

Say, *Right! Collaboration is important in science because then we can use many diverse ideas and see things from different points of view, which is important as we try to design systems that address a variety of needs or criteria and can help as many people as possible.*

Share initial ideas in pairs.* Display **slide H**. Tell students that in order to share ideas and be inspired by the ideas of others, they will pair up with a fellow classmate/engineer three times.

Explain that in each pairing, students will decide who speaks first. The speaker has 1 minute to describe one of their developed ideas. The listener writes notes about the idea in Part 3 of their own handout and identifies whether the idea is meant to help detect, warn people, or reduce damage. Emphasize that this is not the time to ask a lot of questions about the design; it is simply time to record their peer's idea. Then students will switch roles after 1 minute so each partner has the opportunity to share their idea. Give students approximately 10 minutes to engage in 3 pairings. For further guidance on running this activity, see the Guidance callout.

Additional Guidance

While students share, walk around the room and listen to as many pairs as possible. As they have very limited time to learn about each other's ideas, this is not the ideal time to interrupt with clarifying questions. There will be opportunities later to probe for understanding and for students to explain their ideas in greater detail. Instead, use this time to note any patterns that emerged from the proposed ideas. For example, are students mainly sharing ideas for detecting tsunamis rather than reducing damage? Or, perhaps many of the ideas for detecting tsunamis also involve simultaneously warning people, so these ideas are often intertwined.

To help ensure that the activity goes smoothly, consider using your own watch or timer. Tell students to find their first partner, then call "start" for the first partner to share. After one minute, say "switch roles" so the second partner can share. After another minute, say "find a new partner. Repeat the "start", "switch roles", and "find a new partner" steps again for approximately 10 minutes, or until three pairings of students have shared.

Navigate to close day 1. Display **slide I.** Say, *As I walked around, I noticed lots of different ideas for detecting tsunamis, warning people about them, and reducing the damage they cause. Interestingly, I also noticed similarities across many of these ideas. Does anyone want to share any similarities they noticed?* Call on a few students to share.

Close the class with, *In our next class, let's look at the ideas we came up with and consider how we could organize them so we can begin to think about which solutions might be better than others.* Remind students to leave their handouts in the classroom so you can look at their developed ideas before the next class period.

***Strategies for This Initial Ideas Discussion**

During these partner discussions, do not correct students' misuse of language. An Initial Ideas Discussion is used to encourage students to share their prior knowledge on a topic and generate divergent thinking. Some students may refer to wave amplitude, wavelength, seismometers, tsunameters, wave breaks, or tsunami barriers. Rather than stopping them from using these terms, you might ask them to briefly offer an explanation. Avoid pushing for clear, developed definitions; it may be more effective to simply note any new terms that emerge as ones the class needs to learn more about. Students will refine their understanding of these terms as they progress through the unit.

Assessment Opportunity

Building towards: 1.B Apply scientific ideas to design an object, tool, process, or system that detects a tsunami when it starts (cause) and warns people, or reduces damage to communities (effect).

This is the first point in this lesson that you can assess students on this lesson-level performance expectation. You can also assess students on day 2 as they discuss promising and challenging aspects of designs, and on day 3 when the class discusses how to design solutions to reduce the impact of natural hazards on communities.

What to look for/listen for (in the initial designs):

- At least one drawing or written description of an idea to either help detect tsunamis, give people more advance warning, or help reduce the damage caused by tsunamis.
- Ideas that indicate a characteristic of the tsunami wave that would be important to consider in the design, such as the start of the hazard (e.g., earthquake); or how fast, big, or intense the wave becomes; or a method for blocking the wave from reaching a community.

Throughout Lesson 1, look for/listen for these things: (1) agreement that though tsunamis may cause devastation, their effects can be reduced by solutions that detect, warn people, and reduce damage; (2) agreement that some engineering solutions may be more promising or challenging than others; and (3) uncertainty or disagreement about what makes one solution more promising or challenging than another.

What to do: If your students struggle to think of engineering ideas, ask them to consider what might be dangerous about the giant waves reaching land. Use a physical analogy to help them recognize the weight of water: Ask whether they think water is heavy or light. Fill a 5-gallon bucket or similar container with water and ask a student to pick it up. Ask them what it might feel like to get hit by that much water. Remind them that a tsunami wave carries millions of times more water than the bucket. Remind them of the cars, airplanes, and helicopters they saw swept away during the second video clip.

End of day 1

6. Navigation

1 MIN

Materials: *Tsunami: Japan 2011*

Arrange students in a Scientists Circle. Display **slide J.** Return the students' collected handouts. Say, *Yesterday, we brainstormed ideas for how to better detect tsunamis, how to better warn people of an approaching tsunami, and how to reduce the damage caused by a tsunami. Then, you picked two ideas to develop further. Finally, you shared one of your ideas and heard ideas from other students. Let's list those ideas now.* Have students bring their handout and a chair to a Scientists Circle.

Scientists Circle

All the activities on day 2 can be completed in a Scientists Circle. Day 2 gives students opportunities to not only share ideas but also begin evaluating ideas—an integral part of engineering. As students may be new to this process, it is important for them to practice this together in a public format that positions their ideas at the center of the discussion. When students need to complete activities with partners, they can work with a classmate sitting next to them in the circle to minimize the moving of chairs and desks.

7. Share initial engineering ideas. 10 MIN

Materials: *Tsunami: Japan 2011,* Detect Tsunamis poster, Warn People poster, Reduce Damage poster, markers

Elicit ideas and record on class posters. Keep **slide J** displayed. Say, *Last class you shared ideas with each other about how to protect people and communities from tsunamis. Refer to what you recorded in Parts 2 and 3 of your handout as we collect these ideas on a class poster. Think back to one that you got really excited about. It could be your own or someone else's.*

Technologies to help detect a tsunami	Technologies to give people more advance warning that a tsunami is approaching	Technologies that could help reduce the damage from a tsunami

Ask, *Would someone share an idea to get us started?* Have a volunteer stand and share an idea with the class. Say, *First, describe your idea. Then, tell us how it could either detect, warn people, or reduce damage.*

After the student shares, ask them to select another volunteer, or say, *Did anyone have a similar idea?* For the next 10 minutes, record all shared ideas on the corresponding poster (alternatively, one three-column poster could be used if wall space is limited).

Do not discard these posters, as they will be referenced at various points throughout the unit, in particular during Lesson 5 when students explore different types of tsunami barriers, and again in Lesson 6 when students read about a tsunami detection system currently in place.

8. Evaluate initial engineering ideas. 20 MIN

Materials: *Tsunami: Japan 2011*, Detect Tsunamis poster, Warn People poster, Reduce Damage poster, markers, optional: small stickers, sticky notes

Shift to evaluating engineering ideas. Display only the first two prompts on **slide K**. Say, *Part of engineering is coming up with new ideas to solve problems. However, engineers also use their expertise to evaluate a plan that's already being used or one that has been proposed. As part of their evaluation, they ask, "Does this idea show promise?" or "Does this idea seem challenging?" So, let's try that with our ideas.*

Prompt students to turn to Part 4 of their handout. Tell them to individually write down the idea they think shows the most promise and explain their rationale; then, to write down the idea that seems most challenging to implement and explain why. Give students 5 minutes to complete these prompts.

***Supporting Students in Engaging in Argument from Evidence**
This is an opportunity to support students in developing productive argumentation practices. Remind them of classroom norms around discussing or critiquing a classmate's idea. Emphasize that

Prepare for whole-class discussion. Students are now ready to develop criteria and constraints that could be used to evaluate the engineering solutions they proposed on day 1. To help them build toward these concepts, tell them that we will now share our rationales and evaluate the ideas as a class. Say, *In this discussion we will try to identify any patterns for promising ideas and those that may be more challenging. We are not identifying "good" and "bad" ideas because we don't know yet what makes one idea good and another bad. Instead, let's start with our own first impressions about whether an idea seems easier or more difficult to implement.**

Facilitate discussion to evaluate engineering ideas. Ask a volunteer to share one idea they identified as most promising or most challenging and then to explain their reasoning. After the student shares, say to the class, *Did anyone else think something similar about that idea?* If at least 3 students agree, use markers or stickers on the appropriate poster to clearly indicate the idea as either promising (i.e., green dot), or challenging (i.e., red dot). For the next 10 minutes, continue this process by asking other students to share ideas and polling the class for agreement.

critiquing the idea is not the same thing as criticizing the person who came up with it. Encourage students to use language such as, *I agree with the idea that ______ shared or I disagree with this idea because ______*. It may be helpful to remind them to use the Communicating in Scientific Ways poster.

Additional Guidance

During this discussion, when students disagree on an idea, ask for clarification on why some think an idea is promising and why others think it may be challenging. You can add notes on the posters to help students notice how complicated the evaluation process can be and how it's important to consider multiple perspectives. Say, *What may seem promising to one person may seem challenging to another. So it's critical that we understand the "why" in these cases especially. I'll write some notes on the poster to indicate which ideas we may need to think about more. Maybe we'll need more information in order to determine whether that idea is promising or challenging.*

Also, a student may feel bad if their idea is considered a "challenging" solution by their peers. It's important in these cases for both sides to explain their reasoning. However, allowing the student who came up with the idea to have the last word may be effective, as they have a chance to acknowledge the perspectives of their peers as well as an opportunity to ask for clarification of anything said.

This is an important moment to highlight why it's so important to hear multiple perspectives when it comes to engineering design and that real engineers go through a similar process. Push your students to think that variety in ideas is what we strive for, because if everyone has similar solutions for such a complex problem, then it's likely that certain needs or limitations will get overlooked. For example, if we all like the idea of building a massive tsunami wall to protect the shoreline, what happens when there aren't enough resources to build the wall?

For the next 5 minutes, ask students if they notice any patterns in the evaluated ideas. Say, *Do you notice any patterns when you look at all the promising ideas? What if we look at only the challenging ideas? Do any patterns emerge?*

Suggested prompts	Sample student responses	Follow-up questions
Do you notice any patterns if we look at all the promising ideas?	*They don't seem to require inventing any new technology, like cell phones, so we can already communicate and warn people quickly.* *It seems like we could make some of these happen really quickly because we will use existing technology, like GPS and satellite dishes.* *Some probably won't make people change their daily habits, like move out of their homes, so that makes them easier.*	*What makes an idea promising?* *Does this help us figure out something we think all tsunami-related solutions should take into account?* *Does this help us figure out what a tsunami-related solution should be able to do?*
Do you notice any patterns if we look at all the challenging ideas?	*They involve making new things, and that takes lots of time and money.* *We may not know how to build something new because we've never done it before and it'll need to be tested.* *These plans all make people do something they don't want to do, like move away from the ocean.*	*What makes an idea challenging?*

Key Ideas

Purpose of this discussion: To identify patterns in what makes some engineering ideas more promising or challenging than others. As students may be unfamiliar with tsunamis or with evaluating engineering designs by considering criteria and constraints, responses during this discussion will vary. Listed below are some patterns which students may notice. However, it's important at this point **not** to point these out. They will likely emerge as students progress through the storyline in this unit. At the end of the discussion, return to the ideas that we reached consensus around (e.g., this group of solutions may be easier to deploy quickly, these may be cheaper, these may save more lives or protect more property, and so forth). Take this opportunity to introduce the terms *criteria* and *constraints* that can be used to evaluate solutions for tsunamis and related phenomena. This will encourage students to think about tsunamis from an engineering perspective, and may support them in asking more engineering-related questions when they construct the DQB.

Listen for these ideas:

- Most of the promising ideas involved warning people of an approaching tsunami because these solutions seem to cost less money or use fewer resources.
- Many of the ideas around detecting tsunamis seem promising because they use technologies that already exist, like using tools to detect earthquakes.
- It seems like reducing the damage caused by a tsunami will be challenging because that involves building something new, and that requires lots of time and money.

Discuss the need for more information. Say, *Sometimes deciding whether an idea is promising or challenging is difficult, as we see with our list. Take a moment to turn and talk with a partner about the question on the slide: "What do we still need to know about these designs or the hazard itself?"*

Display the third prompt on **slide K**. Read it aloud and ask students to think about what additional information we may need to further evaluate these designs. Give them 1 minute to think alone before sharing with a partner 1 minute. Finally, give students 3 minutes to share their ideas with the class. Say, *If we can understand more about the process engineers use to design and evaluate their plans, then perhaps we can apply a similar process when examining natural hazards that happen closer to us. To help us do this, whenever we come up with an idea or research a possible solution, let's continue to ask what makes this solution promising or challenging.*

9. Navigate to related phenomenon. 8 MIN

Materials: *Tsunami: Japan 2011*, World Map (from *Everest Unit*)

Transition to related phenomena. Display **slide L**. Explain to students that although the focus of this unit has been a tsunami in Japan, scientists and engineers study other natural hazards and design ways to better detect, warn people, and reduce damage. Say, *Now that we've spent a few days looking at and analyzing information about tsunamis, let's think about what other types of natural hazards can affect people and places too. And then let's think about whether we know of any technologies for detecting local hazards, or for warning people that a hazard is about to occur. What other natural hazards have you heard of or experienced?*

Connect to related phenomena.* Ask students to turn and talk to a neighbor about natural hazards they've experienced, been affected by, have read or heard about, or are simply interested in. Give them 2 minutes to discuss.

Prompt students to individually list other natural hazards in Part 5 of their handout. Give them 2 minutes to complete their response.

Connect to local hazards. Display **slide M**. Say, *In the last unit we noticed that earthquakes tend to happen more frequently in certain places. Does anyone remember where?* Call on a volunteer to show the locations on the World Map and explain that earthquakes tend to occur most frequently along the boundaries of plates on Earth's surface. Say, *This means that communities in those areas are more at risk for experiencing an earthquake.*

Ask students to think about which natural hazards are more likely to happen in their communities, and whether there are things they know about those hazards that may help us think about designing solutions for the tsunami hazard. Give them 4 minutes to individually complete the remaining prompts in Part 5. Remind them to be prepared to share these ideas and examples with the class.

***Attending to Equity**

Supporting Emergent Multilingual Students: Asking students to consider related natural hazards may help you situate the anchor in a local context. By helping to make connections between the tsunami and events your students are likely to have experienced, or could experience in their own community, you provide opportunities for them to engage in more meaningful sensemaking, especially if they are permitted to demonstrate their understanding in a language of their choosing. As you do this, keep in mind students' cultures and languages, as this will help make the experience more accessible to your students.

10. Discuss related phenomena. 10 MIN

Materials: *Tsunami: Japan 2011*, Local Hazards poster, Technologies or Related Solutions poster, markers

Construct Local Hazards poster and Technologies or Related Solutions poster. Display **slide N**. Remind students of what we have done in this lesson so far. Say, *So far, we've learned about a tsunami that occurred in Japan in 2011. Then, we brainstormed ideas to detect tsunamis, warn people, and reduce the damage caused by tsunamis. We evaluated some* *of these ideas and discussed what made some promising and others challenging. Now, as we continue thinking about local natural hazards, let's see if we know about any technologies used in our communities that might help us design solutions for the tsunami hazard.*

Point out that **slide N** is related to Part 5 of the handout. Read the slide's first prompt aloud, then give students 3 minutes to share their responses with the class. Repeat for the remaining prompts. As students share, record their responses on two posters: Local Hazards (Experienced or At Risk For) and Technologies or Related Solutions.

Additional Guidance

Students' responses about local hazards and examples of technologies will vary widely by location. Within the time permitted, accept as many responses as possible without probing too much for specificity. Even if a response seems vague, incomplete, or only partially accurate, record it. This is a moment to engage prior knowledge and experiences, not to evaluate students' ideas. Students will have opportunities to rethink some of these ideas in light of new information later in the unit.

11. Assign home learning.

2 MIN

Materials: None

Assign home learning to connect with family resources. Display **slide O**. Invite students to think more about natural hazards when they go home. Prompt them to talk with family members (preferably older ones, who are more likely to have experienced a natural hazard) to learn more about the hazards they have experienced.*

Say, *For home learning, share what we've learned about tsunamis with your family, and then ask if they have heard of or experienced any other natural hazards. It will be helpful to hear about their experiences and what they learned from them. Ask your family members if they remember when they first experienced the hazard and how they learned about what to do when it happened. Hearing from different people may give us more ideas about how to help people and communities prepare and then act when a hazard occurs.*

End of day 2

***Attending to Equity**
This home learning opportunity will help students broaden their thinking to related phenomena beyond the case of the 2011 Japan tsunami. Even if family members live far away and have experienced very different natural hazards, it is important that students hear from people they know and trust about how they learned about these hazards and what to do when they occur. This broadening to related phenomena will give students an opportunity to leverage their family's resources to augment their classroom learning, making the anchoring phenomenon more personally meaningful. There is an additional opportunity to add to this home learning as part of Lesson 2.

12. Navigation to Studying Natural Hazards

5 MIN

Materials: *Tsunami: Japan 2011*, Local Hazards poster, Technologies or Related Solutions poster, markers

Turn and talk about the home learning assignment. Display **slide P**. Give students 2 minutes to talk with a partner about the slide's home learning prompts. Meanwhile, display the Local Hazards poster and Technologies or Related Solutions poster where all students can view them.

Frame the discussion about studying natural hazards and designing solutions. Remind students that after learning about the 2011 Japan tsunami, they brainstormed ideas to help people and communities affected by natural hazards. Say, *Now that we've asked other people about their experiences with natural hazards, we can use what they shared to help us think about how to design ways to protect people and places in the future. Let's take a few minutes and hear what some of you learned from talking with your families.*

Ask for a few volunteers and give them 3 minutes to share their home learning experiences with the class.

Additional Guidance

Record students' ideas on the appropriate posters using a different color marker than previously (to highlight the new additions from home learning). These posters can be used later in the unit to motivate discussions around the criteria and constraints for engineering solutions. Specifically, during Lesson 5, students can think more about criteria and constraints for solutions to other hazards based on how they were discussed in the context of tsunamis. Also, during Lesson 10, students can revisit this discussion to think about which hazard they want to study more deeply.

13. Connect studying natural hazards to designing solutions.

10 MIN

Materials: *Tsunami: Japan 2011*, Local Hazards poster, Technologies or Related Solutions poster, markers

Facilitate whole-class discussion about studying natural hazards and designing solutions. Briefly revisit the Local Hazards poster and Technologies or Related Solutions poster to remind the class of what was discussed previously.

Display **slide Q**. Give students 3 minutes to discuss the prompts on the slide with their neighbor.

For the next 7 minutes, prompt students to share their responses with the class. Remind them to draw from their home learning when appropriate.

The idea here is for students to connect their thinking around tsunamis specifically to natural hazards more broadly. It's important to help them connect why and how we might study the 2011 Japan tsunami with how we might study natural hazards that affect other communities in order to develop a method for evaluating solutions designed to reduce their impact.

Suggested prompts	Sample student responses
How do you think people determine which places are at risk for a natural hazard?	*Maybe look at some maps that show where natural hazards have occurred in the past.* *We could talk to more people who have experienced natural hazards to see how often they happen.* *We could compare everywhere that natural hazards have occurred and see if lots of them happen in certain places.*
How do you think people compare and evaluate solutions for reducing the impact of a natural hazard?	*We need to know how the natural hazard impacts people.* *We need to know what the natural hazard actually does when it occurs.* *Maybe we could see what solutions places have tried, and how they worked for a particular natural hazard.*

Should the conversation stop with only a few ideas shared, transition to the next activity, which is developing questions for the DQB. Students will have more time to consider ideas for further investigation after building the DQB.

14. Develop questions for the Driving Question Board.

8 MIN

Materials: 2-3 sticky notes, markers, science notebook, *Tsunami: Japan 2011*, Detect Tsunamis poster, Warn People poster, Reduce Damage poster, Local Hazards poster, Technologies or Related Solutions poster

Prepare to set up the DQB. Display **slide R**. Say, *We have lots of questions about tsunamis and we have ideas about how to reduce their impact. We also have ideas and questions about other natural hazards, including the things we learned from our families. To set up our DQB for this unit, it may be useful to have two categories for our questions. One category is questions about tsunamis or other natural hazards. The second category is questions about engineering designs for any of those hazards. You can generate questions in both categories. Record them on sticky notes with a marker—one question per sticky note. After a few minutes, we'll quickly review our questions in partners and then get together in a Scientists Circle to create our DQB.*

Write questions individually.* Pass out 2-3 sticky notes to each student and give them 4 minutes to review their notebooks and handouts to generate questions. Remind them that questions can be related to tsunamis or the engineering solutions designed to reduce their impact as well as to other natural hazards or how engineers design and evaluate solutions for those.

Additional Guidance

Encourage students to generate at least one question related to tsunamis or a local natural hazard and at least one question about engineering designs for natural hazards so their questions will be represented on both aspects of the DQB. It might be helpful to take two passes through the DQB (see Alternate Activity callout in next step) to first generate questions about hazards and then generate questions about engineering designs, encouraging students to participate during each pass.

***Supporting Students in Engaging in Asking Questions and Defining Problems**

Initial questions about a phenomenon are intended to clarify what information is known and not known; there are often more questions than answers when scientists begin their investigations. Develop a safe and supportive space for students' uncertainty, and focus on the need to ask and answer questions in order to address this uncertainty, which may require the entire unit to resolve.

Share questions with a partner. Have students turn and talk for 2 minutes with a partner to ensure that their questions for the DQB are clear and productive. Remind them that partners should act as critical peers and ask clarifying questions if they don't understand a question. Students can edit their questions before sharing with the class in the Scientists Circle.

15. Develop the Driving Question Board.

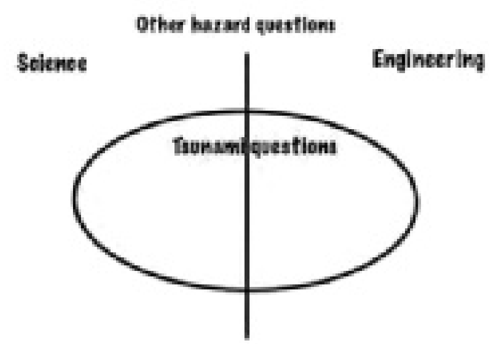
25 MIN

Materials: questions written on sticky notes, *Tsunami: Japan 2011*, science notebook, Detect Tsunamis poster, Warn People poster, Reduce Damage poster, Local Hazards poster, Technologies or Related Solutions poster, DQB, markers

Gather in a Scientists Circle. Display **slide S**. Instruct students that when their questions are ready, they need to bring them along with their handout, science notebook, and a chair to meet in a Scientists Circle around the DQB.

Explain to students how you will create the DQB:

- The first student reads their question aloud to the class, then posts it on the DQB, near the part of the model the question most relates to.
- Students who are listening should raise their hand if one of their questions relates to the question that was just read aloud.
- The first student selects the next student whose hand is raised.
- The second student reads their question, says why or how it relates, and posts it near the question it most relates to on the DQB.
- The student selects the next student, who may have a related question or a new question.
- We will continue until everyone has at least one question on the DQB.



Example format.

Alternate Activity

This activity asks students to consider tsunamis, other natural hazards, and engineering solutions related to both, but it may be difficult for students to develop questions for these categories simultaneously. However, as they will make sense of information regarding natural hazards in order to design or evaluate engineering solutions in this unit, it is important that they have opportunities to practice thinking about and developing questions for each category.

To support students in this, we suggest two options for building the DQB.

Option A - Single-pass DQB:

- Students focus on questions about tsunamis and other natural hazards.
- Then, students focus on questions about engineering solutions for those natural hazards.
- Finally, students bring all their questions to build the DQB.

Option B - Double-pass DQB:

- Students focus on questions about tsunamis and other natural hazards.
- Then, students build the first half of the DQB using the tsunami and natural hazards questions (first pass).

*Supporting Students in Engaging in Asking Questions and Defining Problems

Students share and organize their questions, look/listen for questions about the tsunami in Japan specifically, about tsunamis in general, and about other natural hazards occurring around the world. Similarly, students will likely generate questions about engineering solutions that involve detecting, warning people, and reducing damage caused by tsunamis and other natural hazards.

Look/listen for questions that are open-ended (e.g., why, how) and focus on either tsunamis specifically (e.g., How does the wave form? What happens when it reaches a community?) or other hazards more generally (e.g., Do all hazards happen that fast? How do people know when a hazard is about to impact their community?). If you notice close-ended questions, encourage the student to rephrase the question so that it cannot be answered with a simple yes or no.

- Students focus on questions about engineering solutions for tsunamis and other natural hazards.
- Finally, students build the second half of the DQB around the engineering solutions questions (second pass).

In either approach, the aim is to support students as they consider a complex phenomenon from multiple perspectives.

Build the DQB and organize questions into categories. Display **slide T**, which shows the suggested format for the DQB. As students share, questions will naturally start clustering into groups such as (but not limited to) science questions related to hazards' causes, locations, and frequency of occurrence, as well as engineering questions related to cost, available resources, and what solutions are already being used. Give students approximately 20 minutes to share and add questions to the DQB.*

When students finish sharing and placing questions on the DQB, have them look at the board for any additional organization that can be done. Once all the questions have been organized, ask students to consider the relationship between the "Science" and "Engineering" categories. Say, *If we look at our questions, what link do we notice between our science and engineering questions? How will figuring out our questions about the hazards (science) help us design (engineer) ways to protect people and places? How would you describe the connection between science and engineering?*

After a number of students share and agree on at least one connection between the science and engineering questions, draw a thick arrow connecting "Science" to "Engineering." Label the arrow with one or two agreed-upon connections. Explain that we will return to what this arrow represents in future lessons.

Additional Guidance

In the suggested DQB format, the thick arrow pointing from "Science" to "Engineering" represents the notion that ideas developed by scientists often inform designs developed by engineers. This is not meant to indicate a unidirectional path; engineering design can also drive the need to develop new or different understandings in science. As students begin exploring engineering solutions in greater depth in Lesson 5, they may revisit this arrow on the DQB.

Develop the unit question. Ask students to come up with an overarching question that could drive the whole unit. Say, *We first looked closely at one tsunami that devastated Japan in 2011, and we thought about solutions to help people who may experience a tsunami in the future. Then we began to think about other natural hazards—ones that may happen close to us, ones we have heard about, and ones our family members experienced. Based on our thinking around tsunamis, we began thinking about how we can detect when other hazards occur, how we can warn people about them, and what we can do to reduce the damage. Can anyone share an idea for a main question that puts all our questions together? What is a question that will help us capture this?*

Call upon several students to share their ideas. Listen for any question similar to *Where do natural hazards happen and how do we prepare for them?* and then repeat it aloud, asking the class if that sounds like a useful main question for the unit. When there is general agreement, write that question as the title at the top of the DQB, using the wording the class came up with.

Additional Guidance

The DQB can be referred to at any point during the unit. Often new ideas are considered and added to a classroom consensus model during the "putting the pieces together" lessons within a unit (Lessons 5 and 9 in this unit); these moments offer ideal opportunities for students to consider new questions and document them on the DQB. However, they may also articulate questions at other times (e.g., when completing individual Progress Trackers). To help recenter each unit as an experience driven by student questions, it's important to record any new questions on the DQB as they come up. Additionally, consider revisiting the DQB as the class reaches consensus in answering one or more questions. This helps students visualize the progress made in finding answers.

16. Brainstorm ideas for investigation and information we need. 10 MIN

Materials: science notebook, Ideas for Investigation and Information We Need poster, DQB, markers

Brainstorm ideas for investigation or additional information needed. Display **slide U**. Stay in a Scientists Circle to brainstorm the types of information or investigations that may help to answer the questions on the DQB. Say, *Let's look back at our questions and figure out what information we still need. Whether we are thinking about tsunamis or other hazards, what kinds of information do we need to better understand them and to evaluate technologies designed to reduce their impact?*

Arrange students into small groups of 3 or 4, and assign each group one category of questions on the DQB ("Science of tsunamis", "Science of other hazards", "Engineering solutions for tsunamis" or "Engineering solutions for other hazards"). Tell students to focus on their category of questions and generate ideas for the best data and information that would help answer them. For the next 2 minutes, have the groups discuss their ideas and record them on a new page in their notebooks.

Give each group about 1 minute to report out. Create a poster listing Ideas for Investigation and Information We Need that will remain public throughout the unit. Make sure all groups get to share at least one idea.

17. Navigation 2 MIN

Materials: DQB

Decide where to go next. Suggest to students that before we can tackle the engineering aspects of this unit, the part about how to prepare for a hazard, we need to know more about where they happen. Point to the questions on the DQB related to tsunami location or geography. Say, *We have a lot of great ideas for ways to investigate natural hazards so we can design ways to protect the people and communities they affect. Let's start with the questions we have about the tsunami. We seem to have questions about where they occur. Maybe we can use what we figure out about the locations of tsunamis to help us figure out more about other hazards.*

ADDITIONAL LESSON 1 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

The readings in this lesson encourage students to:

CCSS.ELA-LITERACY.RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.

Where do tsunamis happen and what causes them?

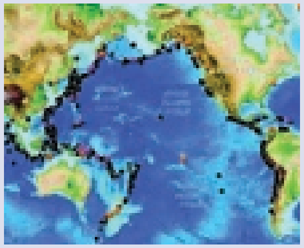
Previous Lesson

We read about and watched video clips of a 2011 tsunami triggered by an earthquake off the eastern coast of Japan, which caused devastating loss of life and structural damage. We developed and modeled several engineering ideas to detect tsunamis, provide advance warning of their approach, and reduce their impact. We thought about what made some engineering solutions more promising or challenging than others. We brainstormed related phenomena and generated a list of data and information we need to better understand where natural hazards occur and how we can prepare for them.

This Lesson

Investigation

2 DAYS



In this lesson, we investigate global patterns in tsunami occurrences and in particular, patterns related to the causes of tsunamis. We study historical data and figure out that most tsunamis are caused by earthquakes. Through analyzing data, we notice that only certain types of earthquakes cause most tsunamis: strong and shallow earthquakes along colliding plate boundaries. We establish a cause-and-effect relationship between those types of earthquakes and tsunami formation. We use this relationship to forecast locations that may be at risk for future tsunamis.

Next Lesson

We will analyze three different wave models to make sense of how an earthquake-driven tsunami forms and moves to shore. We will use different perspectives to understand various aspects of the phenomena, and then we will identify the benefits and limitations of each model.

Building Toward NGSS

MS-ESS3-2, MS-ETS1-1, MS-ETS1-2

What Students Will Do

2.A Use graphical displays (maps) of large data sets to identify spatial and temporal patterns in historical tsunami occurrence.

2.B Use digital tools, including maps and graphs, to analyze large data sets to identify cause-and-effect relationships between characteristics of related geologic forces and resulting tsunamis.

2.C Integrate quantitative and qualitative scientific information to connect cause-and-effect relationships to predict communities at risk for future tsunami occurrence.

What Students Will Figure Out

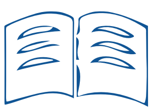
- Tsunamis form as a result of earthquakes, volcanic eruptions, and landslides.
- Not all earthquakes lead to tsunamis; stronger, shallow earthquakes tend to be related to tsunami formation.
- Almost all tsunamis occur along plate boundaries where the plates are colliding.
- Data about where tsunamis have occurred in the past help to forecast where they might happen in the future.

Lesson 2 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**NAVIGATION AND PREDICTION** Revisit the Ideas for Data and Information We Need poster and make predictions about what historical tsunami data might show.	A-B	colored pencil, *Tsunami Predictions*, Ideas for Data and Information We Need poster
2	12 min	**INVESTIGATING TSUNAMI PATTERNS** Using a map, analyze the occurrences and causes of historical tsunamis around the globe. Talk about this in a Building Understandings Discussion.	C-E	*Where do tsunamis happen?* (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer, projector, tape
3	10 min	**COMPARE EARTHQUAKE DATA TO TSUNAMI DATA** Using a swipe map, compare data sets on all recent earthquakes and historical tsunami-generating earthquakes.	F-G	*Comparing All Earthquakes to Earthquakes that Cause Tsunamis* (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer, projector, chart paper, markers
4	10 min	**BUILD CONSENSUS ABOUT PATTERNS** Conduct a Consensus Discussion about patterns in tsunami occurrence and earthquake location and how these might relate to tsunami prediction. Distinguish between correlation and causation.	H	*Tsunami Predictions*, *Where do tsunamis happen?*, *Comparing All Earthquakes to Earthquakes that Cause Tsunamis* (See the **Online Resources Guide** for a link to these items. **www.coreknowledge.org/ckscionline-resources**), computer, projector
5	3 min	**EXIT TICKET** Consider why certain earthquakes cause tsunamis but others do not.	I	index card
				End of day 1
6	3 min	**SHARE IDEAS CONNECTING EARTHQUAKES AND TSUNAMIS** Share initial ideas about how some earthquakes, but not all, are related to tsunamis.	I	index cards from day 1
7	15 min	**EXAMINE TSUNAMIS MORE CLOSELY** Investigate the tsunami data more closely to further develop cause-and-effect relationships between characteristics of earthquakes and tsunami formation.	J	*Connecting Earthquakes and Tsunamis*, *Tuva Graphing Instructions*, www.openscied.org/tsunami-data-set, computer
8	12 min	**SHARE CONNECTIONS BETWEEN EARTHQUAKES AND TSUNAMIS** Come to agreement about what types of earthquakes cause tsunamis.	K	*Where do tsunamis happen?*, *Comparing All Earthquakes to Earthquakes that Cause Tsunamis*, *Connecting Earthquakes and Tsunamis*, chart paper, markers, large sticky notes

Part	Duration	Summary	Slide	Materials
9	5 min	**UPDATE PREDICTIONS** Use cause and effect to refine predictions of where tsunamis are likely to happen.	K	*Tsunami Predictions*, chart paper, markers
10	8 min	**TRACK SCIENCE AND ENGINEERING THINKING** Track the science ideas figured out so far, and consider how engineers can apply them to protect communities.	L	Science Ideas chart
11	2 min	**PROBLEMATIZE THE CONNECTION TO EARTHQUAKES** Use the cause-and-effect relationship to problematize how an earthquake can cause a tsunami to form.	M	
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 2, students are ready to read Student Reader Collection 1 and then respond to the writing exercise.		Student Reader Collection 1: *Types and Frequencies of Hazards*

Lesson 2 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • colored pencil • *Tsunami Predictions* • *Where do tsunamis happen?* • *Comparing All Earthquakes to Earthquakes that Cause Tsunamis* • index card • index cards from day 1 • *Connecting Earthquakes and Tsunamis* • *Tuva Graphing Instructions*	• www.openscied.org/tsunami-data-set • computer	• Ideas for Data and Information We Need poster • Where do tsunamis happen? (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • computer • projector • tape • Comparing All Earthquakes to Earthquakes that Cause Tsunamis (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • chart paper • markers • large sticky notes • Science Ideas chart

Materials preparation (20 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Add an image of the Driving Question Board (DQB) and the Ideas for Data and Information We Need poster onto **slide A**.

Decide if you will use a whiteboard or chart paper for the Tsunami Chain of Events. This will stay visible for the duration of the unit. See *How to Build the Tsunami Chain of Events Poster* for information about how this will build over the unit.

Prepare other charts:

- Science Ideas chart
- Optional: Patterns We Notice chart

Test the following map and graph links to ensure that computers or tablets can load them:

- day 1: StoryMap viewer and Swipe map. (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)
- day 2: Tuva graphs. (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)

Watch the following videos to orient to using StoryMaps and TuvaLabs interface:

- Orientation to StoryMaps. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- Orientation to Tuva Interface. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

This is a map- and graph-intensive lesson that introduces students to sophisticated data analysis, mathematics, and computational thinking practices. The lesson is heavily scaffolded, as some ideas are new. Consider removing scaffolds if your students are ready for an added challenge.

Decide ahead of time whether to display any or all of the maps and graphs to the whole class or within small groups of students. The lesson is written to have the maps on day 1 displayed to the whole class and the graphs on day 2 in small groups. Change this configuration as needed for your classroom. Small-group work is best done with 2-3 students per computer or working together with their own devices. If computers are not available, or the maps or graphs will not load, printed versions have been provided in the student edition.

Be sure you have materials ready to add *magnitude*, *correlation*, *causation*, and *epicenter* to your Word Wall. These words will be familiar if students have done the *Everest Unit*. However, if they have not done that unit, do not post these words on the wall until after your class has developed a shared understanding of their meaning.

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

This lesson supports students in noticing an overall global pattern in where tsunamis occur (using historical data) and also in considering how their occurrence is connected to certain geologic processes. Strong, shallow earthquakes are the primary precipitating geologic force that causes tsunamis to form. Tsunamis can also form from volcanic eruptions, landslides, rare meteorological events, and a combination of these, but the vast majority result from strong underwater earthquakes along colliding plate boundaries, such as the Pacific Rim.

It is important for students to notice a new pattern from each map or graph to drill into a cause-and-effect relationship:

- The first map supports students in identifying the overall historical, global pattern in where tsunamis occur and the primary geologic force that causes them (earthquakes).
- The second map allows students to compare the location of all recent earthquakes to tsunami-generating earthquakes. This enables them to determine that while a relationship exists between earthquakes and tsunamis (correlation), only certain types of earthquakes cause tsunamis to form.
- The third set of graphs allows students to investigate different characteristics of earthquakes that cause tsunamis. From this data, they can glean that shallow (near the surface), stronger (higher-magnitude) earthquakes along colliding plate boundaries cause tsunamis. Earthquakes without these characteristics typically do not cause tsunamis.

This lesson is intentionally tied to students' work in the *Everest Unit*, drawing closely upon ideas related to earthquake patterns. Because earthquakes are the dominant cause of tsunamis (the related geologic force), students can use this information to establish a cause-and-effect relationship between certain types of earthquakes and tsunami formation (and rule out types of earthquakes that do not form tsunamis). This is used to better forecast areas at risk.

Where We Are NOT Going

If students have not figured out the various ways plates move, you need to provide additional support, as plate movement is the primary cause of tsunamis and thus knowing about it is necessary to forecast locations at risk. Specifically, students need to know that Earth's surface is made of plates that move in different directions, causing earthquakes that shift the land or ocean floor.

Also, for this lesson, students should focus on how patterns in data can be used to establish a cause-and-effect relationship between certain types of earthquakes and tsunami formation. Students will build on this to model how these earthquake characteristics lead to tsunami formation in Lesson 3. Because of this, avoid giving away any ideas related to wave formation by the release of energy during an earthquake. Across Lessons 2 and 3, students will figure out that higher-magnitude earthquakes release more energy than lower-magnitude earthquakes. A tsunami wave forms when energy of sufficient magnitude is transferred from the ocean floor to the water above it. The depth of the earthquake is also important because the shift in the crust displaces the water to form a tsunami. Deep earthquakes do not shift the ocean floor like shallow earthquakes do. However, both causal mechanisms will be more fully explored in Lesson 3, so it is not necessary for students to explain this in Lesson 2.

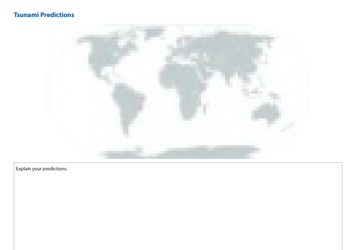
1. Navigation and Prediction

10 MIN

Materials: science notebook, colored pencil, *Tsunami Predictions*, Ideas for Data and Information We Need poster

Motivate the need to explore tsunami data. Display **slide A**. Revisit the Ideas for Data and Information We Need poster from Lesson 1 and ask a few students to share their thinking for items they added to the list. It will likely include students' ideas related to these things:

- where tsunamis happen in the world
- how earthquakes are related to tsunamis
- places that have experienced a tsunami
- why tsunamis happen in some places but not others



Use these ideas to motivate the need to look at tsunami data. Say, *Last time we were wondering where tsunamis happen in the world. Scientists have been tracking tsunamis for a while, and we are going to look at that data today. So our question is, "Where do tsunamis happen and what causes them?"*

Make predictions. Display **slide B**. Say, *Before we look at any data, what ideas do you have about where tsunamis happen? Why do you think they happen there?** Have students turn and talk to a neighbor about the slide's questions. As they discuss their initial ideas, distribute *Tsunami Predictions* to each student and have them tape it into their science notebook. Give them a moment to color in places on their map where they think tsunamis occur and explain why they made their predictions in the box below the map. Encourage a few students to share their initial ideas with the class.

Suggested prompt	Sample student responses	Follow-up questions
Where do you think tsunamis happen?	*where earthquakes happen* *along the coasts* *in the ocean*	*Why do you think so?* *Can you say more about why you think they happen along the coast/in the ocean?*

***Attending to Equity**

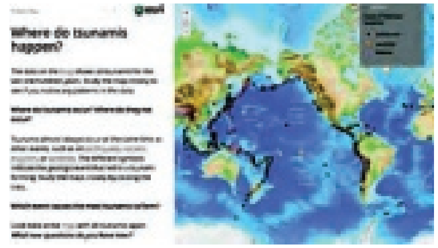
Supporting Emerging Multilingual Students: Before students engage in whole-class discussion, it can be helpful to provide an opportunity to work in pairs, triads, or small groups on ideas related to their reasoning. These smaller group structures can be especially beneficial for emerging multilingual students as a chance to engage in sensemaking with their peers and a space to use their linguistic and nonlinguistic resources to express their ideas (and learn from other students' uses of these resources).

2. Investigating Tsunami Patterns

12 MIN

Materials: science notebook, *Where do tsunamis happen? StoryMap* (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer, projector, tape

Analyze patterns in global tsunami data. Say, *We just made some predictions about where we think tsunamis happen. Let's analyze some data from past tsunamis and see if it can support our predictions. Why would looking at historical data* *help us figure out if our predictions are on track?* Ask several students to share their ideas. Distribute a copy of *Where do tsunamis happen?* to each student. Display **slide C** to show them how to add it to their science notebook.



Introduce the first data set. Display **slide D** and project the first map. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Orient students to the map and have them consider the questions on Part 1 of the handout. Instruct them to view and analyze the map title, text, and legend, and explain what each symbol represents. Ask, *Why would it be important to collect this type of data?* Let a few students respond, and listen for ideas about the importance of knowing where these natural hazards have happened, what caused them, and how they have affected people.

Additional Guidance

Maps are tools used to display data to reveal important spatial patterns. This first map provides an overall indication of where tsunamis happen (and where they don't) and information about related causal geologic forces. Consider students' familiarity with map reading and orient them to the map so they can interpret it appropriately. Use **slide D** to help scaffold this. The map denotes different causes for tsunamis with colors and shapes, allowing students to access the categories of data in different formats. Here are some helpful prompts:

- *What is the title of this map?*
- *What do the symbols mean?*
- *How would you describe the pattern for where most tsunamis occur?*
- *What about where they do not occur? Could we describe that too?*

As students work with the maps in this lesson, allow them to move closer to view different features or provide them with the links to study the maps more closely on their own.

Examine spatial patterns in tsunami occurrence. Give students time to read the text with the map and study the patterns closely. Ask them to record any spatial patterns they observe in Part 2 of their handout, by circling or lightly sketching the areas where tsunamis have occurred. They should also write any patterns they notice in the box.*

Interpret the relationship between geologic forces and tsunamis. The data reveal three primary geologic forces that lead to tsunamis: earthquakes, volcanic eruptions, and landslides. Navigate to each pre-filtered map and have students study the patterns found for each of these forces that can lead to a tsunami forming. Then ask them to rank the forces by which ones cause the most to least tsunamis.

Discuss ideas about the spatial patterns and causes of tsunamis. Display **slide E**. Lead a short Building Understandings Discussion about why these data are important.*

*Supporting Students in Three-Dimensional Learning

Encourage students to use the crosscutting concept of patterns to analyze different data sets about the historical occurrences of a natural hazard. The maps include historical data of tsunamis caused by earthquakes, volcanic eruptions, or landslides. Students can change the data represented on the map by toggling between the different types of geologic forces. Students can identify spatial patterns in tsunamis as well as patterns in the frequency of tsunami occurrence by related geologic force.

*Strategies for This Building Understandings Discussion

A Building Understandings Discussion is useful following an investigation because the purpose is to focus students on drawing conclusions based on evidence. Your role is to invite students to share conclusions and claims and to push them to support those with evidence. Students can disagree and the class does not need to reach consensus on all ideas shared, as areas of disagreement can motivate future investigations. The class may reach consensus that earthquakes cause the most tsunamis. Here are examples of helpful prompts during this kind of discussion:

- *What can we conclude?*
- *How did you arrive at that conclusion?*
- *What's your evidence?*

Suggested prompts	Sample student responses
What patterns did you notice about where tsunamis occurred?	*I noticed there were a lot along the edge of the Pacific Ocean.* *This looks similar to our earthquake data from the Everest Unit.*
Where do they not occur?	*on land* *in parts of the ocean*
From the data, what causes the most tsunamis? How do you know?	*Earthquakes, because there are way more circles on the map than triangles and diamonds.*
How does investigating the causes of tsunamis help us understand where tsunamis happen?	*If we know what causes a tsunami to start, then we can find out where that happens to know where tsunamis happen.*
After looking at this data, do you have any new questions?	*Why are there so many tsunamis along the Pacific Ocean?* *Do they only happen in oceans?* *Do all earthquakes cause tsunamis?*

Assessment Opportunity

Building towards: 2.A Use graphical displays of large data sets to identify spatial and temporal patterns in historical tsunami occurrence.

What to look for/listen for: Students should notice that the locations of tsunamis are similar to the locations of earthquakes shown in the *Everest Unit*. They all occur in oceans or other large bodies of water, but not all parts of the ocean have tsunamis. Tsunamis occur along some coasts and are most frequently caused by earthquakes.

What to do: Some students may struggle with interpreting spatial patterns of historical tsunami occurrence or may be confused by symbols on the map. Use the sketch on *Where do tsunamis happen?* to help them record the spatial pattern they notice. Ask, *What parts of the world have had tsunamis in the past?* Encourage them to point to parts of the map that provide evidence for their thinking and then sketch that onto their handout. Support their interpretation of the symbols by saying, *And what did that circle (triangle, square) on the map represent again?* This will support all students in developing a shared understanding of the data representation.

Also challenge students by asking, *Where do we not see tsunamis?* This is an important perspective to help develop their forecasting ideas by identifying places (e.g., land and parts of the oceans) that do not have tsunamis.

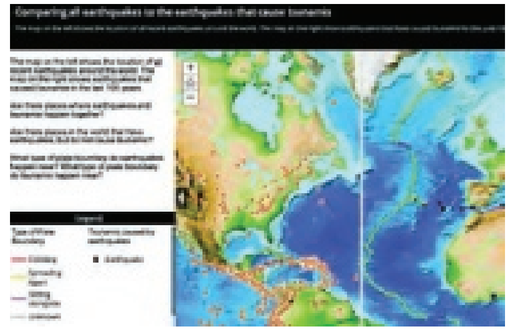
Motivate the transition to the next map by saying, *We noticed that most tsunamis are caused by earthquakes. And we are wondering if all earthquakes cause tsunamis. We've seen earthquake data before in the Everest Unit. Let's look at that data again and compare it to where tsunamis happen.*

3. Compare earthquake data to tsunami data.

10 MIN

Materials: *Comparing All Earthquakes to Earthquakes that Cause Tsunamis* weblink (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer, projector, chart paper, markers

Compare earthquake data sets. Display **slide F** and prepare students to view the next set of data. Project the swipe map. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Give students a moment to orient to the new map, including the text and legend. This map provides data on all earthquakes around the world for the last few years (left) and all tsunami-generating earthquakes for the last 100 years (right). Swipe back and forth to notice where the two data sets do and do not overlap.



As the class explores the swipe map, distribute *Comparing All Earthquakes to Earthquakes that Cause Tsunamis* to each student, and have them capture and describe 1-2 patterns they notice using their handout. Once they have done this, ask whether they see any difference between all earthquakes and tsunami-generating earthquakes in terms of the type of nearby plate boundary. They should record these observations on the handout as well.

Additional Guidance

The swipe map can be projected for the whole class or explored individually or in small groups if computers are available. A swipe map allows students to compare two side-by-side data sets in order to notice similarities and differences. This swipe map includes earthquakes around the world in the last few years along with earthquakes related specifically to tsunami events in the last 100 years. The purpose of this comparison is to either notice or confirm these facts:

- There are far fewer tsunamis than earthquakes, so not all earthquakes cause tsunamis.
- Some areas where earthquakes cause tsunamis match where a lot of earthquakes happen, such as the Pacific Rim.
- There are also places, such as the mid-ocean ridges, that have many earthquakes but do not have tsunamis.
- Earthquakes that cause tsunamis usually occur on plate boundaries that are colliding under the oceans; other earthquakes that do not cause tsunamis happen along spreading boundaries and on land.

These observations will motivate why it is important to learn more about the types of earthquakes that cause tsunamis, which happens on day 2.

If this is the first time that students are seeing and/or using a swipe map, orient them to how it functions by demonstrating the data on each side and then using the “swipe bar” to compare. It might be helpful to pick an earthquake pattern from the left side (such as the small earthquakes along the mid-Atlantic ridge) and compare it to the earthquakes related to tsunamis on the right side.

Share patterns in the data. Display **slide G**. Ask students to share patterns they noticed when comparing the earthquake and tsunami data. Optionally, chart their ideas on a whiteboard or chart paper titled “Patterns We Notice.”

***Supporting Students in Engaging in Using Mathematics and Computational Thinking**

The digital tools (maps, graphs) in the large data sets allow students to look for patterns and trends between earthquakes and tsunamis, and in particular, spatial and linear relationships. To support development of this practice with digital tools, use prompts like these:

- *As ____ changes, does ____ change?*
- *Are there places where ____ occur together? Are there places where they don’t occur together?*
- *What does the data show us about ____?*
- *What evidence from the data supports your idea?*

Suggested prompts	Sample student responses
Are there places in the world where earthquakes and tsunamis occur together?	*the Pacific Ocean* *the Mediterranean*
Are there places in the world that have earthquakes but no tsunamis?	*the Atlantic Ocean, except for maybe near Europe* *The earthquakes that happen on land.*
Did you notice anything about where tsunamis occur and the type of plate boundary near them?	*There were lots of tsunamis associated with earthquakes that occurred on colliding plate boundaries, but not with earthquakes that occurred on boundaries where plates are moving away from each other*

Here are examples of patterns that might emerge from this discussion:

- Lots of tsunamis happen along the Pacific Ocean where a lot of earthquakes happen, but not in the Atlantic even though there are lots of earthquakes there.
- There are earthquakes in other parts of the ocean, like the mid-Atlantic ridge, but those earthquakes are not related to tsunamis (or tsunamis do not happen there).
- There are fewer tsunamis than there are earthquakes around the world.
- Earthquakes that cause tsunamis seem to occur on colliding boundaries, but other earthquakes are on all boundary types.

4. Build consensus about patterns.

10 MIN

Materials: science notebook, *Tsunami Predictions*, *Where do tsunamis happen?*, *Comparing All Earthquakes to Earthquakes that Cause Tsunamis* weblink (See the **Online Resources Guide** for links to these item. **www.coreknowledge.org/cksci-online-resources**), computer, projector

Build consensus about the relationship between historical tsunami occurrence, earthquake location, and tsunami prediction.* Display **slide H**. Remind students of the question we are figuring out, "Where do tsunamis happen and what causes them?" Conduct a Consensus Discussion, eliciting students' observations of the patterns they have noticed and their ideas about areas at risk of tsunamis.

At this point, students have three types of evidence to consider as they build consensus:

- their initial predictions of where tsunamis occur, based on prior understandings of where earthquakes occur (*Tsunami Predictions*)
- the historical data of tsunamis and their causes (earthquakes, volcanic eruptions, and landslides; *Where do tsunamis happen?*)
- the comparison between all global earthquake data and tsunami-generating earthquake data (*Comparing All Earthquakes to Earthquakes that Cause Tsunamis*)

***Supporting Students in Three-Dimensional Learning**

Assessment opportunities for three-dimensional learning on day 1 of this lesson are focused on students analyzing and interpreting data and using mathematics and computational thinking to make sense of patterns in historical tsunami occurrence, while also building the case for a cause-and-effect relationships between certain types of earthquakes and tsunami formation, which will be developed on day 2.

Suggested prompts	Sample student responses	Follow-up questions
Based on the data we analyzed, what can we say about where tsunamis happen in the world?	*They happen in some of the same places where earthquakes (and volcanoes, landslides) happen.* *They happen in the oceans.*	*And where did we see evidence of that?*
What can we say about what causes tsunamis?	*Earthquakes, but sometimes volcanoes or landslides.*	
So if earthquakes cause tsunamis, then when an earthquake happens, can we predict a tsunami will happen?	*Maybe if it is the type of earthquake that causes tsunamis.* *Only some earthquakes cause tsunamis.* *No, because there are lots of places that have earthquakes but no tsunamis.*	
What parts of the world are most at risk for tsunamis?	*Along the coast of the Pacific Ocean and also part of the Indian Ocean.* *also, between Africa and Europe.*	*Can we narrow down parts of the coasts of the Pacific Ocean that have more or less tsunami risk?*
Are there places that are not really at risk for a tsunami?	*Most places along the Atlantic Ocean are not at risk.*	*And what evidence from the map supports that?*
So why do we think more tsunamis happen in ________ (fill in part of the world) but not in these other places?	*Maybe because there are more earthquakes there.* *Maybe there is something about the earthquakes there connected to tsunamis.*	

Key Ideas

Purpose: To motivate the need to understand the cause-and-effect relationships between earthquakes and tsunamis and where tsunamis happen and what causes them.

Look for/listen for:

- related incidences of earthquakes and tsunamis, but not all earthquakes cause tsunamis
- uncertainty about why some earthquakes are related to tsunamis while others are not
- wonderings about characteristics of earthquakes that can cause tsunamis
- ideas about how understanding more about earthquakes can help to understand why some communities are more at risk than others

*Supporting Students in Engaging in Analyzing and Interpreting Data

Although it is not the focal element of this practice for this lesson, this is a good opportunity to distinguish between causal and correlational relationships in data. At this point, students know that earthquakes and tsunamis are correlated and some earthquakes seem to cause tsunamis, but they have not figured out the entire causal relationship. This happens on day 2 when they explore the data more fully.

*Supporting Students in Developing and Using Cause and Effect

This is a good place to highlight that correlation does not always mean causation. In a real sense, just because an earthquake happens does not mean a tsunami will form. Ask students, *If an earthquake happens anywhere in the world, can we predict whether a tsunami will form? What evidence can support our ideas?*

Assessment Opportunity

Building towards: 2.B Use maps (digital tools) to analyze large data sets to identify cause-and-effect relationships between related geologic forces and resulting tsunamis.

What to look for/listen for:

- On the first map, students gather evidence that tsunamis occur in only certain parts of the world, in the oceans, and are mostly caused by earthquakes.
- On the second swipe map, students compare recent earthquake data to earthquakes historically related to tsunamis. Interpretations should include the idea that tsunamis occur in the same place as some earthquakes, but earthquakes also occur in places where tsunamis do not.

These observed patterns motivate looking more closely at earthquake types to understand where tsunamis occur and why. On day 2, students will use a series of graphs about earthquake characteristics to determine which specific kinds of earthquakes are related to (and might cause) tsunamis.

What to do: If students struggle with the swipe map, point them to specific familiar locations (e.g., mid-Atlantic ridge, west coast of South America) and ask if earthquakes occur there or not, and also if tsunamis occur there or not. This will help them notice that not all earthquakes cause tsunamis. This key idea motivates the next investigation of the earthquakes that *do* cause tsunamis.

Revisit how we talk about apparent relationships between things or events.** Remind students of previous words they earned in the *Everest Unit*: *correlation*, or when two things seem to be related to each other, and *causation*, when one thing causes another thing to happen. Place these words on the Word Wall if they are not there.

At this point, students have figured out that earthquakes and tsunamis are related, but they must keep in mind that correlation does not always mean causation. Although not all earthquakes are associated with tsunamis, it seems that some are. The next step is to investigate the causal link between earthquakes and tsunamis. Similarly, tsunamis seem to occur on colliding plate boundaries, but we have not established a causal relationship, so this is also only a correlation.

Additional Guidance

If you have not taught the *Everest Unit*, you might need to introduce the word *correlation* at this point. Tell students that when two things or events seem to be related, such as earthquakes and tsunamis, we call that correlation. Emphasize that this does not necessarily mean that one causes the other to happen, but rather that there is some relationship worth investigating further.

5. Exit Ticket

3 MIN

Materials: index card

Narrow down ideas about the earthquakes that cause tsunamis. Display **slide I** and read its questions aloud: *What do you think is unique or special about the earthquakes that cause tsunamis? What data would you need to see if you are right?* Give an index card to each student and have them write their initial ideas in response to these questions.

Gather the exit tickets for the next class to formatively assess students' current thinking. Students will share their thinking at the beginning of day 2.

End of day 1

6. Share ideas connecting earthquakes and tsunamis. 3 MIN

Materials: index cards from day 1

Share ideas from exit tickets. Display **slide I** again. Ask students to share with the class their initial ideas for why some earthquakes cause tsunamis, but not all earthquakes cause tsunamis. Here are some potential student responses:

- *Only earthquakes occurring underwater cause tsunamis, so earthquakes on land can't.*
- *Only earthquakes on a colliding boundary can cause tsunamis.*
- *Earthquakes have to be really big or strong or have high magnitude to cause a tsunami.*
- *The earthquake has to move the ground a lot to make the water move.*

Additional Guidance

If students have just completed the *Everest Unit*, they have ideas related to plate boundary types, the strength (magnitude*) of earthquakes, and possibly the depth of earthquakes. If not, those ideas will be developed using the series of graphs in the next activity.

If magnitude comes up at this point, remind students that magnitude represents a measure of how strong (or intense) an earthquake is, or how much energy is released in an earthquake. Add *magnitude* to the Word Wall if it is not there already. If it does not come up, wait and add it in the next step when students start working with the graphs.

***Attending to Equity**

Supporting Emergent Multilingual Students: Cognates are words that are similar in both spelling and meaning in different languages. Many science vocabulary terms have cognates across romance languages (e.g., *magnitude* in English = *magnitud* in Spanish). Using cognates, teachers can support emerging multilingual students in making connections between new science vocabulary and their native language(s). This can reduce the vocabulary overload that they may experience in science. Teachers can display cognates on the Word Wall alongside their corresponding vocabulary terms or include cognates in writing using parentheticals.

7. Examine tsunamis more closely. 15 MIN

Materials: *Connecting Earthquakes and Tsunamis*, *Tuva Graphing Instructions* (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer

Prepare to analyze data. Set the stage for analyzing additional tsunami data by saying, *We are trying to figure out why some earthquakes cause tsunamis while others do not. So, we are going to dig into some additional data using new tools to see if we can figure this out.* Give each student a copy of *Connecting Earthquakes and Tsunamis*. Display **slide J** and have students gather in groups of 2-3 per computer to begin their investigation.*

Students will explore a Tuva dataset of tsunamis. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) that displays tsunami wave height data by different variables. Specifically, students will look for patterns in earthquakes' strength (magnitude) and depth to see how they influence the formation and wave height of a tsunami.

The handout, *Connecting Earthquakes and Tsunamis*, has scaffolded questions to guide student construction and analysis of the graphs, particularly focused on choosing independent and dependent variables, and then to guide observation and interpretation of the results. It might be helpful to read Step 1's instructions aloud as a whole class so students are clear about the analysis task. Detailed instructions with screenshots from the Tuva dataset are provided in *Tuva Graphing Instructions*.

Additional Guidance

Students worked with independent and dependent variables in both the *Cup Design Unit* and *Storms Unit* units, so this should not be their first time considering which variable is independent or on the *x*-axis and which is dependent or on the *y*-axis. Nevertheless, the handout provides scaffolding to help create the graphs. For students who already understand independent and dependent variables, consider removing the scaffolds. For students who might struggle with this work, consider providing two colors of highlighters or pencils so they can circle or highlight the *x*-axis variable in one color and the *y*-axis variable in the other as part of Step 1 on the handout, as illustrated below.

How does ______ (independent variable on *x*-axis) affect _________ (dependent variable on *y*-axis)?

- How does the magnitude (strength) of an earthquake affect tsunami formation?
- How does the depth (how near or far from the surface) of an earthquake affect tsunami formation?

It might also be helpful to model constructing and interpreting one graph together as a class.

As students work with the graphs, it might also be important to point out the amount of missing data and/or the use of filtered data to exclude outliers. Tsunami wave height is used in this activity because it is the most complete data set.

As students work through the set of graphs and their handout, encourage them through prompts and questions to describe the patterns they notice and their interpretations of these patterns. This will help develop their understanding of the cause-and-effect relationship between certain types of earthquake and tsunamis.* Here are example prompts:

- *As magnitude increases, what happens to wave height? (Does it increase? Decrease? Stay the same?)*
- *As depth is shallower or nearer to the surface (or deeper), what happens to wave height?*
- *What can we say about earthquakes that cause higher wave heights?*
- *What can we say about earthquakes that cause smaller wave heights?*
- *We know that only some kinds of earthquakes cause tsunamis. Can we use this data to say more about which kinds of earthquakes those are?*

***Attending to Equity**

Supporting Emergent Multilingual Students: Depending on the goals for an aspect of a lesson, it is helpful to intentionally group emerging multilingual students with certain peers. Sometimes this could be peers who know the same languages they do; other times it could be peers whose English language development is slightly more advanced. It is important that this grouping be thoughtful and varied during the unit so students benefit from working with different peers.

***Supporting Students in Developing and Using Patterns**

To support students in using patterns to establish cause-and-effect relationships, consider these prompts:

- What patterns do you observe in the data presented in the graph?
- Does the pattern in the data support the conclusion that higher wave heights are caused by higher magnitudes ? Why or why not?
- Are there ways you can use mathematics to summarize the data that might help you see patterns in the data more clearly, to determine whether higher magnitudes cause higher wave heights?

These and other useful prompts can be found online. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources)**

Alternate Activity

Tuva allows students to annotate graphs digitally and/or download screenshots of the graphs they make. Alternatively, the handout provides space to quickly sketch the graph pattern (it does not need to be perfect) and then annotate it. Based on your classroom technology, either annotating digitally or on the handout is acceptable. What matters is that either method provides a way for students to annotate their observations and then make sense of them to interpret the data.

8. Share connections between earthquakes and tsunamis.

12 MIN

Materials: science notebook, *Where do tsunamis happen?*, *Comparing All Earthquakes to Earthquakes that Cause Tsunamis*, *Connecting Earthquakes and Tsunamis*, chart paper, markers, large sticky notes

Share noticings and patterns from the graph investigation.* Title a piece of chart paper or a whiteboard “Tsunami Chain of Events.” Keep **slide K** projected. Use this Consensus Discussion share out to develop a cause-and-effect diagram to explain the relationship between geologic forces (earthquakes) and the formation of tsunamis.* This will help students use evidence from their data analysis to refine their predictions for where tsunamis happen.

***Attending to Equity**

Supporting Universal Design for Learning: It might be helpful to continue to project the graphs and maps for the class during this discussion so students can walk up to the media and point out patterns in the data. This allows students to *express* their noticings through physical action, and can also help to highlight the patterns and critical features through *representation*.

Additional Guidance

The Tsunami Chain of Events poster will be used throughout the unit, so make sure it is visible to students for the remaining lessons. Use large sticky notes to track cause-and-effect relationships for this lesson and here on, moving them around as needed.

Connect tsunamis and earthquake strength. Ask, *When you investigated how strong the earthquake is and the maximum wave height, did you notice any pattern? Does the strength of the earthquake matter?* Ask students to share what they noticed.

Suggested prompt	Sample student responses
What can we say about how strong (what magnitude) an earthquake is related to a tsunami wave?	*Wave height is usually smaller when the magnitude is smaller.* *The really big earthquakes have higher and higher wave heights.*

Record patterns onto the Tsunami Chain of Events poster to show a cause-and-effect relationship between magnitude and high wave height.

Connect tsunamis and earthquake depth. Similarly, have students share their noticings about the depth of the earthquake and the wave height that results. Add their ideas to the poster.

Suggested prompt	Sample student responses
What does it mean for an earthquake to be at 0 km or 70 km in depth?	*It means where it happens in the crust.* *How deep into the crust.* *Where the epicenter of the earthquake happens.*

***Supporting Students in Developing and Using Cause and Effect**

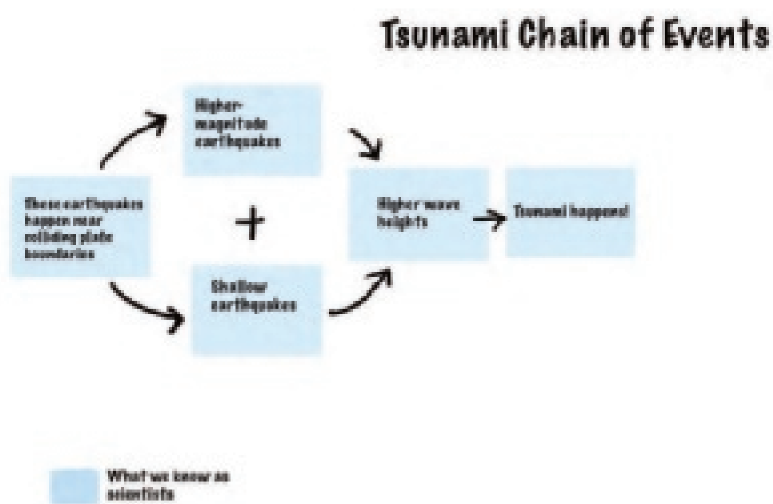
The class begins building a cause-and-effect diagram in service of identifying locations and causes of tsunamis in order to refine their predictions and improve their forecasting of which communities are at risk for tsunami damage. This causal chain will continue to build throughout the unit as more science and engineering ideas are integrated.

Suggested prompts	Sample student responses
Is there any relationship between how deep an earthquake happens in Earth's crust and the tsunami that forms as a result?	*It looks like most tsunamis happen with earthquakes that are 70 km or less.* *And wave heights get a little higher if the earthquake is closer to 0 km.*
So what can we say about shallow earthquakes (earthquakes that happen near the surface of the crust) versus deeper earthquakes?	*The shallower ones are more likely to be related to tsunamis with higher wave height.*
Why do you think shallow earthquakes cause bigger waves?	*Maybe because the earthquake is closer to the water and so it moves more?*

Additional Guidance

Some students may struggle with "shallow" or "near the surface" versus "deep," thinking these refer to the depth of the water instead of the depth inside Earth's crust. Prompt students to consider ideas built in the *Everest Unit* around the plates and depth of the crust. The reason earthquake depth is important for tsunami formation is that deeper earthquakes (>70 km) do not cause as much shift in the ocean floor; shallow earthquakes cause more movement in the ocean floor and are thus more likely to generate tsunamis. The important idea to develop here is that earthquakes closer to the surface of the crust are related to tsunamis. Students will build out the mechanism for this relationship in Lesson 3.

Combine factors and modify the diagram. Say, *OK, we know that strong earthquakes cause tsunamis and shallow earthquakes cause tsunamis. What if you have a strong, shallow earthquake? What do you think would happen?* Students are likely to respond that the tsunami wave height would be even bigger. Say, *OK, let's put these ideas together and modify our diagram.* Add a plus sign between the causes and combine the effects into one sticky note for higher wave heights.



9. Update predictions.

5 MIN

Materials: science notebook, *Tsunami Predictions*, chart paper, markers

Summarize the causal relationships we figured out so far. Ask students, *OK, now that we have seen all this data, what can we say about what causes tsunamis to happen?* Refer to **slide K** again. Listen for these ideas:

- Strong or high-magnitude earthquakes cause them (because as strength or magnitude increases, wave height increases).
- Shallow earthquakes cause them (because as they get shallower, wave height increases).
- Earthquakes need to be in the ocean or underwater to cause them (because there has to be water to form a wave—earthquakes on land won't make a tsunami).
- Earthquakes near colliding plate boundaries seem to cause them more than earthquakes at other plate boundaries (because this is where we see that the most tsunamis have occurred).

Then ask, *What can we say about earthquakes that won't cause a tsunami? Give us your reasoning*. Listen for these ideas:

- weak or low-magnitude earthquakes (because the wave heights are small or nothing)
- really deep earthquakes (because the wave heights are small or nothing)
- earthquakes on spreading boundaries (because they don't usually happen there)

Use cause and effect to refine predictions. Say, *Now that we understand where tsunamis happen and what causes them, let's use this information to revisit our initial predictions and maybe refine our thinking.*

Ask students to use a different colored pencil to revise the map they made their predictions on *Tsunami Predictions* to include what they have now figured out about where tsunamis occur. Then, have students write a quick explanation for why they made changes to their initial predictions.

Assessment Opportunity

Building towards: 2.C Integrate quantitative and qualitative scientific information to connect cause-and-effect relationships to predict communities at risk for future tsunami occurrence.

What to look for/listen for:

- ideas about a causal relationship between shallow, strong earthquakes along colliding boundaries and the formation of tsunamis (and specifically, tsunami wave height increasing)
- predictions that communities in regions where these types of earthquakes occur are most at risk, and that communities in regions that don't have these earthquakes are not likely to experience tsunamis

What to do: Students' revised predictions are a good indicator of how well they have incorporated the new ideas about cause-and-effect relationships between earthquakes and tsunamis. If students struggle with updating predictions, ask these questions:

- *Are communities along the Atlantic coast at risk for tsunamis? Why not? (Tsunamis haven't happened there; they don't have high-magnitude earthquakes; it is a spreading boundary in the middle of the Atlantic.)*

- *Where would we find earthquakes that are strong enough and shallow enough to possibly form a tsunami? Let's look back at the data again...*

Another option to help students piece together the evidence from all three data sources is to include a cause-and-effect diagram during the day 2 whole-class share out, to make the relationship more visible.

10. Track science and engineering thinking.

8 MIN

Materials: science notebook, Science Ideas chart

Introduce the class Science Ideas chart. Display **slide L**. Explain that for this unit, it is important to not only track what we figure out about tsunamis, but also think about how these ideas can be used to protect communities. Create a three-column chart with these headings:

What was our question?	What science ideas did we figure out?	How can engineers use these ideas?

Ask students to share what they figured out about where tsunamis happen. Here are some possible student responses:

- Tsunamis are related to earthquakes, volcanoes, and landslides.
- Almost all tsunamis occur along plate boundaries where the plates are colliding.
- Not all earthquakes are related to tsunamis.
- Stronger, shallow earthquakes cause bigger tsunamis to form.

Now ask students how engineers might use this information to protect communities. Here are some possible student responses:

- Knowing where tsunamis (or hazards) have happened before lets us know where they might happen again.
- Knowing what causes a tsunami to form lets us know when it might happen.
- If an earthquake that is strong and shallow happens, then we can warn people.
- We can identify the places in the world that are most at risk of tsunamis because of the types of earthquakes that happen there.

Additional Guidance

There is not always a one-for-one connection between science ideas and engineering applications, but the purpose of this poster is to help students make explicit connections between the science ideas and how those can be applied when appropriate.

11. Problematize the connection to earthquakes. 2 MIN

Materials: None

Problematize how an earthquake makes a tsunami wave. Display **slide M**. Ask students to turn and talk briefly about their thinking for *how* a strong, shallow earthquake can cause the formation of a tsunami. If time allows, have a few students share their initial ideas.

Home Learning Opportunity

Encourage students to ask their family or friends what natural hazards have happened in their local area in recent years (or any area the students have lived in previously, if they are new to the community). If this investigation already occurred during Lesson 1, it does not need to be repeated.

Importantly, students can ask their friends, family, and/or caregivers what caused those local hazards to happen.

If students have high interest, they can also investigate locations in the world where active hazards are happening using the PDC Disaster Alert interactive map. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) This map displays recent hazards.

ADDITIONAL LESSON 2 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.6.2: Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it contributes to a topic, text, or issue under study.

This lesson engages students in interpretation of text and data from interactive maps to determine the pattern of tsunami occurrence and establish a cause-and-effect relationship between related geologic forces and the resulting hazard.

Supporting Students in Making Connections in Math

CCSS.MATH.CONTENT.6.SP.B.4: Display numerical data in plots on a number line, including dot plots, histograms, and box plots.

CCSS.MATH.CONTENT.6.SP.B.5.B: Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.

Students display and interpret data on scatter plots and are asked what is represented by the “magnitude” and “depth” of an earthquake, as well as the “wave height” that results.

Types and Frequencies of Hazards

1 **Natural Hazards, Visualized**

2 **Hazards Depicted in Art and Literature**

Literacy Objectives

- ✓ Summarize key points related to natural hazards.
- ✓ Distinguish cause(s) and effect(s) related to the human impacts of natural hazards.
- ✓ Organize related details about one natural disaster to develop a news report.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 1 and 2.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a video script for a one-minute news segment in response to the reading.

Instructional Resources

Student Reader

Collection 1

Science Literacy Student Reader, Collection 1
"Types and Frequencies of Hazards"

Exercise Page

EP 1

Science Literacy Exercise Page
EP 1

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 1: What happens to a community when a tsunami occurs?
- Lesson 2: Where do tsunamis happen and what causes them?

Standards and Dimensions

NGSS

Disciplinary Core Idea ESS3.B: Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.

Science and Engineering Practices: Analyzing and Interpreting Data; Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Patterns; Stability and Change

CCSS

English Language Arts

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

WHST.6-8.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

RL.6.9: Compare and contrast texts in different forms or genres (e.g., stories and poems; historical novels and fantasy stories) in terms of their approaches to similar themes and topics.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

natural hazard

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

gale
gradient
index
magnitude
pandemic
storm surge
waterspout
wildfire

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (MONDAY)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Natural Hazards unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *There are two reading selections in Collection 1.*
    - *In the first, you will interpret data about natural hazards on graphs, charts, and maps, looking for patterns related to location and time.*

- *In the second selection, you'll see how artists and writers interpret events caused by natural hazards to create lasting works of literature and art.*
- Distribute Exercise Page 1. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate a script for a one-minute video news segment related to a natural hazard event.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

Exercise Page

EP 1

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What types of graphic displays in this collection provide quantitative data about natural hazards?	*color-coded maps, a multi-bar graph, double-line graphs, and a table*
What effects did the volcanic eruption, as described by Pliny the Younger, have on people?	*People fled in terror and were likely to trample one another.* *They left their houses for the open fields.* *Stones and ash fell on them.* *Some died of suffocation from poison gases.* *Their chariots fell over.*
What is a waterspout?	*It's a natural hazard that occurs at sea, like a tornado on the sea surface.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
How do the places on Earth at risk from a tsunami compare to the places at risk from an earthquake?	*Tsunami risks are high along some ocean coasts. But people who live inland from the coast AND in the middle of a continent can be at risk from earthquakes.*
What clues were there in the letter from Pliny the Younger that a tsunami could have been involved in the disaster he described?	*He wrote how the waves were extremely high and about how the sea water "seemed to roll back upon itself" from the shore.*
What clues in the lyrics of "The Wreck of the Edmund Fitzgerald" suggest that the storm was not entirely unexpected?	*It refers to the "gales of November" meaning that strong, scary winds can be expected in November.*

- Refer students to the Exercise Page 1. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to develop a script for a one-minute news video about one of the events depicted in literature or art in the second reading.*
  - *The tone of your news report should be objective, meaning you keep your opinions out.*
  - *Do be respectful of the people involved, especially those who died or were injured.*
  - *Start with a sentence that explains the point of the video—where you are and what just happened.*
  - *Write directly to the audience.*
  - *Read your script aloud, and make changes to get it to sound natural.*
- Explain that a well-organized script must be clear enough for another person to produce the video.
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page

EP 1

4. Facilitate discussion.

(FRIDAY)

Facilitate class discussion about the reading collection and writing exercise. While this OpenSciEd unit focuses on one type of natural hazard—tsunamis—the first reading in Collection 1 introduces students to several other examples, each with a different type of graphic data display to explore. The second reading demonstrates how writers and visual artists of the past have responded to natural hazard events and preserved impactful records of their effects on humans.

Pages 4–9 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "Natural Hazards, Visualized"?	*It identifies several natural hazards and explains how to read graphical data displays about them, such as maps, graphs, and charts.*
What kinds of data on these displays can community leaders use to make decisions about how to deal with natural hazards?	*Some displays show how frequently a hazard occurs in their community. Knowing this, leaders can decide how important it is to develop warning systems.* *Some displays show locations where the hazard occurs.* *One display, the pandemic line graph, shows which members of a community are affected more than others.* *Another display, for drought, shows both the frequency and severity of the hazard for a local community.*
Take a look at the display and caption under "Storm Surge and Hurricane Graphs" What do you know about storm surges, and where could you find out more about them?	*I think the "surge" is water coming from the ocean onto the land.* *Not much. Maybe hurricanes cause storm surges?* *What about the surge of water from the tsunami in Japan? Is that related?* *We can search for this term online and look for videos or articles from the weather services that will explain it.*
The Wildland Fire Potential Index takes some time to interpret. How would you explain the wildfire forecast for the region where you live on July 13, 2021?	*Answers will depend on the geographic region.* *Where we live near Los Angeles, California, the colors on the map are orange and red. That means the index was in the range from 100 to 247. Those are high numbers and warm colors, so the risk was very high.*
What can you infer the numbers on the color gradient mean when they are 249 and higher?	*I don't think they mean that the risk of wildfire is greater because the colors are cool grays and greens. And the gradient uses light blue for water, where it's impossible to have a wildfire.*

Student Reader

Collection 1

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—Students with color vision deficiency (CVD)—about 1 in 12 males and 1 in 200 females—may have a difficult time interpreting some of the graphics, for example, distinguishing reds from greens (the most common deficiency) and blues from yellows. As a teacher, knowing a student has CVD is important so that you can avoid giving these students assessment tasks that require color vision.

SUPPORT—The strength of the song's lyrics and rhythms will be more apparent if students listen to the original musical recording as they read.

Pages 6–12 **Suggested prompts**	**Sample student responses**
Volcanic eruptions can be very dangerous to people and wildlife. Interpret the volcano map to describe the risk to living things in and near the community called Battle Ground, WA.	*The land around this town is color coded light brown, and the key shows that means there can be lava flows there from a volcanic vent other than the one on top of Mount St. Helens. That means that somewhere near the town is another volcano.*
Looking at the two line graphs about the COVID-19 pandemic, what kinds of questions do you think scientists should ask to try to explain the male-female differences?	*What characteristics of males make them more likely to die of COVID-19?* *Does the difference in deaths hold true for all ages of people or just certain ages?* *Is the difference related to behavior and not physical traits?* *Is the difference the same in all states?* *Is the difference the same in other countries, or does the difference only exist in the United States?*
Are the natural hazards described in this reading sudden or gradual in their timing?	*Both. Earthquakes, hurricanes, storm surges, wildfires, and some kinds of volcanic eruptions happen pretty fast.* *Smog, lava flows, pandemics, and droughts seem to take place over longer periods of time.*
What is the general purpose of the second selection, "Hazards Depicted in Art and Literature"?	*It shows examples of literature and art that communicate information about historic natural disasters.*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first article reveals mostly where and when hazards occur. The second article details the effects on people and gets you emotionally involved.*
Let's say you chose to write your news video script about the eruption of Mt. Vesuvius in 79 CE. What details did you look for in the letters that could be described by a reporter shortly after the disaster?	*I looked for details that explained how the mountain, sky, houses, roads, and boats may have looked a few days later. I also looked for details that might tell what happened to people, such as the uncle who died along the shoreline.*
Which of the two paintings did you react to more strongly? Explain.	*the one called* Gulf Stream, *because the boat was close enough to see that the man on it could no longer sail or steer his boat and the sharks swimming around his boat were terrifying* *the one called* Great Wave, *because the three boats look so tiny next to the big wave that I know the sailors are doomed*

Page 13 **Suggested prompts**	**Sample student responses**
According to the song "The Wreck of the Edmund Fitzgerald," what conditions contributed to the sinking of the boat?	*It was a time of year when strong winds blew from the north, causing tall waves on the lake.*
What were the human impacts of the storm that wrecked the Edmund Fitzgerald?	*Twenty-nine men died, the families of the dead mourned their loss, and the searchers may have been in danger looking for survivors.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 1, students should, from a template provided, write a script for a one-minute news report about one of the natural hazard events depicted in the second reading selection—the eruption of Mt. Vesuvius in 79 CE, a hurricane or great wave off the coast of Japan, a storm and waterspout in the Atlantic Ocean, or an early November storm on Lake Superior. Scripts should describe the natural conditions and their effect on humans and human-made structures.

Look for evidence that the science content in the scripts is based on details in the work of art or literature and that the science about the natural hazard is stated accurately.

Online Resources

EXTEND—After writing their own scripts, students may be interested to see how the "pros" did it for some of the events (and related events) described in the readings. Have students watch videos of news reports of natural disasters, and then invite them to read their own scripted reports of the historical events described in the art and literature in this collection.

What causes a tsunami to form and move?

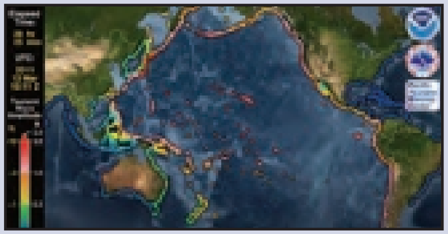
Previous Lesson

We investigated patterns in historical tsunami data and figured out that most tsunamis are caused by strong, shallow earthquakes on colliding plate boundaries. We established a cause-and-effect relationship and used it to forecast locations at risk for future tsunamis.

This Lesson

Investigation

3 DAYS



NOAA

We analyze three different wave models to make sense of how an earthquake-driven tsunami forms and moves to shore. We use different perspectives to understand various aspects of the phenomena, and then we identify the benefits and limitations of each model. We add new science and engineering ideas to our Tsunami Chain of Events poster.

Next Lesson

We will use the Tsunami Chain of Events poster to construct an explanation of the related geologic forces that cause a tsunami to form, and we will also forecast impact for communities at risk. We will consider how to protect communities from the effects of a tsunami. We will revisit the Driving Question Board and document responses to questions we can answer.

Building Toward NGSS

MS-ESS3-2, MS-ETS1-1, MS-ETS1-2

What Students Will Do

3.A Analyze and interpret data from different wave models to identify patterns in how the tsunami wave forms and moves toward shore, changing height (amplitude) as it interacts with the ocean floor.

3.B Evaluate the limitations and benefits of different wave models for explaining how tsunamis form from a movement in the ocean floor (cause), and how they move and change as they approach the shore (effect).

What Students Will Figure Out

- Physical waves form from a single point of disturbance or movement, and then move outward in a circular pattern from that point.
- The bigger the movement of the ocean floor, the greater the disturbance of the water above it.
- When a wave approaches shore, it gets taller until it reaches the shore, where it collapses and flows, or runs up onto the shore.
- The bigger the wave is when it reaches shore, the farther onto the land the water will flow.
- As water waves move and interact with surrounding land at the shore and in the ocean, they transfer energy to the land and reflect off its surface. As this continues, the waves get smaller and smaller due to losing energy that has been transferred to their surroundings.

Lesson 3 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Brainstorm ideas for how an earthquake under the ocean can result in a tsunami.	A	
2	20 min	**ANALYZE THE FOIL PAN MODEL** Watch how water behaves in a foil pan system when the bottom of the pan is moved abruptly. Record and share observations and interpretations, and connect them to tsunamis in a Building Understandings Discussion.	B-D	*Wave Investigations*, 6.5 - Lesson 3 Foil Pan Model (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer, projector
3	20 min	**ANALYZE THE NOAA TSUNAMI MODEL** Watch a computer-generated visualization model of data collected about the 2011 Japan tsunami that models how the water in the Pacific Ocean behaved. Record and share observations and interpretations and connect them to tsunamis in general.	E-G	*Wave Investigations*, 6.5 - Lesson 3 NOAA Tsunami Model (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer, projector
				End of day 1
4	5 min	**NAVIGATION** Reflect on what we have learned from the first two wave models about how an earthquake causes a tsunami. Identify what we still want to figure out.	H	*Wave Investigations*
5	25 min	**ANALYZE THE TSUNAMI WAVE MODEL** Watch a computer-generated visualization model of data that models how water behaves after an earthquake occurs underneath the ocean and the resulting wave reaches the shore. Record and share observations and interpretations and connect them to tsunamis in general.	I-K	*Wave Investigations*, 6.5 - Lesson 3 Tsunami Wave Model (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer, projector
6	15 min	**REFLECT ON THE BENEFITS AND LIMITATIONS OF THE THREE WAVE MODELS** Use our recorded observations and analyses to create a chart comparing the benefits and limitations of each wave model.	L-M	*Wave Investigations*, Comparing Different Wave Models chart
				End of day 2
7	15 min	**REFLECT ON NEW SCIENCE IDEAS** In a Scientists Circle, discuss and record the science ideas figured out so far to help answer our questions about tsunamis.	N	Science Ideas chart

Part	Duration	Summary	Slide	Materials
8	20 min	**UPDATE THE TSUNAMI CHAIN OF EVENTS AND CONSIDER ENGINEERING IDEAS** Use our observations and analyses of the three wave models in a Consensus Discussion to explain how an earthquake causes a tsunami to form and move. Reflect on how this information could be useful to engineers for protecting communities from tsunamis.	O	Tsunami Chain of Events poster, large sticky notes, markers, Science Ideas chart
9	10 min	**NAVIGATION** Brainstorm whether the key pieces of data for tsunami hazards would also apply to predicting and protecting against other natural hazards.	P	Science Ideas chart, Local Hazards poster and Technologies or Related Solutions poster

End of day 3

Lesson 3 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• *Wave Investigations* • science notebook		• 6.5 - Lesson 3 Foil Pan Model (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • computer • projector • 6.5 - Lesson 3 NOAA Tsunami Model (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • 6.5 - Lesson 3 Tsunami Wave Model (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • Comparing Different Wave Models chart • Science Ideas chart • Tsunami Chain of Events poster • large sticky notes • markers • Local Hazards poster and Technologies or Related Solutions poster

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

If you taught the *Unit 6.4: What causes Earth's surface to change? (Everest Unit)* prior to this unit, you may want to keep some of its words up on your Word Wall to support students in continuing to use scientific language they have worked with already. In this lesson, *epicenter* (earned in the *Everest Unit*) and *amplitude* will be used in analyzing tsunami wave behavior. Although students should have had experience with using these words by now, it is necessary to put them on the Word Wall due to their importance when modeling how earthquakes cause tsunamis.

Alternative option: For day 1, the class analyzed a video of a physical wave model using a foil roasting pan. If you have the time and supplies, demonstrate this model live in your classroom. Place a large disposable foil roasting pan on top of two bricks or thick books so you can access the pan from underneath without moving it around. Fill the pan ¼ full with water. After the water stops moving, use a solid thin object, such as a metal butter knife or the handle of a large metal spoon, to push up slowly on the bottom of the pan in one spot. Hold this for a few seconds until the water stops moving. Instruct students to watch what happens to the water. Then release this quickly to simulate an earthquake and the resulting water movement. It can be helpful to have a student capture a slow-motion video of this demonstration so the class can watch what happens to the water several times.

For day 2, make a Comparing Different Wave Models chart ahead of time to be completed with the class. You may need more than one piece of chart paper for this chart. There is an example of what this poster might look like later in the teacher guide.

For day 3, have the Tsunami Chain of Events poster from Lesson 2, markers, large sticky notes; the Science Ideas chart from Lesson 2 ready to add new ideas; and the Local Hazards poster and Technologies or Related Solutions poster.

Online Resources

Lesson 3 • Where We Are Going and NOT Going

Where We Are Going

In the previous lesson, students figured out that certain types of earthquakes result in tsunamis. Now, we want to figure out how this happens. We analyze three wave models that highlight different aspects of wave behavior, then synthesize this information to develop a conceptual model for how a tsunami forms, moves across the ocean, and interacts with the shore. Students build on what they learned in the *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)* and *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)* about how energy can transfer from one object to another. Using this conceptual model, we figure out that a tsunami that is really tall, moving pretty fast, and originating in close proximity to a community will more likely cause significant damage to that community. We identify key data needed to determine how to detect future tsunamis, such as an earthquake's strength and distance from shore. We consider generalizing these types of data (how big the causal event is, how fast the hazard is happening, and how far from a community it is occurring) to consider whether they could be used to forecast and minimize damage from other types of natural hazards.

Where We Are NOT Going

Though we analyze what happens when waves interact with one another and notice that their energy seems to change when doing so, we only make sense of what happens when waves interact with and reflect off land, like the shore or ocean floor. Beyond recognizing that waves reflect off other types of matter, we are not figuring out additional properties of waves, such as the superposition of wave interference, as these are above the grade-band.

Importantly, fully developing the middle school DCIs for waves is the focus of another unit, the *Unit 8.2: How can a sound make something move? (Sound Unit)*. In the present unit, we leverage student understanding from Grade 4 about water waves and build on that to link them to a causal mechanism (a geologic force) and also how their movement impacts communities once a wave interacts with a shoreline. These science ideas are used as a context to build more generalized ideas about how to forecast hazards and mitigate the effects on communities. This lesson is not intended to build more sophisticated ideas about waves; rather, students are applying previous ideas to a new, more sophisticated context.

LEARNING PLAN FOR LESSON 3

1. Navigation

5 MIN

Materials: None

Recall conclusions from the previous lesson. Display **slide A** and say, *Last class, we figured out that a major cause of tsunamis are certain types of earthquakes that happen under the ocean. So what are your predictions for the answer to our next lesson question,* "What causes a tsunami to form and move?"

Have students turn and talk with a partner about possible reasons why a tsunami can result from an earthquake. Then, ask a few partners to share their ideas and support students in recalling what they learned about the connection between earthquakes and tsunamis in Lesson 2.

Suggested prompts	Sample student responses
What did we figure out was the primary cause of earthquakes?	*We found that earthquakes happen when plates interact at their boundaries or edges.* *And when we looked at where plate boundaries are found on Earth, we saw earthquakes occurring where the plates are colliding and where they are spreading apart.*
Do earthquakes under the ocean always result in a tsunami?	*No, only certain types of earthquakes.* *For a tsunami to occur, the plates have to move toward each other and collide.*
Which types of these earthquakes are likely to cause tsunamis? Which types of these earthquakes are less likely to cause a tsunami?	*We figured out that earthquakes that are strong (high magnitude) and shallow can cause a tsunami.* *Earthquakes that are weaker (lower magnitude) or deeper under the surface don't usually lead to tsunamis.* *Tsunamis are more likely to occur at a boundary where plates are colliding than where plates are moving apart or past each other.*

Say, *Now that we have more information about what types of earthquakes cause a tsunami, let's see if we can figure out how this happens.*

Recall prior experiences with water waves. Prompt student ideas with, *Let's begin by thinking about our own experiences with water. Think about a time when you were using or playing with a large amount of water, like in a bathtub, kitchen sink, pool, or lake. Imagine the water is calm and not moving, but then something enters the water, like a boat going across the lake, a bar of soap falling into the bathtub, or a dish being put into the sink. What happens to the water? What*

***Supporting Students in Developing and Using Systems and System Models**
Students will analyze data from different models of waves to figure out how a tsunami forms and moves. Each model is limited in what it can represent. On the last day of the lesson, students use what they have figured out from each model to evaluate its benefits and limitations in answering the lesson question.

are some ways the water moves after it is disturbed by these objects? Accept all students' reflections from what they remember seeing happen, but listen for these ideas:

- The water moves back and forth in waves within the container or across the surface when something disturbs it.
- If something drops into the water, little waves move away from the spot where the item was dropped.
- If something moves through the water, the water moves with it and seems to bunch up around the item. When the item stops, the water keeps moving back and forth in waves.
- If someone jumps in a pool, it splatters all over, away from the spot where they jumped in.

Say, *All of these examples involve something moving the water from above or from the side. However, we know that tsunamis form from strong, shallow earthquakes occurring below the water, on the ocean floor. Now, let's imagine what would happen if instead of the water being moved by something from above, you could move a spot on the bottom of a container of water to mimic the motion of an earthquake disturbing the ocean floor. What do you predict you would see happen to the water? How would the water move?*

Introduce the use of wave models.* Tell students that we will analyze three different wave models to collect data about how waves form and move. Note that with the third model, we will also see what happens when a tsunami reaches shore.

Say, *Before we look at these models, let's think about what kinds of wave data we want to collect from them to help us answer our questions about tsunamis.* Elicit students' initial ideas with prompts like those below.

Suggested prompts	Sample student responses
What are some things we want to figure out about waves in general that we could then use to figure out how tsunamis form and move?	*How waves start.* *How waves move.* *What happens to make waves slow down or get smaller.* *What happens to make waves get bigger.* *What happens when waves reach the shore.* *What happens with waves far out in the ocean.*
Now that we know tsunamis happen when plates collide and cause an earthquake under the ocean, what are some things we might want to figure out about what happens at the ocean floor when the plates collide?	*Does the ocean floor move?* *What happens to the ocean floor that causes the water to start moving?* *Does the ocean floor break or crack open like we saw happen with other earthquakes?*

Say, *Let's be thinking about these ideas for collecting data as we investigate the wave models.*

2. Analyze the foil pan model.

20 MIN

Materials: *Wave Investigations*, 6.5 - Lesson 3 Foil Pan Model (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer, projector

Orient students to the handout. Distribute a copy of the *Wave Investigations* handout to each student and take a moment to orient them to the rows and columns where they will record their observations and interpretations.*

Introduce the Foil Pan Model. Display **slide B** to present the first model of the foil pan filled with water and raised on two bricks, allowing access underneath the bottom of the pan. Say, *Let's begin by making observations of how water behaves when the surface below it is disturbed. After you watch the video of this first model, you'll use your handout to keep track of what you saw happening with the water.*

Project 6.5 - Lesson 3 Foil Pan Model (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) for the class. Play the video at least twice, pausing after each viewing to have students record their noticings in the "What I see" column of their handout.*

Alternate Activity

If you have the time and supplies, demonstrate this model live in your classroom. Place a large disposable foil roasting pan on top of two bricks or thick books so you can access the pan from underneath without moving it around. Fill the pan ¼ full with water. After the water stops moving, use a solid thin object, such as a metal butter knife or the handle of a large metal spoon, to push up slowly on the bottom of the pan in one spot. Hold this for a few seconds until the water stops moving. Instruct students to watch what happens to the water. Then release this quickly to simulate an earthquake and the resulting water movement. It can be helpful to have a student capture a slow-motion video of this demonstration so the class can watch what happens to the water several times.

Share observations and connect the model to the real world. Say, *Remember, we are trying to figure out how an earthquake causes a tsunami to form and move. So as we share what we saw happening with the water in this investigation, let's also think about how the different parts in the foil pan model relate to an actual tsunami. For example, what would the water in the pan represent in the real world?* Students should say the ocean.

Continue this brief discussion, using prompts like those below to talk through how the water moved and how the model relates to the real world.

Suggested prompts	Sample student responses	Follow-up question
What were some of the things you noticed happening in the foil pan? What happened when the bottom of the pan was moved?	*When the pan moved up, the water seemed to move up and out of the way from the space where the pan moved up. Then when the pan moved back down in place, the water moved back toward the center.*	*If we want to use this to help us figure out tsunamis, then what does the bottom of the pan in this investigation represent in the real world?* *(The ocean floor.)*

***Supporting Students in Engaging in Analyzing and Interpreting Data**

Students will make "What I see" and "What it means" statements for each model used in this lesson. This is similar to the Identify and Interpret (I^2) sensemaking strategy (used for numeric data and graphs) in helping students break down information-rich data into smaller pieces to interpret, enabling them to use the data to provide evidence for a phenomenon.

***Attending to Equity**

Supporting Universal Design for Learning: As students hear one another's observations from the Foil Pan Model or respond to your questions, they may ask to watch the video again. Be prepared to show it again to ensure that all students have a common understanding of the phenomenon. For some students, the task of watching and recording observations can be challenging; offering another viewing supports *engagement* by providing a new purpose for rewatching it to focus on different aspects of the phenomenon.

In this lesson, there will be two other videos to watch and make sense of, so this strategy will be useful for those as well.

Suggested prompts	Sample student responses	Follow-up questions
What did you notice the water do as it moved away from the part of the pan that was moved?	*It moved in circles away from that spot until it reached the edge of the pan. Then it seemed to bounce off the side of the pan, or reflect off in a different direction.*	*How might this be similar to a tsunami?*
What caused the water to move in circles or ripples away in all directions?	*When the pan was let go and moved downward, the water moved that way too and then continued to move away from this spot until it reached the edge of the pan.*	
When the water waves reached the edge of the pan, what happened next?	*The water reflected off the edge and moved back toward where it came from.*	*What does the edge of the pan represent in the real world? (Maybe the shore or an island or other things the ocean collides with.)*
What did you notice happening with the waves over time?	*By the end of the video the water was moving much less.* *It seemed like the size and speed of the waves was less over time.*	
I saw that too. So if the waves are decreasing in size and speed, then how do you think the wave's energy after it hit the edge of the pan compared to its energy before it hit the edge?	*There was less energy after it hit the wall of the container.* *I am not sure, but since the waves were smaller and moving less over time, maybe some of the energy was transferred to the edge of the pan.*	

Highlight energy transfer in the wave models. Tell students, *When waves interact with and reflect off an object, some of their energy is transferred to that object, just as we noticed when the waves interacted with the edge of the pan. So with less energy, the waves get smaller over time. As you analyze the next two models, watch for what happens as the waves interact with other objects to see whether there is evidence of energy transfer.**

***Supporting Students in Developing and Using Energy and Matter**

This is a good opportunity to highlight and encourage students to consider the crosscutting concept of Energy and Matter as they analyze data from the different wave models. It is important to understand that the wave forms from a transfer of energy from the ocean floor, and that how the wave moves is connected to energy transfer as it approaches shore. Students will reconsider these ideas later in the unit as they evaluate design solutions.

***Supporting Students in Engaging in Developing and Using Models**

The purpose of using the Wave Investigations handout is to support students in making connections between the large-scale, real-world phenomenon of a tsunami and the models used in the classroom. Students often struggle to connect a simulation or physical model with the real-world phenomenon being investigated. This analysis tool provides the space for students to consider the models' different components and how these components can help them figure out what is occurring in an actual tsunami.

Additional Guidance

Prior to this unit in the sequence, students have learned that all matter is made of particles (smaller pieces) and that these particles move and transfer energy to other particles. In the *Cup Design Unit*, when students investigate why drinks cool down over time and why some cups keep drinks cool longer, they figure out that particles are arranged close to each other in a solid, with some space between them in a liquid, or with a lot of space between them in a gas. Students also figure out that these moving particles transfer energy when they collide; we see evidence of this energy transfer through temperature changes. If your students have not gone through the *Cup Design Unit*, you may need to support them when explaining how the energy within the wave decreases as energy is transferred to particles in the water and the land/pan.

Keep in mind that ideas about energy transfer and waves will be revisited more fully in the *Collisions Unit* and *Sound Unit* later in the program.

Share interpretations to make sense of the model.* Display **slide C**. Say, *Now let's pause and reflect on how what we saw happen with the waves in the pan can help us understand how tsunamis form and move. We'll do this for each of our three models*. Give students 5 minutes to work with a partner to complete the first row of *Wave Investigations* with their interpretations of the model.

Assessment Opportunity

Building towards: 3.A.1 Analyze and interpret data from different wave models to identify patterns in how the wave forms initially and moves toward shore, changing the height (amplitude) of the wave as it interacts with the ocean floor.

What to look for: Students use three different wave models in this lesson. After analyzing each model, the class pauses to share what has been figured out about the waves in the model and real-life tsunamis in the ocean. From the Foil Pan Model, listen for students to identify the following key ideas:

- The up-and-down motion of the pan bottom (or ocean floor) causes the water above it to move in a similar pattern (up and down), causing large waves to form.
- Waves form above the spot where the pan bottom is disturbed (moved). These waves move outward in a circular or ripple pattern from that location.
- These waves continue to move out in all directions until they reach the edge of the pan.
- At the edge of the pan, the waves collide with the pan wall and then reflect back away from the wall.
- The waves get smaller over time. Waves seem to transfer energy to the pan wall.

What to do: Some students may struggle with recording observations while watching the video of this model. Make the video available to students to watch repeatedly on their own outside of class, so they have enough time to make sense of what they are observing and can find patterns of cause and effect to explain how a tsunami forms and moves. Another option, if the technology is available in your classroom, is to watch the video once as a class and then have students play it again in small groups to make their observations. As they rewatch the video, encourage them to focus on the interactions between the waves and the sides of the pan. Also, encourage them to think about the movement of the bottom of the pan as the earthquake. This will help them make stronger connections between an earthquake on the ocean floor and a tsunami forming and moving.

In addition to these ideas, if time is available and you have the materials, this model can be shown as a live demonstration in the classroom, where students would gather around the pan and make observations in small groups or as a class. This demonstration could be repeated multiple times.

Combine analyses of the model and connect to tsunamis. Display **slide D**. Say, *I heard some of you mention that the waves in the foil pan are many times smaller than a tsunami in the ocean, but I also heard some of you describe how analyzing the waves in this model can help us figure out more about tsunamis. Let's share our thinking.* Facilitate a Building Understandings Discussion using prompts like those below. Remind students that they can add notes to their handout about each other's observations and interpretations.

Suggested prompts	Sample student responses
What were some connections that you and your partner captured about how the wave moved in the Foil Pan Model?	*The wave began when the bottom of the pan was moved.* *Once it started, the wave continued until it reached the edge of the pan.* *The wave moved out in all directions from the point where it started.* *When the wave reached the edge, it collided and reflected back toward the middle.*
And, how does this compare to a tsunami? What can this tell us about how tsunamis form and move?	*We think tsunamis also move like these waves, but are much bigger because the ocean is so big.* *The tsunami also probably starts where the ocean floor is moved by the earthquake.* *The tsunami probably moves away from this spot in all directions like the wave in the pan, until it reaches the shore or an island.*
In the pan, we saw the waves reach the edge and then reflect back, and over time get smaller and smaller. We also thought the wave transferred some energy to the pan edge. How might a tsunami be similar to this?	*Maybe when the wave reaches the shore, it transfers energy to the shore.* *Yeah…like waves on the shore of the ocean or lake, they move back and forth…maybe that is like the waves reflecting off the edge of the pan.*

Key Ideas

Purpose of the discussion: This brief discussion supports students in thinking about what we can figure out about a real-world phenomenon from a small-scale model. As students work to make sense of what is represented in the Foil Pan Model, support them in making connections to what they have already experienced with water waves in their own life, what they see happening in the pan, and what this helps us figure out about tsunamis.

Listen for these ideas:

- Waves can occur when there is a disturbance or movement of the surface above or below the water. For a tsunami, the disturbance happens at the ocean floor when a strong, shallow earthquake happens.
- Waves continue to move in all directions until they collide or interact with other matter, like the shore.
- When waves collide with other matter, they transfer energy and reflect away from that matter in the opposite direction.

Reflect on the model's usefulness. Say, *It seems like we found some connections between what we saw happening in the pan and what we think happens when a tsunami occurs, but we still have some questions. Would you say this is a useful model to use as we try to figure out aspects of the tsunami, or is it too different from the real world?* Students should suggest limitations like these:

- This model is only somewhat helpful because it is missing parts of a tsunami in the ocean.
    - *There is no shore.*
    - *It is way too small of an amount of water compared to the ocean.*
    - *The ocean isn't all the same depth of water like in the pan.*

Identify questions to investigate with additional models. Ask students, *Okay, what are some questions we still have about tsunamis that we would want to model and analyze more closely?* Students should suggest questions like these:

- What happens when a tsunami reaches land?
- What does a tsunami look like right when it begins out in the ocean?
- If the ocean is deep where an earthquake happens, is the tsunami as big?
- How does the wave change as it moves in the ocean?

3. Analyze the NOAA Tsunami Model.

20 MIN

Materials: *Wave Investigations*, 6.5 - Lesson 3 NOAA Tsunami Model (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer, projector

Introduce the NOAA Tsunami Model. Display **slide E**. Say, *I have another model to share with you. This is a computer-generated visualization model created by scientists at the National Oceanic and Atmospheric Administration, or NOAA, using data collected about the 2011 Japan tsunami that we investigated in Lesson 1. To create this model, the scientists take a whole bunch of data, including measurements of wave height and put this data in a form that allows us to see and make sense of changes over time.* Tell them they will use their same *Wave Investigations* handout to record observations and interpretations.

Project 6.5 - Lesson 3 NOAA Tsunami Model (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Remind students to simply watch the video the first time through and then make initial observations on their handout afterward. Play the video several times to elicit new observations.*

***Attending to Equity**

Supporting Universal Design for Learning: The NOAA Tsunami Model is somewhat complicated. It is important to take time to help students make sense of what the different keys and colors *represent*. Play the video a few times and pause it periodically. It can be helpful to have students share different things they notice and describe what they represent. For example, someone might notice

Additional Guidance

In this visualization model, the key for amplitude on the bottom left shows a scale ranging from 0 to 10+ feet high. Point out to students, or ask students what 10+ feet is referring to. In Lesson 1 we read that when the 2011 tsunami reached Japan, the waves that hit the shore were up to 30 feet high. It is important for students to realize that the dark red color signifies all waves that are 10 feet or greater, *not* only 10 feet.

Share observations and interpretations to make sense of the second model. After watching the visualization several times, pause to make sense of the data that is being represented. Use prompts like those below to guide this discussion. As you work on sensemaking as a class, it can be helpful to have volunteers come up and point out what they are explaining or referring to in the computational model. Encourage students to continue to add to *Wave Investigations* as they hear observations that they may not have recorded.

Suggested prompts	Sample student responses
What part of the world is represented in the video?	*We can see all of the Pacific Ocean and the land and countries around it.*
The colored key on the side says, "Tsunami Wave Amplitude." Does anyone know what amplitude *means?*	*How tall a wave is.* *The height of a wave from the surface of the water, or waterline (lowest point).*
What are some things you noticed about the amplitude of the waves that reached the different shores?	*Well…the darker red, or taller waves, were closer to where the earthquake occurred, but there were still pretty big waves even across the ocean, on the shore of the west coast or South America.* *It looked like the waves that reached the west coast were light red and orangish, so it seems like they were still pretty big.* *Near Japan, the color was very dark red, which is an amplitude of over 10 feet, and we read that some areas of Japan had waves over 30 feet!*
So what happened right at the beginning of the video?	*The earthquake that happened near Japan caused the tsunami.*
What is that place called where an earthquake occurs?	*the epicenter*
And then what happened?	*We saw the way the water, or waves, moved from that spot where the earthquake happened. And they moved out across the ocean.*
Did anyone notice how much time passed in the visualization model?	*over a day* *like 35 hours or so*

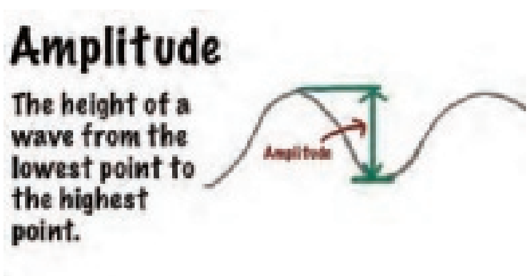
the colorful bar with numbers on the left side, titled "Tsunami Wave Amplitude." Ask this student to come up, point to the bar, and explain what it is so everyone understands what is being referred to.

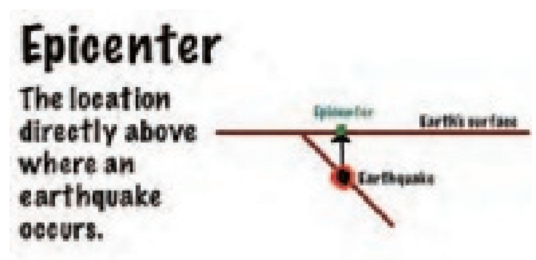
Suggested prompts	Sample student responses
Over the 35 hours, what can we summarize happened during this time?	*It took the wave that long to move across the ocean!* *The wave started near Japan, and it looked like it kept moving across the ocean until it collided with something else, like an island or something. Then it would reflect off that island and keep moving.*
Some of you thought you saw that the wave generated near Japan moved across the whole Pacific. Did the waves make it across the whole ocean?	*Yes!* *I saw it reach the west coast of the United States and even down near the Andes in South America!*

Additional Guidance

The discussion about the NOAA model uses words students should bring into this unit from previous experiences. *Amplitude* is a term they should have learned in Grade 4, 4-PS4-1: "Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks)". This term is helpful for referring to the height of water waves formed by earthquakes. In the *Everest Unit* prior to this one, students encountered and made sense of the word *epicenter* as they figured out how earthquakes are related to changes in Earth's surface. They encounter this word again with the NOAA model in describing the location where the earthquake occurs, causing waves to travel away from that point in all directions.

If you taught the *Everest Unit*, you may wish to keep *epicenter* up on your Word Wall. If these two words are not on your wall at this time, you may wish to add them to support conceptualizing what they refer to, as they will be used again in this unit. Here is an example of how these words might look on the Word Wall:





Display **slide F**. Give students a few minutes to work with their partner to complete the second row in their handout.

Assessment Opportunity

Building towards: 3.A.2 Analyze and interpret data from different wave models to identify patterns in how the wave forms initially and moves toward shore, changing height (amplitude) as it interacts with the ocean floor.

What to look for/listen for: After analyzing the NOAA Tsunami Model, listen for students to identify the following key ideas:

- These waves move out from the location where the plates move and collide with one another (the earthquake's epicenter) in all directions.
- The waves farther out in the ocean where the earthquake first happens (nearer to the epicenter) are not as big as the ones near the shore.
- As the waves move toward the shore, their height (amplitude) changes (based on the color scale in the model), in most cases getting taller as they get closer to land.
- The waves that reach land closer to where the earthquake happens are taller than those that reach land farther from the epicenter.
- Waves reflect off (or bounce off) things they collide with in the ocean, like shorelines and islands.

What to do: This visualization model is complex due to the amount of different measurements being represented. Some students may struggle with recording observations while watching. Watch the visualization several times so they have enough time to make sense of what they are observing and are able to find patterns of cause and effect. If possible, watch the video once as a class and then have students play it again in small groups to make their observations. If students do not develop all the ideas listed above, their engagement with the two other wave models may support the development of these ideas from a different perspective.

Combine analyses of the second model and connect to tsunamis. Show **slide G**. Say, *What were some connections you and your partner made between the model we analyzed and how a tsunami behaves?* Ask different pairs to share what they discussed, and encourage students to add to their handout if they hear ideas they agree with but had not recorded yet.

Key Ideas

Purpose of the discussion: As students work to make sense of what is represented in the NOAA Tsunami Model, support them in connecting what they have seen in this model to what they learned about the 2011 Japan tsunami from Lesson 1. The goal is for students to continue to develop their conceptual model for how and why a tsunami occurs.

Listen for these ideas:

- Tsunamis can move pretty fast.
- Tsunamis keep going until they run into land. We think that when this happens, they transfer energy to the land before they reflect away from it.
- Larger tsunamis would have more water that reaches the shore, which could mean more energy is transferred to the land. Maybe this is why they are so damaging to some areas?

- The waves out in the ocean are smaller in height (amplitude) than the waves near the shore. We wonder why the waves get taller as they move closer to land.

Summarize the big ideas developed so far. Ask, *How can we sum up what we figured out so far today about tsunamis?* Let a few students share ideas from either the Foil Pan Model or the NOAA Tsunami Model. Tell students we will investigate one more model during the next class.

End of day 1

4. Navigation

5 MIN

Materials: *Wave Investigations*

Reflect on the second model's usefulness. Display **slide H**. Say, *Okay, let's think about the two models we analyzed in our last class. After we analyzed the foil pan model, we still had questions about how a tsunami forms and moves across the ocean. Did the NOAA model help us figure out any more about that?* Encourage students to look back at *Wave Investigations* if needed.

Here are some examples of student responses:

- The NOAA model helped us see that the wave does move across the whole ocean, like the water in the foil pan.
- We saw that waves continue across the ocean until they interact with any land, even land in the ocean, like islands.
- The NOAA model helped us see that the height (amplitude) of the wave is less out in the ocean and greater closer to land.

Identify questions for further investigation. Say, *So the second model helped us figure out a little bit more about tsunamis, but we still have some unanswered questions. What are some things we're still wondering about?* Students should suggest things like these:

- We still don't know what happens when a tsunami gets closer to the shore and interacts with the land.
- We still don't know why tsunamis look like they are taller near the shore than out in the ocean where they first begin.

5. Analyze the tsunami wave model.

25 MIN

Materials: *Wave Investigations*, 6.5 - Lesson 3 Tsunami Wave Model (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer, projector

Introduce the Tsunami Wave Model. Display **slide I** and prepare students to investigate the final model. Say, *This is a computer-generated simulation model that scientists designed using data from tsunamis caused by earthquakes. In the first two models we analyzed, we saw the water wave movement from above, as if we were looking down on the ocean. In this model, we will shift perspective, seeing most of the model from a side view.*

Play the simulation model 6.5 - Lesson 3 Tsunami Wave Model (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). As before, you will show the video repeatedly, so encourage students to simply watch it the first time through before recording observations in the last row of their *Wave Investigations* handout in the "What I see" column.

Additional Guidance

It may be challenging for students to make sense of this computer-generated simulation model of what happens when an earthquake occurs under the ocean. The simulation begins at the shifting ocean floor and follows the movement of water all the way to shore. Students may need support in figuring out what they are looking at in this model. If the technology is available, you may wish to provide access to the video for students to watch in small groups, or on their own outside of class.

Share observations and interpretations to make sense of the model. After watching the simulation model several times, pause to make sense of it as a class. Use prompts like those below to help guide this discussion.

Suggested prompts	Sample student responses	Follow-up questions
What are some things you saw happening with the water wave in this model?	*We saw what happened from the side at the location of the earthquake. Later, it shifted to show the wave from above.* *In the far distance, we could see something that looked like the shore.* *Then we looked at the wave from the side again, all the way until it reached the shore.*	
In the first part of the video, what is being represented? What did we see happening?	*We saw the ocean floor break and one part moved upward, causing the water to move upward and form a wave almost immediately.*	*And what does the breaking ocean floor represent in the real world? (The plates colliding under the ocean, causing an earthquake.)*
This model showed the ocean floor breaking when the plates collided and caused an earthquake. How did this movement of the ocean floor affect the water?	*When the ocean floor broke, it moved upward. This movement upward looked like it made the water move upward too.*	*What does this movement of the water upward in the model represent in the real world?* *(The water moves and a tsunami starts.)*
What seems to be happening between the ocean floor and the water to cause the water to move?	*The ocean floor transfers energy to the water, which makes it move.*	
So, if the ocean floor transfers energy to the water, causing waves, what happens next?	*The waves move out in ripples away from this spot.*	*What does this movement of the wave from the spot the ocean floor broke to the shore represent in a real-world tsunami? (When the tsunami moves fast toward the land.)*

Key Ideas

Purpose of the discussion: The Tsunami Wave Model has many components that map nicely to the real-world phenomena. After this brief discussion about the different aspects of the model, students work again with a partner to reflect on how what they saw in this model helps us make sense of what is happening with the ocean floor and the movement of the wave when a tsunami forms.

Listen for these ideas:

- As the ocean floor moves upward, it transfers some of its energy to the water, causing the water to move.
- The wave moves away from where the earthquake happened and toward the shore.
- The wave changes over time; it gets bigger.
- The height (amplitude) of the wave seems small until the middle to the end of the video, when the water above the ocean floor becomes shallower. Then the wave gets much bigger.

Display **slide J**. Give students a few minutes to work with their partner to complete the third row in their handout.

Assessment Opportunity

Building towards: 3.A.3 Analyze and interpret data from different wave models to identify patterns in how the wave forms initially and moves toward shore, changing height (amplitude) as it interacts with the ocean floor.

What to look for/listen for: After analyzing the Tsunami Wave Model, listen for students to identify the following key ideas:

- When a strong, shallow earthquake happens and causes part of the ocean floor to move up and another part to move down (vertically), a tsunami can happen.
- These waves move out from the location where the ocean floor moves.
- The height (amplitude) of the waves that are farther out in the ocean (closer to the epicenter) is less than the ones that reach the shore.
- As the waves move toward the shore where the water above the ocean floor is shallower, the amplitude increases.
- When the wave reaches shore, it seems to fall over itself and spread out or run up onto the land.
- The bigger the wave that reaches the shore, the more it will move onto land.

What to do: Some students may struggle with recording observations while watching, as this visualization model changes perspectives and location of what is being represented. It may help to play the video once all the way through, telling students to simply watch and not take notes. Then play it a second and perhaps a third time, pausing at incremental places to allow students to reflect on three segments of the model as they record their observations: The beginning of the video shows the ocean floor snapping and breaking, then a flyover shows the wave moving out from the epicenter. The next part shifts to show how the wave amplitude changes as the water above the ocean floor becomes shallower. The last part shows the wave reaching the shore. Another option, if the technology is available, is to watch the video once as a class and then have students play it again in small groups to make observations.

Combine analyses of the third model and connect to tsunamis. Show **slide K**. Say, *What were some connections you and your partner made between the model and how an actual tsunami behaves?* Ask a few pairs to share what they discussed and encourage students to add to their handout if they hear ideas they agree with but have not recorded. Some students may wish to have you play the Tsunami Wave Model again so they can come up and point out things they discussed with their partner.

Key Ideas

Purpose of the discussion: As students work to make sense of what is represented in the Tsunami Wave Simulation, support them in making connections to what they see happening from the point when the ocean floor moves until the wave reaches land. The goal is for students to continue to develop their conceptual model for how tsunamis form and move.

Listen for these ideas:

- When the ocean floor moved, it immediately pushed the water up with it. We think this is how a tsunami happens in the real world when the plates collide and there is an earthquake.
- When the ocean floor pushed the water up, energy was transferred from the movement to the water.
- At first the wave was not very big, but as the water above the ocean floor became shallower, the wave's height (amplitude) increased. This happened closer to shore.
- The amplitude of the wave was much higher by the time it reached the shore.
- Once the wave reached the shore, it crashed onto the land—like it was falling over. Say, *Okay, wow! We have analyzed three different wave models. Let's take stock of how we can use each model to help us explain how an earthquake could cause a tsunami.*

6. Reflect on the benefits and limitations of the three wave models.

15 MIN

Materials: *Wave Investigations*, Comparing Different Wave Models chart

Gather in a Scientists Circle. Ask students to bring *Wave Investigations* along with a chair to a Scientists Circle. Display **slide L**. Once together, have them turn and talk, saying, *Share with a partner what you think was helpful about each model to help us explain a tsunami and what was incomplete (or limiting) about each model.*

After partners have had a few minutes to share, display **slide M**. Tell the class that we will revisit each wave model and talk about what we figured out from each one, and also any limitations of the model—in other words, what was incomplete about the model for helping us explain what happens when a tsunami forms and moves. Encourage students to use what they discussed with their partner and wrote on their handout.*

Discuss the models' benefits and limitations and record what is shared on the Comparing Different Wave Models chart. An example of a completed chart is below.

***Supporting Students in Engaging in Developing and Using Models**
This lesson uses three different ways to model the generation and movement of water waves, including tsunamis. Each one allows students to learn something new about the phenomenon, while it also has limitations that do not

Model	Benefits of this model	Limitations of this model
Foil Pan Model	Shows waves forming and rippling out from the part of the pan that is moved. Shows how waves reflect off the pan walls. Shows what happens to the energy of the wave when it collides with the side of the foil pan--the wave transfers energy and reflects back.	The water was all at the same depth, so it doesn't model how these waves affect the land when the depth changes. We could only see what happens when the water collides with a vertical wall of the pan, not a shallower shoreline. The waves are very small compared to a tsunami.
NOAA Tsunami Model	We can see that water in the ocean moves like the water in the pan and that a tsunami that begins far away from the United States can still affect the shores of the west coast. We can also see how strong the waves are along all the shorelines of the Pacific. This model is made from actual data of the 2011 Japan tsunami.	We can use this to see how the wave moved across the ocean and how intense the waves were that hit shore all along the Pacific, but we don't see any effects on the land beyond the shore. We can't clearly see how the depth of the water might have been different, like at different shorelines, and how this might have affected the waves.
Tsunami Wave Model	We can use this to get an idea of what happens when a large wave reaches shore but without anyone getting hurt and without any houses being damaged. We can see the ocean floor breaking, like in an earthquake, and how the water moves outward from this point toward the shore. Data of real waves were used to make this model.	It is only computer-generated and not real. The different views make it difficult to see everything that is happening at once. We have to analyze and put together the different pieces to try to make sense of what is happening with the wave.

Once the chart is complete, have students look back over what was recorded. Ask them to look for any similarities between the parts of each model that are mentioned in the chart. For example, it will likely include an entry for each model about the movement of the waves. Also, ask them to look for any similarities between the limitations of each model.* For example, the Foil Pan Model and the Tsunami Wave Model are at much smaller scales than the ocean, which may affect what we are seeing the waves do in those models.

Conclude class by asking, *How did looking at more than one model help us in our analysis of an earthquake-driven tsunami?* Students should say something about how each model helped us figure out some things about water waves and how they move, but that we were able to get a more complete understanding of the behavior of water waves when we considered all three models.

fully represent the phenomenon. Comparing multiple ways to model achieves two purposes:

- Students develop a critical lens for evaluating the limitations of models and can see those limitations across different ways of modeling the same phenomenon.
- It prepares students to think like an engineer by using multiple models to study a phenomenon in order to fully understand how it works and how to design solutions necessary to address an identified problem.

Assessment Opportunity

Building towards: 3.B Evaluate the limitations and benefits of different wave models for explaining how tsunamis form from a movement in the ocean floor (causes), and how they move and change as they approach the shore (effect).

What to look for/listen for: Students' ability to identify the benefits and limitations of the three wave models used to explain how an earthquake can cause a tsunami. Students work with a partner initially to look back through what they have recorded about waves, earthquakes, and tsunamis from the models analyzed on days 1 and 2, and they identify benefits and limitations in partners and as a class. See the example Comparing Different Wave Models chart in this Teacher Guide.

What to do: Students may struggle to identify limitations, as this term may be unfamiliar in this context. Encourage them to revisit what they observed and recorded in *Wave Investigations* to help them realize that the word *limitations* refers to the models' inability to give us a complete picture of what happens during a tsunami. Provide example(s) to help them see that none of these models alone is a full explanation, but if they put together the pieces they observed in each simulation, they have a more complete picture of how a tsunami forms and moves.

End of day 2

7. Reflect on new science ideas.

15 MIN

Materials: science notebook, Science Ideas chart

Convene a Scientists Circle. Have students bring their science notebook and a chair to a Scientists Circle. Display the Science Ideas chart where everyone can see it, and write the lesson question in the first column. Display **slide N** and give students a few minutes to think about the prompts on the slide. Encourage them to write their ideas into their science notebook.

Ask students to share some ideas for how earthquakes on the ocean floor cause tsunamis. As students share, record their ideas in the second column of the Science Ideas chart. Here are some examples:

- The movement of the ocean floor up and down, during an earthquake, causes the water above it to move.
- Waves are formed when this water movement happens.
- The bigger the movement of the ocean floor, the greater the disturbance of the water above it.

Then, ask students to share some ideas for how the wave moves and what happens as it nears the shore. Continue to record these on the chart. Here are some examples:

- These waves move out like ripples from the epicenter in all directions.
- As the waves move toward the shore where the water is shallower, their height (amplitude) increases.
- When the wave reaches the shore, it crashes onto the shore and then spreads up onto the land.
- When this happens, it transfers energy to the land.
- The bigger the wave that reaches the shore, the more water will move onto the land and transfer its energy.

Additional Guidance

Wait to update the engineering column of the Science Ideas chart until after updating the Tsunami Chain of Events poster.

8. Update the Tsunami Chain of Events and consider engineering ideas. 20 MIN

Materials: Tsunami Chain of Events poster, large sticky notes, markers, Science Ideas chart

Facilitate a Consensus Discussion to update the Tsunami Chain of Events poster. Display **slide O**. Say, *Let's return to our Tsunami Chain of Events. In our last lesson we figured out that higher-magnitude, shallow earthquakes lead to higher waves and then a tsunami can happen. Now, we know more about how a wave forms from this kind of earthquake. So let's add that to the poster.* Using prompts like those below, guide students to identify the motion of the ocean floor and the water above it.

Additional Guidance

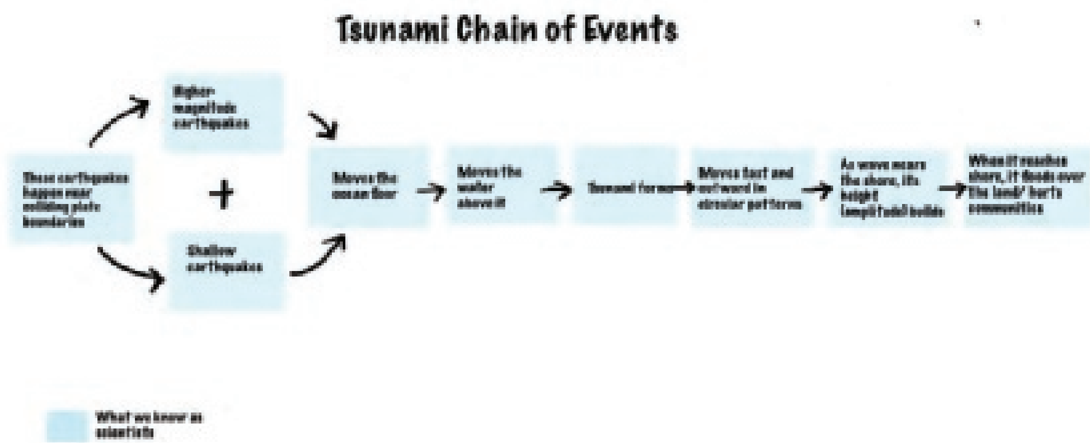
The Tsunami Chain of Events poster was started in Lesson 2, using large sticky notes as steps in the chain to show cause-and-effect relationships. Some of the sticky notes from Lesson 2 may need to be shifted as the class comes to consensus. For example, students previously figured out that higher-magnitude, shallow earthquakes cause greater wave heights, leading to tsunamis. At this point, it is important to add the new ideas that this type of earthquake causes the ocean floor to move, which causes water to be displaced above it, which then causes a tsunami to form.

Suggested prompts	Sample student responses
What happens to the ocean floor when this kind of earthquake occurs?	*The ocean floor moves.*
When the ocean floor moves, how does this affect the water?	*The water moves too.*
For a tsunami to form, how is the ocean floor moved?	*up and down* *One part of the land moves up and the other moves down.*

Say, *Okay, so let's update our Tsunami Chain of Events to capture what is happening to the ocean floor.* Modify or add large sticky notes on the poster accordingly. See example below. Continue the discussion by saying, *We also have figured out more about what happens with the wave after the tsunami forms.* Use prompts like those below to elicit the rest of the tsunami chain of events.

Suggested prompts	Sample student responses
Once the ocean floor cracks and moves, causing the water above it to move and form a tsunami, what happens with the water waves?	*The wave moves away from the spot where the earthquake happened in a circular or ripple pattern until it reaches the shore.*
Does this happen fast or slow?	*Fast!*
What happens to the wave as it gets closer and closer to shore or land?	*As the wave gets closer to land, it gets taller when it reaches the shore where the water is shallower. The water that is part of the wave gets pushed up higher.*
When it reaches the shore, what happens to the wave?	*The wave crashes onto the shore and transfers its energy to whatever it collides with. This can lead to flooding and to communities being hurt.*

Say, *Okay, so let's add more to our Tsunami Chain of Events to capture what is happening with the tsunami as it moves toward the shore.* Add large sticky notes to complete the poster. See example here:



Update the Science Ideas chart to include engineering applications. Brainstorm how these science ideas could be useful to engineers. Say, *Now that we have figured out all these science ideas about how tsunamis form and what happens when they reach the shore, let's think about how these ideas can help engineers develop ways to protect communities.*

Ask students how engineers might use this information to protect communities. As ideas are shared and the class agrees, add them to the third column of the Science Ideas chart. Here are some example ideas:

- Knowing the types of earthquakes that cause tsunamis will help us to monitor for those earthquakes so we can warn communities when one occurs.
- Knowing the location of a strong, shallow earthquake in relation to communities will help to determine who needs to be warned and when.

- Knowing the locations where this type of earthquake has happened in the past will help to develop different ways to stop or block the tsunami before it affects people and communities.
- If we know how fast a wave is moving, we can determine who needs to be warned first.
- If we know what the land looks like where a tsunami will come to shore, we can determine where would be best to build new buildings so they won't be affected by tsunamis.

9. Navigation

10 MIN

Materials: Science Ideas chart, Local Hazards poster and Technologies or Related Solutions poster

Consider the use of tsunami science ideas for other natural hazards. Draw the class's attention to the Local Hazards poster and Technologies or Related Solutions poster from Lesson 1. Display **slide P** and read the question aloud: *If we could get these same key pieces of data about a different natural hazard, do you think they could be used to predict where that hazard will occur and to figure out ways to protect communities?* Have students turn and talk about that question with a partner for a minute or two.

After a few minutes, help students consider how to generalize the tsunami science and engineering ideas to other hazards with prompts like these:

- *Why is it important to know where these things happen and when they happen?*
- *Do you think knowing how big the hazard is, how fast it is moving, and how close it is to communities would all be important pieces of data to consider for other hazards?*
- *What similar types of data for other hazards do you think we could use to help predict where these hazards might occur in the future?*

Let a few students share their ideas. Then tell the class that throughout the unit, we will continue to work on the tsunami hazard, but it is important to keep in mind how the tsunami ideas might be helpful to consider for other hazards.

How can we forecast where and when tsunamis will happen and which communities are at risk?

Previous Lesson

We analyzed three different wave models to make sense of how an earthquake-driven tsunami forms and moves to shore. We used different perspectives to understand various aspects of the phenomena, and then we identified the benefits and limitations of each model.

This Lesson

Putting Pieces Together

1 DAY

Using the Tsunami Chain of Events poster as evidence from previous lessons, we construct an explanation of the related geologic forces that cause a tsunami to form, and we forecast impact for communities at risk. Then we use what we know about tsunamis—where they happen and how they form and move—to consider how to protect people and property from their effects. We revisit the Driving Question Board to determine which questions we can answer.

Next Lesson

We will revisit the coastal communities of Japan to evaluate existing solutions designed to protect them from tsunamis. We will define our problem and identify criteria and constraints for evaluating solutions. We will use a systematic process to determine which solutions might be promising for these communities. We will consider how needs vary from one community to another and what is needed if a solution fails.

Building Toward NGSS

MS-ESS3-2, MS-ETS1-1, MS-ETS1-2

What Students Will Do

4.A Apply scientific ideas to construct an explanation for how sudden changes in the ocean floor during an earthquake lead to the formation of a tsunami.

4.B Construct an explanation that includes qualitative relationships between variables (distance to epicenter, shoreline topography) that predicts which communities are most at risk for damage as a result of a sudden change.

What Students Will Figure Out

- Tsunamis happen suddenly and can travel at high speeds over great distances; depending on where the tsunami forms, communities have more or less time to respond.
- Locations close to water, at lower elevation, and with high population have greater risk for tsunami damage.

Lesson 4 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION: FORECAST RISK TO COMMUNITIES** Use the Tsunami Chain of Events to forecast risk of damage to people and property by tsunamis.	A	*Forecasting Risk to Communities*, Tsunami Chain of Events poster, marker
2	20 min	**USE EXPLANATIONS TO FORECAST RISK OF TSUNAMIS** Use ideas from previous lessons to construct explanations about how geologic forces, such as earthquakes, can cause tsunamis to form.	B	*Explaining and Forecasting Tsunami Risk*
3	10 min	**REVISIT THE DRIVING QUESTION BOARD** Revisit the Driving Question Board (DQB) and determine which questions can now be answered. Work in partners or small groups to document answers to those questions.	C-D	sticky dots, black markers, 5-x-8 index cards, tape, pushpins (optional)
4	5 min	**NAVIGATION: MOTIVATE THE NEED TO REVISIT ENGINEERING DESIGN** Revisit initial ideas and designs from Lesson 1 for detecting, warning, and reducing damage caused by a tsunami. Motivate the need to evaluate existing solutions.	E	*Tsunami: Japan 2011*, sticky dots
				End of day 1
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 4, students are ready to read Student Reader Collection 2 and then respond to the writing exercise.		Student Reader Collection 2: *Forecasting the Unpreventable*

Lesson 4 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• *Forecasting Risk to Communities* • *Explaining and Forecasting Tsunami Risk* • sticky dots • science notebook • *Tsunami: Japan 2011*	• black markers • 5-x-8 index cards • tape • pushpins (optional)	• Tsunami Chain of Events poster • marker

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Online Resources

Lesson 4 • Where We Are Going and NOT Going

Where We Are Going

This lesson focuses on students checking their understanding of the geologic forces that cause tsunamis to form, and using their new understandings about how tsunamis form and move across the ocean to predict which communities are most at risk for damage and why.

Where We Are NOT Going

Although the student assessment deals with warning signals being sent to areas at risk for a tsunami, the details of those systems and how much warning time they give are not addressed here. Those systems will be explored more fully in Lessons 5-7.

1. Navigation: Forecast Risk to Communities

5 MIN

Materials: *Forecasting Risk to Communities*, Tsunami Chain of Events poster, marker

Revisit the Tsunami Chain of Events. Point to the Tsunami Chain of Events poster and say, *In the last few days, we've figured out how tsunamis form. Now that we understand the Tsunami Chain of Events, we can use what we know to forecast which communities are most at risk for tsunamis.* Distribute a copy of *Forecasting Risk to Communities* to each student.

Show **slide A** and say, *A high-magnitude, shallow earthquake has occurred at a colliding plate boundary in the Pacific Ocean, which has formed a tsunami. Turn and talk with a partner to brainstorm these questions:*

- *Where are people and property at risk for damage from tsunamis?*
- *What other pieces of information do you want to know to better determine which places are at risk?*
- *How will that extra information help you forecast which places are at risk?*

Pause to allow students to brainstorm with their partners. Ask, *From what we know now—that this type of earthquake occurred and a tsunami formed—which places are potentially at risk for damage from tsunamis?* Listen for student responses such as this:

- *It could be anywhere!*
- *Tsunamis seem to happen more often near ______.*

Anywhere? So, a tsunami from this earthquake could damage people and property in Europe? Point to where Europe is located on the map in the handout. Listen for student responses such as this:

- Well, not anywhere…places with land touching the Pacific Ocean, because that's where the earthquake happened and the tsunami formed.

Circle the sticky notes on the poster that say "Higher-magnitude earthquakes" and "Shallow earthquakes." Write "Places with land touching a body of water that has these kinds of earthquakes are at risk" on the chart paper next to the circle. Say, *So, do all the places that touch the Pacific Ocean need to be ready for a tsunami to arrive? What other information do you want to know about the earthquake to help you decide which places are at risk?*

Listen for student responses such as these:

- We want to know where the earthquake happened.
- We want to know what the land is like at the shore.

Ask, *How does knowing where the earthquake happened help us forecast which places are at risk for tsunami damage?* Listen for student responses such as these:

- The wave moves outward in a circular pattern, so places that are closer will get the tsunami first.
- The wave loses energy as it travels, so places that are farther away are less at risk for damage.

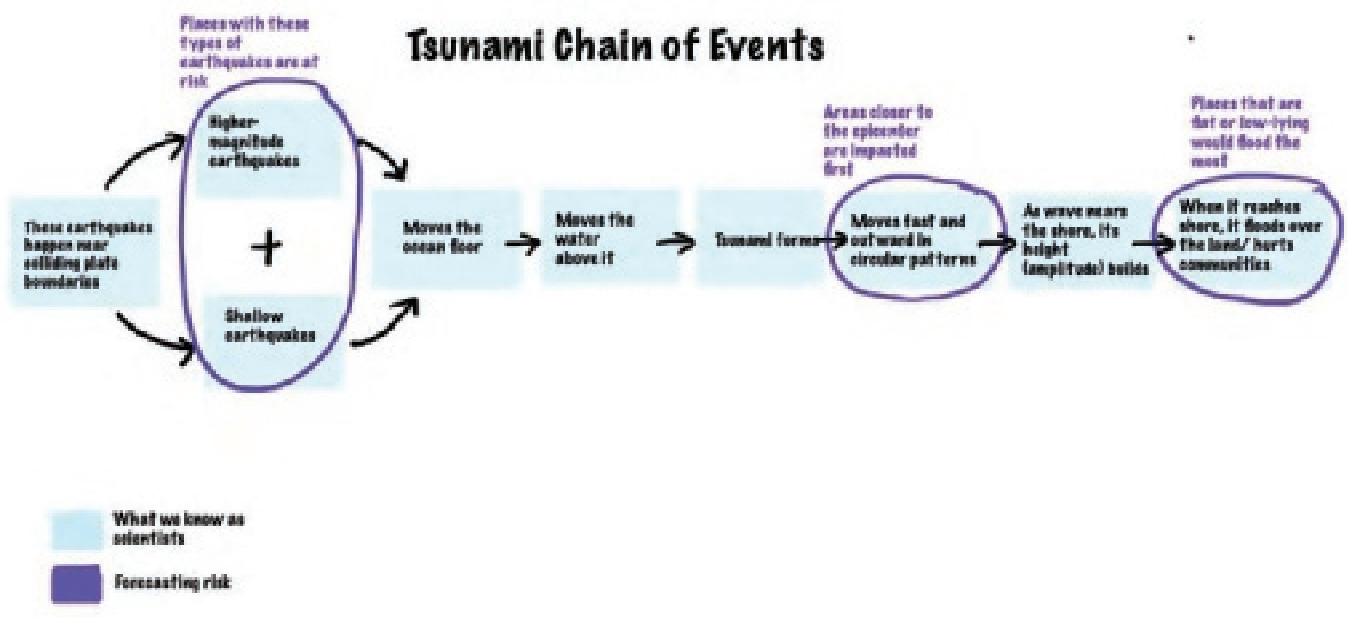
Circle the sticky note that says “Moves fast and outward in a circular pattern.” Write “Areas closer to the epicenter are impacted first and more severely” on the chart paper next to the circle.

Ask, *How does knowing what the land is like at the shore help us understand which people and communities are at risk?*

- We know that flat or low-lying places will get flooded the most in a tsunami, so people and property in those areas are most at risk for damage.

Circle the sticky note that says “When it reaches shore, it floods over the land/hurts communities.” Write “Flat or low-lying places are flooded the most” on the chart paper next to the circle.

The Tsunami Chain of Events poster might now look like this:



2. Use explanations to forecast risk of tsunamis.

20 MIN

Materials: *Explaining and Forecasting Tsunami Risk*

Introduce the assessment. Say, *Now that we have used the Tsunami Chain of Events to identify characteristics of areas at risk for damage from tsunamis, we are going to apply it to forecast risk for tsunami damage in a new situation. Use resources from your notebook and the Tsunami Chain of Events to help you work through this scenario individually. This is an opportunity to use what we have learned about tsunamis to construct explanations for a tsunami event.**

* Supporting Students in Developing and Using Stability and Change

In this assessment, students incorporate ideas about how sudden events, such as a high-magnitude, shallow, ocean floor earthquake, can suddenly disrupt the stability of a region. Depending on proximity to

Distribute a copy of *Explaining and Forecasting Tsunami Risk* to each student. Give students a few moments to orient themselves to the assessment, then show **slide B** and say, *Imagine that a shallow earthquake of 7.6 magnitude occurs along a colliding plate boundary in the Pacific Ocean. Should tsunami warning signals be sent out to countries along the Pacific Ocean? Use what we know about tsunamis and how they affect places along coastlines to do these things:*

- *Explain whether this type of earthquake could cause a tsunami to form and how it happens.*
- *Rate the level of risk for damage and how quickly each of the four different locations will be impacted.**
- *Determine which place is most at risk for damage from a tsunami and explain why you think so.*
- *Determine which location should be prioritized for resources to protect against future tsunamis.**

Complete and collect the assessment. Give students about 20 minutes to complete the assessment. Collect their work as they finish.

Assessment Opportunity

Building towards: 4.A Apply scientific ideas to construct an explanation for how sudden changes in the ocean floor during an earthquake lead to the formation of a tsunami.

4.B Construct an explanation that includes qualitative relationships between variables (distance to epicenter, shoreline topography) that predicts which communities are most at risk for damage as a result of a sudden change.

What to look for/listen for: Students should make connections that when sudden shifts in the ocean floor form a tsunami, it can move quickly across the ocean and cause damage when it reaches the coastlines. They should use scientific ideas of how waves move and qualitative variables such as relative distance to the epicenter and local shoreline topography to rank order the risk of four places, determine which place needs immediate action, and determine where tsunami-mitigation funds should be prioritized.

What to do: If students struggle in developing explanations and/or ranking the risk of different places, call attention to supports embedded in the assessment, such as pictures and descriptions. Also consider these prompts to help their sensemaking:

- Remind students to support their claims with evidence from their Tsunami Chain of Events poster and observations made during the first 3 lessons of the unit.
- Provide sentence stems (on a sheet of chart paper) to help students write a claim supported by evidence. For example, "Place.________ is most at risk for damage from a tsunami. I know this because__________".
- Remind students that damage resulting from a tsunami is associated with the loss of lives and properties; they should consider the potential people and property that might be impacted in each place.

Use *Scoring Guidance for Explaining and Forecasting Tsunami Risk* to help you assess students' ability to construct an explanation that describes how sudden geologic forces (i.e., an earthquake) in the ocean floor can cause a tsunami, how different communities may be at varying risk of damage, and which communities should be prioritized for tsunami mitigation resources.

the earthquake, communities will have more or less time to respond. This is a key crosscutting concept for understanding why we forecast which communities are at risk for tsunami hazards and develop different mitigation strategies to protect those communities from damage.

* Supporting Students in Engaging in Constructing Explanations and Designing Solutions

Students have had multiple opportunities to construct explanations using evidence and reasoning throughout the grade 6 units. This explanation task introduces the new challenge of ranking places at risk and using key science ideas to develop a rationale for communities' varying risk based on community characteristics and what they have learned about how tsunami waves form and move.

* Attending to Equity

Supporting Empathy and Emotions: Make sure that students develop an understanding that the triggering event for natural hazards is often out of people's control. Natural processes occur on Earth all the time, such as the earthquakes in the Pacific Ocean in the anchoring lesson (Lesson 1) and again in this assessment task. These events are hazardous because the outcomes impact people and property; but through forecasting and assessing risk, we can prepare people and respond quickly. This assessment

Alternate Activity

Instead of completing *Explaining and Forecasting Tsunami Risk* individually, students can work in small groups on parts of the assessment. Utilize this option if students have struggled with constructing explanations in previous units or if you want to promote discourse within small groups or peer review of explanations. If you select this option, encourage students to use the Communicating in Scientific Ways poster to practice developing and coming to group consensus on their explanation.

Also, consider providing the option of completing the assessment orally for students who may need this modification.

Additional Guidance

This is an individual Assessment Opportunity for the DCI element ESS3.B Natural Hazards *(Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events).* Tsunami forecasting is a combination of using historical data to know which communities are at risk, using real-time earthquake data to know whether a tsunami could result, and then studying how waves form and move to understand how quickly and severely they may damage communities. If students are struggling with ideas related to this DCI, consider making connections to forecasting experiences they have likely experienced in their local community, such as these:

- Weather forecasts for severe storms: Ask students how they think weather forecasters know that a storm is approaching—what conditions might exist? (Link back to ideas in the *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit).)*
- Predicting high fire danger: Students living in places prone to fires likely have experiences with "high fire danger" signs or forecasts. Ask students what data scientists use to know the fire danger is high (e.g., high temperatures, dry fuel, high winds).

Use these local examples to help students make connections to the data that tsunami forecasters use to predict whether a tsunami will form, and if it does, which communities will be affected. Students will also revisit risk and forecasting of other hazards on day 1 of Lesson 10.

task may bring up negative emotions from students who have experienced a hazard. Encourage students by letting them know that we can assess risk for different communities and better protect them from damage by using data and science ideas.

*** Attending to Equity**
Supporting Emerging Multilingual Students:
When students are tasked with expressing their ideas, allow them to do so through linguistic (oral and written language) and nonlinguistic (e.g., drawings, graphs, symbols, gestures) modes. Providing emerging multilingual students with such opportunities allows them to use all of their resources to express meaning.

It is also helpful to intentionally group emerging multilingual students. This could be peers who know the same language, or it could be peers whose English language development is slightly more advanced. It is important that these groupings be thoughtful so that they benefit from working in pairs or small groups.

3. Revisit the Driving Question Board.

10 MIN

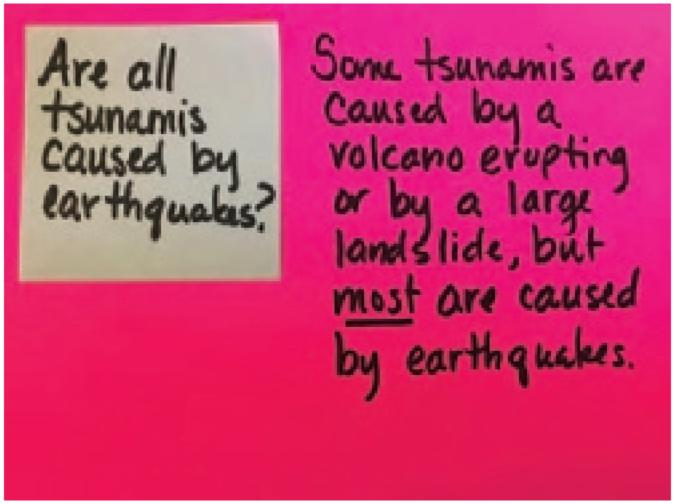
Materials: sticky dots, black markers, 5-x-8 index cards, tape, pushpins (optional)

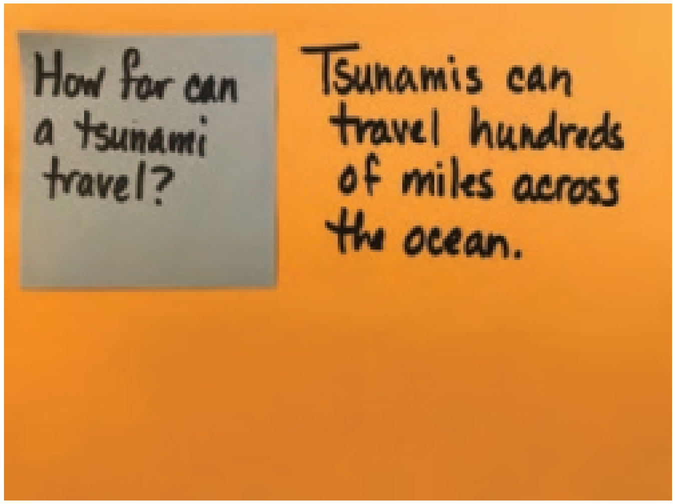
Review questions on the DQB. Show **slide C** and say, *Now, let's revisit the DQB. Take a few minutes to look through the questions on the board, and put sticky dots on those that you think we can now answer based on what we have learned about tsunamis up to this point. We will then work in partners or small groups to document answers to those questions.*

Ask students to gather around the DQB, then give them 2-3 minutes to individually place sticky dots on questions they feel they can answer. Have them step back and review the selected questions. After a minute or two, ask students to share their selections.

Suggested prompt	Sample student responses
Under which categories did we find questions that we can now answer?	*Some of the questions we tagged are under the category of "Causes of Tsunamis."* *Some of the questions that ask "Where Tsunamis Happen."* *Some are about the "Kind of Damage Tsunamis Cause" when they hit a coastline.* *Some questions that ask about the "Size and Strength of Tsunamis."*

Document and post answers to selected questions.* Show **slide D** and have students work either in pairs or in groups of 3 to select a question with a sticky dot and return to their desks. They should tape their selected question to the upper-left hand corner of a large (5-x-8) index card, then use a black marker to write the answer on the index card. While students work, write the category titles on large index cards, and use tape (or pushpins) to post these cards near the DQB. Leave room under each category card for answered questions. As students finish, have them use tape (or a pushpin) to post their answered question (that is, their taped-together question and index card answer) under the appropriate category. All unanswered questions will remain on the DQB.





Additional Guidance

The categories on your DQB and the questions selected may differ slightly from those in the sample responses here. However, students should select questions that focus on the geologic forces that trigger tsunamis, the motion (or energy) that occurs as tsunamis move across the ocean and onto land, and the effects of tsunamis on coastlines and coastal communities.

Alternate Activity

Please note that this activity may take more than the allotted 10 minutes, especially if students have little or no experience documenting answers to questions from the DQB. If you do not have enough time to complete this activity in class, each student can select a question and tape it to an index card to take with them as a home learning assignment. They can document the answer to their assigned question at home and return the completed card at the beginning of the next class period.

4. Navigation: Motivate the Need to Revisit Engineering Design

5 MIN

Materials: science notebook, *Tsunami: Japan 2011*, sticky dots

Motivate the need to revisit engineering designs with new science ideas in mind. Say, *We have a pretty good understanding of what causes tsunamis, where they happen, how they move, and the types of places where they impact people and property. If we can forecast where tsunamis are more likely to cause damage, then we can do something about it—we can try to prepare and protect people and property from this natural hazard.*

Show **slide E** and ask students to turn back in their notebooks to *Tsunami: Japan 2011* from Lesson 1. Give them a minute to find the handout, then say, *Take a few moments to look back at your own ideas and the ideas you recorded from others for tsunami detection, warning, and reducing damage. Think about what we now know about tsunamis. Which designs for detection, warning, and reducing damage do you think are still promising? Place a sticky dot next to any ideas you think might be worth investing time and resources into.*

Give students a minute or two to work individually. Then say, *Turn to a partner and share one idea you marked with a sticky dot in your handout.*

As students finish sharing, summarize the lesson by saying, *Our next steps will include examining and evaluating existing solutions to determine how well they protect people and property during a tsunami.*

* Supporting Students in Engaging in Constructing Explanations and Designing Solutions

This lesson prepares students for the engineering evaluation portion of this unit. Students have had engineering design experience in the *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)*. Use that previous experience to remind them that engineers **design solutions** to mitigate the effects of natural hazards using scientific principles, and that those design solutions must go through rigorous evaluation to determine how well they meet criteria and constraints. Beginning in Lesson 5, students will use criteria and constraints to **evaluate** a variety of tsunami detection, warning, and mitigation systems designed by engineers to protect people and property.

SCIENCE LITERACY: READING COLLECTION 2

Forecasting the Unpreventable

1 **Tsunami Models**
2 **Dear Scientist Column**
3 **Cranky Yankee Blog**
4 **The Cascadia Subduction Zone**
5 **COVID Forecasts**

Literacy Objectives

- ✓ Summarize key points related to forecasting natural hazards.
- ✓ Organize related details about mathematics related to natural hazards in a visual presentation.
- ✓ Distinguish between credible and noncredible sources.
- ✓ Translate text to visual/graphic representation of ideas.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 3 and 4.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare an infographic in response to the reading.

Instructional Resources

Student Reader
Collection 2

Science Literacy Student Reader, Collection 2
"Forecasting the Unpreventable"

Exercise Page
EP 2

Science Literacy Exercise Page
EP 2

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 3: What causes a tsunami to form and move?
- Lesson 4: How can we forecast where and when tsunamis will happen, and which communities are at risk?

Standards and Dimensions

NGSS

Disciplinary Core Ideas ESS3.B: Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.

ETS1.C: Optimizing the Design Solution
Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design.

Science and Engineering Practices: Analyzing and Interpreting Data; Using Mathematics and Computational Thinking; Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Systems and System Models; Stability and Change

CCSS

English Language Arts
RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.8: Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

WHST.6-8.2.D: Use precise language and domain-specific vocabulary to inform about or explain the topic.

Math

CONTENT.7.SP.C.5: Understand that the probability of a chance event is a number between 0 and 1 that expresses the likelihood of the event occurring. Larger numbers indicate greater likelihood. A probability near 0 indicates an unlikely event, a probability around 1/2 indicates an event that is neither unlikely nor likely, and a probability near 1 indicates a likely event.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

pandemic

probability

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

accurate

amplitude

anthropology

epidemiologist

subduction zone

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Natural Hazards unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *First, you will read how scientists build models to predict how much time it will take a tsunami to travel from its source to shorelines around the world.*
  - *Next, you'll read a mock ask-a-scientist newspaper feature to learn how the shapes of tsunamis differ from other water waves.*
  - *Then, you'll read a fictitious blog post from a person who complains that all bad weather is blamed on climate change and that this shouldn't be so. Then someone posts a comment to present another viewpoint.*
  - *You'll also read an article about an earthquake fault zone right along the coast of California, Oregon, and Washington. The author presents evidence to support the claim that the fault is the source of strong earthquakes and tsunamis about every 243 years.*
  - *Finally, you'll take a close look at some graphs produced by epidemiologists that attempt to forecast the impact of a pandemic.*
- Distribute Exercise Page 2. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate an infographic highlighting several mathematical ideas presented in this collection.*

Exercise Page

EP 2

- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What factors do scientists use to estimate when a tsunami wave will hit a particular coastline?	*the speed of the wave through the water, the shape of the ocean floor, and where landmasses are located*
What kinds of evidence can scientists use to learn when in the past tsunamis have struck land?	*physical evidence, by looking at the changes in the land and plants* *historical evidence, by comparing records of the same event from different countries* *anthropological evidence, such as stories passed down from one generation to the next*
How can governments use epidemiologists' pandemic forecasts?	*to make decisions about which businesses can be open and whether people need to wear masks in public*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
How does understanding the movement of a water wave inform scientists who are trying to forecast where a tsunami will hit land?	*They know that a wave starts from a single point and then moves outward in a circular pattern. So, a tsunami wave would move outward from the epicenter of the earthquake in all directions and can hit land on any side of the ocean.*
Why do tsunami waves increase in amplitude before they strike land?	*When a tsunami wave gets closer to shore, the ocean floor is shallower, slowing down the lower levels of the water to cause a wave to crest.*
When scientists predict the damage of the next Cascadia subduction zone tsunami, what characteristics of the land should they look at?	*They should look for low-lying, flat land along the ocean shore. These are areas that will have the most flooding.* *Narrow inlets and harbors will have the greatest wave height.*

- Refer students to the Exercise Page 2. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
    - *As you know from your work in Unit 2, an infographic shows a nicely arranged and limited number of important ideas. This time, you'll find four or five mathematical ideas in the readings to highlight.*
    - *Try to choose ideas related to using numbers from at least three different reading selections.*
    - *Again, don't worry about your infographic having the perfect layout or perfect drawings. Consider it a draft that you want to share before creating a polished final product.*
    - *The important criteria for your work are in the evaluation checklist. Refer to them as you plan, write, and use color in your design.*
- Explain that a well-organized infographic has a theme described in the title, interesting data, and usually a simple color scheme.
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page

EP 2

4. Facilitate discussion. (FRIDAY)

Facilitate class discussion about the reading collection and writing exercise. Students begin the reading activity with an article explaining how scientists use and improve models to forecast when a tsunami will strike specific land areas. Two other selections in the collection are related to tsunamis. The remaining two explore forecasts of storms and pandemics.

Pages 14–17 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "Tsunami Models"?	*It describes models that are used to predict the arrival times of tsunamis and shows how to graph their accuracy.*
According to the image that shows the arrival times of the first wave how far can a tsunami wave travel?	*clear across the Pacific Ocean and even around the tip of South Africa to reach coasts along the Atlantic Ocean*
How would scientists determine the accuracy of the simulation of first wave arrival times?	*They would need to compare the arrival time values on the model with the actual arrival times for that tsunami.*
What is the general purpose of the second selection, "Dear Scientist Column"?	*It uses an ask-a-scientist format to explain why the height of a tsunami depends on where it hits the shore.*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first article explains how scientists predict the time when a tsunami wave will arrive at different coastlines. The second article focuses on the height and shape of the tsunami when it hits different coastlines.*
After reading the definition of amplitude *in the "Word to Know" box, explain where the resting point of a tsunami wave is located.*	*probably at sea level where the water is flat*

Student Reader

Collection 2

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Online Resources

Pages 18–23 **Suggested prompts**	**Sample student responses**
What is the general purpose of the third article, "Cranky Yankee Blog"?	*The first part is a blog post that tries to persuade the audience that blizzards and hurricanes have nothing to do with climate change. The second part is a comment to the blog explaining why the original post is misleading.*
Take a look at the "Spot the BS" box. Can you list the ways this cranky blogger misrepresents facts? How does the blogger try to convince readers that climate change is not a real threat?	*The blogger is saying that some people are saying ALL hurricanes and blizzards are caused by climate change.* *The blogger also says, "The climate has always been changing." That is true, but it is the rate of change that is a threat.*
Look at the "Consider the Source" box. What information does the commenter provide that makes him seem like a credible source?	*The commenter says he is a scientist and gives his education level—PhD—and says he teaches in a college chemistry department.*
How is understanding the explanation of the word probabilities *in this reading important?*	*The scientist's argument depends on it. The blogger needs to understand that global warming affects the temperature of sea water, and because of this, more frequent and more severe storms will probably occur.*
What is the general purpose of the fourth article, "The Cascadia Subduction Zone"?	*It describes three sources of evidence that support the claim that there was a really big tsunami in the Pacific Ocean on January 26, 1700.*
Look at the "Dig into Data" box. What data in the article most strongly support the argument that the oceanic Juan de Fuca plate is, in fact, subducting?	*I think the physical evidence about the trees all dying at the same time is the most convincing evidence.*
How is the anthropological evidence from the Huu-ay-aht First Nation similar to the historical evidence from Japan?	*Both are forms of history, one recorded in writing and the other a spoken (oral) history.*
How do you think the scientists know there is a pattern of earthquakes and tsunamis every 243 years?	*They must have found evidence that there was an earthquake and tsunami before the one in 1700. Maybe it was physical evidence because the Japanese record only goes back 500 years. But the oral history of the First Nation might go back further.*
What is the general purpose of the fifth article, "Covid Forecasts"?	*It shows how graphs can be used to display both actual data and predictions of how a pandemic will affect people.*

SUPPORT—Some students will need to refresh their understanding from studying waves in Grade 4 of the Core Vocabulary term *amplitude*. Allow these students to play with the "Waves on a String" simulation on the PhET website. If they choose the setting for "No End," it may help them in relating the amplitude of a wave on a string to a side view of a wave in water.

SUPPORT—Point students to videos with animations that make the motions of the Cascadia subduction zone easier to see and understand. After listening, have students turn off the sound and narrate the animations themselves.

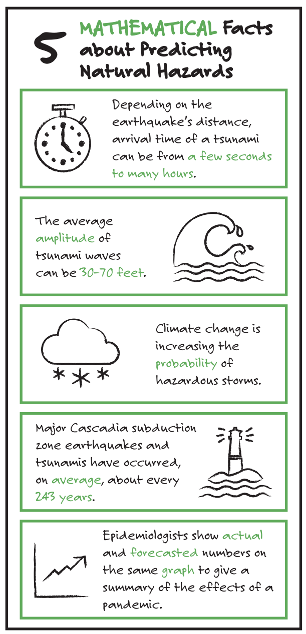
Page 23 Suggested prompts	Sample student responses
On the "National Forecast" graphs, which parts show actual deaths, and which show forecasted deaths?	*Actual deaths are the black data points and lines. The dark red points and lines are forecasts.*
On the "National Forecast" graphs, why are the tan shaded areas very wide in the first graph and very narrow in the second graph? Is there more uncertainly about the weekly numbers?	*No, they are different widths because the scales of the graphs' y-axes differ.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 2, students should design and develop text and illustrations for an infographic that highlights how mathematical ideas support the science of forecasting natural hazard events. All of the reading selections in Collection 2 have mathematical references, but students may choose to refer to only three of the readings.

Look for evidence that students have accurately identified mathematical concepts or facts, have expressed their ideas with clearly worded text, and have used care in designing their layouts. An exemplary example of an infographic is shown below, but keep in mind that the checklist on the Exercise Page indicates that only four examples are required.



Use the checklist provided on the Exercise Page to supply feedback to each student.

Online Resources

EXTEND—For students who wish to use an online tool to design their infographics, point them to appropriate design apps or websites. Most of these tools have templates from which to choose layouts, design text, and colors and can be used with tablets or computers. Check the privacy policy of any tool to make sure it conforms with your school's internet-use policies. Or, instead of online tools, any drawing or presentation app on students' devices can also be used to design infographics.

How can we reduce damage from a tsunami wave?

Previous Lesson

We used the Tsunami Chain of Events poster to construct an explanation of the related geologic forces that cause a tsunami to form, and we forecasted impact for communities at risk. We considered how to protect communities from the effects of a tsunami. We revisited the Driving Question Board and documented responses to questions we could answer.

This Lesson

Investigation

3 DAYS

We revisit the coastal communities of Japan affected by the 2011 tsunami to see what solutions were used to protect them and what other existing solutions could be evaluated for future use. We define our problem and identify criteria and constraints for the solutions based on community needs. We evaluate each solution using a systematic process to determine which ones might be most promising for these communities. We consider what it means for a solution to be promising for one community versus another, and what technologies are needed if the solution in place fails.

Next Lesson

We will read about a complex system of instruments used to detect tsunamis. We will learn that tsunami warnings are only sent when specific criteria are met regarding the triggering earthquake event and whether the resulting tsunami is predicted to reach land.

Building Toward NGSS

MS-ESS3-2, MS-ETS1-1, MS-ETS1-2

What Students Will Do

5.A Make an oral argument based on a systematic evaluation process using relevant scientific principles to support or refute the ability of different existing solutions (structure) to mitigate the effects of tsunamis and meet the needs of at-risk communities (function).

What Students Will Figure Out

- Engineers account for relevant scientific principles and potential impacts on people and the natural environment when designing and evaluating solutions.
- Clearly identifying the design problem, criteria, and constraints allows for the evaluation of solutions and increases the likelihood that a solution will meet the needs of communities at risk.
- Effective solutions to reduce damage from tsunamis need to not only dissipate the energy of the wave and deflect the water, but also meet the needs of communities at risk.

Lesson 5 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	4 min	**REVISIT STUDENT-CREATED DESIGNS FOR TSUNAMI MITIGATION** Consider initial designs from the anchoring phenomenon. Note similar structures among students' ideas and consider additional data needed to improve or evaluate designs.	A	*Tsunami: Japan 2011*
2	8 min	**LEARN ABOUT THE RYOISHI SEAWALL** Read a case study about Ryoishi, Japan, and listen to a resident's story. Consider why residents rebuilt the village in the same area affected by the 1930s tsunami and what caused the seawall to fail again.	B-D	*What happened in Ryoishi Bay?*, computer, projector, 6.5 - Lesson 5 Fisherman's Experience (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), Tsunami Chain of Events poster
3	10 min	**DETERMINE RYOISHI'S PROBLEM AND POSSIBLE CRITERIA FOR SOLUTIONS** Use the Ryoishi case study to determine the problem we are trying to solve and the criteria for any solution.	E	*Evaluating Solutions to Protect Communities from Tsunamis*, chart paper, markers
4	15 min	**WATCH AN ENGINEERING TEST VIDEO AND EVALUATE SOLUTIONS AGAINST OUR CRITERIA** Watch a video of an engineer testing common tsunami solutions, and assess its credibility. Record and analyze data gathered by the engineer. Rank the solutions according to our criteria.	F-H	*Evaluating Solutions to Protect Communities from Tsunamis*, computer, projector, 6.5 - Lesson 5 Testing Wave Blocking Designs (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), Evaluating Existing Solutions chart, markers, Oysters Clean the Bay! (Filtration Time-Lapse) (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) optional
5	8 min	**DETERMINE A RATING SCALE AND IDENTIFY THE NEED FOR MORE INFORMATION** Choose a rating scale and use it to compare the tsunami-mitigation solutions. Think about other possible considerations for evaluating these solutions.	I-J	index card or science notebook, Evaluating Existing Solutions chart, markers

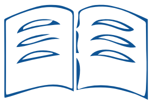
End of day 1

Part	Duration	Summary	Slide	Materials
6	3 min	**SURFACE IDEAS FOR ADDITIONAL CONSIDERATIONS** Share students' ideas from the previous class's exit ticket.	J	
7	10 min	**IDENTIFY CONSTRAINTS OF EXISTING SOLUTIONS** Read more about Ryoishi and the surrounding area. Identify constraints on which existing solutions might work for Ryoishi.	K-L	*Evaluating Solutions to Protect Communities from Tsunamis*, *Comparing Ryoishi to Nearby Communities*, chart paper, markers, (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) optional
8	10 min	**READ ABOUT EXISTING SOLUTIONS** Read about the features of existing solutions and their criteria and constraint ratings.	M-N	*Existing Solutions for Coastal Communities*
9	5 min	**REVISIT OUR CRITERIA AND CONSTRAINTS** Review our criteria and constraints charts and consider whether to add constraints from the reading to help us assess which solutions make the most sense.		*Existing Solutions for Coastal Communities*, Criteria for Solutions chart, Constraints for Solutions chart, markers
10	10 min	**RANK EXISTING SOLUTIONS ACCORDING TO RATINGS** Use solution ranking cards to order the solutions from best to worst, based upon how well they meet each criterion and constraint.	O	*Tsunami Solution Ranking Cards*
11	7 min	**INTRODUCE THE DECISION MATRIX** Introduce the decision matrix to better organize and compare solutions based upon how well they meet the criterion and constraints. Begin entering information into the matrix.	P-Q	*Tsunami Solution Ranking Cards*, *Decision Matrix*
				End of day 2
12	8 min	**ORGANIZE INFORMATION INTO THE DECISION MATRIX** Use the matrix to reorganize useful information for evaluating the solutions and decide which one(s) may be best for Ryoishi.	Q-R	*Tsunami Solution Ranking Cards*, *Decision Matrix* OR *Completed Decision Matrix*

Part	Duration	Summary	Slide	Materials
13	2 min	**MAKE AN INITIAL DECISION** Use a sticky dot to show which solution may work best for Ryoishi.	S	one sticky dot, Evaluating Existing Solutions chart
14	10 min	**ENGAGE IN A CONSENSUS DISCUSSION** Engage in a Consensus Discussion to determine which solution best fits Ryoishi's needs. Determine that the choice of solution is dependent upon prioritized criteria and constraints, and that trade-offs must be made for each solution.	T	*Decision Matrix* OR *Completed Decision Matrix*, *Comparing Ryoishi to Nearby Communities*, Evaluating Existing Solutions chart, chart paper, markers
15	10 min	**DETERMINE CRITERIA AND CONSTRAINTS VALUED BY RYOISHI** Review Ryoishi's needs. Designate primary and secondary criteria and constraints on the decision matrix.	U-V	*Comparing Ryoishi to Nearby Communities*, *Decision Matrix* OR *Completed Decision Matrix*, Evaluating Existing Solutions chart, markers
16	8 min	**REFINE SOLUTION CHOICES AS A CLASS** Discuss updated decisions based upon new priorities. Determine that the answer is still not clear, but has been narrowed down. Compare the process to the decisions and trade-offs made by actual engineers.	V	*Decision Matrix* OR *Completed Decision Matrix*
17	5 min	**REFLECT ON THE TSUNAMI CHAIN OF EVENTS** Consider and discuss how engineers can help to mitigate the effects of a tsunami on a community. Add engineering ideas and solutions to the Tsunami Chain of Events poster.	W	Tsunami Chain of Events poster, large sticky notes, markers
18	2 min	**DETERMINE NEXT STEPS** Brainstorm what else can be done to protect people from a tsunami in case of a structure failure.	X	*Tsunami: Japan 2011*

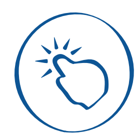
End of day 3

Lesson 5 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Tsunami: Japan 2011* • *What happened in Ryoishi Bay?* • *Evaluating Solutions to Protect Communities from Tsunamis* • index card or science notebook • *Comparing Ryoishi to Nearby Communities* • *Existing Solutions for Coastal Communities* • *Tsunami Solution Ranking Cards* • *Decision Matrix* • *Decision Matrix* OR *Completed Decision Matrix* • one sticky dot	• *Tsunami Solution Ranking Cards*	• computer • projector • 6.5 - Lesson 5 Fisherman's Experience (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • Tsunami Chain of Events poster • chart paper • markers • 6.5 - Lesson 5 Testing Wave Blocking Designs (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • Evaluating Existing Solutions chart • Oysters Clean the Bay! (Filtration Time-Lapse) (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) optional • Japan Revives a Sea Barrier article (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), optional • Criteria for Solutions chart • Constraints for Solutions chart • large sticky notes

Materials preparation (30 minutes)

Online Resources



Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Ensure that you can play the following videos:

- Fisherman's Story. 6.5 - Lesson 5 Fisherman's Experience (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

- JBA Wave Tank Testing. 6.5 - Lesson 5 Testing Wave Blocking Designs (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- Optional Mangrove Testing at either Oysters Clean the Bay! (Filtration Time-Lapse) or Mangrove Forest: Coastal Erosion Mitigation (See the **Online Resources Guide** for links to these item. **www.coreknowledge.org/cksci-online-resources**)

Print per student:

- *Evaluating Solutions to Protect Communities from Tsunamis*
- *Existing Solutions for Coastal Communities*
- *Decision Matrix* OR *Completed Decision Matrix* (see Alternate callout later in this guide)
- *What happened in Ryoishi Bay?*
- *Comparing Ryoishi to Nearby Communities*

Print per group:

- *Tsunami Solution Ranking Cards*, cut out a set of cards for each group

Prepare a chart titled "Evaluating Existing Solutions" with a row for each of the 8 discussed solutions, organized by category, and leaving space at the bottom of the chart for additional notes on constraints and complications (described later in this guide):

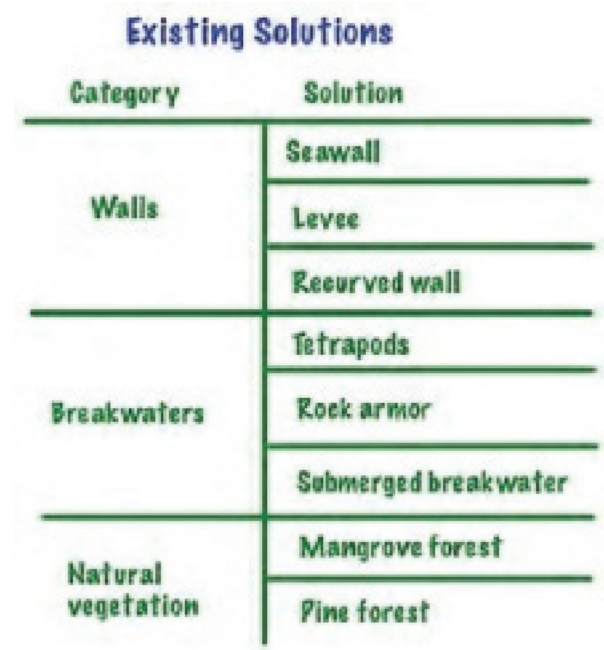
- Walls: Seawall, Levee/sea dike, Recurved wall
- Breakwaters: Tetrapod, Rock armor, Submerged breakwater
- Natural vegetation: Mangrove forest, Pine forest

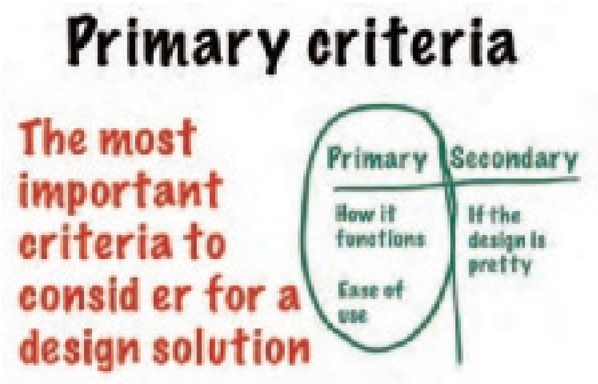
Practice pronouncing Ryoishi, Japan (it is similar to "ree-o-i-shee"). You can listen to online pronunciation tools or watch 6.5 - Lesson 5 Fisherman's Experience (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) for pronunciation.

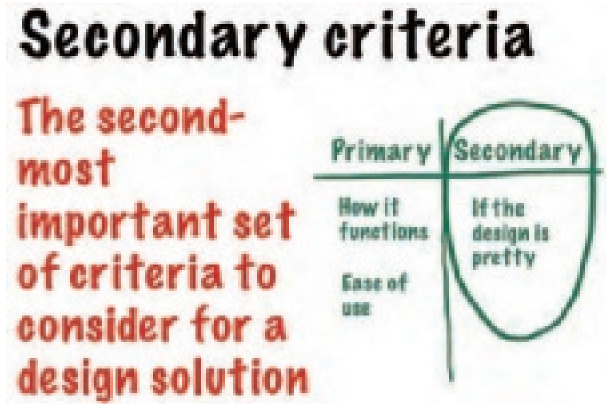
IMPORTANT NOTE: Levees or sea dikes are commonly used worldwide to reduce flooding from waves and storm surges. The video refers to them using both terms. Please be cognizant that there is a homonym that is offensive and may bother some students. We suggest that you say "levee or sea dike" in combination when talking about the structure, or just "levee." *Levee* is the word used by Japanese tsunami survivors in Lesson 7, so it is important now for students to associate that word with this structure.

Be sure you have materials ready to add the following words to the Word Wall: *criteria, constraints, primary criteria/constraints, secondary criteria/constraints,* and *trade-offs*. Do not post any of these words on the wall until your class has developed a shared understanding of its meaning.

UPDATE MINI







Lesson 5 • Where We Are Going and NOT Going

Where We Are Going

This lesson presents a variety of existing solutions designed to reduce the damage from a tsunami wave. These are real solutions used along coastlines and waterways around the world. The purpose of the lesson is for students to clearly define the problem that the solution will address, and use clearly defined criteria and constraints to evaluate each solution. After learning about Ryoishi and surrounding areas in Japan through a reading, *What happened in Ryoishi Bay?* (Lexile estimate: 810L-1000L), students use Ryoishi as the community context for evaluating the appropriateness of each solution through a handout, *Existing Solutions for Coastal Communities* (Lexile estimate: 810L-1000L), and then make an oral argument to support which one best meets the community's criteria and constraints. It is important for students to understand that each design solution has its own benefits and challenges, and what works for one community may not work for another (based on community constraints, such as the area's physical geography or societal needs).

Where We Are NOT Going

For each criterion and constraint, students qualitatively rate each tsunami-mitigation solution. Much of the quantitative data for each solution is above grade level or not publicly available. For the purpose of this lesson, a relative ranking of the solutions is sufficient and grade-appropriate, as it is more important that students use a systematic process to justify their rankings.

LEARNING PLAN FOR LESSON 5

1. Revisit student created designs for tsunami mitigation. 4 MIN

Materials: science notebook, *Tsunami: Japan 2011*

Revisit designs from Lesson 1. Say, *Last class, on Tsunami: Japan 2011, you marked designs and ideas you had from Lesson 1 for protecting communities from tsunamis. Then you shared these with a partner.*

Project **slide A**. Ask a few students to share out the designs that they felt were most promising to protect communities from tsunamis. Point out that building walls or some other type of barrier seems to be a common design idea.

Ask students what additional information we might need to help us decide between design solutions or identify features that are important to include in our designs. Tell the class that we have data on a variety of solutions, which we could use to learn more about how different features perform in a tsunami. Ask, *If we compare the performance of existing tsunami solutions, like walls or barriers, how could that help us figure this out?* Potential responses are below.

Suggested prompt	Sample student responses
If we compare the performance of existing tsunami solutions, like walls or barriers, how could that help us figure this out?	*We could see what kinds of walls or barriers people have built and compare them to our ideas.* *We might be able to see what kinds of walls or barriers worked the best. And we can see which types didn't work as well so we can avoid those.* *We can identify features of walls or barriers that worked well and incorporate them into our designs.*

2. Learn about the Ryoishi seawall. 8 MIN

Materials: *What happened in Ryoishi Bay?*, computer, projector, 6.5 - Lesson 5 Fisherman's Experience (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), Tsunami Chain of Events poster

Revisit tsunami pictures and introduce Ryoishi. Display **slide B**. Remind students that we viewed pictures of tsunami locations with seawalls in Lesson 1. Tell them that the images on the slide are of a different place in Japan that was also struck by the tsunami in 2011. Point out the green crane and explain that this picture is from near Ryoishi, a small fishing village on the coast of Japan. Say, *In this village, it was believed that the seawall should have been able to withstand a tsunami, but it unfortunately failed. Because we are interested in some type of barrier or wall as a solution, let's read a short case study and then watch a video to learn about what happened in Ryoishi.*

*** Attending to Equity**
Supporting Emerging Multilingual Learners:

The Lexile estimate of this reading is 810L-1000L. Provide opportunities for emerging multilingual students to break down the meaning of scientific words used in the lesson. Provide

Display **slide C.** Explain to students that this set of images is of the village of Ryoishi. This image set shows Ryoishi before and after the 2011 tsunami. Allow students to share some noticings they have about the pictures, spending no more than 1 minute on this step.

Read a Ryoishi case study. Display **slide D**. Distribute *What happened in Ryoishi Bay?* to each student. Make sure students read the slide and ask any clarifying questions before reading the case study. Ask them to consider the Tsunami Chain of Events as they think about their answers to the slide's questions:

- What are some general characteristics of a tsunami?
- What characteristics must the 2011 tsunami wave have had in order to cause this damage?
- Why would people continue to live in Ryoishi after it was struck by a bad tsunami in the 1930s?
- Why would it be important to consider other solutions to reduce or prevent future tsunami damage?

Give students 5 minutes to read the case study and discuss with their partners how they might use what they've read to answer the questions on the slide.

Watch an interview of a Ryoishi resident.* Tell students that we will now watch an interview of a Ryoishi resident that was recorded shortly after the tsunami. As they watch the video, they should consider how they might use what they learn in responding to the questions on **slide C**. Show 6.5 - Lesson 5 Fisherman's Experience (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Discuss the Ryoishi seawall questions. As a class, discuss the questions on the slide. Students should note that Ryoishi's residents felt safe to rebuild because they trusted the government's solution to the problem. They should also note that the reason the seawall failed in the 2011 tsunami was because it wasn't able to dissipate the waves' energy. Example prompts and responses are below.

Suggested prompt	Sample student responses
Look back to the Tsunami Chain of Events we built. What are some of the characteristics of a tsunami wave?	*We learned that big tsunamis are caused by strong earthquakes near the surface of the ocean floor.* *We learned that tsunami waves are taller than normal waves.* *We learned that the waves can move quickly and that they cause more damage in areas that are shallower or have land that easily washes out to sea.* *We learned that the waves have a lot of energy, and when a wave strikes something, some of the energy transfers to the object.*

an opportunity to discuss any preconceptions about the meaning of the word(s) and draw upon their personal experiences to make sense of them.

*** Attending to Equity**

Supporting Empathy and Emotions: The interview is an emotional first-person account of how this fisherman has been affected by a tsunami more than once. Some students may feel upset by what he experienced; they may have experienced a similar loss of home, or know someone who has. The interview was chosen to draw out ideas about how people assess their risk in light of engineered solutions designed to keep them safe, such as the Ryoishi seawall. Bring to the forefront that the fisherman and his family responded appropriately by evacuating, which saved their lives. The key idea from the video is to highlight the importance of engineers considering for "whom" (the stakeholders) they are designing solutions, as well as the importance of ensuring that people understand their risk for hazard(s) and how to respond when they occur.

Suggested prompts	Sample student responses
What characteristics must the 2011 tsunami have had in order to cause this damage?	*It must have been tall and have hit that wall with a lot of force.* *Maybe the energy was too much for the wall and it broke.* *The wave must have had more energy than the wall could take.*
Our article said that Ryoishi had been struck by a bad tsunami in the 1930s. Why would people continue to live in the area after that happened?	*The government used data from other tsunamis to design the seawall, so they felt it should have been safe.* *The seawall was improved, so it should have been able to protect the residents.* *The fisherman said that he felt safe, so they had moved there from the hillside.*
Why would it be important for engineers to consider other solutions to reduce or prevent tsunami damage?	*Maybe there was something other than a seawall that could have better protected Ryoishi.* *There may be more than one solution that could work for some problems.* *Walls and barriers can break, like we saw in Ryoishi, so it could be important to have other solutions in case that happens.* *We had a lot of designs that we considered in Lesson 1. Maybe one of them would have worked better.*

Additional Guidance

At this point, students should be able to identify relevant characteristics of a tsunami that they need to account for when evaluating solutions. These characteristics come from the Tsunami Chain of Events poster built across Lessons 2-4. If students need assistance, reference the poster to help them make connections between the science ideas they learned and what occurred in Ryoishi. Help students pull out the specifics they have learned about wave height, energy, earthquake depth and magnitude, and location.

3. Determine Ryoishi's problem and possible criteria for solutions. 10 MIN

Materials: *Evaluating Solutions to Protect Communities from Tsunamis*, chart paper, markers

Consider how to evaluate existing solutions for Ryoishi. Say, *We know that Ryoishi had a seawall that failed. There may be other options for protecting communities like Ryoshi from tsunamis in the future. When examining these solutions, maybe we can create something like a rubric or checklist to determine which might be a better solution for this community.*

Ask students the following questions:

- *What would a solution need to be able to do to reduce damage in Ryoishi?*
- *Why would it be helpful to create a rubric or checklist to help us evaluate different solutions?*

Let a few students share initial ideas. Support them in determining that a rubric or checklist could be used to evaluate how well each design meets the needs of the community and then use the findings as evidence for future recommendations.

Define the problem and considerations for a solution. Display **slide E**. Distribute *Evaluating Solutions to Protect Communities from Tsunamis* to each student. Explain that the handout will help us decide what to consider when evaluating potential solutions for Ryoishi. Give students 3 minutes to record their answers to the questions in Part 1 of the handout. Then ask the class to share what ideas they have proposed. The class should work toward agreement on defining the problem and what the solution needs to do.* Sample prompts and responses for this discussion are below.

Suggested prompts	Sample student responses
What do we know about Ryoishi that helps us understand why the community is at risk for tsunamis?	*It is right on the bay.* *The area has been hit by a tsunami before and people have rebuilt in the same area.*
What is the problem we are trying to solve?	*Ryoishi's seawall failed during the 2011 tsunami, even though everyone thought it was safe. We need to consider other potential solutions for Ryoishi.*
What is something we think our solution should do during the tsunami to protect Ryoishi?	*We need it to block waves from hitting the village.* *We need a solution that pushes the wave back out to the ocean.* *We need a solution that is really tall and can block really high waves.* *Waves of that magnitude have a lot of energy—we need a solution that will reduce the energy.*

* Supporting Students in Engaging in Argument from Evidence

To evaluate competing solutions, the class needs to agree on what the problem is and identify the criteria and constraints they will need to consider in order to solve the problem. An important aspect of developing the practice of argumentation is developing and sharing their initial ideas, so that the class can consider differing perspectives and priorities across the class, work toward agreement on defining key criteria and constraints, and then analyze the solutions to determine whether they meet the relevant criteria and constraints.

Transition to identifying criteria. Say, *OK, so we now have some ideas about what we need this solution to be able to do to protect Ryoishi from a tsunami. Remember when we defined the criteria for what our cup had to do in the Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)? It had to keep a liquid cold at a certain temperature. Let's use that same thinking to define how we will know if these solutions will work to protect a community from a tsunami wave. What would we expect it to be able to do?* Give students a moment to write some ideas onto Part 2 of the handout.

Then, ask students to share their ideas for criteria and highlight areas of agreement across those ideas. Students might suggest the following ideas:

- The solution would need to break up the wave before it reaches the shore.
- The solution would need to block the wave.
- The solution would need to not allow water to get to the shore.

Track ideas of agreement on a class chart titled "Criteria for Solutions". Press students to provide a rationale for each criterion based on the science ideas they have learned so far. Add *criteria* to the Word Wall.

Additional Guidance

During Lesson 1, students implicitly used criteria and constraints to guide the development and evaluation of their initial designs. They have also previously developed and tested designs using predefined criteria and constraints in the *Cup Design Unit*. In this lesson, we use language to make these criteria and constraints explicit when talking about the existing solutions. At this point, we talk about the specific criteria that a solution must meet, such as not letting water from a wave get past it. Later in the lesson, we will identify constraints that limit the types of solutions that can be used in a particular community. If students have not done *Cup Design Unit* prior to this unit, you will need to provide additional time to develop their understanding of *criteria*.

Now that the class has a better idea of the criteria to consider when evaluating solutions, explain that we can evaluate and compare these solutions to see how well they meet these criteria.

4. Watch an engineering test video and evaluate solutions against our criteria. 15 MIN

Materials: *Evaluating Solutions to Protect Communities from Tsunamis*, computer, projector, 6.5 - Lesson 5 Testing Wave Blocking Designs (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), Evaluating Existing Solutions chart, markers, Oysters Clean the Bay! (Filtration Time-Lapse) (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) (optional)

Introduce the video of an engineer testing solutions. Say, *So we know our goal for a solution for Ryoishi is to keep both the people and the village safe. There are several solutions advertised by engineers to reduce the impacts of a tsunami. We have a video of an engineer we can watch testing scale models of each solution to see how effective they are.*** *We can then use this data to compare the designs.*

Assess the source of the information. Project **slide F** and have students read the text in Part 3 of *Evaluating Solutions to Protect Communities from Tsunamis* to learn about the source of the video. Ask students these questions to determine whether the source is providing reliable information:

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**
Although scale models were used in *Unit 6.4: What causes Earth's surface to change? (Everest Unit)*, this can be a great opportunity to remind students that scale models help us observe and investigate systems that are normally too large

- *Who made the video?*
- *Why did they make the video?*
- *Who is the speaker?*
- *Do we think this is a reliable source of information? Why?*

Through this conversation, the class should come to agreement that the video is a credible source for learning more about the existing solutions. Evidence to support this conclusion includes that it comes from an engineering group and the speaker is an engineer, which means that they have knowledge and experience to teach others about tsunami solutions.*

Identify the test parameters and review solution criteria. Project **slide G**. Use the picture to explain how the engineer will use the wave tank to show how the tsunami solutions work. Point out where the "shoreline" is and the reservoir where the excess tsunami water will end up, so the water can be measured once it has passed the shoreline.

Project **slide H**. Before viewing the video, have students quickly recall what they are looking for in the tests. Prompts and example responses are below.

Suggested prompts	Sample student responses
What criteria are we using to evaluate these solutions?	*How well a solution blocks the wave from hitting the shore or community.*
How will we know if one of these solutions is more effective than another one?	*The solution is better if it keeps most of the water from reaching the shore.* *The solution is better if it reduces the energy of the wave more than another one, letting less water up on the shoreline.* *The solution is better if it doesn't break when the waves hit it.*

Watch the video and record observations. Prepare students to take notes about each solution in Part 3 of their handout. Tell them that in the video, the water that passes the shoreline and reaches the reservoir will be measured using a 125mL beaker; instruct them to figure out and write down this amount of water in their notes about each solution.

Point out that we cannot rank the solutions until after we learn about each one, so we will not write in that column of the table until after we finish our video analysis.

Show Testing Wave Block Designs (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) pausing after each test for notetaking. If you also want to show how well mangroves work against waves, use one of these videos. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**.)

or small to examine in other ways. It may be beneficial to ask students why we are looking at scale models, and not building actual walls to test. These scale models can be used to analyze how certain structures reduce the energy of a tsunami and prevent the water from reaching the shore. Using models enables us to investigate how these solutions work on a smaller, more accessible scale.

* Supporting Students in Engaging in Argument from Evidence

Over the course of this lesson, students evaluate the performance of man-made and natural structures that are recommended by engineers and advertised to be a potential solution for tsunamis for different communities. At this point, students evaluate the solutions and their performance by analyzing a video of tests in a wave tank. Later, students further critique the performance and suitability of these solutions based upon the constraints of the communities where they may be placed. Students build an understanding that although these solutions are advertised as reducing the impact of a tsunami, the constraints of a given community and the structures' ability to reduce the amount of energy reaching the shore cause certain solutions to function better for some communities than others.

Analyze the video and chart the data. After watching and recording observations for all the tests, say, *How do we know whether these solutions work?* Students will point out that some solutions let water pass to the reservoir. They should suggest that we will know which solution will work better based on whether any water gets past the shoreline.

Ask a few students to report the amounts of water that got past the "beach" and into the reservoir in each test, and how parts of each solution block, break up, or lower the energy of the tsunami wave.* Record the water measurements publicly on the Evaluating Existing Solutions chart for students to reference. They should identify the following amounts:

- Beach - 125 mL
- Sea wall - 50 mL
- Levee/sea dike - 125 mL
- Recurved wall - 0 mL
- Rock armor - 5 mL
- Submerged breakwater - 0 mL
- Mangrove forest - 0ml (qualitatively determined based on wave movement observed on the other side of the mangroves)

Rank solutions based on the criteria. Using data from Part 3 of the handout and the Evaluating Existing Solutions chart, ask students how they would rank the solutions based on the agreed-upon criteria, starting with the water that got past them. Students will likely rank them as follows:

- 0 mL: Recurved wall, Submerged breakwater, Mangrove forest (but doesn't seem very sturdy like the others)
- Rock armor - 5 mL
- Seawall - 50 mL
- 125 mL: Beach and Levee/sea dike

Once the ranking is complete, ask, *So, based on what we saw happen with each of the suggested solutions, what should we recommend to Ryoishi and why? In addition to the amount of water that made it past each type of solution, are there other criteria we need to account for?* Let students share some ideas and explain why they would choose one solution over the other.

Additional Guidance

Students may disagree on the overall best solution because some solutions are tied. The purpose at this point is not to choose the "best" solution, but to be able to say that some are "better performing" when compared to others using the criterion, and that using data allows for a more systematic comparison.

* Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information

This lesson provides multiple opportunities to challenge students to critically consider a source of information and whether it is reliable. This can help them develop the following element of this practice: *gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.*

* Supporting Students in Developing and Using Structure and Function

The structures of the existing tsunami solutions have specific features that lead to the dissipation of energy from a wave. A wave striking any structure will inherently have some of its energy dissipated in the collision, but some design solutions also function to direct the remaining energy in all different directions (including toward the shoreline). Students should identify which structures are shaped in ways that direct this energy back out to the ocean or dissipate enough energy to reduce the impact on the shore.

5. Determine a rating and identify the need for more information. 8 MIN

Materials: index card or science notebook, Evaluating Existing Solutions chart, markers

Discuss a rating scale to compare existing solutions. Display **slide I**. Say, *We have observed several different solutions. How could we rate them in a way that clearly communicates to others how well they meet the criteria? From your experience, what rating systems do other individuals and companies use that can be easily understood and shared with others?*

Students will respond with a variety of ideas but will likely identify the five-star rating system used by many retailers and consumers, with 5 being best and 1 being worst.* If not, prompt them with, *When you or someone you know buys a product, have you ever seen a star rating scale? What would a five-star rating indicate? What would a one-star rating indicate?*

Compare the solutions' performance using a five-star rating scale. Work with the class to determine ratings out of 5 for each solution and record them on the Evaluating Existing Solutions chart. These ratings will allow for a relative comparison of each solution on each criterion.

Project **slide J.** Give each student an index card, or have them use their science notebook, to write their thinking in response to this exit ticket: *Is keeping water from getting to the community the only criterion we need to consider? Is there anything else we need to consider when determining which solution would work better than others for Ryoishi?*

- If yes, explain why.
- If no, list other ideas for consideration.

Additional Guidance

Use this exit ticket to analyze students' thinking regarding additional criteria or constraints that we should consider. This thinking will be used to start day 2.

*** Attending to Equity**

Support for Universal Design for Learning:

The five-star rating scale was purposely chosen for this lesson because it is widely used and likely familiar to students. For students who may struggle with language or symbolism, they may benefit from a visual reminder in class that describes one-star versus five-star, such as "Did not perform well" or "Worst performance" and "Performed very well" or "Best performance," respectively. This rating scale can be modified as desired to use another symbol, format, or text to provide greater accessibility through *representation*.

End of day 1

6. Surface Ideas for Additional Considerations 3 MIN

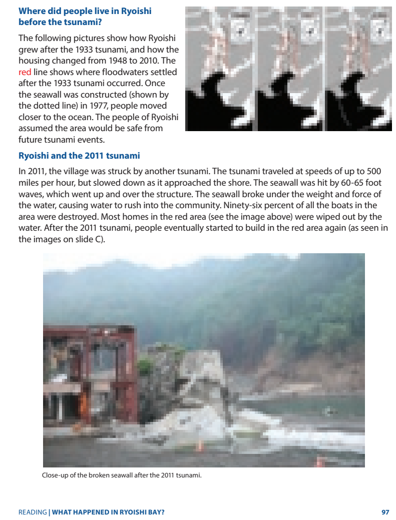
Materials: None

Surface additional considerations in choosing a solution. Display **slide J** again. Refer to the exit tickets from day 1 and ask students to share some of their ideas for additional things that need to be considered before making a decision for Ryoishi. Students will likely bring up ideas such as these:

- Ryoishi residents might prefer one solution over another, or be able to afford one but not another.
- Ryoishi residents might need a solution that can protect them while maintaining their ability to access the water, because they are a fishing community.
- Ryoishi might have some other issue that might impact how a solution functions in the area.

7. Identify constraints of existing solutions. **10 MIN**

Materials: *Evaluating Solutions to Protect Communities from Tsunamis, Comparing Ryoishi to Nearby Communities,* chart paper, markers, (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)


Where did people live in Ryoishi before the tsunami?

The following pictures show how Ryoishi grew after the 1933 tsunami, and how the housing changed from 1948 to 2010. The red line shows where floodwaters settled after the 1933 tsunami occurred. Once the seawall was constructed (shown by the dotted line) in 1977, people moved closer to the ocean. The people of Ryoishi assumed the area would be safe from future tsunami events.

Ryoishi and the 2011 tsunami

In 2011, the village was struck by another tsunami. The tsunami traveled at speeds of up to 500 miles per hour, but slowed down as it approached the shore. The seawall was hit by 60-65 foot waves, which went up and over the structure. The seawall broke under the weight and force of the water, causing water to rush into the community. Ninety-six percent of all the boats in the area were destroyed. Most homes in the red area (see the image above) were wiped out by the water. After the 2011 tsunami, people eventually started to build in the red area again (as seen in the images on slide C).

Close-up of the broken seawall after the 2011 tsunami.

READING | WHAT HAPPENED IN RYOISHI BAY? 97

Consider issues that might limit possible solutions for Ryoishi. Display **slide K.** Ask students to turn and talk briefly about this question: *If we only consider our own criteria when evaluating solutions, will we be picking the best overall solution for Ryoishi? Why or why not?* Record these onto Part 4 of the handout.

Have students share their ideas. They should respond that while we might pick the best device based upon our criteria, it might not work for the people who live there, and might impact their lives and jobs as fishermen. Tell the class that we have another reading about Ryoishi and the surrounding areas that might help us understand more about the community's needs when choosing the best solution.

Read about the needs of Ryoishi and Kamaishi, and note potential constraints. Distribute *Comparing Ryoishi to Nearby Communities* to each student. Project **slide L.** Say, *This reading might help us make a more informed decision about the best solution for the area. Once we have more information, we can look closer to determine which solution best meets the criteria, while also meeting the needs of the land and the people who live and work there.*

As students read through *Comparing Ryoishi to Nearby Communities* with a partner, have them record other potential considerations they may think of in Part 4 of *Evaluating Solutions to Protect Communities from Tsunamis.* They should also note anything that might affect which solution would work best for Ryoishi's residents.

Additional Guidance

If time allows, show students this video about the breakwater in Kamaishi. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**.)

Reintroduce the word "constraints." Remind students that back in our *Cup Design Unit*, we used the term "constraints," and that today we have been brainstorming constraints. Say, *Alright, we have identified some additional features of any potential solution that might narrow down which solution is possible for Ryoishi. We call these additional features you have identified "constraints" because they constrain or limit what solution is possible for the community. Some of these constraints may also affect how well the proposed solutions could function.*

Add *constraints* to the Word Wall.

Chart student ideas. Write the title "Constraints for Solutions" on a blank sheet of chart paper and post it alongside the day 1 Criteria for Solutions chart. Ask students to share out some of the potential constraints they listed in their handout while you record them on the chart—these can be formed as questions or statements (not all of these will come up initially):

- Will it affect fishing? (impact on boat traffic for fishing)
- Can the residents afford it? (cost)
- Does it block their access to the ocean? (economy—fishing or tourism)

- Does it block their view of the ocean? (maintaining the beauty of the coast or ocean)
- How long will it take to build? (timeline to build)
- Will it hold up over time? (maintenance)
- Will it hurt marine life? (environmental impact)
- Will this solution impact any other communities? (unintended consequences of diverting water or energy)
- Will it cause things to be better or worse for the areas surrounding it? (impacting the land or organisms in a positive or negative manner)

Tell students that having now identified some constraints, we need to do a little more investigating into the existing solutions to see how well each one meets the constraints, and functions under the constraints, before we make a decision for Ryoishi.

8. Read about existing solutions. 10 MIN

Materials: *Existing Solutions for Coastal Communities*

Provide detailed information on eight solutions. Distribute *Existing Solutions for Coastal Communities* to each student. A full-color version of this handout is also provided in the student edition. Tell the class that the text in the handout explains more about how these solutions work and how well they meet the criterion we've identified as well as a set of various constraints, which are similar to the constraints we just developed.

Explain the handout's rating scale. Project **slide M**. Point out the five-star rating scale that is applied to the list of criteria and constraints used to evaluate each solution. Explain that the first row in this sample rating scale shows our criterion, and the rest of the rows list potential constraints.

Highlight the use of stars to represent the score on the rating scale. The more stars a solution has, the better it meets the given criteria or constraint. Draw students' attention to cost on the example rating chart. Explain that 5 stars means that a solution meets the cost constraint well, so this particular solution is very affordable—it isn't rated as the most affordable, but it is still reasonably priced compared to some others, as it has a rating of 4 out of 5 stars.

Read about design solutions. Project **slide N**. Review with students the questions that we need to try to answer from our reading:

- What are the key features of each type of solution?
- How well does the solution meet our criteria?
- How well does the solution perform when considering other constraints?

Have students read the text 2 times with a partner. Encourage them to underline, highlight, and annotate the text with notes on important features that will help us figure out which solution would be the best at protecting Ryoishi from a tsunami.

9. Revisit our criteria and constraints.

5 MIN

Materials: *Existing Solutions for Coastal Communities*, Criteria for Solutions chart, Constraints for Solutions chart, markers

Revisit criteria and constraints on class charts. Remind students that we have developed a class Criteria for Solutions chart and Constraints for Solutions chart. Revisit these charts and ask students if they want to add any other constraints that were referenced in the reading.

Additional Guidance

Building a strong list of criteria and constraints, based on scientific principles and community needs, is important for students to evaluate the existing solutions, and, in particular, how well they might work for Ryoishi. Direct students to look back at *Existing Solutions for Coastal Communities* if they are struggling to find something to add. If students are not able to bring out these ideas, elicit them with prompts like these:

- **Cost:** Some of these solutions seem expensive. Can any community afford them, or do we need to consider something else?
- **Time to build:** We know tsunamis in the area happened without much warning. Do we know if we have a lot of time to build these structures?
- **Maintenance:** Some of these structures seem to require upkeep. Is that important for these communities to consider?
- **Environmental impact:** As we were looking at the solutions, we saw mangroves. Why are we considering mangroves if they don't seem to do as well against a tsunami? What are the specific characteristics of that solution that may be important criteria?
- **Blocking ocean views:** We looked at the breakwater idea in the last class. Why do some people not like it? Should that be an important criterion too?
- **Impact on boats and traffic:** We learned that breakwaters can block entry to ports. Is that an important consideration for solutions in some communities?

10. Rank existing solutions according to ratings.

10 MIN

Materials: *Tsunami Solution Ranking Cards*

Introduce the solution ranking cards. Now that students have identified criteria and constraints for evaluating tsunami-mitigation solutions, suggest that we use them to compare the solutions with the needs of Ryoishi. Say, *We have some informational cards that summarize how each solution did with the criterion and constraints from our readings. Let's use these cards to rank the solutions by their ratings.*

Assign students to small groups of 3-4 and distribute a set of pre-cut solution ranking cards from *Tsunami Solution Ranking Cards* to each group. Give them 1-2 minutes to orient to the information on the cards. Point out that each card lists all of that solution's ratings on the criterion and constraints, along with explanations, for easy comparison and reference.

If students previously included additional constraints on their handout or the class chart, we can address them later on when we make judgments on which solution best meets the needs of a community. But for now, focus on the criteria and constraints on these cards because we have ratings data for them for each of the eight solutions.

Organize the solutions from best to worst. Project **slide O.** Explain to students that they will physically move the cards around on their desks to identify how well each solution meets the identified criterion and constraints, and put them in order from best solution to worst solution for the community of Ryoishi. Give groups a few minutes to try to order the cards from best solution to worst solution. Encourage them to identify a common way of referencing performance with the cards' location—for example, cards at the top of the desk = the better-performing solutions.

Some students may disagree as they try to order the cards. Visit these groups and ask why they are having disagreements. Listen, but do not offer any suggestions for solving their disagreement.

Discuss why this sorting task is difficult. After a couple of minutes of indecision and problem solving from groups, bring the class together again. Say, *It seems that we have run into some problems sorting our cards. What are some of the issues we are seeing?*

Here are some examples of student responses:

- The rating scores are sometimes the same—one solution isn't always better than another for the criterion or certain constraints.
- We had to rank some solutions the same and we can't tell which one is better.
- Some solutions were rated really well for the criterion, but not so well on constraints. There isn't just one clear solution that works well.
- The cards keep moving around based upon the criterion and constraints—it's hard to determine how they should be ranked.

Say, *Interesting. It's like you're saying that the designs can't be cleanly organized by comparing each solution to one another, and that their ranking seems to depend on which certain criteria and constraints we are sorting by at that moment. We need a better way to rate these.*

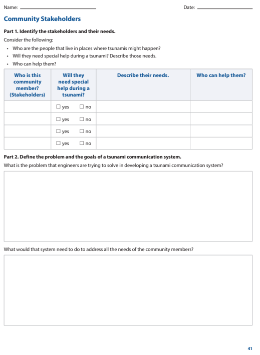
11. Introduce the Decision Matrix.

7 MIN

Materials: *Tsunami Solution Ranking Cards, Decision Matrix*

Orient students to the decision matrix. Project **slide P.** Distribute a copy of *Decision Matrix* to each student. Explain that this tool, called a decision matrix, will help us better evaluate the existing solutions by providing a way to systematically rank each solution by its scores on our criterion and constraints—which will help us better determine the best solution for Ryoishi.

Complete matrix examples as a class. Project **slide Q.** Tell students that we will use the solution ranking cards to add all the ratings for each solution to the matrix. After we have added all of the solution cards to the chart, we can more easily see how the criterion and individual constraints compare across the solutions. Explain that we will practice filling in the matrix by doing a few examples together.


Name: ______ Date: ______

Community Stakeholders

Part 1. Identify the stakeholders and their needs.

Consider the following:

- Who are the people that live in places where tsunamis might happen?
- Will they need special help during a tsunami? Describe those needs.
- Who can help them?

Who is this community member? (Stakeholders)	Will they need special help during a tsunami?	Describe their needs.	Who can help them?
	☐ yes ☐ no		
	☐ yes ☐ no		
	☐ yes ☐ no		
	☐ yes ☐ no		

Part 2. Define the problem and the goals of a tsunami communication system.

What is the problem that engineers are trying to solve in developing a tsunami communication system?

What would that system need to do to address all the needs of the community members?

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Have students return to their small groups and take out their solution ranking cards. Say, *Grab the card for solution A, seawall, and look at it with your team. We have this solution's criterion and constraint ratings on the card. Let's start by recording our criterion, ability to break or block waves, in the green box that says "Criterion" at the top of the column.*

After a moment, ask, *What rating does seawall have for ability to break or block waves?* Students should respond that it has a star rating of 3 out of 5. Say, *Let's write that rating in the box where the seawall row and the criterion column meet*. Explain that little stars can be hard to draw, so instead of drawing stars, we can just write the number of stars, 3, in that box.

Say, *Now, let's look at the first constraint, impact on boats/ocean traffic. Write that in the green box for "Constraint 1." What rating was seawall given for this constraint?* Students should respond that it has a star rating of 5 out of 5. Give them a moment to write 5 in the appropriate box. Then have the groups finish writing the constraints in the column headers and recording the rest of the rating data for seawall in the matrix.

Tell students that with the time left today, and at the start of the next class, we will continue this process until all the solutions' criterion and constraint ratings are filled in. Remind them that if they have extra criteria and constraints to consider, such as the impact of the solution on other communities, they can add more columns and come up with ratings for each solution based upon our science ideas of how waves interact with it.

Alternate Activity

If time is projected to be short on day 3, a prefilled matrix is completed on the alternate handout, *Completed Decision Matrix*. The column headers currently reflect the criteria and constraints from the solution cards, but should be adapted between day 2 and day 3 to include any additional class-agreed-upon criteria and constraints, along with changing any wording to reflect what students think the headers should be based upon the class charts from day 2. To allow for additional time on day 3, this modified and completed chart can be distributed at the beginning of class on day 3. Although it may feel convenient to skip using *Decision Matrix* on day 2, it is still recommended to complete part of the matrix with students to help build their understanding of what each row and column means and should look like before they presented with a completed matrix on day 3.

Explain to students that in the next class, we will continue the process of evaluating the solutions by comparing their ratings in our matrix.

End of day 2

12. Organize information into the Decision Matrix.

8 MIN

Materials: *Tsunami Solution Ranking Cards, Decision Matrix* OR *Completed Decision Matrix*

Revisit the task from the previous class. Project **slide Q** again. Ask students what we were doing at the end of the last class, and what our next steps are. They should say that we need to add the rest of our solutions' ratings to our decision matrix. Have students gather in their small groups.

If a version of *Completed Decision Matrix* was constructed as an alternative to completing *Decision Matrix*, distribute the handout to each student at this time and skip the instructions in the next paragraph.

Evaluating the solution against our criterion and constraints:

Solution	Criterion Break waves	Constraint 1 Impact on boats	Constraint 2 Impact on marine life	Constraint 3 Impact on ocean view	Constraint 4 Cost	Constraint 5 Time to build	Constraint 6 Maintenance
A. **Wall-** Seawall	3	5	4	1	3	3	3
B. **Wall-** Levee or sea dike	2	5	3	4	5	4	4
C. **Wall-** Recurved wall	5	5	4	2	2	3	3
D. **Breakwater-** Tetrapod	4	3	2	4	4	4	3
E. **Breakwater-** Rock armor	3	3	3	4	5	4	3
F. **Breakwater-** Submerged breakwater	4	4	2	5	1	2	4
G. **Natural vegetation-** Mangrove forest	3	5	5	4	4	1	4
H. **Natural vegetation-** Pine forest	2	5	5	3	5	1	4

Finish filling in the matrix in small groups. Instruct groups to take out their solution cards and their copy of *Decision Matrix* and complete the matrix. Remind them that the higher the rating, the better the solution meets that criterion or constraint.

Consider which solutions might work for Ryoishi. Project **slide R.** The slide provides guidance on how to navigate making a group decision about which solution(s) would best protect Ryoishi. Ask students to talk within their groups about which solution seems best by looking from column to column in the matrix and comparing the solutions' criterion and constraints ratings against each other.

As students work, ask them about which existing solutions that they think are better for Ryoishi. For detailed guidance on how to push their thinking in general, as well as questions to ask about the individual solutions, see *Questions for Solution Reasoning*.* Students may disagree on which solution would work best, and some may argue that certain criteria or constraints are more important than others. Some may also argue that what works best for Ryoishi may not work well for the surrounding communities, such as when Kamaishi's seawall directed more water toward Ryoishi in the last tsunami.

Discuss disagreements and initial decisions as a class. Some groups may come to a consensus, while others may struggle to identify a single top solution, even after discussing their individual reasonings with each other. Bring the whole class back together to share groups' current initial decisions. Leverage any disagreement and uncertainty to help students see that this decision is more complex than considering only one column of the matrix. Validate their experiences by stating that these decisions are not easy, and that engineers must make these difficult decisions based upon the identified needs of the group or community. Examples of student scenarios and responses to them are below.

Example scenario	Example questions to ask students
Students argue that the solution that is the highest rated overall is the best for the town.	*Are all the criteria and constraints equally important?* *Would that solution best meet the needs of Ryoishi and its residents?* *Would that solution have any ripple effects that might cause more damage to other communities? Would the solution work well for Ryoishi, but possibly do more harm to other communities?*

* Supporting Students in Engaging in Argument from Evidence

While students are discussing each existing solution, they are working on developing the practice of argumentation. They are weighing the evidence for each solution and comparing the evidence across solutions to figure out which solution may or may not be most appropriate for this community. They will struggle to come to agreement and may ultimately disagree on which solution is a better or worse fit for a community based on the evidence. Remind students of the classroom norms as well as the sentence starters on the Communicating in Scientific Ways poster. These are two helpful resources for students to draw upon as they engage in argumentation.

Example scenario	Example questions to ask students
Students argue that one constraint is more important to consider than another constraint.	*Are some constraints more important than others in this decision? How do we know?* *Are there other constraints that also need to be considered?* *Should we consider more than one as more important than the rest? How do those constraints impact your decision?*
Groups disagree on deciding between two or more solutions.	*What would make one solution better than the other?* *How did the rankings change or justify your choices?* *What are you valuing when making this decision?* *Is there a solution that can work well for Ryoishi and also limit the tsunami's impact on the surrounding areas at the same time?*
Students agree on one solution quickly.	*What made you select this choice? Do you think every resident of Ryoishi would agree with you? Why or why not?* *Are there other things that the residents of Ryoishi may believe are more important than what you are valuing in your matrix? Why or why not?* *If this solution is installed at Ryoishi, will it negatively impact any other areas, causing them to have a tsunami experience worse than it would have been without the solution at Ryoishi? Why or why not?*

13. Make an initial decision.

2 MIN

Materials: one sticky dot, Evaluating Existing Solutions chart

Place sticky dots chart. Project **slide** S. Say, *It seems that we have made progress, but after listening to our groups, it doesn't seem like all groups, or even all individuals in each group, agree on which solution may work better for Ryoishi. Let's take stock to see what solutions we are thinking will work better, and consider our choices.*

Pass out a sticky dot to each student. Go over the directions on the slide with students:

- Place a sticky dot on the chart next to the solution you think will work best for Ryoishi.
- As you place your sticky dot, consider this question: Why do you think that solution will work better than others?

14. Engage in a consensus discussion.

10 MIN

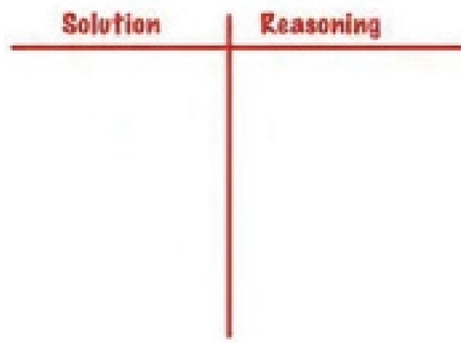
Materials: *Decision Matrix* OR *Completed Decision Matrix, Comparing Ryoishi to Nearby Communities,* Evaluating Existing Solutions chart, chart paper, markers

Convene a Scientists Circle. Have students bring their completed matrix handout to the circle, and sit next to someone from another group if possible; this will allow rankings from best to worst to be shared across multiple groups in the next step. Ask students to look at the Evaluating Existing Solutions chart and make initial observations regarding the sticky dots' distribution. Reflect on the point that not everyone agreed on the same solution. Wonder aloud with students why this happened.

Turn and talk to compare initial decisions for Ryoishi.* Project **slide T.** Have students turn and talk to a partner about the following prompts:

- Looking at your matrix, which solution did you or your group think would work best for Ryoishi?
- Why do you think that is the best solution?

Share chosen solutions as a class. Elicit responses from the circle. Remind students that even though we are trying to pick the best solution for the area, each solution was designed to help reduce the impacts of a tsunami. As the first student shares their chosen solution and their reasoning, record their solution and reasoning on the chart paper. If they have trouble identifying or remembering their reasoning from the previous class, direct them to look back at their matrix to determine how they made their choice.



Ask if anyone else identified a different solution that they think would work to meet Ryoishi's needs, or chose the same solution but for a different reason. Have additional students also share their choice and their reasoning, and record these on the chart paper. Then ask, *Why would we identify different solutions to protect Ryoishi if we were all using the same ratings?*

Discuss why the chosen solutions differ. Engage students in a discussion of what could have led to selecting different solutions, even though we all have the same ratings in our matrices. Ask guiding questions such as these:

- *What did you consider as you made your choice?*
- *I heard group ________ say that they chose _________ as the best fitting solution. Why would that have been different than group _______?*
- *Group ____ also debated two solutions. Did any other groups debate a different solution? Why was there any debate if we all have the same ratings?*
- *Did any groups have trouble coming to a consensus? What made your decision difficult to make?*

Establish the importance of valuing different constraints. Facilitate a brief discussion to help students realize that they were placing more or less value on certain constraints than others, which led to different decisions about which solution might best fit Ryoishi. If students do not immediately point this out, redirect them to look at the chart that was just made and consider what reasoning was given for the different answers.

*** Supporting Students in Engaging in Argument from Evidence**

In the practice of argumentation, students evaluate the evidence at hand and decide whether it supports or refutes one or more claims. This practice is particularly beneficial for students to develop as they are evaluating competing solutions. It is not important that they come to the "one correct answer," but rather that they sort through and weigh the evidence and reasoning from their data and their peers, to consider why certain solutions hold more or less promise for one community versus another.

Consider why choosing a solution can be challenging in real life. Explain that engineers make these value decisions when considering potential solutions to problems. Push students to consider why not settling on one solution can be challenging for engineers. Example prompts and responses are below.

Suggested prompts	Sample student responses
Why could it be challenging for engineers to come to consensus on a solution?	*We had problems deciding what was important, so engineers may pick different criteria or constraints that they think are important too.* *Engineers may not know which solution to go with!* *Each solution has different building requirements and impacts—we have to know what to build before we start to build it.*
How can we make sure that we are making the best decision for the community?	*The right decision would be based on criteria and constraints that Ryoishi wants and needs the most.* *We need to really base the decision around Ryoishi's biggest needs.* *The best solution will be based on the needs of Ryoishi. We have to rank solutions like Ryoishi would.*

Assessment Opportunity

Building towards: 5.A Make an oral argument based on a systematic evaluation process using relevant scientific principles, to support or refute the ability of different existing solutions (structure) to mitigate the effects of tsunamis and meet the needs of at-risk communities (function).

What to look for/listen for: Listen for students to use criteria and constraints to evaluate existing tsunami-mitigation solutions using a systematic process that accounts for community needs and the stated performance of the design solutions. Important ideas include:

1. The design solution must account for relevant scientific principles (e.g., it dissipates the wave's energy), the needs of the community (e.g., economic activity), how well the structure would function for surrounding communities (how well it will function in this scenario vs. its proposed functionality), and its environmental impacts (e.g., on marine life).
2. Clearly defining and prioritizing criteria and constraints is necessary when evaluating and choosing a solution for a given community.
3. Communities have different criteria and constraints, so the evaluation process should also consider impacts on neighboring communities. Students should realize that the proposed performance of a structure in one area may affect other areas in ways that might negate the intended result, such as the seawall at Kamaishi having a negative effect on Ryoishi.

What to do: There are multiple opportunities on day 3 to assess this lesson-level performance expectation. This Consensus Discussion is the first opportunity to press students to use evidence and reasoning from the investigations on days 1 and 2 to support their claims about which solutions might be most effective. Through argumentation, students refine their thinking about which solutions are more or less effective for Ryoishi and the surrounding areas. However, it is not important to come to agreement on one particular solution; rather, the purpose is to develop an understanding that engineers use systematic processes to decide which solutions might be most promising and must also consider their broader effects on surrounding areas. Throughout day 3, as students argue for their chosen solutions, press them with questions such as, "What is your reasoning for that?" "Why do you think that criterion or constraint is more important than others?" and "How might that solution work for Ryoishi and what would be the trade-offs, either for Ryoishi or the surrounding communities?"

15. Determine criteria and constraints valued by Ryoishi.

10 MIN

Materials: *Comparing Ryoishi to Nearby Communities, Decision Matrix* OR *Completed Decision Matrix,* Evaluating Existing Solutions chart, markers

Remind ourselves of Ryoishi's needs with a partner reading. Redistribute *Comparing Ryoishi to Nearby Communities* to each student. Say, *We still don't seem to be in agreement about what solution might work the best for the area. Last class, we learned more about Ryoishi and considered what the community's criteria and constraints might be. Let's reread this text with a partner to think critically about what criteria and constraints might be more important for Ryoishi than others.*

Project **slide U.** While partners are reading, draw a vertical line on the bottom of the Evaluating Existing Solutions chart, and label the left section "Criteria/constraints important to Ryoishi" and the right section "Possible complications."

After 3 minutes, lead a class discussion to determine what criteria might be most important to Ryoishi, and if any other factors make the Ryoishi problem more complicated than simply ranking criteria and constraints. As students offer criteria, list them on the left side of the chart. Record possible complications on the right side. Example prompts and responses are below:

Suggested prompt	Sample student responses
What important things did we discover as we read about Ryoishi and Kamaishi?	*We learned that Ryoishi was very close to Kamaishi.* *Ryoishi was a small fishing village, compared to Kamaishi.* *Big workplaces and more people seemed to be in Kamaishi.* *Ryoishi was more rural and was a home for smaller fisherman operations.* *Kamaishi has tourism, bigger fishing operations, and some steel.* *That breakwater off of Kamaishi could have led to a bigger wave hitting Ryoishi than Kamaishi.*

Suggested prompts	Sample student responses
After reading about Ryoishi, what criteria or constraints seem more important now than other criteria or constraints?	*It seems like the tsunami was way worse in Ryoishi Bay than in Kamaishi. The biggest problem is safety.* *The criteria we identified should be really important, especially since people are living there again.* *I don't think that views of the beach are as important in Ryoishi, since ecotourism is more in Kamaishi.* *They definitely need easy access for their boats. That's an important thing for a fishing village.* *As we think about what works for Ryoishi, we have to make sure that the solution won't make the tsunami worse for another community.*
Does anything make this situation more complicated than just looking at criteria and constraints for Ryoishi?	*Kamaishi needs protection, but protecting it can make things worse for Ryoishi. Maybe we need to consider the other towns around it and how each solution will affect the other towns.* *Some criteria and constraints will be more important than other criteria and constraints, but how do we rank them?*

Introduce primary and secondary criteria and constraints. Say, *When engineers work on these problems, they need to prioritize their criteria and constraints for different communities, just like we did. We can define primary and secondary criteria and constraints to help us determine which are most important and should be given more weight when evaluating solutions. Primary criteria or constraints are the most important things to consider, while secondary criteria or constraints are still important, but should be considered after the most important ones.*

Add *primary criteria/constraints* and *secondary criteria/constraints* to the Word Wall.

Assign primary and secondary criteria and constraints. Project **slide V**. Instruct students to look at their decision matrix and to star or circle the most important criteria and constraints for Ryoishi.

16. Refine solution choices as a class.

8 MIN

Materials: *Decision Matrix* OR *Completed Decision Matrix*

Poll students on their priorities. Bring students back together and ask what criteria and constraints they listed as primary. Quickly take a class poll by reading each criterion and constraint aloud, and have students raise their hand when the one they selected as primary is read. Point out that not all students designated the same criteria and constraints as primary. Do a second pass through the list, and ask students to raise their hands for what they think is the one most important primary criterion and constraint. Acknowledge the difference in students' priorities. Do not spend more than 2-3 minutes on this step.

Share solution choices based upon criteria and constraints. Ask students to look back at the decision matrix with a partner and consider which solutions seem to be a better fit for Ryoishi based upon the primary criteria and constraints we have identified. The questions on **slide** V can be used as a guide.

Once students have had a few moments to reanalyze the solutions, ask them to share their updated choice and their reasoning. After the first student shares, ask the class if they agree with that choice. Point out that we may not agree on a solution, but that is OK as we are still working toward coming to consensus by narrowing down to a few solutions.

Introduce trade-off thinking. Help students to figure out that the existing solutions still don't perfectly fit all of our criteria and constraints, and that engineers deal with decisions like these every day. These decisions and considerations are called trade-offs. Sometimes we need to compare criteria and constraints against each other to determine which are more important in making an informed decision about what solution to recommend for a given problem. Sometimes these choices also have effects on other criteria, systems, or groups, and we must weigh those effects as well to determine what is most appropriate for the situation. Even with primary criteria and constraints identified, we will still have trade-offs, and that is OK.

Add *trade-offs* to the Word Wall.

17. Reflect on the tsunami chain of events. 5 MIN

Materials: Tsunami Chain of Events poster, large sticky notes, markers

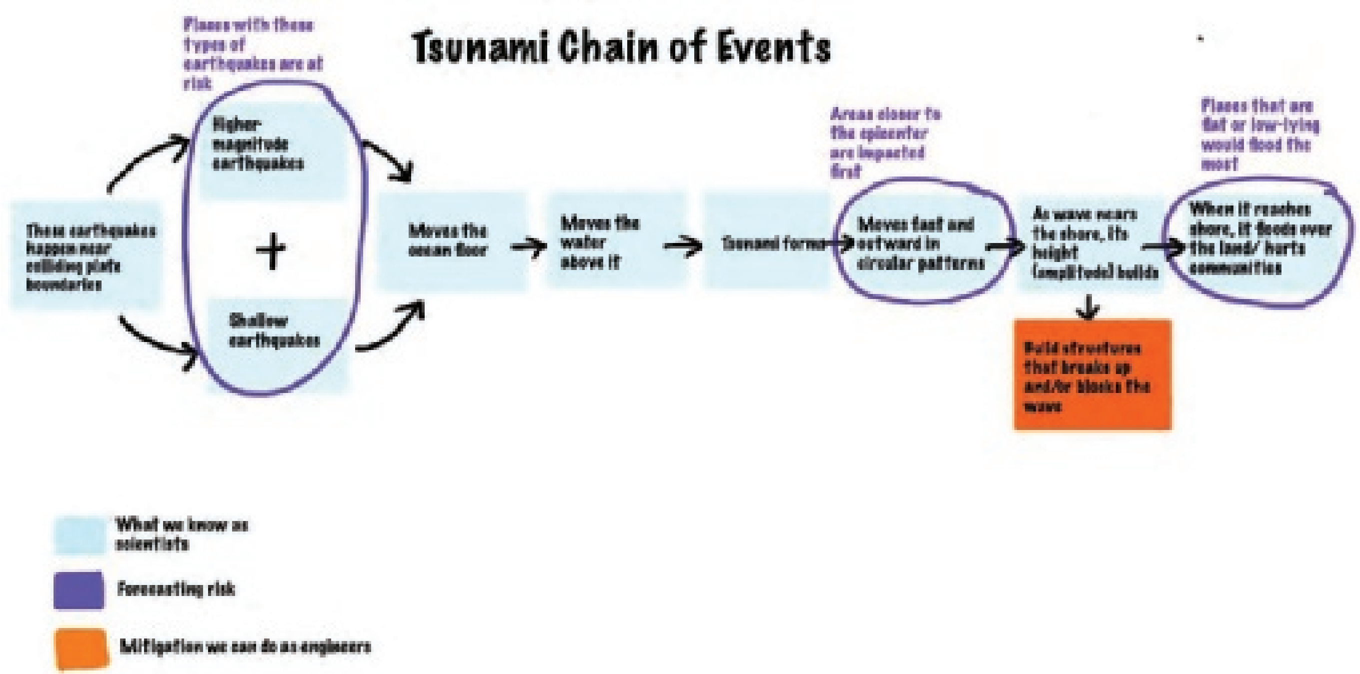
Reflect on our Tsunami Chain of Events. Project **slide W.** Ask students to consider what we have done as engineers over the course of this lesson, and what we have learned that we could do as engineers to help communities. Example prompts and responses are below:

Suggested prompts	Sample student responses
We started this lesson by thinking about a problem that certain communities have. What is the problem we have been trying to solve?	*We knew Ryoishi had a seawall that failed, and we needed to find a better solution for protecting the community from tsunamis.*
What did we think the criteria would be for the solution?	*It would need to break up the wave.* *It would need to reduce the wave's energy.* *(This response will depend on how students have explained the energy reduction of a tsunami wave on the Criteria for Solutions chart.)*

Suggested prompts	Sample student responses
So as engineers, what can we do to help lessen, or mitigate, the effects of a tsunami on communities?	*We can build a solution that can break up or reduce the energy of the wave before it reaches the shore.*
Great. Let's look at our chain of events. Where would this idea fit in the chain? Where would this solution be constructed?	*All of the solutions are built close to the shoreline, so maybe under the shoreline box.* *The solution that we would build would hopefully reduce the amplitude of the wave. We should add it there.*

Add engineering ideas and solutions to the Tsunami Chain of Events poster. Point out that so far, we have used one sticky note color on the poster to represent what we know as scientists. Because we are adding what we can do as engineers, we should indicate that with a different color sticky note. Add an item to the key that denotes the color change for a new section of sticky notes titled, "What we can do as engineers."

Add a sticky note of the new color that says "Build structures that break up and/or blocks the wave" under the sticky note that says "As wave nears the shore, its height (amplitude) builds." Draw an arrow from the old note to the new one to represent that this engineering idea and science idea are connected. The Tsunami Chain of Events poster may now look like this:



18. Determine next steps.

2 MIN

Materials: *Tsunami: Japan 2011*

Determine next steps. Project **slide X**. Bring students back together and have them discuss the following prompts with a partner:

- We looked at 8 different solutions for Ryoishi. Each solution seemed like it would work, but both the seawall and breakwater failed to fully protect the towns in past tsunamis.
- If a solution fails, like if a seawall breaks, what else can be done to protect the people in the community from the tsunami?
- Are there other design features we brainstormed from the tsunami phenomenon in Lesson 1 that we could look into?

Connect to the anchoring phenomenon. Allow students to share from their initial ideas for protecting people on Lesson 1's *Tsunami: Japan 2011*. Many of these will include a warning system to let people know about an impending tsunami. Use those ideas to navigate by saying, *So, it sounds like we have some ideas of how we can still detect and warn people in case a solution fails to protect a community. Let's look at that next.*

ADDITIONAL LESSON 5 TEACHER GUIDANCE

Supporting Students In Making Connections in ELA

The texts in this lesson supports students in developing the following reading standards:

- CCSS.ELA-LITERACY.RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.
- CCSS.ELA-LITERACY.RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6-8 texts and topics*.
- CCSS.ELA-LITERACY.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

LESSON 6

How are tsunamis detected and warning signals sent?

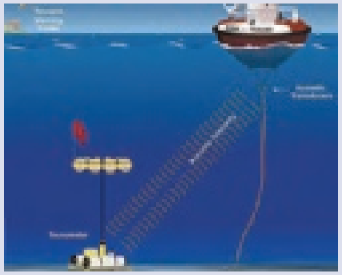
Previous Lesson

We revisited the coastal communities of Japan to evaluate existing solutions designed to protect them from tsunamis. We defined our problem and identified criteria and constraints. We used a systematic process to evaluate solutions and determine which ones might be promising for these communities. We considered how needs vary from one community to another and what is needed if a solution fails.

This Lesson

Investigation

1 DAY



NOAA

In this lesson, we read about how tsunamis are detected using a complex system of instruments set up on land (seismometers), the ocean surface (surface buoys), and the ocean floor (tsunameters), as well as in space (satellites). We read that tsunami warnings are sent only when specific sets of criteria are met. The first set involves the location, strength, and depth of the detected earthquake. The second involves whether the tsunami is expected to reach land.

Next Lesson

We will listen to tsunami warning signals and read accounts of tsunami survivors from Japan and what they did when an earthquake and tsunami occurred. We will identify community stakeholders, develop criteria and constraints for tsunami communication solutions, and evaluate different ways tsunami preparation and response are communicated. We will read a case study about a school in Kamaishi that included education as part of their plan. From this we will learn that there are many ways to communicate with community stakeholders before and during a tsunami event.

Building Toward NGSS

MS-ESS3-2, MS-ETS1-1, MS-ETS1-2

What Students Will Do

6.A Critically read scientific text to understand how a system designed to detect tsunamis follows specific criteria (related to earthquake activity) and constraints (related to signal transmission).

What Students Will Figure Out

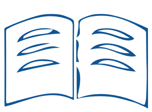
- Tsunamis happen suddenly and can travel at high speeds over great distances. Depending on where the tsunami forms, communities may have more or less time to respond.
- To help prevent or reduce loss of life, we need to detect a tsunami quickly and accurately in order to provide timely information to an at-risk community.
- Criteria and constraints for a tsunami detection system must consider the available scientific information (earthquake data) and design limitations (signal transmission through air and water).

Lesson 6 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Recall how the 2011 tsunami impacted Ryoishi. Revisit why tsunami plans sometimes do not involve building large-scale structures such as seawalls or breakwaters.	A	*Tsunami: Japan 2011* (from Lesson 1), Detect Tsunamis poster, Warn People poster, Reduce Damage poster (all from Lesson 1)
2	25 min	**DO A CLOSE READING ON HOW TSUNAMIS ARE DETECTED AND WARNING SIGNALS SENT** Read an article about how the DART II system works to detect tsunamis and send warnings. Consider design constraints for such a system.	B-C	*Reading: How are tsunamis detected and warning signals sent?*
3	8 min	**SUMMARIZE IDEAS FROM THE READING** Summarize ideas from the reading in partners and class discussion. Identify the criteria for a tsunami detection system.	D	*Reading: How are tsunamis detected and warning signals sent?*
4	5 min	**UPDATE THE TSUNAMI CHAIN OF EVENTS POSTER** Update the Tsunami Chain of Events poster with what we have figured out about how tsunami detection and warning systems work.	E	Tsunami Chain of Events poster, markers, large sticky notes
5	2 min	**NAVIGATION** Wonder about what happens once a tsunami is accurately predicted to reach land. How is a tsunami warning communicated?	F	

End of day 1

Lesson 6 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Tsunami: Japan 2011* (from Lesson 1) • *Reading: How are tsunamis detected and warning signals sent?*		• Detect Tsunamis poster • Warn People poster • Reduce Damage poster (all from Lesson 1) • Tsunami Chain of Events poster • markers • large sticky notes

Materials preparation (10 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Display posters from Lesson 1:

- Detect Tsunamis poster
- Warn People poster
- Reduce Damage poster

Students also need to retrieve Lesson 1's handout, *Tsunami: Japan 2011*, from their science notebook.

Be sure you have materials ready to add words to the Word Wall. After the reading, add or review the following terms:

- Words we encounter: *seismometer*, *tsunameter*, *buoy*, *satellite*, *sonar*
- Words we apply from previous lessons or units: *epicenter*, *magnitude*

Online Resources

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

The purpose of this lesson is to provide students with information about the systems designed to detect tsunamis and send warnings. Tsunami detection systems are complex, with many parts (some on land, some in space, and some on the ocean surface and ocean floor). These systems are designed not only to detect tsunamis but also to predict whether they will reach land. If certain criteria are met, the system sends out a warning. The Lexile reading estimate of the reading is 810L-1000L.

Where We Are NOT Going

Though the idea of signal transmission comes up during the reading, this unit does not address how signal transmission occurs or why certain types of transmission (analog and digital) may be beneficial under different circumstances.

1. Navigation

5 MIN

Materials: science notebook, *Tsunami: Japan 2011* (from Lesson 1), Detect Tsunamis poster, Warn People poster, Reduce Damage poster (all from Lesson 1)

Recall the Ryoishi case study. Project **slide A**. Have students revisit *What happened in Ryoishi Bay?* from Lesson 5. Ask them to recall what they found out about how the tsunami impacted Ryoishi. Prompts and examples of student responses are below.

Suggested prompts	Sample student responses
What happened in Ryoishi during the 2011 tsunami?	*The seawall failed during the tsunami. Water poured over the wall and flooded the town.*
If people want to stay in Ryoishi, what do we need to think about in order to prepare for future tsunamis?	*We need to make sure that the seawall is strong enough to withstand stronger and taller tsunamis than the one that hit in 2011.* *Like we saw in Ryoishi, we may need to think of other solutions besides a seawall.* *If a seawall fails, then we still need other plans to prevent people from dying and protect places where people live and work.*

Revisit our initial non-seawall engineering ideas. Display the Detect Tsunamis poster, Warn People poster, and Reduce Damage poster from Lesson 1. Prompt students to think specifically about their ideas that did not involve building large structures. Say, *Back in Lesson 1, when we first thought about preparing for a tsunami, we came up with some designs that did not involve building seawalls or any similarly large structures or barriers. What were some of those ideas?* Examples of student responses to this prompt are below.

Suggested prompt	Sample student responses
What were some of those ideas?	*We thought about ways to better detect tsunamis so people have more time to evacuate.* *We thought about more effective ways to warn people about a tsunami.*

Discuss our promising design solutions. Guide students to reexamine the green dots used on the posters during Lesson 1 to indicate the design solutions that showed promise. Say, *Let's look back at how we evaluated some of our original ideas from Lesson 1.* Ask them to think about which ideas from Lesson 1 they originally classified as promising, and explain what made them promising. Prompts and examples of responses are below.

Additional Guidance

If students struggle to recall their thinking around which ideas were promising and which were challenging, prompt them to review Part 4 in *Tsunami: Japan 2011* from Lesson 1, day 2. This handout instructed students to select one idea as promising and one as challenging, and to explain their rationale. For further guidance, prompt them to look back at the Criteria for Solutions chart and Constraints for Solutions chart from Lesson 5, which explored the criteria and constraints of several design solutions.

Suggested prompts	Sample student responses
Why did we think some of our design solutions were especially promising? *What else made those ideas promising as compared to others?*	*They involve technology that we already have, such as satellites and GPS.* *They seem cheaper because they don't need as many materials.* *They could be set up quicker because we might not need to build any large structures.*

Foreshadow the close reading. Tell students that we will now consider the ideas we had related to detecting tsunamis and sending warnings. Say, *From the posters and our discussion, it looks like we have a few ideas involving how we can detect tsunamis and how we can warn people to evacuate. I have an article that will help us understand how one commonly used tsunami detection system works.*

2. Do a close reading on how tsunamis are detected and warning signals sent.

25 MIN

Materials: *Reading: How are tsunamis detected and warning signals sent?*

Introduce the reading. Distribute *Reading: How are tsunamis detected and warning signals sent?* to each student. The Lexile reading estimate of this passage is 810L-1000L. A full-color version of the reading and a close-up of the map are also included in the student edition. Project **slide B**. As a class, use 5 minutes to set the purpose for this activity. Say, *Let's make sure we know what our purpose is for reading the article.* Prompts and examples of responses are below.

Suggested prompt	Sample student responses
What do we want to know more about? What might this reading help us figure out?	*We want to know more about ways to prepare for tsunamis that do not involve building large seawalls.* *We want to know more about how we detect tsunamis so we can warn people.*

Have students write the purpose for reading the article at the top of their handout, as follows: *How are tsunamis detected and warning signals sent?*

***Attending to Equity**

Supporting Universal Design for Learning: Teachers can support all students in forming a deeper understanding of newly "earned" vocabulary by representing the new term in several ways. For example, students can (1) write the term, (2) draw a representation of the term, (3) use their own words to write an explanation for what the term means, and (4) use the new term in a sentence.

This strategy is particularly helpful for **emerging multilingual students**.

Review the close reading strategies. Remind students that close reading requires reading more than once with different purposes and using strategies to interact with the text. Review the steps listed on **slide C**. Then give students 20 minutes to read the article with a partner.

Students who finish the reading early should discuss with their partner which terms from the reading can be added to the Word Wall.*

Say, *This article uses a number of technical terms, some of which we know and some which may be new to some of us. Let's take a moment to see which terms we can add to our Word Wall.* Ask for volunteers to offer terms to add to the Word Wall. Encourage them to share why they feel these words are useful to add and how they would define them.

Additional Guidance

After the reading, ask students which terms they would like to add to the Word Wall. If the term is new for students, categorize it as a "word we encounter." If it was used in a previous unit, list it under "words from a previous lesson or unit". For the term to be considered a "word we earn", students should be able to connect its meaning to the larger ideas discussed in the unit thus far.

Terms you might consider adding during this lesson include:

- Words we encounter: *seismometer, tsunameter, buoy, satellite, sonar*
- Words from a previous lesson or unit: *epicenter, magnitude*

Many of the terms in this reading are specific parts of a tsunami warning system. It is more important for students to understand the system overall, and to see that each piece is designed to fulfill certain criteria. Because these specific terms will likely not apply to many other hazards, it is not essential to remember them, and thus they may remain as words we encounter. However, if students begin to discuss and use the terminology around the specific instruments later in the lesson, consider shifting these words to be words we earn.

The term *epicenter* was encountered in *Unit 6.4: What causes Earth's surface to change? (Everest Unit)*, and *magnitude* in Lessons 2 and 3 of this unit. In this lesson, students add to their understanding of these terms in the context of tsunamis.

Alternate Activity

The reading introduces several devices and technologies involved in tsunami detection. Although students may have limited firsthand experience with such instruments, they can access simplified versions of them through free applications on digital devices.

For example, "Hamm Seismograph" (freely available on iOS and Android devices) can be used to graphically display vibrations associated with seismic waves caused by earthquakes. By holding and moving a digital device in multiple directions and at different frequencies, students can mimic earthquakes of varying magnitudes.

Observing how the energy associated with an earthquake is translated into a visual display gives students a more concrete sense of what a seismometer measures and the role it plays in the tsunami detection system discussed in the reading. Alternatively, some local science museums display examples of seismometers which detect vibrations in the floor as patrons walk, run, or jump nearby.

Consider design constraints. Ask students to share their thoughts regarding the "Stop to Wonder" prompt near the end of the reading. *Say, What might be some constraints that engineers need to consider when designing a tsunami detection system like the one in the reading?*

After allowing for student responses, follow by saying, *Engineers decided that the tsunameters needed to be located near the ocean floor in order to detect large waves. They also decided to keep the tsunameters in "sleep" mode much of the time. Why do you think the tsunameters are sometimes in "sleep" mode and not always in "active" mode? Why might engineers consider this a worthwhile trade-off?*

If students struggle with these ideas, guide them to think about this in terms of constraints on a designed system. Remind them about the term *constraints* from Lesson 5. Say, *When engineers design a system to perform a certain function, sometimes they need to think about certain limitations or constraints. Thinking back to the last lesson, what was one of the constraints that engineers had to consider when designing a system to detect and warn tsunamis?* Prompts and examples of student responses are below.

Suggested prompts	Sample student responses
What might be some constraints that engineers need to consider when designing a tsunami detection system, like the one in the reading?	*They need to know how much everything costs to see if they have the money and people to run everything.* *They need to figure out if some locations are inaccessible or difficult to reach.*
Why do you think the tsunameters are sometimes in "sleep" mode and not always in "active" mode?	*The tsunameter doesn't always need to be on, like when there isn't an earthquake.* *So it doesn't run out of power as frequently.*
Why might engineers consider this a worthwhile trade-off?	*The ocean floor is very far down, and it's difficult and expensive to keep going down there to replace batteries.* *It's too difficult and time consuming to keep bringing up tsunameters from the ocean floor to replace them or change their batteries.*

Key Ideas

Purpose of this discussion: Help students identify one design idea and potential trade-offs in the detection and signaling technologies used for tsunamis.

Look for/listen for these ideas: Keeping the tsunameter in "sleep" mode vs. "active" mode is a design feature with these trade-offs:

- Keeping the tsunameter in "sleep" mode when not needed prolongs the lifespan of the instrument's power source.
- Changing batteries in the tsunameter entails bringing the instrument to the surface, which is a difficult, long, and expensive process.
- Changing batteries in the tsunameter by sending a person or submersible down to the ocean floor is costly and very dangerous.

3. Summarize ideas from the reading. 8 MIN

Materials: *Reading: How are tsunamis detected and warning signals sent?*

Summarize ideas from the reading.* Project **slide D.** Prompt students to think about the main pieces of information presented in the reading. Guide them to first look back at their annotated text and briefly discuss the three questions on the slide with their partner. Tell them we will then discuss these questions as a class.

Say, *Remember, because we saw that big structures like seawalls don't always protect people from a tsunami, we wanted to know more about how we detect tsunamis so that we could warn people in case one is coming. What do people need to know in order to prepare for a tsunami?* Examples of student responses to this prompt are below.

Suggested prompt	Sample student responses
What do people need to know in order to prepare for a tsunami?	*They need to know if an earthquake that may cause a tsunami has occurred.* *They need to know if a tsunami is getting closer.* *They need to know when a tsunami may arrive so they know how much time we have to evacuate.* *They need to know how bad the tsunami will be, so they know if we need to evacuate.* *They need to know how tall and fast the tsunami is to determine how and when to warn people.*

Prompt students to read and think about the second question on **slide D**. Say, *What must a tsunami detection and warning system be able to do?* Examples of student responses are below.

Suggested prompt	Sample student responses
What must a tsunami detection and warning system be able to do?	*It must accurately detect the location, depth, and strength of an earthquake.* *It must quickly signal to the buoy system to wake up the tsunameters.* *It must accurately detect the presence of a large wave on the surface.* *It must quickly alert scientists of an incoming tsunami.* *It must accurately forecast the tsunami's arrival time and wave height before it reaches shore.*

Present the third question on **slide D**. Say, *How can we make a diagram of a tsunami detection and warning system working together?*

This question summarizes the main parts of the detection system from the reading, including the parts on land, in space, and in the ocean. It may be easier for students to answer by making a diagram. However, encourage them to

***Supporting Students in Three-Dimensional Learning**

This text represents an opportunity to integrate aspects of the three dimensions of the NGSS. Students obtain and communicate information from the text about a system (the overall network of sensors across land, space, and sea), and subsystems (the tsunameter and how it operates on the ocean floor) that are focused on detection and warning of earthquakes and tsunamis. These systems have their own criteria and trade-offs that impact how well they work. Through critically reading about the system and its parts, students can gain a better understanding of how the system works to protect communities.

spend less time on the artwork and copying pictures from the reading by modeling how to make a schematic diagram instead, with symbols or shapes representing parts of the system (for example, use boxes to represent parts that send signals and use arrows to represent signals).

Ask students if there's a term that describes the list of what the detection and warning system should do. Say, *In the previous lesson, we found out that in designing or evaluating systems, engineers sometimes refer to a list of requirements, or things that a design must be able to do to be considered successful. What do we call those things?*

Students should recall that engineers use sets of criteria to help evaluate the success of a particular design. If they struggle to recall this term, guide them to look at the Word Wall or the Criteria for Solutions poster from Lesson 5. Say, *An engineer designing a tsunami detection and warning system must be sure that it meets these criteria.*

Assessment Opportunity

Building towards: 6.A Critically read scientific text to understand how a system designed to detect tsunamis follows specific criteria (related to earthquake activity) and constraints (related to signal transmission).

What to look for/listen for: After the third paragraph in the reading, students should understand that this tsunami detection system is only triggered if an earthquake meets specific criteria (the earthquake must be underwater, strong, and shallow). After the fifth paragraph, they should identify one constraint of the system, as the signals must be able to travel through air, water, and space, thus requiring the use of both satellite and sonar signals. Finally, in the "How does a tsunameter work" paragraph, students should offer a range of explanations for why the tsunameter is designed to have both "sleep" and "active" modes, including that the instrument uses more power while active, which may reduce its effective lifetime. They should identify this as a constraint on the system.

What to do: If students struggle to identify criteria and constraints in the tsunami detection system, pause and reflect on how these have been discussed up to this point. To help specifically with the tsunameter in "sleep" and "active" mode, make the analogy to whether a person requires more energy when they are asleep or when they are active. If they struggle to see why energy consumption is problematic, have them consider where the instrument gets energy to function: First, ask where most appliances or machines get their energy. Then, ask how getting energy down to the tsunameter many thousands of meters below the ocean surface may be problematic (i.e., its location is completely dark, freezing, and under immense pressure). Finally, ask students to think about this in terms of cost and danger (i.e., *Why might extending the life of a tsunameter be better than having one that is always in active mode? Why is it not safe to send people down to replace the batteries?*).

4. Update the Tsunami Chain of Events poster.

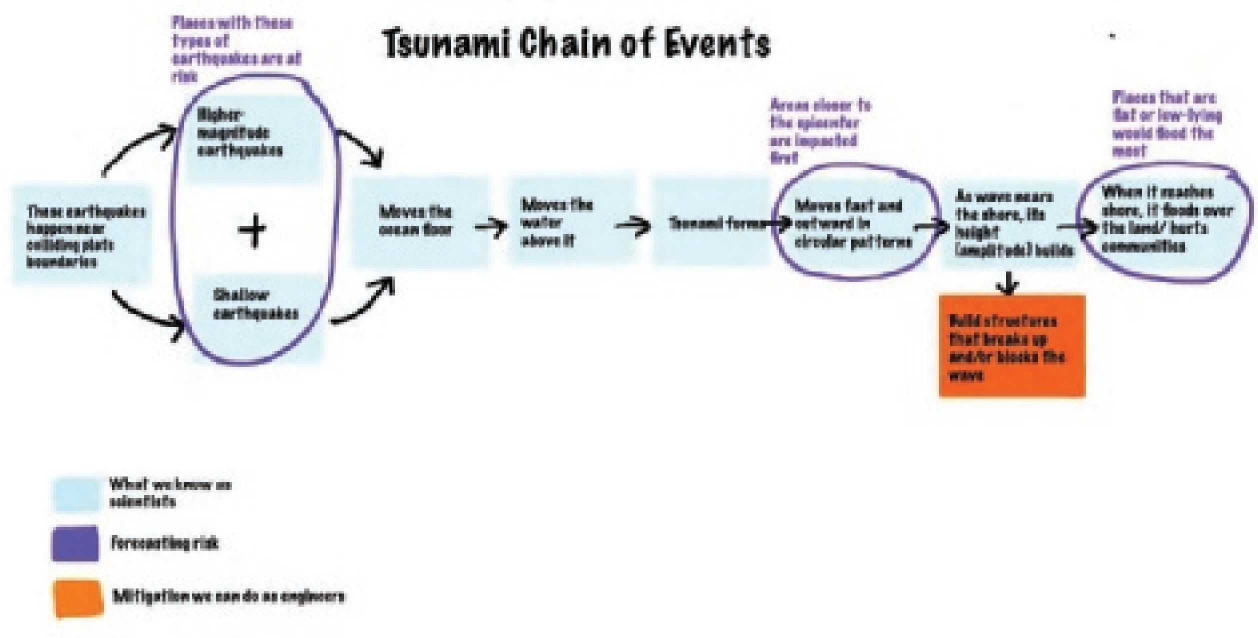
5 MIN

Materials: science notebook, Tsunami Chain of Events poster, markers, large sticky notes

Update the Tsunami Chain of Events poster. Project **slide E**. Explain that we will add new information from the reading to the Tsunami Chain of Events poster.

Say, *Remember that this unit is not just about the 2011 tsunami, but also about designing ways to protect communities from tsunamis. Therefore, understanding the connection between science and engineering is critical. One way to keep track of* *these connections is to add information from the reading to our Tsunami Chain of Events poster. This will help to show how engineers use science ideas, in this case about tsunami formation, to inform their engineering designs.*

Recall that after Lesson 5, the chain of events looked like this:



After displaying the Tsunami Chain of Events poster, ask, *As we look back at this chain of events, at which points do you think a tsunami detection and warning system might play an important role? Are there certain parts of the tsunami detection and warning system that you think connect to more than one part of this diagram?*

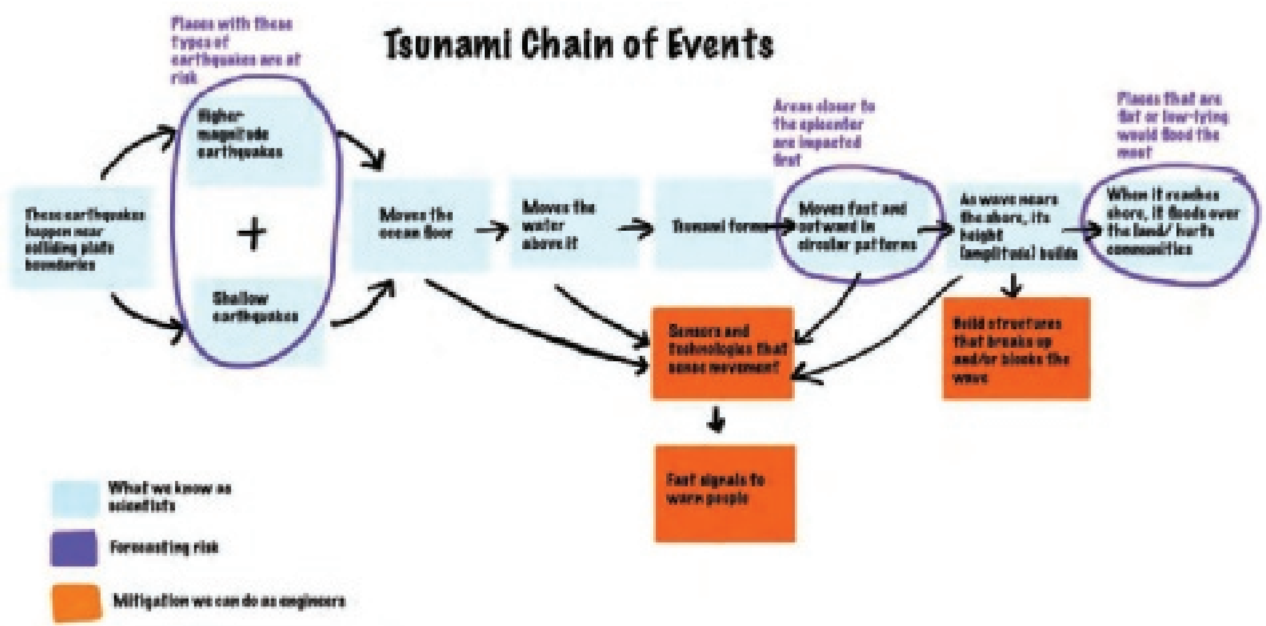
Ask students to share their ideas for possible connections. Record ideas onto the chart using large sticky notes—be sure to use the same color sticky notes as those added in Lesson 5 to indicate that these connections involve aspects of engineering designs. Prompts and examples of student responses are below.

***Supporting Students in Developing and Using Cause and Effect**

Connecting systems to cause and effect: The cause-and-effect diagram may also be used to highlight that tsunami mitigation strategies often involve subsystems working together. For example, to help protect at-risk communities, engineers may elect to build structures to block the wave and also use seismometers and tsunameters to detect a tsunami ahead of time so they can warn a local population to evacuate. The combination of these smaller subsystems (represented by orange sticky notes) may contribute to a more robust and effective overall system of mitigation.

Suggested prompts	Sample student responses
As we look back at this chain of events, at which points do you think a tsunami detection and warning system might play an important role?	*The seismometer on land detects and measures earthquake magnitude, which helps determine whether a tsunami-causing earthquake may have occurred.* *The tsunameter underwater measures the movement of water in the ocean, which helps determine whether a high enough wave has been generated by an earthquake.* *The sophisticated computers back on land use data from the tsunameters to predict if and when a tsunami may reach the shore.*
Are there certain parts of the tsunami detection and warning system that you think connect to more than one part of this diagram?	*I think the seismometer from the system could connect to the earthquakes or to the movement of the ocean floor, since those may be related.* *Perhaps the detection system connects to the movement of water or the moment a tsunami forms because of the tsunameter.*

Following this discussion, the cause-and-effect diagram may look like this:*



Additional Guidance

Regarding the diagram, keep in mind that the number and types of connections shared by students may vary. It is not essential for the class chart to look exactly like the example provided. It is more important that students be able to identify a moment (or moments) within the chain of events when the use of a tsunami detection and warning system may be most useful in protecting communities.

5. Navigation

2 MIN

Materials: None

Motivate the next step. Display **slide F**. Guide students to think about what happens once a tsunami is detected and predicted to impact land. Say, *So, an earthquake has occurred in the ocean, and the DART II system has accurately and quickly signaled that a tsunami is approaching. The local government is about to issue a tsunami warning to people nearby. What should we be concerned with at this step?*

Focus on responses associated with the communication of the warning. For example, how soon should the warning be sent? Do they wait for more information? How do they send out the message? What is in the message? All these ideas set students up to think more about the technologies, criteria, and constraints involved in communicating before and during a tsunami.

ADDITIONAL LESSON 6 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

The science text that is the focal activity of this lesson supports the following English Language Arts standards:

- CCSS.ELA-LITERACY.RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.
- CCSS.ELA-LITERACY.RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6-8 texts and topics*.
- CCSS.ELA-LITERACY.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
- CCSS.ELA-LITERACY.RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

LESSON 7

What are ways we can communicate with people before and during a tsunami?

Previous Lesson

We read about a complex system of instruments that detects tsunamis, and we learned that tsunami warnings are sent when specific criteria are met regarding the triggering earthquake event and whether the resulting tsunami is predicted to reach land.

This Lesson

Investigation

2 DAYS

We listen to what a tsunami warning signal sounds like and notice and wonder about how people know what to do when they hear it. We read real accounts of tsunami survivors from Japan and what they did when the earthquake and tsunami occurred. We identify the stakeholders who the warning signal must work for, and then develop criteria and constraints for tsunami communication solutions. We evaluate different ways tsunami preparation and response are communicated to stakeholders and also read a case study about a school in Kamaishi that included education as part of their plan. From this, we learn that there are many ways to communicate with community stakeholders before and during a tsunami event.

Next Lesson

We will develop a system model to represent what we've learned about detecting, warning people, and reducing damage from tsunamis. We will analyze the importance and purpose of the subsystems and generalize the process engineers use to develop systems and solutions to address a local hazard.

Building Toward NGSS

MS-ESS3-2, MS-ETS1-1, MS-ETS1-2

What Students Will Do

7.A Integrate written text with multimedia displays of tsunami warning and preparedness systems to clarify additional ways communities at-risk of tsunami can mitigate potential future effects.

7.B Evaluate communication systems, using a systematic process and agreed-upon criteria and constraints, to determine how well the system (structure) communicates with stakeholders (function).

What Students Will Figure Out

- Groups of people can be affected by hazards in different ways, depending on their access to (1) early warning information, (2) resources to protect themselves and property, and (3) ability to evacuate when necessary.
- Groups particularly at-risk during a hazard are older people, children, people who speak a different language, and those who are sick or require assistance.

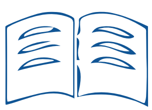
- Effective plans account for the people living in a place and the resources communities need to respond appropriately.
- Communication strategies include educating the community before a natural hazard happens and alerting people when the hazard is happening.
- A variety of communication strategies (e.g., signs and symbols, warning sounds, multiple languages) are necessary to ensure that all people at risk understand how to respond quickly and safely in the event of a hazard.

Lesson 7 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**BUILDING UNDERSTANDINGS DISCUSSION ABOUT WARNING SIGNALS** Listen to real tsunami warning signals and notice and wonder about the next steps to respond.	A	6.5 - Lesson 7 Audio Alerts for Tsunami Warning (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
2	8 min	**READ STORIES FROM JAPAN** Read quotes and stories from survivors of the Japanese tsunami about how they felt when the earthquake struck and tsunami warning signals were sent.	B	*Voices from Japan Tsunami Survivors*
3	12 min	**IDENTIFY COMMUNITY STAKEHOLDERS** Using stories from the community residents of Japan, students identify stakeholders and their needs.	B-C	*Voices from Japan Tsunami Survivors*, *Community Stakeholders*, chart paper, markers
4	12 min	**IDENTIFY CRITERIA AND CONSTRAINTS FOR COMMUNICATION SYSTEMS** Identify criteria and constraints for communication systems designed to warn people of a hazard.	D-F	*Community Stakeholders*
5	1 min	**HOME LEARNING** Assign home learning for students to notice all the ways they receive communication outside of school	G	
				End of day 1
6	10 min	**AGREE UPON CRITERIA AND CONSTRAINTS** Share criteria and constraints from day 1 and incorporate any new ideas that surfaced during the Home Learning.	H	*Evaluation Matrix*

Part	Duration	Summary	Slide	Materials
7	15 min	**EVALUATE COMMUNICATION CASE STUDIES** Evaluate different communication options and come to consensus on how well they meet agreed-upon criteria and constraints.	I-K	*Evaluation Matrix, Tsunami Communication Examples*, 6.5 - Lesson 7 Audio Public Service Announcement (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) chart paper, markers
8	12 min	**READ ABOUT KAMAISHI SCHOOL CASE STUDY** Evaluate the value of having a preparedness plan in place when a natural hazard occurs.	L	*Reading: Kamaishi East Junior High School*
9	5 min	**UPDATE TSUNAMI CHAIN OF EVENTS** Update Tsunami Chain of Events to include new ideas.	M	Tsunami Chain of Events, large sticky notes, markers
10	3 min	**NAVIGATION** Motivate the need to take stock in all the different systems to protect communities from tsunamis.	N	index card
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 7, students are ready to read Student Reader Collection 3 and then respond to the writing exercise.		Student Reader Collection 3: *Minimizing Damage*

Lesson 7 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Voices from Japan Tsunami Survivors* • *Community Stakeholders* • *Evaluation Matrix* • *Tsunami Communication Examples* • 6.5 - Lesson 7 Audio Public Service Announcement (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • *Reading: Kamaishi East Junior High School* • index card		• 6.5 - Lesson 7 Audio Alerts for Tsunami Warning (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • chart paper • markers • Tsunami Chain of Events • large sticky notes

Materials preparation (15 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

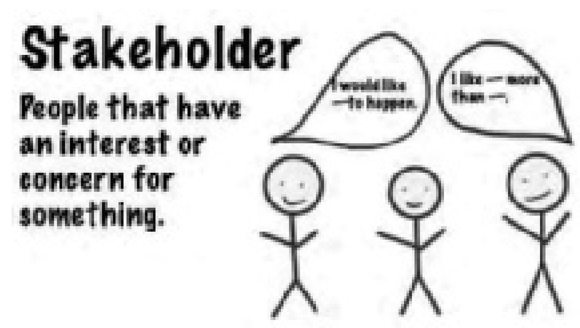
Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make sure the audio can play for 6.5 - Lesson 7 Audio Alerts for Tsunami Warning. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Between day 1 and day 2, modify slide H to reflect student ideas that are generated on *Community Stakeholders*.

Several communication examples are provided for students to analyze, including multiple cell phone apps, flyers, infographics, and an audio Public Service Announcement at 6.5 - Lesson 7 Audio Public Service Announcement (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Consider supplementing these options with any local resources for your community.

Be sure you have materials ready to add the following words to the Word Wall: *stakeholder* and *system*. Do not post these word(s) on the wall until after your class has developed a shared understanding of their meaning.



Lesson 7 • Where We Are Going and NOT Going

Where We Are Going

The focus of this lesson is helping students understand the communication systems (i.e., education, preparation, and warning systems) in place to help people prepare and respond when a natural hazard is imminent. Preparing residents to respond is a critical aspect of mitigating the effects of natural hazards. This preparation includes helping people understand their risk for a natural hazard, recognize warning messages and sounds, know when to shelter and when to evacuate, and know where to go and how to get there calmly and safely. The lesson supports students in thinking through the criteria and constraints associated with designing and evaluating communication systems for tsunamis. They will apply their ideas to a local hazard in Lesson 10.

Where We Are NOT Going

Equity of access to resources and the ability to prepare, evacuate, and recover from natural hazards are very important issues for communities to address in a comprehensive, effective communication plan. However, this lesson only focuses on a few groups of people with special needs (e.g., elderly, sick, children, and non-dominant language speakers). If instructional time allows, it is important to address issues of inequity related to hazards by acknowledging that different groups of people are affected disproportionately by hazards. While not included beyond the groups previously identified, this lesson could be expanded to discuss places and/or groups of people within a community that are at risk of being adversely affected by a hazard.

1. Building Understandings Discussion About Warning Signals

8 MIN

Materials: science notebook, 6.5 - Lesson 7 Audio Alerts for Tsunami Warning (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Additional Guidance

Supporting emotions and empathy: This lesson integrates the alarm system sounds and the experiences and feelings tsunami survivors had as they received the warning signals of an approaching tsunami. The tales include grief at the loss of homes and people and feelings of being scared. Students might experience similar emotions as they learn about how people responded in the tsunami event and why education and communication solutions are key parts of a system designed to protect communities. Be prepared for students to struggle with fright or grief after hearing or reading about natural hazard damage.

Prepare students for what they will hear.* Display **slide A**. This lesson begins with an audio clip of Japan tsunami warning signals, including alerts from cell phones, TVs, loudspeaker announcers, and sirens. Say, *We are about to listen to the signals that people receive after a tsunami is detected. As we listen, think about what the community residents might be feeling, seeing, or hearing during the moments before a tsunami arrives. We will listen one time through without writing—just close your eyes and listen. The second time through, we will make notes about what we Notice and Wonder. Consider as you listen: Who are the people hearing this warning? What will they do next?*

Play the audio clip at 6.5 - Lesson 7 Audio Alerts for Tsunami Warning. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Ask students to close their eyes, put their heads down, and just listen to the alarm signals being sent to residents. The clip is 1:30 long. Once it has been played, ask students to take out their notebooks, and as the clip is played a second time, ask students to record what they Notice and Wonder about in their science notebooks.

After the students have listened twice through the clip, say, *Last class, we found out that warnings are sent after a tsunami that will reach land is detected. We just heard some of those warnings. What did you Notice and Wonder as you listened to the audio clip?*

Suggested prompt	Sample student responses
What did you notice about the sounds we heard?	*The sounds were a little scary.* *They had a lot of different sounds.* *I couldn't understand what the person was saying.* *It sounds like some were on cell phones but others were loudspeakers.*

***Attending to Equity**

Supporting Empathy and Emotions: Listening to sirens and alarming alerts can trigger a stress response in students. They are purposely designed that way to alert people to danger. However, it is important for students to experience the sounds they can expect to hear in a dangerous event, so that they can respond appropriately when they hear the sound. If students don't have experience hearing warning signals, they could become scared or panicked during the event. The Kamaishi case study on day 2 is a good example of how practicing listening to and responding to warning signals can help students be prepared in the event a natural hazard event occurs.

Support for Universal Design for Learning: Consider how some students may react to loud or alarming noises. If needed, the clip has lower tones starting at 1:08 through the end of the clip, where there is an announcer with very low sirens heard in the background. This section of the audio might be more appropriate to play for students who are sensitive to loud or alarming noises.

Suggested prompt	Sample student responses
What do you wonder about?	*I am wondering whether everyone knows what the sound means.* *I wonder how they get the sound to people in all those different ways.* *I wonder about the people who don't have cell phones or can't hear.* *I wonder how they know what to do, especially if they don't speak the language.*

Acknowledge that alarm and warning signals can be scary. Let students know these signals are often loud and scary, and that they are designed that way so that people are alerted to potential danger. Say, *It can be a scary thing to get a warning signal like that. Have you ever experienced that before?* Let students share their experiences to surface-related phenomena, such as

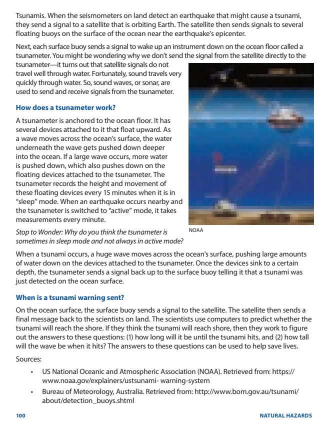
- tornado warnings on the TV;
- "Amber alerts" on the phone; and
- fire/tornado/active shooter drills in the school.

2. Read stories from Japan.

8 MIN

Materials: *Voices from Japan Tsunami Survivors*

Transition students to consider accounts from the Japanese tsunami. Display **slide B.** Say, *On March 11, 2011, when the earthquake and tsunami struck Japan, people had to react to the warning signals. We have some stories from some of those people about what they did and how they felt as it was happening.*


Tsunamis. When the seismometers on land detect an earthquake that might cause a tsunami, they send a signal to a satellite that is orbiting Earth. The satellite then sends signals to several floating buoys on the surface of the ocean near the earthquake's epicenter.

Next, each surface buoy sends a signal to wake up an instrument down on the ocean floor called a tsunameter. You might be wondering why we don't send the signal from the satellite directly to the tsunameter—it turns out that satellite signals do not travel well through water. Fortunately, sound travels very quickly through water. So, sound waves, or sonar, are used to send and receive signals from the tsunameter.

How does a tsunameter work?

A tsunameter is anchored to the ocean floor. It has several devices attached to it that float upward. As a wave moves across the ocean's surface, the water underneath the wave gets pushed down deeper into the ocean. If a large wave occurs, more water is pushed down, which also pushes down on the floating devices attached to the tsunameter. The tsunameter records the height and movement of these floating devices every 15 minutes when it is in "sleep" mode. When an earthquake occurs nearby and the tsunameter is switched to "active" mode, it takes measurements every minute.

NOAA

Stop to Wonder: Why do you think the tsunameter is sometimes in sleep mode and not always in active mode?

When a tsunami occurs, a huge wave moves across the ocean's surface, pushing large amounts of water down on the devices attached to the tsunameter. Once the devices sink to a certain depth, the tsunameter sends a signal back up to the surface buoy telling it that a tsunami was just detected on the ocean surface.

When is a tsunami warning sent?

On the ocean surface, the surface buoy sends a signal to the satellite. The satellite then sends a final message back to the scientists on land. The scientists use computers to predict whether the tsunami will reach the shore. If they think the tsunami will reach shore, then they work to figure out the answers to these questions: (1) how long will it be until the tsunami hits, and (2) how tall will the wave be when it hits? The answers to these questions can be used to help save lives.

Sources:

- US National Oceanic and Atmospheric Association (NOAA). Retrieved from: https://www.noaa.gov/explainers/ustsunami- warning-system
- Bureau of Meteorology, Australia. Retrieved from: http://www.bom.gov.au/tsunami/about/detection_buoys.shtml

100 NATURAL HAZARDS

Divide students into groups. Each group will read at least three accounts using *Voices from Japan Tsunami Survivors*. If time allows, they can read more. Ensure that groups choose different accounts to read about so that all stories are read by one or more pairs of students in the classroom. As students read, ask them to pay close attention to the following:

- Who is this person?
- What was their experience like?
- What else would you like to know about their experience?*

Let students read quietly for 3–5 minutes and then talk about these questions with their partner and be ready to share what they learned with the class.

***Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information**

Use this text as an opportunity to support students in developing the element of: *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*. Students will draw on text, media, and visual displays to better understand the criteria and constraints for effective communication systems. At this point, students are drawing on qualitative information from survivor stories (written text) about how they responded.

3. Identify community stakeholders.

12 MIN

Materials: *Voices from Japan Tsunami Survivors, Community Stakeholders,* chart paper, markers

Identify characteristics of community members from the stories. Continue to display **slide B.** Ask partners to share stories from *Voices from Japan Tsunami Survivors* with the class. Use the questions on the slides to help focus students' sharing with the whole class.

Suggested prompts	Sample student responses
Who is this person?	*a grandmother* *a student* *a teacher* *a business owner*
What was their experience like?	*She saw water coming and it just kept coming.* *The student knew that a tsunami was coming and planned to go to the hills as soon as the shaking stopped.* *She couldn't understand the announcements.* *He knew they needed to evacuate right away.*
What else would you like to know about their experience?	*I'm wondering if the grandma was safe where she was on the hill.* *I'm wondering how the students knew what to do.* *I'm wondering if the teacher was able to figure out what the announcement meant.* *I'm wondering if the business owner and his employees made it to safety.*

Alternate Activity

Consider creating a table or graphic organizer to track student ideas to these questions to compare similarities and differences in how people might receive and respond to warning signals.

Define stakeholders. Say, *It sounds like most of these people either knew what was happening, or someone warned them. However, there were some people that didn't quite know what was happening. They all survived the tsunami in Japan, but they had different experiences based on who they are and what they knew about tsunamis.*

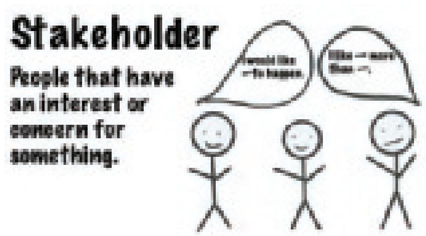
Take a moment with students to define "stakeholders" for students. First, ask students, *As we work together to figure out ways to protect and warn communities about tsunamis, how might we use these first-hand accounts to evaluate different*

***Attending to Equity**

Supporting Emergent Multilingual Students: Teachers can support all students, particularly emerging multilingual students, in forming a deeper understanding of newly "earned" vocabulary by representing the new term in multiple ways. For example, students can (1) write the term, (2) draw a representation of the term, (3) use their own words to write an explanation for what the term means, or (4) use the new term in a sentence.

The representation for stakeholders (people who have an interest or concern or investment in something) should mostly illustrate the people who will be impacted by the design solution (in this case, a warning system that communicates to people how and when to respond).

solutions? Let students share some ideas, such as how the designs need to work for all people in the community.



Say something like, *Engineers who design solutions, such as seawalls and communication systems, want to make sure solutions work for all the people affected. These people are called stakeholders because they all have a "stake" in what design solutions might work best for them and their community. And some stakeholders have certain needs while others need something else.*

Add "stakeholders" to the Word Wall.*

Identify stakeholders for tsunami warning signals. Display **slide C** and distribute *Community Stakeholders*. In partners, using Part 1 on the handout, have students identify individuals or groups of people that are represented by the stories they read about. Challenge students to think about any special assistance the stakeholders might need during an emergency. Give partners about five minutes to work on this.

Share stakeholders as a class. Bring students back together to share their list of stakeholders and needs as a class. Title a T-chart with "Stakeholders" on the left column and "Assistance?" on the right column. Allow partners to share their ideas. To avoid duplicate ideas, use questions like:

- Did anyone else identify that stakeholder group?
- Did you have the same needs?
- Would you add something to what ______ already identified?

Identify special needs for consideration. Once you have generated a list of stakeholders and their needs, ask students: *Are there individuals or groups that have special considerations that we should think about? Are there groups of people we haven't identified? For example, are there groups of people in the community that might have trouble evacuating quickly?*

Add a star to those stakeholders to identify them as a higher at-risk group during an evacuation and note the reason using a different color marker. Examples include the following:

Who is this community member? (Stakeholders)	Will they need special help during a tsunami?	Describe their need	Who can help them?
Business Owner	○ yes ✔ no		
Grandparent	✔ yes ○ no	Helping evacuating to high ground quickly	family, neighbors
Young Student	✔ yes ○ no	Help knowing where to go and get there safely	Teachers, older students
Salesperson	○ yes ✔ no		

- Younger children (might not know where to go or how to get there; cannot drive).
- People who might not be able to evacuate quickly (elderly or ill people may not be able to move quickly enough for an evacuation; may not be strong enough to climb onto objects).
- People who don't have technology (they may not see or hear the signal).
- People who are traveling and do not know the area and/or local language (they won't know where to go or might not be able to interpret the language).

Transition students to now consider what a communication system needs to do to protect the most people. Say, *Now that we know who needs to know a tsunami is coming, let's consider what communication solutions we need to protect as many people as possible.*

4. Identity criteria and constraints for communication systems.

12 MIN

Materials: *Community Stakeholders*

Identify the potential problems and goals of an effective communication system. Display **slide D.** Using Part 2 of *Community Stakeholders* have students consider what design problem engineers are trying to address when they put together communication systems for natural hazards and also the goals of an effective system. It might be helpful to frame these two questions in this way:

- What is the problem that engineers are trying to solve when they develop hazard communication systems?
- What would that system need to be able to do to address the community stakeholders' needs?

Pause here to discuss the use of the word "system." Students have used this word before in previous units, but it takes on a new meaning at this point when referring to hazard communication systems. Ask students to come to a shared understanding of how the word "system" is being used. An example might be: "A system is a set of parts that work together to perform a particular function/job. And sometimes larger systems have smaller subsystems that work together."

In this case, a hazard communication system includes ways to both alert people to what is happening and also help them respond in the safest possible way. Add "system" to the Word Wall.

Let students discuss with a partner the answers to the questions for a few minutes. Then, ask students to share with the whole class.

Suggested prompts	Sample student responses
What is the problem that engineers are trying to solve when they develop hazard communication systems?	*They are trying to save as many people as they can.* *They are trying to make sure as many people know what to do as possible.*
What would that system need to do to address all the needs of the community stakeholders?	*It would need to have different ways of communicating with different groups of people.* *It would need to reach the largest number of people possible.* *People would need to know what to do before the tsunami happens too.*

Define criteria and constraints for the communication system. Say, *OK, now that we have an idea of what the problem is and the goals of the system, let's figure out what the system has to do to work and what potential limitations or* *constraints we might need to consider. Let's think about one criteria and one constraint together, and then you and your partner can brainstorm one or two more.*

Display **slide E**. Together, brainstorm one possible criteria for a communication system. For example:

Identify Criteria What *must* the system be able to do to work?	Why is this an important criterion?
It must reach as many people as possible.	By alerting as many people as possible, we can save more lives.

Then, brainstorm one possible constraint for a communication system. For example:

Identify Constraints What might limit the system that is put into place?	Why is this constraint important to consider? Is there a particular stakeholder group that we should consider?
The communication of the warning signal should include multiple modes of communication (audio, visual, and haptic warnings). The technology used for the warning signals should reach all areas within the community.	By having different modes of communication, it is more likely to reach a larger group of people, including those people who need additional audio, visual, or vibration options. Community members who are not able to hear, see, or feel the signals will be in more danger.

To help facilitate student thinking about possible criteria or constraints for a system, display **slide F**. This slide provides students with ideas for what might be a criteria or a constraint for communication. However, it is fine for students to think outside of this list. Below are some possible ideas that might emerge from the students' brainstorm.

Question to consider from handout	Criteria and Constraints that students might identify (these may also include limitations on the technology itself)
Who gets alerted?	**Possible Criteria:** All people in the affected area are notified of the hazard. **Possible Constraints:** Georeferenced alerts are sent to all cell phone users within the tsunami zone, but users might opt-out of alerts, or those without cell phones might not receive an alert.
What media options should be available to send a signal?	**Possible Criteria**: Offer as many ways to hear, see, or feel a warning signal. **Possible Constraint:** Warning signal should use at least 3 different forms of media, such as cell phone alerts, sirens, and TV announcements. But there are limitations on the technology: some people do not use media; distance from a siren might be too great to hear.
Can all people hear, see, or feel some kind of warning signal or alert?	**Possible Criteria**: Communication systems must include a warning signal that can be seen, heard, and felt (haptic) to reach as many people as possible. **Possible Constraint:** Some people have limited access to media and may not receive the signal.

Question to consider from handout	Criteria and Constraints that students might identify (these may also include limitations on the technology itself)
What languages or symbols should be used in this kind of system?	**Possible Criteria**: At least two widely spoken languages are used in the announcements; recognizable symbols clearly mark evacuation routes. **Possible Constraint:** Visitors may not speak or read either of the two widely used languages in the region. Also, the symbols used in a particular region may be culturally relevant and therefore unrecognizable as visitors to a region may not recognize the same symbols or may interpret their meaning differently.
What does the message need to say to warn people?	**Possible Criteria**: Communicates warning in everyday language so people understand. **Possible Constraint:** All world languages cannot be **communicated** at once—some subgroups may be left out. Signals may take too long to transmit to a different language (maybe there is a loop time for messages). If only audio, those with hearing issues would not be alerted and if only visual, those with vision **impairments** might struggle.
What are the evacuation routes and places for people to shelter? How are these routes marked?	**Possible Criteria**: Evacuation routes are well-marked with signs that have words and symbols. **Possible Constraint:** Safe evacuation sites might not be quickly accessible for all people depending on the distance. Some people may not understand the signage or know where to look for it if from out of the area.
How will people know what to do when the warning signal goes off?	**Possible Criteria**: Education programs, pamphlets, maps, and signs are used to spread the message of what to do. **Possible Constraint:** Formal educational systems may not be available to all populations in a tsunami-prone region.

Gather student handouts and use the students' brainstormed criteria and constraints to pose a list of them for the evaluation process on day 2, using an edited version of **slide H**. Scan the student responses and find at least three common criteria that will be used to consider communication options on day 2. Choose criteria that might be focused on the type or amount of text, language of text, clearness of symbols, and the use of multi-modes of communication (e.g., combinating symbols with text).

Assessment Opportunity

Building towards: 7.A Integrate written text with multimedia displays of tsunami warning and preparedness systems to clarify additional ways communities at-risk of tsunami can mitigate potential future effects.

What to look for/listen for: Look for clearly identified stakeholders with particular needs for emergency communication, and then look for corresponding criteria and constraints that address those needs but might limit what can be used to develop or evaluate potential solutions. Use the previous example table to see specific example student responses.

What to do: If students are struggling to connect stakeholder needs with criteria and constraints of communication systems, use a local or relevant example to walk them through the process. For example, ask students: *If there is a fire in our school, how do we, the stakeholders, receive the warning? Would all people in our class receive the alert? What might prevent someone from receiving it? Is there only one alert style or more than one (e.g., sound, lights, vibrations, others)?* Using an example familiar to students might help access their knowledge about different criteria and constraints for communication systems. Other examples could be Amber alerts or tornado warnings; consider also using non-emergency communications, such as the school announcements or announcements at sporting events or theme parks.

5. Home Learning

1 MIN

Materials: None

Assign Home Learning. Display **slide G**. Say, *As you experience communication outside the classroom between now and the next class, pay attention to all the ways you send and receive communication. Think about whether there are any ideas from your experience that we should consider. Jot these down and bring these ideas with you to class next time.*

End of day 1

6. Agree upon criteria and constraints.

10 MIN

Materials: *Evaluation Matrix*

Share a list of criteria and constraints. Introduce a shared set of criteria and constraints from student ideas developed at the end of day 1. Say, *I looked through your ideas from our handout where you brainstormed possible criteria and constraints. I condensed the list for us to use for our work today. Take a look and see if I left off something that we should include.*

Display **slide H**. Give students a moment to look through the list of criteria chosen from their work on day 1. Then ask students if they have any clarifying questions or criteria to add that were not captured.

Add new ideas from Home Learning. Remind students of their home learning assignment and ask them if they noticed any new information we should consider regarding ways we send or receive communication. Ask, *Did you notice where you send and receive communication outside of school? For example, what information did you notice on signs, through talking, or on an app?**

Ideas that might surface include the following:

- Visual communication: billboards, signs, TV ads
- Audio communication: streaming radio or music channels, alerts on phones or smartwatches, smart home devices, radio, loudspeakers, announcement systems
- Haptic communication (this might not come up): touch or tapping feelings from devices such as smart watches, tablets, cell phones

***Attending to Equity**

Supporting Universal Design for Learning: As you gather students ideas about communication, be mindful of different ways students access communication based on their needs. Some students might receive more communication through auditory processes, whereas others might connect with visual processes. Ask for contributions of ideas that include multiple means of *perception and representation*.

As students share, ask them to see if their new ideas about how they communicate are represented already on the list on **slide H** or if they want to add something that is missing.

Pass out *Evaluation Matrix*. Ask students to record the agreed-upon criteria and constraints or limitations from the slide onto the first row of the matrix on the handout so they are ready to evaluate different communication systems.

7. Evaluate communication case studies. 15 MIN

Materials: *Evaluation Matrix*, *Tsunami Communication Examples*, 6.5 - Lesson 7 Audio Public Service Announcement (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), chart paper, markers

Evaluate different communication options using criteria and constraints. Display **slide I.** Divide the class into 10 groups of students (2–3 per group). There are multiple communication options that will be evaluated using a jigsaw method with at least two groups evaluating each option. Students can use *Tsunami Communication Examples* in the student edition or supplement with additional or alternate examples as needed. One example in another language is included in the selection, and an audio Public Service Announcement (PSA) is also available at 6.5 - Lesson 7 Audio Public Service Announcement (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) A variety of examples allows students to evaluate the affordances and constraints of different modes of communication.

Alternate Activity

Choose groupings that fit your class size and context. However, having more than one group evaluate each communication option will provide the opportunity for students to build consensus on their ratings of each option. If only one group reviews an option, offer additional support to help build consensus within the group. For example, encourage students to use the Communicating in Scientific Ways chart and evidence from the images to support their ratings of each option against the criteria and constraints.

Groups will work separately at first to review the resource and rate it against the criteria. Groups will also list possible community constraints that might limit how the solutions could work for the community, or students might even list constraints of the technology itself. Give students 5 minutes to do this initial pass. They will rate only the options on their assigned row.

***Supporting Students in Engaging in Argument from Evidence**

As groups engage in this discussion, center their focus on how their evidence can be useful for evaluating claims and persuading others about the validity of their ideas. When students are engaged in the work of argumentation, they should explicitly build from evidence, past experiences, and/or shared observations to support their conclusions.

List the Communication System Solution	Criteria 1 *Reach all people*	Criteria 2 *Use everyday language*	Criteria 3 *Help people respond*	List possible constraints
Flyer	●●●	●●●	●●●●●	*Uses limited language, requires lots of reading, only 1 form of information*
Infographic	●●●●●	●●●●●	●●●●●	*Only seen where posted, small text*
Pamphlet	●●●●●	●●●	●●●●●	*Really small text, only in one format*
Cell Phone App 1	●●●	●●●	●●●●●	*Limited cell phone access, some people might have difficulty with app*
Cell Phone App 2	●●●	●●●●●	●●●●●	*Limited cell phone access*

Display **slide J** with new instructions. The two groups assigned to the same communication options will need to meet together and come to consensus on how they rated the option and what constraints the communication option might have.*

Share ratings across groups. Once groups have shared agreement on their assigned communication option, reconvene the class to share the results. Title a chart as "Communication Options" (or project a blank *Evaluation Matrix* onto a whiteboard). Ask the groups to share their ratings and record their thinking for the class.

Ask students if they notice any patterns in the ratings, and whether they think one option is better than the others. For example, ask, *Does one of these options seem to do everything really well? Why or why not?*

Assessment Opportunity

Building towards: 7.B Evaluate communication options using a systematic process and agreed-upon criteria and constraints to determine how well the design (structure) serves to communicate to stakeholders (function).

What to look for/listen for: Listen for agreement within the jigsaw groups about what their assigned communication option does well and what are its limitations. Then, across all groups, as a whole class, listen for ideas about how some communication options meet some criteria very well, while others meet other criteria well. The purpose of this work is to better understand that by combining multiple forms of communication, systems can address multiple stakeholder needs.

What to do: If students struggle to come to an agreement within the group, ask students, *Does that fit the criteria we laid out? How do you know?* Or, *Does it fit some criteria well, but not others?* When combining work across the groups, encourage students to consider patterns in what they are noticing, such as, *Which of these options does ____ well? Which of these options does not do ______ well?*

Discuss the benefits of having multiple options available. Come back together as a whole class and pose this question using **slide K**: *Why would it be important to have multiple modes of communication in the event of a hazard? Would you know what to do when you hear a warning signal?*

Suggested prompts	Sample student responses
Why would it be important to have multiple modes of communication in the event of a hazard?	*to reach the largest number of people* *to have a backup in case one thing fails*
Would you know what to do when you hear a warning signal?	*Maybe if I had heard it before and knew where to go.* *I am not sure if I would know what to do. Stay here or leave? I don't know.*

Transition to the next reading. Say, *We have great communication options, and they do some things well and other things not as well. Having multiple options in place provides a backup, especially when one thing fails. We are going to read about some students' experiences during the tsunami when their warning system broke, and we are going to see what back up plan they had in place.*

8. Read about Kamaishi School case study.

12 MIN

Materials: *Reading: Kamaishi East Junior High School*

Introduce students to the Kamaishi Junior High School. Display **slide L**. Say, *We know that having multiple options in place is a good idea so that we can reach as many people as possible and also in case something fails. Let's see how some kids dealt with this same situation.*

Have students first read and mark up a copy of *Reading: Kamaishi East Junior High School*. There is a full color version of the story in the student edition. As they read, have students consider the following:

- What communication plans did this school have in place?
- What worked well or didn't work well?
- Is there anything about this case that we haven't thought of yet?

Give students 5–8 minutes to read about Kamaishi. Then, reconvene the whole class to discuss the Kamaishi experience.

Suggested prompts	Sample student responses
What communication plans did this school have in place?	*They had an announcement system.* *They knew where to evacuate.*
What worked well or didn't work well?	*The announcement system broke, so that didn't work well. But then the kids started shouting to each other and helped the younger kids and some elderly people too.* *They knew they needed to evacuate quickly and help others, so that is what they did.*
Is there anything about this case that we haven't thought of yet?	*They worked with an expert beforehand to know what to do.*

Highlight the importance of knowing how to respond in a hazard. Say, *It looks like the students in Kamaishi were still able to remain safe, even when one part of the system designed to protect them failed! Some of the ideas you mentioned about how they stayed safe made it sound like they had a plan for what to do if a tsunami warning sounded.*

Suggested prompt	Sample student responses
How could having a plan help in the event of a natural hazard?	*We've seen things break when hazards happen, so you need to know how to protect yourself if that happens.* *They happen suddenly, and sometimes you might not know what to do, so having a plan ahead of time makes it easy to do the right thing when you need to.*

9. Update Tsunami Chain of Events.

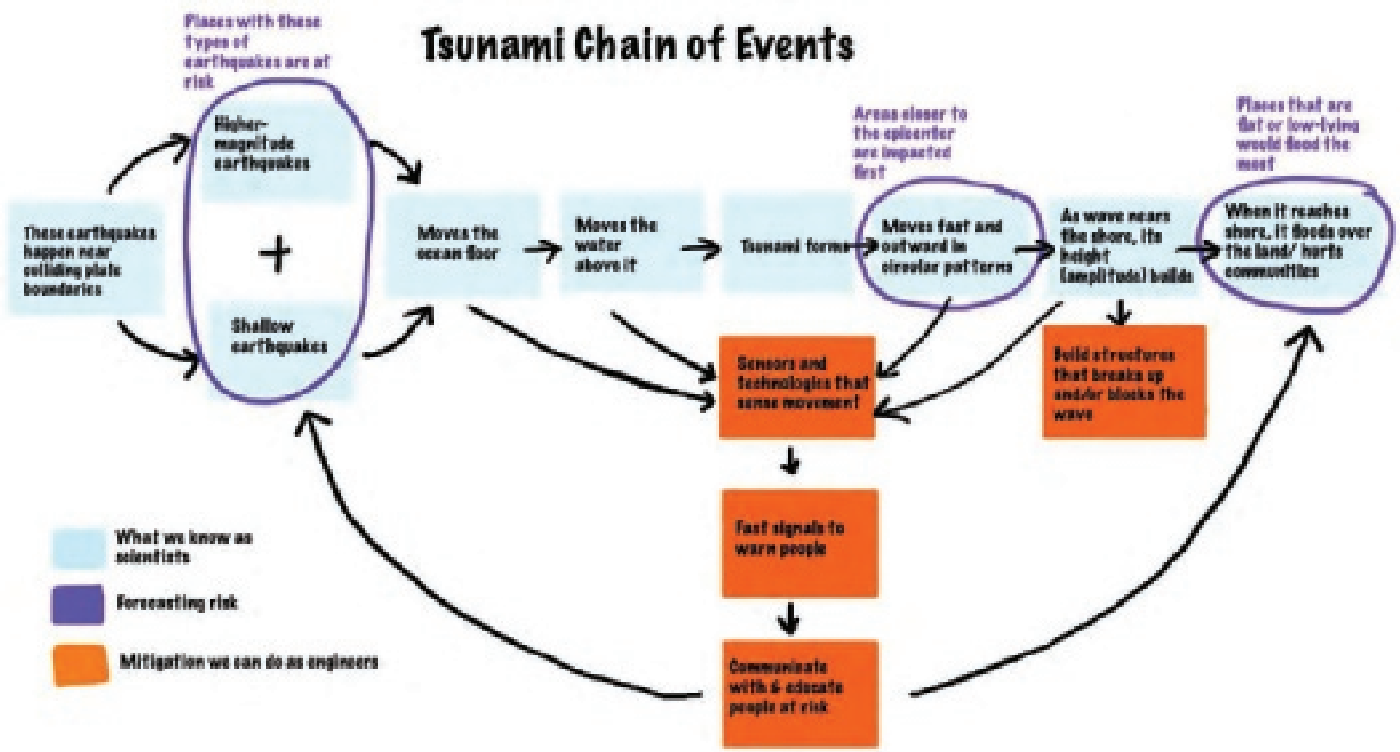
5 MIN

Materials: science notebook, Tsunami Chain of Events, large sticky notes, markers

Update Tsunami Chain of Events. Display **slide M** and prompt students to add new ideas to the Tsunami Chain of Events. Ask students, *What new ideas could we add that engineers consider as part of communicating before and during tsunamis?* Ideas can include the following:

- Communicating before a hazard by letting people know they are at risk and how they should respond.
- Communicating during a hazard to warn people quickly and tell them how to respond or act in the moment.
- Providing different means of communication to alert as many people as possible.

Summarize student ideas and add them to the Tsunami Chain of Events by adding a large sticky note (or several) about communicating and educating people to prepare and respond. Importantly, connect these ideas to the sections of the chart that were highlighted in Lesson 4. These "purple" ideas were added to forecast who is at risk in Lesson 4. Now we are connecting to those ideas by communicating with those communities at risk.



10. Navigation

3 MIN

Materials: index card

Motivate the reason to take stock of ideas. Say, *It looks like many coastal regions in Japan use more than one of these systems simultaneously. For example, Ryoishi had a seawall and warning system, and so did Kamaishi. It had breakwaters, sirens, and the schools did hazard education training. I wonder what it looks like when all these systems are put together. How do you think they work together?*

Display **slide N**. Give each student a notecard and give them a few minutes to consider:

- How do all these systems work together to protect communities from tsunamis?

Collect these cards to use as navigation of ideas into Lesson 9.

ADDITIONAL LESSON 7 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

The texts in this lesson supports students in developing the following reading standards:

- CCSS.ELA-LITERACY.RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.
- CCSS.ELA-LITERACY.RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6–8 texts and topics*.
- CCSS.ELA-LITERACY.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

SCIENCE LITERACY: READING COLLECTION 3

Minimizing Damage

1 **Contrasting Natural Hazards**
2 **Natural Hazard Survival 101**
3 **Disaster Domino Effect**
4 **Tsunami Measurements**

Literacy Objectives

✓ Summarize key points related to minimizing the damage of natural hazards.
✓ Organize related main ideas about minimizing earthquake and tsunami damage.
✓ Analyze visual/graphic representations and describe them verbally.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 5–7.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a summarizing outline in response to the reading.

Instructional Resources

Student Reader

Collection 3

Science Literacy Student Reader, Collection 3
"Minimizing Damage"

Exercise Page

EP 3

Science Literacy Exercise Page
EP 3

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 5: How can we reduce damage from a tsunami wave?
- Lesson 6: How are tsunamis detected and warning signals sent?
- Lesson 7: What are ways we can communicate with people before and during a tsunami?

Standards and Dimensions

NGSS

Disciplinary Core Idea ESS3.B: Natural Hazards: Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (MS-ESS3-2)

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Patterns; Systems and System Models; Stability and Change; Scale, Proportion, and Quantity

CCSS

English Language Arts

RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text

Language.6.5: Demonstrate understanding of figurative language, word relationships, and nuances in word meanings.

Math

CONTENT.6.EE.A.1: Write and evaluate numerical expressions involving whole-number exponents.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

magnitude

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

accurate
contagious
density-dependent
infectious
radiation
reactors
tsunameter

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Natural Hazards unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *First, you will read how the severity of a natural hazard event changes with the scale of the event. In the first example, you'll learn how the density of a population affects the spreading of contagious diseases. In a second example, you'll learn how an earthquake magnitude scale changes from one level to the next.*

- *Next, you'll read an infographic to learn four things people can do to prepare for a natural hazard event.*
- *Then, you'll read a timeline showing the cause-and-effect relationships that were triggered by the earthquake off the coast of Japan on March 11, 2011.*
- *Finally, you'll read an article explaining how NOAA (U.S. National Oceanic and Atmospheric Administration) scientists use, collect, record, and interpret data about tsunami waves.*

Exercise Page

EP 3

- Distribute Exercise Page 3. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
    - *For this assignment you will be expected to write the missing main ideas in an outline summarizing this collection.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
    - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
    - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
    - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
    - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
    - *Revisit the reading selections to complete the writing exercise.*
    - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What does it mean when an infectious disease is described as "density-dependent"?	*It means that there is a greater danger to people when they live close together, as in many cities.*
What kinds of information should be in a natural hazard safety plan?	*where the people in your family/home can meet, a map of a safety route, emergency phone numbers, and a paper road map*
According to the timeline, what were two of the many effects of the 2011 tsunami on Japanese nuclear power plants?	*The tsunami caused flooding, and radiation was released into the air.* *The tsunami caused the power plants to stop producing electrical energy and the roof to blow off of one power plant.*

Suggested prompt	Sample student response
What is a tsunameter network?	*It is made up of buoys in the ocean that have instruments that detect changes in sea level and, using satellites, send the data to scientists' computers.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
How does the infographic about preparing for natural hazard events fit into the communications system we explored in Lesson 7?	*An infographic or poster is but one of many ways to communicate with people before, during, and after a natural disaster. Other ways have to be used to reach all stakeholders, such as young children, the elderly, people who do not have technology, and people who speak other languages.*
How is a tsunameter network a kind of system?	*It has several parts, and the parts interact.*
The third reading about the domino effect and the chain of events poster we used in class both use metaphors. What are they metaphors for? Which one works best for you, and why?	*They both represent how one event led to another during the 2011 tsunami. I like the domino metaphor because it reminds me of the action and sounds I hear when I set up dominoes and watch them hit one another until they all fall over.* *I like the chain metaphor because I can think about how the links in a chain are all connected.*
What kind of data display does the reading about tsunameters in Collection 3 have that the reading from Lesson 6, "How are tsunamis detected and warning signals sent?" does not have?	*It has line graphs showing the changes in the water column (sea level) height from two different buoy stations.*

Exercise Page

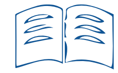
EP 3

- Refer students to the Exercise Page 3. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation is to complete an outline that summarizes main ideas from all the readings in Collection 3.*
  - *When you work on the outline is up to you. You could begin it as you preview the selections, as you read for understanding, or afterward to review them.*
  - *When you copy the outline, leave a couple of lines of space for each main idea you will fill in.*
  - *Make sure the main ideas are in the same order the author presented them.*
  - *Don't forget to use the same style and write complete sentences.*
  - *Spend a couple of minutes reading your completed outline to make sure it is in your own words.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion.

Facilitate class discussion about the reading collection and writing exercise. Several NGSS Crosscutting Concepts are prominent themes in this collection. In the first reading, Scale, Proportion, and Quantity inform the discussion of density-dependence and earthquake magnitude. The second reading encourages students to think about Systems and System Models. The third focuses on Cause and Effect, and the fourth develops Patterns by showing students how graphs can be interpreted to find patterns in data.

Student Reader



Collection 3

Pages 24–31 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Contrasting Natural Hazards"?	*It explains that some natural hazards, such as contagious diseases, are made worse where there are lots of people close together and that some earthquake hazards are worse because they release more energy.*
What do the black boxes on John Snow's map represent?	*places where people who were sick with cholera lived*
Take a look at the "Dig into Data" box. About how many of the more than a million earthquakes in a year are of a magnitude that can cause minor to catastrophic property damage?	*around 1,670*
What is the general purpose of the second selection, "Natural Hazard Survival 101"?	*It describes things people can do to reduce damage and injuries from earthquakes, tsunamis, wildfires, and floods.*
Which of the four precautions may be the most difficult for families to follow? Why?	*probably the first one, to move away from hazard zones, because people may not be able to leave their jobs and family members who live nearby*
Look at the photo of the Tsunami Hazard Zone marker. You can see homes all around. So, how would such a post be helpful?	*It can remind the people who live in that neighborhood to be prepared for the next tsunami so they can escape being hurt.*
What advice would you give your family members about using social media sites to get accurate alerts about natural hazards?	*They should stick to following government agencies, such as the National Weather Service, NOAA, and the US. Geological Survey. These will have the most up-to-date and accurate information. Also, they should avoid social media posts that are from individuals or organizations they have never heard of.*
What is the general purpose of the third article, "Disaster Domino Effect"?	*It describes the timeline of effects caused by the March 11, 2011, tsunami in Japan.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—The earthquake magnitude scale is a logarithmic scale, chosen to make it easier to compare a wide range in severity of earthquakes. However, it is not easy to understand because it involves thinking about exponents. Students can get a feel for what the numbers in the magnitude scale represent by playing with the USGS's online "How Much Bigger. . . ?" calculator. Encourage them to begin by entering sequential numbers (e.g., 4 and 5) into the calculator and noticing the difference in the magnitude (the degree of motion or amplitude of the waves) versus the difference in energy release of those two earthquakes.

Pages 30–33 **Suggested prompts**	**Sample student responses**
If you are not sure what the concerns are related to the release of radiation from nuclear reactors, how could you find out?	*I could look it up in an online encyclopedia or dictionary.*
Nuclear power plants produce electricity. They also need electricity from outside sources to keep their cooling systems running safely. What kinds of natural hazards might affect the electricity supply into a power plant?	*floods, earthquakes, tornadoes, hurricanes*
What is the general purpose of the fourth article, "Tsunami Measurements"?	*It explains how to interpret graphs showing changes in the height of sea level before and during earthquakes and tsunamis.*
Which part of this article shows how smaller systems interact to make a larger system?	*The map of the Pacific Ocean shows the locations of individual buoys, each of which is a system with parts. But, if you look at the map as a whole, you realize that all these small systems have to work together for scientists to map the direction and speed of tsunamis.*
Look again at the "Dig into Data" box. DART Buoy 21418 detected numerous 1-meter drops in sea level after the earthquake. What do you think this data set suggests?	*Maybe there were smaller earthquakes after the first big one.*
Take a look at the "Consider the Source" box. How might this affect NOAA's credibility as an organization?	*It makes NOAA very credible and a reliable source of information for early tsunami warnings.*

CHALLENGE—If they have not already learned how, have students apply their understanding of exponents to expressing and comparing these numbers using scientific notation. Have students move the decimal point to after the first digit and then count the number of places it moved. That number is the exponent following 10 in the equations below:

$1{,}800{,}000{,}000{,}000 = 1.8 \times 10^{11}$

$56{,}000 = 5.6 \times 10^{4}$

EXTEND—There is a wealth of online videos related to tsunamis, DART and other tsunami warning systems, and the 2011 tsunami in particular. Using an "At first I thought/Now I think" writing prompt, have students record how their thinking about the topic changed as a result of watching and reflecting on one of the videos.

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 3, students should complete the outline framework provided to describe two or more main ideas for each of the four readings in Collection 3. Look for evidence that the main ideas are in the sequence the reading presented them and that they are important ideas related to the overall topic of minimizing the damage of natural hazards.

Minimizing Damage

I. Contrasting Natural Hazards

   A. Some natural hazards are more dangerous if there are more people in the area.

   B. On the earthquake magnitude scale, the severity of the earthquake increases by 10 times from one whole number on the scale to the next.

II. Natural Hazard Survival 101

A Try to live in areas that are not prone to natural disasters.

B. Stay connected to reputable sources of disaster information.

C. Make an evacuation plan with the people you live with.

D. Make sure your home has extra food and water and a backup way to heat them.

III. Disaster Domino Effect

A. Close to where the tsunami hit, thousands of people died, a nuclear power plant exploded, and radiation was released into the air.

B. Far from where the tsunami hit, 4 million people in Tokyo lost electrical power.

IV. Tsunami Measurements

A. Instruments in the ocean measure and send scientists changes in the ocean depth and pressure.

B. By comparing data from instruments spread throughout the ocean, scientists can predict when a tsunami will strike a coastline.

Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 8

Which emergency communication systems are the most reliable in a hazard?

Previous Lesson

We listened to tsunami warning signals and read accounts of tsunami survivors from Japan and what they did when an earthquake and tsunami occurred. We identified community stakeholders, developed criteria and constraints for tsunami communication solutions, and evaluated different ways tsunami preparation and response are communicated. We read a case study about a school in Kamaishi that included education as part of their plan. From this we learned that there are many ways to communicate with community stakeholders before and during a tsunami event.

This Lesson

Investigation

1 DAY

We discuss the importance of having reliable communication systems during a hazard and then gather information using digital tools and mathematics concepts to compare different communication systems to one another over time. We develop a shared understanding that communication technologies use different types of signals to send and receive messages. Some signals and technologies are more reliable means of communication. However, a combination of different ways of communicating during a hazard is better than using only one technology alone.

Next Lesson

We will develop a system model to represent what we've learned about detecting, warning people, and reducing damage from tsunamis. We will analyze the importance and purpose of the subsystems and generalize the process engineers use to develop systems and solutions to address a local hazard.

Building Toward NGSS

MS-ESS3-2, MS-ETS1-1, MS-ETS1-2, MS-PS4-3

What Students Will Do

8.A Use digital tools and/or mathematical concepts to integrate and synthesize information to compare the reliability of emergency communication systems.

What Students Will Figure Out

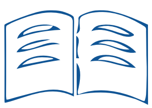
- Communication technologies use different equipment and signals to transmit and receive information during a hazard.
- Digital signals use technology that makes them more reliable means of communication than analog signals.
- A combination of communication technologies are important to use during a hazard to ensure as many people receive the warning messages as possible.

Lesson 8 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Brainstorm which communication systems are more or less reliable and why or why not.	A	chart paper or whiteboard, markers
2	20 min	**GATHER INFORMATION ABOUT EMERGENCY SYSTEMS AND SIGNALS** Gather information from text, audio, and visual resources to better understand different types of signals used in communication systems.	B–C	*Obtaining Information Notetaking Guide*, Computer, *Sending Warning Signals* (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
3	15 min	**BUILDING UNDERSTANDINGS ABOUT RELIABILITY OF SIGNALS IN AN EMERGENCY** Share ideas as a whole class and develop new ideas about how different communication technologies are more or less reliable in an emergency.	D–E	chart paper or whiteboard, pre-generated list of stakeholder groups (optional)
4	3 min	**NAVIGATION** Motivate the need to take stock in all the different systems to protect communities from tsunamis.	F	index card

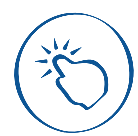
End of day 1

Lesson 8 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• *Obtaining Information Notetaking Guide* • index card	• Computer • internet access to *Sending Warning Signals*	• chart paper or whiteboard • markers • pre-generated list of stakeholder groups (optional)

Materials preparation (20 minutes)

Online Resources



Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

If you have access to computers or tablets for students in groups of 2-3, practice opening the StoryMap, *Sending Warning Signals*. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Review the StoryMaps so that you know how to help students navigate them and the embedded videos, texts, and maps.

Depending on how much class time you have, consider breaking this reading up into parts so students only read a section of it and then share information across groups.

If you do not have access to computers or tablets, consider the following options or a combination of them:

1. Have students use their personal devices to view their assigned StoryMap.
2. Use the print-based alternative: *Sending Warning Signals.* A color copy of this reading is also located in the Reading section of the *Student Edition* and can be printed as handouts for students to annotate and attach to their science notebooks. If using the print-based versions, students can watch videos here:
   a. The Telegraph
   b. Bell Telephone Operators
   c. Tornado Sirens
   d. Comparing Analog and Digital Signals

   (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)

Lesson 8 • Where We Are Going and NOT Going

Where We Are Going

This lesson is focused on helping students develop ideas about the development of different emergency communication systems and the reliability of those systems. In particular, systems that use digital signals produce a more reliable means of communication, which is important during a hazard. This lesson is specifically designed to build students' understanding of **PS4.C: Information Technologies and Instrumentation.** Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.

Students first learn about the evolution of different communication technologies. They learn about digital and analog signals as part of this work, including how reliable these signals are for communication. Importantly, students develop ideas about how a variety of systems all have a variety of advantages and disadvantages, but when combining different technologies and systems, the more people can reliably get the warning messages.

Where We Are NOT Going

As designed, this lesson does not include ideas about waves or the electromagnetic spectrum, even though this is a critical underlying idea necessary to understand the technologies used for communication. These ideas are developed more fully in *OpenSciEd Unit 8.2: How can a sound make something move? (Sound Unit)* and *OpenSciEd Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit),* and will also be addressed with more sophistication and depth in high school. Since this unit is designed to come before those two units in the OpenSciEd Scope and Sequence, the emphasis of the PS4.C is focused on the reliability of the technology based on the type of signal. This lesson does not fully address the wave aspects of these different technologies.

LEARNING PLAN FOR LESSON 8

1. Navigation

5 MIN

Materials: chart paper or whiteboard, markers

Recall the need for multiple types of communication systems. Project **slide A.** Say, *Remember last time we read about the Kamaishi students who, because of their hazard education, knew what to do during the tsunami, even when the announcement broke during the earthquake. We were curious about which systems work better or are more reliable in an emergency. What would some ideas we had?* Allow students to recall some ideas they shared at the end of Lesson 7.

Transition to considering reliability of communication systems during an emergency. Say, *We want our system to be "reliable," but what does that word really mean?* Give students time to think before responding. Sample ideas students might share include:

- It always works
- It lets people know with enough time to react, and doesn't happen after the hazard
- It does what it is supposed to do

Wait to post the word to Word Wall until after students complete the StoryMap activity. Instead, ask, *So, what makes one communication system more reliable or "better" in emergencies? How do we know the system is more reliable?* Capture student ideas on a chart paper or whiteboard. It is also OK for students to be uncertain as to what makes certain communication systems more reliable in emergency situations.

Suggested prompt	Sample student response
What makes one communication system more reliable or "better" in emergencies?	*It uses a communication system that most people have, like cell phones.* *It uses newer or better technology.* *It can reach everyone that needs the alert and doesn't fail or glitch.* *It doesn't easily break like the warning system did in Kamaishi.*
How do we know the system is more reliable?	*It has been tested during a hazard and worked.* *I don't really know.*

2. Gather information about emergency systems and signals.

20 MIN

Materials: *Obtaining Information Notetaking Guide*, Computer, https://arcg.is/1GymW0

Set the purpose for gathering information. Say, *It sounds like we need to learn more about what makes a warning system or signal reliable*. Project **slide B** and pass out handout, *Obtaining Information Notetaking Guide*. Have students write the question they are trying to answer at the top of their handout, as follows: *"Which emergency communication systems are the most reliable in a hazard?"*

Review strategies for gathering information from text and media. Remind students that close reading requires reading more than once with different purposes and using strategies to interact with the text. Review the different strategies listed on the slide.

Introduce the StoryMap. Project **slide C.** Have students gather in small groups, either with one device or each individually with a device. Say, *This StoryMap uses a number of technical terms, some of which we know and some which may be new to some of us. As you read, record those terms on your handouts so we can add them to our Word Wall.*

Additional Guidance

Consider reading the first paragraph together. Ask for volunteers to offer terms to add to the Word Wall. Encourage them to share why they feel these words are useful to add and how they would define them. Also encourage students who finish the StoryMap early should discuss with their partner which terms from the reading can be added to the Word Wall. There is an opportunity to add them to the Word Wall during the discussion as well.

Alternate Activity

If you do not have enough computers or devices for students to work in groups, there are two alternative ways to facilitate this activity: (1) have students use their personal phones or other internet-connected devices to view their StoryMap, or (2) use the text-based versions of the materials. See the preparation section of this lesson for more information.

View StoryMaps in groups. Give students 10-15 minutes to access to the *Sending Warning Signals* StoryMap at https://arcg.is/1GymW0. They should read the text and listen to the audio and video in the StoryMap and record noticings on their handout. It is often beneficial for students to read through it twice to gather more details.*

As students work, circulate among groups to check on their progress. Use prompts like the following to help students focus on important information about different technologies and the reliability of signals they use to communicate.**

Share and synthesize information about the reliability of different communication technologies.* After 10-15 minutes of reading and listening, give students 5-10 minutes to work as a group to synthesize the important ideas about they learned from the StoryMap by taking notes on *Obtaining Information Notetaking Guide*.

*** Attending to Equity**

Supporting Universal Design for Learning: The reading in the StoryMap is long and includes several embedded audio-visual assets to help depict concepts presented in the map. The combinations of text, audio, and visual information can assist students in perceiving information through multiple means of *representation*.

However, some students may benefit from using the paper version of the reading in order to write or highlight different aspects that are important or that they have questions about. If they use the paper version of the reading, be sure to play the audio portions from the StoryMap map to augment their understanding of the concepts presented in the reading.

*** Supporting Students in Developing and Using Systems and System Models**

Some useful prompts to help focus student thinking as they work through the text include:

- *What are the different components of this system (e.g., the telegraph, the radio).*
- *How does the person receiving the message interact with the system?*

Assessment Opportunity

Building towards: 8.A.1 Use digital tools and/or mathematical concepts to integrate and synthesize information to compare the reliability of emergency communication systems.

What to look/listen for: Use students' individual handouts and small group discussions:

- Ideas of how technologies have changed over time, but some technologies are still used today to alert people in a hazard.
- Ideas about how technologies use different systems for communication.
    - Wired v. Wireless
    - Broadcast to each individual household v. broadcast across an entire area
- Ideas for why some signals (i.e. digital) are more reliable than others.
- Ideas for what causes some communication technologies to be limited in their ability to warn people.

What to do: The reading contains sophisticated ideas and concepts for students, and many students will not have developed middle school ideas about different waves and technologies that use waves to transmit signals. That is OK. Students will build additional ideas in later OpenSciEd units and in high school about different waves and technologies that use waves to send signals. For now, focus students' noticings and ideas about how different technologies have evolved and improved over time. In particular, the use of digital signals allows for a more reliable means of communication, which is the goal of an emergency communication system.

3. Building Understandings About Reliability of Signals in an Emergency 15 MIN

Materials: chart paper or whiteboard, pre-generated list of stakeholder groups (optional)

Add new words to the Word Wall as needed during this discussion.* If needed, take a moment for students to share and clarify the meaning of words from the reading. Add words throughout this discussion to the Word Wall.

Facilitate a Building Understandings Discussion comparing different signals. Project **slide D**. Ask students to share what new ideas they have about analog and digital signals and their reliability. Determine that modes of communication can vary based upon signal type and that digital signals are generally more reliable than analog signals. Keep track of student ideas about analog and digital signals as they share them and record them somewhere visible in the room, such as on a piece of chart paper or whiteboard. Example prompts, responses, and an example chart are below.

Suggested prompt	Sample student response
In our reading we learned about two different types of signals. What were they?	*Analog and digital.*

- *What might prevent the person from receiving a message from this system?*

* Supporting Students in Engaging in Using Mathematics and Computational Thinking

As students work through the StoryMap and figure out ideas from the text and media, they are working on the following element: *Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem.* Prompt students with questions such as:

- How does _____ technology compare to ____. What evidence in the reading supports that idea?
- How did ____ technology sound compared to _____? Why do you think one is more clear than the other?
- Which type of signal or technology would be the most reliable in an emergency?
- If you were designing an emergency communication system, how could you use some ideas from this reading to make sure your system alerts the most people?

Suggested prompts	Sample student responses
What type of signals did we learn about that were analog?	*hitting something like a drum* *using smoke or a flame* *morse code* *ringing bells or setting off a siren* *telephones with a phone line in the past* *analog radio signals*
What type of signals were digital?	*phone apps and alerts* *digital radio signals* *loudspeakers*
What were some of the pros and cons of each signal type?	*Analog signals aren't generally as expensive as digital signals. It's cheaper to make a fire to alert someone than to make a radio station.* *Digital signals can be received further away than analog signals.* *Digital signals stay clearer and easier to understand from further away.*
We mentioned that digital signals are clearer further away than analog signals. Why would that be an important difference?	*If we were to have a natural hazard occur we could let people know further away.* *Sometimes we can't hear analog signals that far away, so having a digital signal can help save more people.* *Sometimes, like in Kamaishi, the analog siren that alerts the whole town may fail. The digital signal can be sent to everyone individually.*
Why might we want some form of a digital signal to be sent during a natural hazard?	*The digital signal can reach a lot of people far away quickly.*

Say, *Interesting. We've learned a lot about analog and digital signals. Which type of signal might be the best way to inform all of our stakeholders about a hazard?*

Ask students to share out any of the stakeholders that they identified in Lesson 7. Create a list of the stakeholders next to the analog and digital signals chart. Go down the list of stakeholders with students to determine which type of signal might work better for some stakeholder groups and what signal types/communication methods aren't as promising, and that reliability matters in a natural hazard.* Example prompts and responses are below.

*** Attending to Equity**

Supporting Universal Design for Learning: Teachers can support all students in forming a deeper understanding of newly "earned" or "encountered" vocabulary by representing the new term in several ways. For example, students can (1) write the term, (2) draw a representation of the term, (3) use their own words to write an explanation for what the term means, and (4) use the new term in a sentence.

This strategy is particularly helpful for **emerging multilingual students**.

Alternate Activity

In Lesson 7, students generated a list of stakeholders on Part 1 of *Community Stakeholders*. If students cannot remember specific stakeholders, ask students to reference this handout. Alternatively, a list of common stakeholders can be made before this lesson begins based on the stakeholders students have identified on *Community Stakeholders* and placed by the analog and digital chart at this time.

Suggested prompts	Sample student responses	Follow-up questions
Let's look at one of our stakeholder groups—younger children. What methods of communication would work best for them, analog or digital?	*Most kids are in schools during the day, so maybe a digital signal like a loudspeaker to let them know what is happening.* *Kamaishi still needed the analog signal of people yelling at each other.* *Most kids and their parents or teachers these days have phones. I think a digital signal may reach a lot of younger people.*	*Do loudspeakers always work? Why might we want to consider if the type of signal works consistently?* *Is this the only type of signal or method of communication that they should receive?*
What about those that do not speak the common language of the location they are in?	*Those people would need something translated.* *They would need a digital signal that is translated. An analog signal like a tornado siren would let them know that something is happening, but they wouldn't know exactly what the hazard or instructions are.*	*Would a traditional analog signal such as a siren make sense to this group?* *What pros and cons would an analog vs. digital signal have for this stakeholder group?* *What methods could provide them with information and directions during a hazard in the language they are comfortable with?*
What about business people or those that work inside?	*They may not be able to hear an analog or digital radio signal if they don't have their radios on, but a digital signal like a push alert might go to their phones.*	*Is it still beneficial to have an analog signal of some kind for this group? Why?* *But does everyone have a phone to get a push alert?*
What about those that live in a remote location?	*We definitely need to have a signal that can reach them far away.*	*What type of signal is more reliable in a remote area? Why?* *Why does reliability matter?*

Assessment Opportunity

Building towards: 8.A.2 Use digital tools and/or mathematical concepts to integrate and synthesize information to compare the reliability of emergency communication systems.

What to look/listen for:

- Ideas of how technologies have changed over time, but some technologies are still used today to alert people in a hazard.
- Ideas about how technologies use different systems for communication.
    - Wired v. Wireless
    - Broadcast to each individual household v. broadcast across an entire area
- Ideas for why some signals (i.e. digital) are more reliable than others.
- Ideas for what causes some communication technologies to be limited in their ability to warn people.

What to do: If students are struggling comparing communication systems, ask students about very specific communication systems, such as morse code versus push notifications. Ask students about how they are similar or different, and their benefits and drawbacks for each stakeholder group. If students are struggling with comparing analog and digital signals, have students focus on the types of technologies that use each type of signal. Ask students to compare their reliability and utility in a natural hazard. If students are struggling with what system may be more reliable for certain stakeholder groups versus others, ask students how that stakeholder group generally receives their information, and what type of information that stakeholder group would need. Consider if that form of communication is analog or digital, and then ask students the pros and cons of it being in that form. Ask students to then determine how reliable that would be in a hazard, and if that is the only method of communication needed for that stakeholder group. If students are struggling with identifying digital as a more reliable method of communication, focus students back on the storymap. Ask students to consider those that live in remote locations or those that are not in a place to hear sirens or others and determine which method is more likely to reach that stakeholder group with a clean signal.

Turn and talk about communication types (optional). Say, *It sounds like there are a variety of warnings that would work during a hazard, both analog and digital.* Project **slide E.** Ask students to turn and talk to a partner about the question on the slide. If your students have already arrived at the conclusions below, proceed on to the navigation into the next lesson.

- What type(s) of signals should we use during a natural hazard?
- Should we use only one method, analog or digital?
- Why or why not?

Allow students to respond. Guide students to determine that a digital signal is an option that meets the needs of many stakeholders, but multiple methods of communication are a good idea during a natural hazard. Students should suggest that we need a variety of communication methods, both analog and digital, to alert people during a natural hazard such as a tsunami. Students should also conclude that while we have the ability to use both analog and digital signals, digital signals tend to be the most reliable and reach the most people in a short period of time.

4. Navigation

3 MIN

Materials: index card

Motivate the reason to take stock of ideas. Say, *It looks like many coastal regions in Japan use some systems of communication and ways to reduce damage simultaneously. For example, Ryoishi had a seawall and warning system, and so did Kamaishi. It had breakwaters, sirens, and the schools did hazard education training. I wonder what it looks like when all these systems are put together. How do you think they work together?*

Display **slide F.** Give each student a notecard and give them a few minutes to consider: *How do all these systems work together to protect communities from tsunamis?* Collect these cards from students. Review the cards and look for common ideas across students. These ideas will be revisited during the navigation into Lesson 9.

ADDITIONAL LESSON 8 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

The texts in this lesson supports students in developing the following reading standards:

- CCSS.ELA-LITERACY.RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6–8 texts and topics*.
- CCSS.ELA-LITERACY.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Supporting Students in Making Connections in Math

- CCSS.MATH.CONTENT.6.SP.B.5.B: Summarize numerical data sets in relation to their context, such as by describing the nature of the attribute under investigation, including how it was measured and its units of measurement.

As students read about different signal technologies, they encounter real-world representations of how signals are mathematically represented on graphs as either waves or points. For many students this might be the first time they've made mathematical connections to communication and information technologies. While not a key focus of the lesson, this does provide an opportunity to encourage students to notice how we can represent these science ideas using mathematical representations.

LESSON 9

How can we model the systems put into place to protect communities?

Previous Lesson

We discussed the importance of having reliable communication systems during a hazard and then gathered information using digital tools and mathematics concepts to compare different communication systems to one another over time. We developed a shared understanding that communication technologies use different types of signals to send and receive messages. Some signals and technologies are more reliable means of communication. However, a combination of different ways of communicating during a hazard is better than using only one technology alone.

This Lesson

Putting Pieces Together

1 DAY

We revisit past lessons to categorize and organize what we have learned about the systems and subsystems involved in detecting, warning people, and reducing damage from tsunamis. We work together in a Scientists Circle to develop a systems model that identifies the relationships within and between subsystems and understand how they work together to meet the goals of a community. We generalize the process that engineers engage in to solve problems and use what we have learned to develop a plan to address a local natural hazard.

Next Lesson

We will investigate the general patterns of risk of other natural hazards in the United States and determine our local level of risk for each hazard. We will choose a natural hazard, obtain and evaluate information from a variety of sources, and develop a plan and final communication product. We will evaluate our final plans and products using constraints and criteria for effective communication with our stakeholder groups.

Building Toward NGSS

MS-ESS3-2, MS-ETS1-1, MS-ETS1-2

What Students Will Do

8.A Construct a system model to represent the interactions of subsystems designed to detect, warn communities, and reduce damage from a tsunami hazard.

What Students Will Figure Out

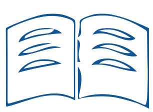
- Engineers can design a system for responding to hazards that includes design solutions to forecast, detect, warn and communicate with people and reduce damage.
- Each part of the system is dependent on another part of the system; subsystems work together to meet the criteria for the overall system.
- Engineers engage in a generalized process to define problems, develop solutions, and optimize those solutions.

Lesson 9 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	12 min	**LOOK BACK AT WAYS TO PROTECT PEOPLE AND PROPERTY** Turn and Talk to a partner about ways to protect people and property. Create a chart and organize ideas into categories.	A-B	Ways to Protect People and Property chart
2	15 min	**CREATE TSUNAMI SYSTEM CONSENSUS MODEL** Transfer the components of each subsystem into a consensus model to show how the subsystems interact across a larger, more complex system.	C-D	Tsunami Chain of Events, Ways to Protect People and Property chart, markers, large sticky notes
3	8 min	**CREATE WHAT WE DO AS ENGINEERS CHART** Create a process diagram to illustrate how the class used engineering ideas and practices to evaluate parts of the system.		"What We Do as Engineers" sticky notes, What We Do as Engineers poster, markers
4	5 min	**CONDUCT ENGINEERING SELF-ASSESSMENT** Complete engineering self-assessment.	E	*Engineering Self-Assessment*
5	5 min	**LOOK BACK AT RELATED PHENOMENA** Look back at related phenomena from Lesson 1 and determine what students can do to help with natural hazards.	F	Related Phenomena poster from Lesson 1

End of day 1

Lesson 9 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Engineering Self-Assessment*		• Ways to Protect People and Property chart • Tsunami Chain of Events • markers • large sticky notes • "What We Do as Engineers" sticky notes • What We Do as Engineers poster • Related Phenomena poster from Lesson 1

Materials preparation (10 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

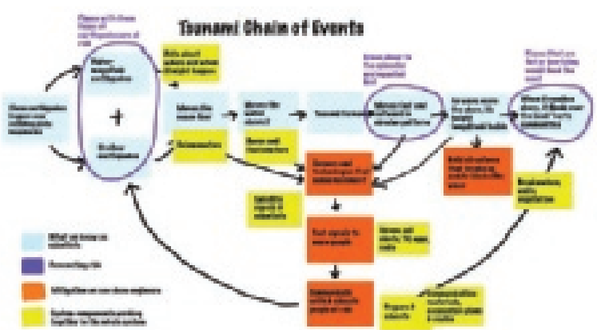
Create a three-column chart titled, “Ways to Protect People and Property”

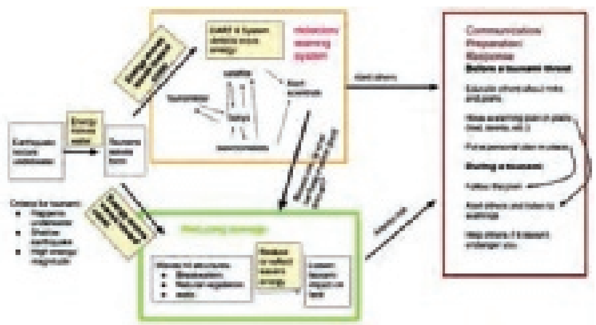
- Detect and Forecast
- Warn and Communicate
- Reduce Damage

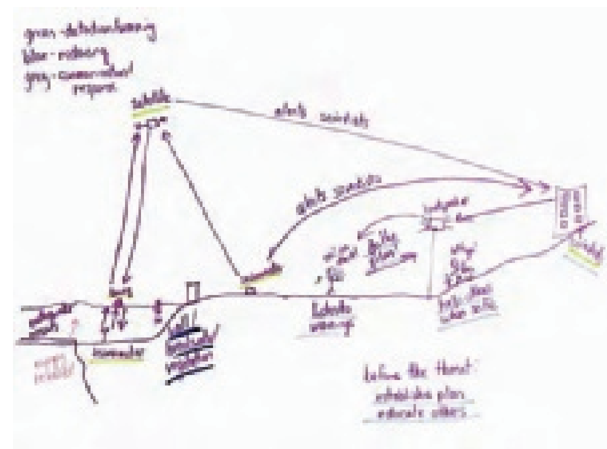
Decide which option you will use to build a System Model to represent the larger system for tsunami protection.

- **Option 1**: Add the System Model directly to the Tsunami Chain of Events. Add sticky notes and arrows as needed to map the different subsystems (design solutions and technologies) onto different aspects of the Tsunami Chain of Events.
- **Option 2**: Build a System Model representation on a separate chart next to the Tsunami Chain of Events. Continue to facilitate a conversation about which point in the Chain of Events each design solution and technology is present to protect communities.

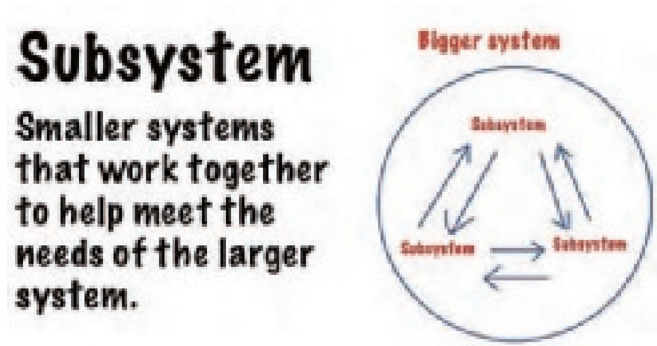
Option 1 is represented on the left below; There are pictorial and conceptual examples for Option 2 in the center and on the right.







Create a subsystem Word Wall card.



Create a chart titled, “What We Do as Engineers.”

Construct large 6x8 stickies or large notecards with the following phrases for “What We Do as Engineers” chart:

- We evaluate and compare solutions among one another.
- We identify trade-offs when choosing one solution over another.
- We define our problem.
- We identify criteria and constraints.
- We identify our stakeholders.

Have the Related Phenomena poster from Lesson 1 available.

Lesson 9 • Where We Are Going and NOT Going

Where We Are Going

This lesson will focus on helping students develop a model that will illustrate how the subsystems they have been learning about in Lessons 5–7 work together to protect communities. The lesson centers on taking stock of the science and engineering ideas students have been learning to create a model that students can then apply to other natural hazards. Equally important is making the engineering process explicit for students and giving students an opportunity to assess their engagement in the engineering process.

Where We Are NOT Going

The model will be used to explain the interactions of the subsystems, but the overall system model will not be used to predict or explain the behavior of the overall system. Students will not be assessing the reliability of the system nor testing the system. Students will also not identify the iterative testing cycle within the engineering process.

1. Look back at ways to protect people and property.

12 MIN

Materials: science notebook, Ways to Protect People and Property chart

Revisit ways to detect, warn, and reduce damage. Remind students that we have been working to understand what can be done to protect people and property during tsunamis and other natural hazards. Say, *We've figured out a lot about tsunamis and different systems that are used to detect, warn, and reduce damage related to tsunamis. Before we look at local hazards that impact us, we need to take a moment to put all these ideas together.*

Display **slide A.** Direct students to draw and label the 3 columns on the next clean left-hand page in their notebooks. Explain that we will reuse the categories from Lesson 1 to take stock of the components of the different systems. The three columns should have similar labels that were used in Lesson 1 with some additional ideas picked up along the way related to predicting/forecasting and preparing and communicating.

- Detect and Forecast (when and where a tsunami might happen)
- Warn and Communicate (to prepare and respond when it happens)
- Reduce Damage (structures to break up or block the wave)

Additional Guidance

You can streamline the headings to "Detect," "Warn People," and "Reduce Damage" if that is easier for students to align with Lesson 1, but be sure that predicting/forecasting where and when these events happen and preparing and communicating risk and how to respond are parts of these bigger categories.

Brainstorm design solutions and technologies. Ask students to work in partners or small groups to brainstorm as many different design solutions and/or technologies that they encountered across the unit that would be part of one of these categories. Do one example together first. Say, *We looked at the use of seawalls in Lesson 5. Which of these categories does a seawall fit?* (Reducing damage.) Give students a few minutes to brainstorm where they would fit different solutions.

Generate a public list of system components. Project **slide B.** Ask students to share out what parts they identified from our past lessons. Chart their ideas using the same columns as slide A. As students share, ask which category they placed each part of the system into and why. Possible ideas are as follows:

Detect and Forecast	Warn and Communicate	Reduce Damage
The DART II System • seismometers • buoys • tsunameter • satellites • scientists Looking at data to know where and when it might happen	Warn • send warnings when it happens (sirens, text, TV) • follow evacuations routes • help others (elderly, children) safely Communicate • education programs • communication plans • infographics and other public materials • mark evacuation routes	Design solutions such as • breakwaters, like tetrapods • walls • natural vegetation

Additional Guidance

If possible, leverage students' prior experience with systems and subsystems from the previous units: *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)*, *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)*, and *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)*.

Students should develop a list of the components of the system in the previous chart. If students are missing components on the class chart, use the following prompts to help guide students to include more components (not all of these need to be listed, but try to elicit as many as you can):

Detect and Forecast

- Think back to Lesson 6. How do we know a tsunami is coming? What system is already in place to detect tsunamis?
- What are the parts of the DART II system that we read about?
- How did we know where and when these things might happen? What data did we use for detection or to forecast where and when it might happen?

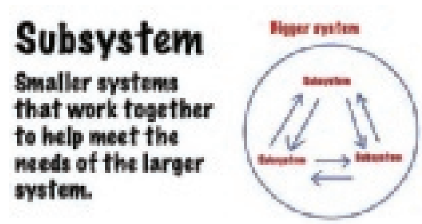
Warn and Communicate

- In our last lesson, we learned how people felt and responded during a tsunami. What warned them that a tsunami was coming?
- What do we need to do ahead of time to make sure we are safe during the event?
- When people are alerted of a tsunami, what should they do?

Reduce Damage

- What did we learn about in Lesson 5 that helps reduce damage?
- What type of design solutions did we look at? What were the main categories?

Revisit systems and subsystems. Say, *Throughout this unit, we have been analyzing and investigating these three areas of a tsunami protection system and figured out how different parts work. Why do you think it is called a system?* Students might say because it is made of parts that work together to protect people.



Say, *We know that these areas we identified from Lesson 1 are systems. These systems are all part of our larger tsunami protection system. When we have these smaller systems that are part of a larger system, we call them subsystems. These subsystems interact to help meet the overall criteria for the larger system.*

Add the term *subsystem* to the Word Wall. Say, *Let's see if we can explain how these subsystems work together to protect communities when tsunamis happen.*

2. Create tsunami system consensus model. 15 MIN

Materials: science notebook, Tsunami Chain of Events, Ways to Protect People and Property chart, markers, large sticky notes

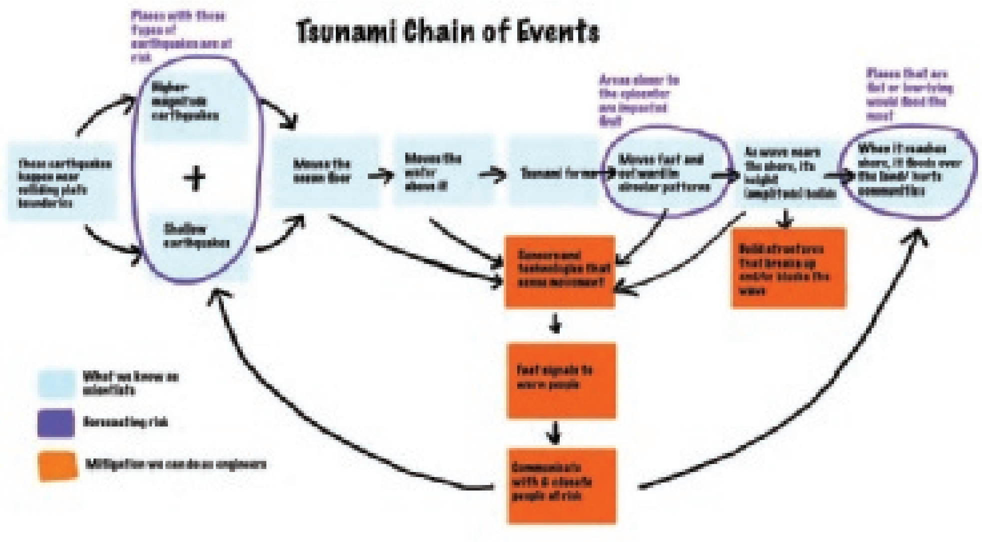
Gather in a Scientists Circle to build a Systems Model. Gather around the Tsunami Chain of Events and the Ways to Protect People and Property chart. Project **slide C**.* Set the purpose of building a Systems Model to identify the different components of the engineering subsystems and, importantly, with how they are connected and function together to detect, warn, and reduce damage as part of the Tsunami Chain of Events. Say, *We've been learning about all these subsystems, and we are ready to connect them all together to better understand how we can protect people and property when tsunamis happen.*

The Tsunami Chain of Events currently has science ideas about where tsunamis happen, why there, how they form, and how they move. It also has different approaches that engineers can take to mitigate the effects of tsunamis. At this point, students will add the different components of the subsystems to the chain of events so that they can then focus on interactions between the subsystems.

***Supporting Students in Developing and Using Systems and System Models**
Across Lessons 5–7, students have been figuring out how different subsystems function independently. This is the moment in the unit where students will build a larger, more complex system that connects the functions of the subsystems to show how they interact within one another to protect communities at certain points in the Tsunami Chain of Events.

Later in this lesson, the systems analysis helps students determine the connectivity between subsystems to support the goals of a larger system. By analyzing the subsystems and their larger

The current Tsunami Chain of Events looks like this:



Map subsystems onto a larger System Model.* Point to the Ways to Protect People and Property chart. Say, *Now that we have all of the basic components of our system, let's see if we can arrange them into a larger system representation to show how they are connected. We will use the Tsunami Chain of Events to guide our work so that we can see how this system works at different points during a tsunami. We will use a different color to represent the subsystems.**

Start with Detection and Forecasting subsystems. Using the "Detect and Forecast" column on the "Ways to Protect People and Properties" chart, map the different design solutions and technologies onto the Tsunami Chain of Events. Remind students that tsunamis don't happen every day, and for the system to be used, it has to start with an event. Start the process by asking students what the first event is that has to occur for a tsunami to form. Students should say that an earthquake has to occur and reference the starting point on the Tsunami Chain of Events. Ask students which subsystems (e.g., design solutions) would be activated or used when that occurs. Add these design solutions on sticky notes to the Tsunami Chain of Events.

Say, *OK, so we've mapped different design solutions that are important at this point of a tsunami. What happens next? Which design solutions come into play in the next part of a tsunami?*

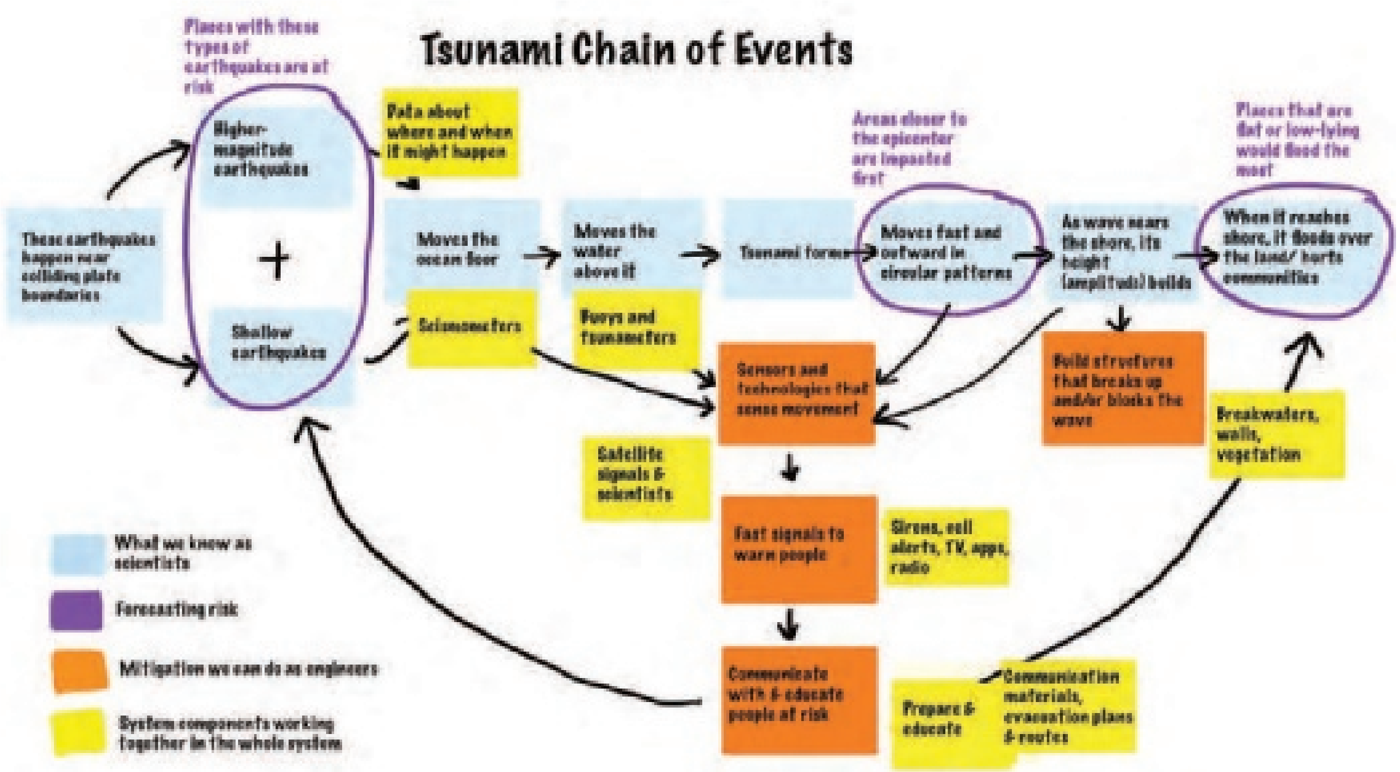
Repeat these steps for the different subsystems in the "Warn and Communicate" and "Reduce Damage" columns of the chart. As the class does this work, encourage students to communicate with one another about what each sticky note says and where to place it on the Tsunami Chain of Events.

If mapped to the Tsunami Chain of Events, it will look similar to this, with the new yellow sticky notes presenting design solutions that work at different points in the chain:

contributions to the overall system, students can begin to see the interconnectivity of the tsunami subsystems to meet the overall criteria for the larger system.

*Supporting Students in Engaging in Developing and Using Models

Students gain experience with this practice through multiple opportunities to construct a model of a system and its interactions, including first categorizing the parts of the subsystems and then working together as a class to develop a consensus system model of the whole system.



Make connections between all the subsystems working together.* Have a Consensus Building Discussion to come to an agreement about how the larger system works together to protect communities. Say, *We've got all these subsystems that work at different points when a tsunami happens. Let's talk through how they are connected together.*

***Attending to Equity**

Universal Design for Learning: Boxes have been color-coded to make explicit the representation of the subsystems that interact within the bigger system along the Tsunami Chain of Events. While color coding is a useful way to quickly reference the parts of the model, you can also use letter or number coding to label the boxes in the system model to help ensure accessibility for all students. Whichever representation is used, create a key to track what colors, symbols, or letter or number codes represent different parts of the system.

Key Ideas

Purpose of the discussion: To come to an agreement that there are many different subsystems (e.g., design solutions and technologies) that work together at different points during a tsunami event.

Look for/listen for the following:

- Ideas about how subsystems connect to one another along the Tsunami Chain of Events, such as the following:
  - Using data, we know where tsunamis might happen, so we put sensors in those places.
  - Those sensors pick up movement of the ocean floor or water and send satellite signals.
  - Those signals alert scientists who may issue tsunami warnings.
  - Tsunami warnings alert community members to respond.

    - Community members know how to respond because they have been educated on how to prepare and respond.
    - They evacuate to safe places while structures in the community are in place to protect people and property for when the tsunami arrives.
- Ideas for how having multiple subsystems allows us to protect and warn as many people as we can.

Suggested prompt	Sample student responses
How are the subsystems connected to one another in a larger system?	*The data helps us know where to put sensors. It also helps us know where to build structures to protect people. The structures that we built are there to break up the wave and protect property and people, but we still have to detect and warn when it will happen.* *When the movement happens, the sensors send warning signals. Those signals then help us alert people that something is coming. The faster the signal, the more time people have to respond.* *All the communications systems then send out the alerts and because people know they are at risk, they can know what to do.*

Transition to discuss why having multiple systems is important. Project **slide D**. Allow the students a moment to turn and talk to a neighbor about the questions on the slide. Then, lead a discussion regarding the questions on the slide to understand the complexities of the subsystems and the criteria of the overall system.

Suggested prompts	Sample student responses	Follow-up questions
Look at each piece of the system. Why does this system have so many components and interactions?	*Because one part of the system can't do everything. You can't just detect it or build a design solution and that's it.* *The components of the system have to talk to each other so they can figure out the threat and let people know. They all rely on each other.*	*Why can't you just have a single part of the system functioning on its own?* *What do you think would happen if we removed a part of the system, such as the DART II subsystem or even just the buoys in the DART II system?*
	We would lose a connection within the system and we may have more false alarms, or people may not get warned in time. It could be bad.	*Do you think there is even more to the system that we didn't learn about?*
Each piece of the system had to meet certain criteria. What would you say the main, number one criterion of the entire system is?	*To keep people safe from a tsunami.* *To prevent or minimize damage from a tsunami.*	*Does a particular component of a system need to meet the criteria, or does the whole system need to meet the criteria? Why?* *No, the parts have to work together as parts of a whole system.*

Suggested prompts	Sample student responses	Follow-up questions
What would happen if a component of a subsystem was removed? Would it affect the overall system? Why or why not?	*Some subsystems might not work as well.* *I think it depends on the component of the subsystem. Different components have different effects.* *Maybe it depends on the component. Like, if you got rid of something, then added something back in. For example, if you swapped out a wall for a breakwater, it wouldn't affect the system too much, but if you changed the way you warned people, that could be better or worse.*	*Can you give an example and predict what it would do to the overall system?* *Why would the specific component matter? Why would they have different effects?* *How would you have to assess if that change was for better or worse? What would you use to evaluate the change in the system?*
We learned about Ryoishi, and considered specific trade-offs when looking at design solutions. What trade-offs do you think different communities would make when choosing components within this system designed to minimize damage from a tsunami?	*Maybe they would want to have more public education because they can't put up a big seawall, which could put more people at risk.* *Not having a seawall, like a recurved wall, is tricky, but if they have a recurved wall and not easy access to the beach, they miss out on tourism money to live.*	*Why would that be a trade-off?* *Are there other trade-offs that might have to be weighed with this system?*

Assessment Opportunity

Building towards: 8.A Construct a system model to represent the interactions of subsystems designed to detect, warn communities, and reduce damage from a tsunami hazard.

What to look for/listen for: Connections should be determined between various parts of the subsystem. Students should be able to articulate: (1) systems are comprised of subsystems that work together as a system, (2) parts of the subsystem cannot fully protect a community on their own, and some rely on feedback from other parts of the system, and (3) while the system works to meet the needs of the individual community, the system components and interactions may have to be altered when applied to other communities or situations.

What to do: If students are struggling with:

1. Subsystems working together as a system to meet the needs of the community, press students to explain how the system would be affected if the larger subsystem was taken out of the system and if the system could still meet the criteria of the community as effectively.
2. Considering the importance of the subsystems to meet the goals of the larger system, place a hand or a sticky note over a single component of a subsystem. Ask students how the subsystem would change if the component was removed and what effects it would have on the larger system.
3. Seeing the potential changes to the system to address the needs of other communities, push students to consider a change in location, like a crowded tourist destination. Ask students what new constraints would be prioritized, if the system would have new constraints based upon the location, and what parts of the system would most likely have to be altered to meet the constraints of the community.

3. Create What We Do as Engineers chart.

8 MIN

Materials: "What We Do as Engineers" sticky notes, What We Do as Engineers poster, markers

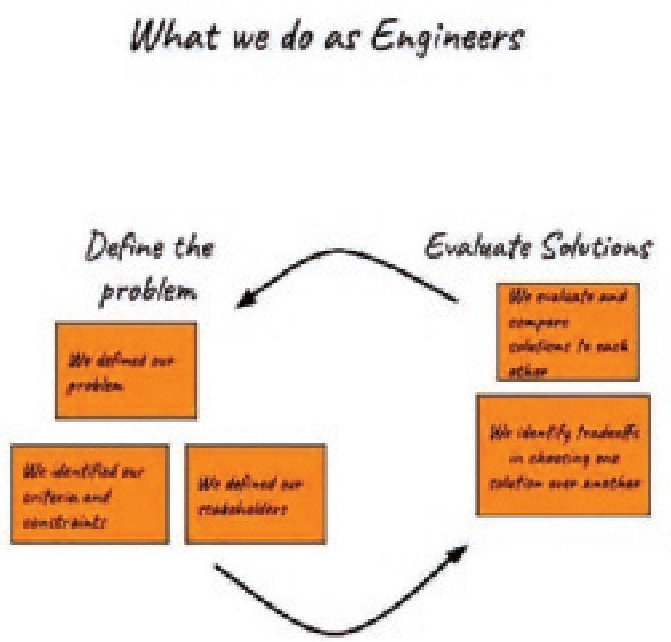
Continue in the Scientists Circle and transition to reflecting on the process. Say, *We have learned some pretty interesting things about these systems put into place to protect people. The systems and how they are constructed seem to depend on criteria specific to the event and the communities. They also seem like they have parts that are dependent on other parts to provide protection. Let's talk about how we think this system came about.*

Suggested prompts	Sample student responses
How do you think engineers develop systems like this?	*I think the system took a long time.* *It was definitely developed by a lot of people who knew what they were doing and knew the science behind it.* *The system was developed according to the criteria and constraints.* *It must have taken a lot of planning.*
What process did we have to go through to figure out what would work best for the tsunami hazard?	*We had to learn about the tsunami first.* *We had to learn about how it worked and how it impacted people.* *We had to learn about design solutions and how they met the criteria and constraints of the people who lived there.* *We had to learn about other ways to protect people, like early warning systems and detection.*

Display "What We Do as Engineers" cards. As students are explaining the process, display any matching "What We Do as Engineers" cards for students to see. Say, *We have gone through quite the process to figure out how to best protect from tsunamis. We have had to learn a lot, and in each lesson we went through a process to figure out the best solutions. These are things that all engineers do when they design solutions.*

Say, *If we were to try and represent what we did as engineers, do you think we could organize the process we went through to optimize our thinking?*

Create a "What We Do as Engineers" chart. Start by asking students about the first thing we did as engineers—we learned about the problem. Pull this card out of the group and place it at the top of the chart paper. Ask students if any other cards would be a part of the process of defining a problem. Students might identify the following cards that go into this category:



- We defined our problem.
- We identified our criteria and constraints.
- We identified our stakeholders.

Ask students what we did after we learned all we could about our problem. Lead students to identify that we evaluated and compared existing design solutions. Pull that card and place it in a different area of the board. Remind students that we thought about those parts of the existing designs and how they work to help reduce energy but also considered other constraints. Ask students if any other cards go with that. Students should select the last remaining card, identifying trade-offs in choosing one solution over another. At this point, these two cards should be placed together in a separate area of the chart paper:

- We evaluate and compare solutions to each other.
- We identify trade-offs in choosing one solution over another.

Remind students that at this point we started to look at parts of the system and did not get to continue with designing a solution. Instead, we went back and looked at our stakeholders and criteria one more time to evaluate how well the system met the needs of the community. Ask students if we currently have a step like that on the cards. Students should identify that we already have an area for defining a problem.

Say, *It seems that we already have an area for this. Are they connected? Is it OK to go back to this step and check our work?* Give students a moment to verify that it is OK to go back and confirm the effectiveness of the solution against the criteria and constraints and needs of stakeholders.

Work with students to determine that 2 arrows should be added between the design process areas as seen in the diagram. Label the two sections "Define a Problem" and "Evaluate Solutions."

Say, *We know the process engineers went through to design and analyze this system. Let's see how well we did working through the same process!*

Alternate Activity

There are many options for how to represent how engineering design was accomplished in this unit. Students might want to represent it linearly or in another format. All representations are welcome; the more important idea is that students understand different aspects of the design process and that moving back and forth between those aspects is a natural way engineering design works.

4. Conduct engineering self-assessment.

5 MIN

Materials: *Engineering Self-Assessment*

Conduct the self-assessment. Project **slide E**. Distribute *Engineering Self-Assessment*. Explain to students that this handout has broken down the notecards on the "What We Do as Engineers" chart into smaller, easier to assess pieces. Tell students we can use these areas to check our individual progress on using these engineering ideas to develop a system of solutions. Show students how to use the 1–3 scale to evaluate themselves.

Point out that all students should explain their ratings using the last question on the handout. If students are stuck between two ratings, tell the students to pick one and give their reasoning in this space. Tell students they will hand this in when they are finished, and they will be given teacher feedback on the same form.

Give students time to complete the handout. Have students turn in the self-assessment when they are finished.

Assessment Opportunity

Self-assessments are valuable tools to gauge student understanding. Students rely on a feedback loop involving the student and teacher for personal academic growth. Use this assessment to determine any perceived areas of challenges and successes from a student's perspective, and provide timely feedback for the students (either on the front or back of this paper) regarding their perceptions and reality. Remember to give some positive feedback for every critique to help build the student's self-efficacy in the engineering process.

Alternate Activity

This self-assessment can be done digitally using an online survey tool. A Google form example is included with the online unit materials. Make a copy and customize this for your classroom.

5. Look back at related phenomena.

5 MIN

Materials: Related Phenomena poster from Lesson 1

Look back at related phenomena. Project **slide F**. Bring the class back together once all self-assessments have been completed. Ask students to Turn and Talk regarding the questions on the slide. Have students share their ideas with the class. Example prompts and student responses are below.

Suggested prompts	Sample student responses
In this unit, we studied a natural hazard that was really important to one community. Think back to what we gathered for related phenomena. What other natural hazards could affect us?	*Tornadoes happen here pretty often.* *Hurricanes hit here a lot—like every summer.* *We get a lot of really bad snow storms every winter.* *We have really big thunderstorms and high winds and hail.* *Flooding happens since we are so close to the river.* *We get fires every summer/fall, and so we are always really cautious not to cause one.*
What systems are in place like the Tsunami System?	*Well, we do tornado drills and have shelters to protect us. Plus there are sirens that go off too.* *We have big levees along the river to keep it from flooding.* *We get weather forecasts and warnings when a bad storm is coming.*
What can we do to help our community prepare for a natural hazard?	*We can make a plan and share it with others.* *We can teach people how to assess their risk and look for warning signs.* *We can help people prepare and take steps to protect themselves.*

Additional Guidance

If students are having trouble coming up with ways they can help prepare for a natural hazard, remind students that we have read about students who helped their community of Kamaishi during the 2011 tsunami. Ask students the following:

- What is something that others your age did that we learned about to help before and during the natural hazard?

Say, *Next class maybe we can use all the ideas we have figured out to prepare our own communities or other communities for hazards that might affect them.*

LESSON 10

How can we effectively prepare our communities for a natural hazard?

Previous Lesson

We used what we learned to develop a system model that identifies the components and processes involved in detecting, warning people, and reducing damage from tsunamis. We generalized the process engineers use to solve problems and determined that we should use what we've learned to address a local natural hazard.

This Lesson

Putting Pieces Together

2 DAYS

In this lesson, we investigate the general patterns of risk of other natural hazards in the United States. We determine our local level of risk for each hazard. We then choose a natural hazard, gather information, and plan for communication to an identified stakeholder community at risk for the hazard. We obtain and evaluate information from a variety of sources, including agencies and organizations that focus on hazards and emergencies, and then develop a plan and final communication product. We evaluate our final plans and products using constraints and criteria for effective communication with our stakeholder groups.

Next Lesson

There is no next lesson.

Building Toward NGSS

MS-ESS3-2, MS-ETS1-1, MS-ETS1-2

What Students Will Do

9.A Use digital tools to analyze patterns in large data sets (maps) of the history of natural hazards in regions and use this information to forecast future risk.

9.B Critically read scientific texts adapted for classroom use to obtain scientific and technical information related to predicting the locations and severity of a hazard and understanding the response systems designed to mitigate the effects.

9.C Communicate scientific and technical information in writing and/or oral presentations about a system designed to meet the criteria and constraints for communicating with identified stakeholder groups about a natural hazard.

What Students Will Figure Out

- All communities are impacted by natural hazards with different levels of risk, and these hazards often require different ways to detect risk, warn people, and reduce damage.
- Knowledge about hazards (the causes of the hazard, locations at greater or lesser risk, how to design solutions, and how to respond when it happens) can empower us and others to design solutions to save lives.

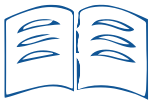
- Effective communication and response plans account for the needs of people living in a place and the available resources to respond.
- Communication strategies include educating the community before a natural hazard happens and alerting people when the hazard is happening.

Lesson 10 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**REVISIT RELATED PHENOMENA POSTER** Look back at related phenomena from Lesson 1, and use the list to brainstorm how to communicate a plan to members of the community.	A	Related Phenomena poster
2	15 min	**ASSESS RISK USING HISTORICAL DATA** Assess general patterns of regional risk of natural hazards as well as local community risk.	B-C	*Assessing Hazard Risk*, *Hazard Risk Maps*, (See the **Online Resources Guide** for a link. **www.coreknowledge.org/cksci-online-resources**), computer, projector
3	10 min	**BUILD CONSENSUS ABOUT GENERAL PATTERNS OF RISK VERSUS LOCAL RISK FOR NATURAL HAZARDS** Build consensus about general patterns of natural hazard occurrence versus local risk for natural hazards.	C	*Assessing Hazard Risk*, Assessing Risk chart, markers
4	10 min	**EXPLAIN RISK** Choose a hazard and use data to explain local risk of the natural hazard occurrence.	D	*Assessing Hazard Risk*
5	5 min	**COMPLETE EXIT TICKET** Brainstorm ideas for additional information and data needed to investigate other natural hazards further.	E	*Assessing Hazard Risk*, chart paper, markers
				End of day 1
6	5 min	**REVISIT IDEAS FOR SCIENCE AND ENGINEERING INFORMATION** Revisit student ideas generated at the end of day 1.	F-G	

Part	Duration	Summary	Slide	Materials
7	8 min	**DETERMINE WHERE STUDENTS CAN MAKE AN IMPACT ON THE SYSTEM** Revisit Ways to Protect People and Property chart from Lesson 9 and determine what parts of the system students can contribute to in order to make an impact on a community.		Ways to Protect People and Property chart
8	15 min	**CONSIDER SCIENCE IDEAS AND COMMUNITY NEEDS** Consider what stakeholder groups to share hazard communication plans with and how to effectively communicate with those groups.	H-J	*Determining Stakeholder Needs, Project Options*, chart paper, markers
9	10 min	**DETERMINE HAZARD INFORMATION AND BEGIN COMMUNICATION PLAN** Organize relevant information about the selected natural hazard, and develop a plan to effectively communicate with the selected stakeholder group(s).	K-N	*Determining Stakeholder Needs, Hazard Communication Planning, Project Options, Natural Hazards Around the World*
10	85 min	**BEGIN NATURAL HAZARDS COMMUNICATION PLAN** Develop a project to effectively communicate natural hazard information to selected community stakeholder groups.	O	*Determining Stakeholder Needs, Hazard Communication Planning, Stakeholder Criteria and Constraints Peer Feedback Form, Self-Assessment: Giving and Receiving Feedback, Peer Feedback Guidelines, Obtaining and Communicating Information about Natural Hazards*, computer, variable project materials
11	15 min	**EVALUATE OUR DQB QUESTIONS AND CELEBRATE** Gather around the Driving Question Board and place sticky dots on the questions we think we have made progress on.	P-Q	5 sticky dots, *Family Hazard Plan, Family Hazard Plan: Hazard-specific Information*
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 10, students are ready to read Student Reader Collection 4 and then respond to the writing exercise.		Student Reader Collection 4: *Communities and Cooperation*

Lesson 10 • Materials List

	per student	per group	per class
Lesson materials Student Procedure Guide  Student Work Pages 	• *Assessing Hazard Risk* • *Hazard Risk Maps* • *Determining Stakeholder Needs* • *Project Options* • *Hazard Communication Planning* • *Natural Hazards Around the World* • *Stakeholder Criteria and Constraints Peer Feedback Form* • *Self-Assessment: Giving and Receiving Feedback* • *Peer Feedback Guidelines* • *Obtaining and Communicating Information about Natural Hazards* • science notebook • 5 sticky dots • *Family Hazard Plan* • *Family Hazard Plan: Hazard-specific Information*	• Natural Hazard Risk Map (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • computer • variable project materials	• Related Phenomena poster • computer • projector • Assessing Risk chart • markers • chart paper • Ways to Protect People and Property chart

Materials preparation (30 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

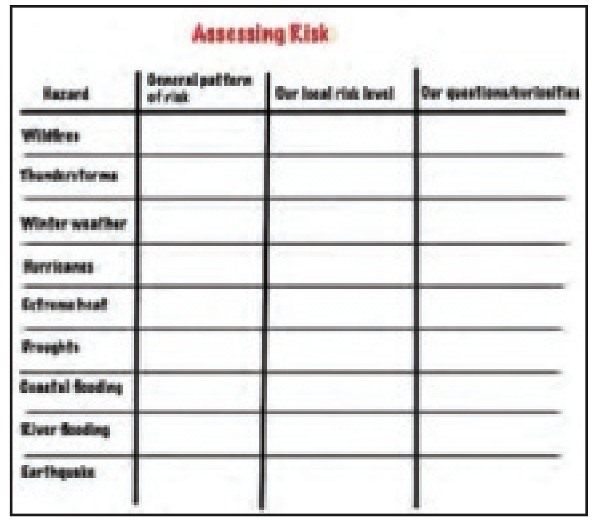
Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test the digital maps. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) or make available the color printed maps in the student reference section of the student edition.

Create an Assessing Risk chart listing all natural hazards with columns for a general pattern, local risk, and wonderings.

Use *Hazard Communication Project Choice and Platform Information* to learn about digital tool options and modify the student handout, *Project Options* to account for any acceptable use policy or classroom limitations.

Gather any materials that students will need (chart paper, markers, pencils, etc.) and ensure the class has computer access for the duration of this lesson if they pursue a digital choice.



Assessing Risk

Hazard	General pattern of risk	Our local risk level	Our questions/curiosities
Wildfires			
Thunderstorms			
Winter weather			
Hurricanes			
Extreme heat			
Droughts			
Coastal flooding			
River flooding			
Earthquakes			

Use *Potential Accompanying Standards* to identify possible accompanying project standards. Adjust as necessary for your classroom.

Display the Lesson 1 Related Phenomena poster and Lesson 9 Ways to Protect People and Property chart.

Lesson 10 • Where We Are Going and NOT Going

Where We Are Going

The focus of this lesson is for students to use and apply ideas figured out while investigating the tsunami hazard to a hazard that affects their community or a community of interest. The lesson is intended to help them understand more about the hazard, the community's general and local risk for the hazard, and how they (and others) will need to respond if it happens.

Where We Are NOT Going

Students will not have time to investigate and evaluate all the existing design solutions to detect risk, warn people, and reduce damage from a local hazard like they did for the tsunami hazard. However, this opportunity could be provided as an extension for high interest students.

LEARNING PLAN FOR LESSON 10

1. Revisit related phenomena poster.

5 MIN

Materials: Related Phenomena poster

Transition to hazards that students have experienced or are curious about.* Say, *Last class we ended by thinking about other natural hazards that worry us. We know tsunamis may not happen to our community, but there are other hazards that we are concerned about.*

Additional Guidance

The intention of this lesson is to have students investigate local hazards that their own community is at risk for or a natural hazard that sparks their interest or curiosity. While it is important for students to understand how to prepare for and respond to a hazard in their own community, some students might have high interest in other natural hazards that they hear about on the news or that have affected their family or friends. Students may also have past experiences with learning about and preparing for their local hazards and may already know what to do and how to respond in the event that a hazard strikes. The lesson is written as though the hazard is a local hazard, but this lesson can be modified to include other hazards that impact other communities in the United States (based on students' experiences and/or interests).

Direct students to look back at the Related Phenomena poster from Lesson 1. Ask students if they would like to add any additional natural hazards they are concerned or curious about. Add in any new suggestions from students.

Turn and Talk about local natural hazards.* Project **slide A.** Have students Turn and Talk to a partner about these questions:

- What natural hazards can affect our community?
- How do we know our level of risk for these hazards?

Ask students to share their ideas.

Suggested prompts	Sample student responses
What natural hazards can affect our community?	*Accept all relevant responses.*
How do we know our level of risk for these hazards?	*Because it happens here a lot. (student experience)* *We can look at data to see what our risk is for a hazard, just like we looked at tsunami data. (look at data)*

***Attending to Equity**
Supporting Empathy and Emotions: At this point in the unit, students will transition to focusing on local hazards or hazards that spark interest or curiosity. If your community has experienced any recent hazards, be mindful that some students might have traumatic experiences that may surface, particularly those that caused damage and deaths. One option would be to have them research the hazard because creating a communication plan might empower them and help them feel less anxious, because they'll know how to respond in the future. It might be better for some students to choose another hazard with less emotional connections. Opening the opportunity to explore other hazards that might not be local can still allow them to prepare for hazards they may experience in the future.

2. Assess risk using historical data.

15 MIN

Materials: *Assessing Hazard Risk, Natural Hazard Risk Maps* interactive (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), computer, projector

Elicit ideas about data we need. Display **slide B.** Ask students, *Think back. What data did we use to determine which places in the world were most at risk for tsunamis?* Students should mention the maps and graphs used in Lesson 2. Ask, *How could we use a similar type of data to assess our risk for other natural hazards?* Student ideas may include:

- Analyzing data on maps to see where hazards happen.
- Analyzing data on graphs or in other text to see how often they happen, how severe they can get, or if they happen at certain times of year.

Distribute Part 1 of *Assessing Hazard Risk*. Display or provide copies of *Hazard Risk Maps*. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Orient students to the maps using a few prompts:

- What is the data we are looking at? How do you know?
- What does the legend say about the maps?
- What is our handout asking us to do with this data?*

Display **slide C**. Once students are oriented to the maps and the handout, have students work in groups for approximately 15–20 minutes to assess general patterns of occurrence in the listed natural hazards.* They should also assess their local level of risk of each hazard and note any questions or curiosities about the hazard. Groups should complete Question 1 together. They will complete Questions 2 & 3 later in the lesson.

***Supporting Students in Engaging in Using Mathematics and Computational Thinking**
Orient students to the data provided within the digital tool and the expectations for analyzing the large data set. Model one hazard together as a class to help students understand how they can use the large data set to identify general regional patterns of risk as well as their local level of risk. If students have worked with many large data sets, less orientation and scaffolding may be necessary.

***Attending to Equity**
Supporting Universal Design for Learning: Work through one hazard as a whole class to model collaboration and expectations for group work to enhance student engagement with the data. Ask students prompts, such as: *What are we looking for in the data? How might we capture our ideas as a group? How can we ensure everyone can participate in working with this data?*

3. Build consensus about general patterns of risk versus local risk for natural hazards. 10 MIN

Materials: *Assessing Hazard Risk*, Assessing Risk chart, markers

Build consensus about patterns of risk.* Continue to display **slide C**. Once students have completed Question 1 on the handout, pause to build consensus across their findings as a class. Use the premade Assessing Risk chart to record the patterns of regional and local risk for each natural hazard. Ask students:

- How would you describe the general pattern of risk for _____ hazard? Do others agree? Did you notice anything different?
- What about our local risk? What level is it? (Very High, High, Moderate, Low, Little to None)
- What wonderings do you have about this hazard? Have you had prior experiences with this hazard?

Work through each hazard, and record areas of agreement, disagreement, or questions.

***Supporting Students in Developing and Using Patterns**
Use this opportunity to emphasize how maps can be used to see general overall patterns of risk for a natural hazard and also identify the level of risk for a local community. This allows students to see that levels of risk for different hazards vary for communities across the US.

4. Explain risk. 10 MIN

Materials: *Assessing Hazard Risk*

Transition to individual explanations.* Display **slide D.** When students have completed assessing patterns of risk for the provided natural hazards, come to general agreement about these patterns of risk as a class and have them work individually to answer Question 2 and 3 on *Assessing Hazard Risk*. Give students 10 minutes to write their ideas on their own.

Assessment Opportunity

Building towards: 9.A Use digital tools to analyze patterns in large data sets (maps) of the history of natural hazards in regions and use this information to forecast future risk.

What to look for/listen for:

- Students identify general regional patterns in different natural hazards.
    - Example: A general pattern for coastal flooding would be limited to places along the coast only (and not anywhere interior to the United States), whereas thunderstorms show a pattern of greater risk in the eastern/central portion of the United States and Florida.
- Students assess their local risk for various natural hazards.
    - Will vary based on your local community.
- Students identify future risk for a local hazard.
    - Response should include level of risk of a hazard, their ideas or experiences with severity or frequency of a hazard, and ideas for additional data they would need (e.g., how big or intense it could be, how fast it might happen, how well can people respond).
- Students should justify why it is important to communicate to a community about a natural hazard.

***Supporting Students in Three-Dimensional Learning**
Encourage students to identify and use patterns and trends they obtained from the digital tools of large data sets (i.e., hazard risk maps) as part of their explanations about likely future risk of a hazard for their communities and other communities.

Use *Assessing Hazard Risk* as an example for student ideas to look and listen for.

What to do: For Question 1, model one hazard as a whole class to set the expectations for how groups should work through the remaining hazards. Talk aloud the general regional pattern you notice related to the hazard, including where it doesn't happen often. For Questions 2 and 3, if students struggle to identify one hazard that their community is at risk for (or choose one from several natural hazards), have students group the hazards into high-, medium-, and low-risk categories (to help them prioritize higher risk hazards or tell them to highlight the natural hazards where the risk is moderate to very high for their community). Then, prompt students to consider their own experiences or wonderings about a hazard with which they are at higher risk for Question 2. For Question 3, students may choose any natural hazard but must identify a community at moderate to high risk and why a communication plan would be important based on the data.

5. Complete exit ticket.

5 MIN

Materials: *Assessing Hazard Risk*, chart paper, markers

Share interest in investigating other hazards. Display **slide E**. Ask a few students to share their responses to Question 3 from *Assessing Hazard Risk*. After they share their answers to what natural hazards they would want to investigate, prompt students to generate a list of data or information they would like to have to further investigate the natural hazards. Document these ideas on chart paper or a whiteboard.

Additional Guidance

If time allows, make one chart with science-related ideas, such as what causes the hazard, how often they happen, how intense or big it can get, etc. Then make a second chart with engineering-related ideas, such as what communities can do to protect themselves from a hazard (e.g., structures, technologies, communication plans, education). If time is short, have students jot down a few ideas onto an index card or scrap paper and turn it in before they leave.

Use this generation of ideas to gather supplemental materials and resources to help students investigate other hazards. Collect *Assessing Hazard Risk* from students to gather their ideas for which hazards they are interested in investigating, what data or information they might need, and plan for the next few days of instruction.

Additional Guidance

After class, review the chart to look for what data students might need for each identified hazard. Between days 1 and 2, look over the cards for each hazard and determine if students will need any supplemental materials to enhance their investigations. Websites, such as the NOAA and USGS sites, are accessible and include student-friendly language and resources, if needed, for different hazards.

End of day 1

6. Revisit ideas for science and engineering information. 5 MIN

Materials: None

Revisit chart from day 1. Display **slide F**. Refer students back to the chart of science and engineering ideas completed on day 1. Ask students to look over the list and add any additional ideas or data they might need to the chart. As students wrap up adding to the chart, share the summary of the main hazards students would like to know more about and the data or information that they would need to learn more about these hazards.

Turn and Talk about the use of the hazards information. Display **slide G.** Say, *OK. We have now identified hazards of interest. We also know what data we would like to have to learn more about them. But what are we going to do with this information?*

Allow students a moment to turn and talk to a partner about the prompt on the slide.

- What should we do with this information about our hazards once it is collected?
- What do scientists and engineers do with their hazards information?

Students should identify a variety of things we can do with the information, including presenting to someone about that hazard. When discussing what scientists and engineers do with the hazards information, remind students that in Lesson 9 we had spent some time considering what scientists and engineers did as part of the overall system and that we might find some ideas by looking back at our class chart.

7. Determine where students can make an impact on the system. 8 MIN

Materials: Ways to Protect People and Property chart

Revisit the Ways to Protect People and Property chart from Lesson 9. Direct students to look back at the Ways to Protect People and Property chart. Lead a discussion to identify the ways in which students could share the information they gathered to impact the community. Guide students to determining that they can make an impact by focusing on the Warn and Communicate section, specifically by communicating with communities about the hazard. Example prompts and responses follow.

Suggested prompt	Sample student responses
Let's look at our Ways to Protect People and Property chart. We are collecting a lot of data. What areas do we think this data comes from?	*The data we want is about the hazard, so maybe the Detect and Forecast section.* *We have already collected data on when and where it might happen, so we have data from the Detect and Forecast section.*

Suggested prompts	Sample student responses
Since we have information from the Detect and Forecast section, what do scientists and engineers generally do with this data?	*Engineers design solutions to the problem, like making tetrapods in some areas at risk for tsunamis.* *Scientists use the data to monitor for if and when a hazard will start.* *Engineers use what we know to create monitoring and sensing devices for the hazard.* *Engineers and scientists also use the information to communicate with those at risk.*
After looking at what scientists and engineers do with the information, is there one area that we, as students, can also contribute?	*Well, we can't actually build something that will reduce damage. We don't have the budget for it.* *We could maybe focus on the Warn and Communicate section.* *We can communicate with people about the hazard, like the students did in Kamaishi.*
Why is warning and communication an important part of what scientists and engineers also do with hazards?	*Because if people know what to do when a hazard is happening, then all the systems that scientists and engineers design can help save them or protect them.* *If people don't know what to do, like when sirens go off, then it is harder to protect them.*

8. Consider science ideas and community needs.

15 MIN

Materials: *Determining Stakeholder Needs, Project Options*, chart paper, markers

Determine who to share information with. Project **slide H.** Say, *So far, we have determined that we should communicate with communities that are most at risk from our chosen hazard. Who in the community should we communicate our information to?*

Give students a moment to turn and talk to a partner about the questions on **slide H**.

- Who in a community might need to know about hazards?
- Should we also consider any people outside of the community?
- Are there any specific groups of people that are in every community at any given time?

Allow students to share their responses to the first two questions. Students should determine that anyone who lives in the community should know more about the hazard, as well as anyone else that might be visiting the community or live in the area of risk.

Create a community stakeholder chart. Focus on the last question on the slide by creating a chart of groups of people that are present in every community. Students should be able to identify a list of people similar to the following list. This list is not all-inclusive and could be expanded depending on student experiences with varied members of the community.

- Elderly or older citizens
- Ill citizens
- Young children
- Adults or parents
- Travelers/tourists
- Those who do not speak the dominant language
- Those without vehicles or means of transportation
- People without technology

After students share, ask students if we have a term for the people who are directly affected by this hazard and might benefit from this information. Remind students that we have called this group of people our stakeholders. Add the title, *Community Stakeholders*, to the top of the chart.

Identify stakeholder criteria and constraints. Project **slide I.** Ask students to turn and talk about the questions on the slide.

- Do all people need to know the same information about a hazard?
- Are there specific instructions or considerations for different groups of stakeholders?
- Do all stakeholders use the same methods for getting information?

Allow students to share their ideas with the class.

Suggested prompt	Sample student responses
Do we think that all people need to know the same information about a hazard?	*Yeah, the community will need to know what the warning signs are so they can be safe during the hazard.* *They need to know if they are at a place where they may be at risk.* *They need to know how bad the hazard is going to be to know where to go or what to do.* *They have to know it's coming and be alerted to respond.* *All people need to know the basics, like where it strikes and what to do.* *Maybe different people need to know specific information to be safe.*

Suggested prompts	Sample student responses
Would an adult need to know the same information as a kindergartener about what to do and how to respond to a hazard?	*No, the adult would need to know specifically what to do, but the kindergartener would probably need to know to look for an adult or for someone who can help them.*
So are there things that we need to consider that are different for each stakeholder group?	*Yeah, like little kids would need different instructions and information about a hazard than an adult.* *Some people might need more detailed information.* *Some stakeholder groups like those that don't speak the language would have to get their information differently than those that speak the language.* *The elderly might have different needs than others depending on the hazard.*
If different stakeholders need to know different things about their hazard, does that also mean that they might need to hear the information from different sources or methods?	*I think we have to reach different people in different ways, just like they do for tsunamis in Japan. We have to use different methods because not everyone will pay attention to the exact same method.* *Maybe we need two different methods, like a commercial or a newspaper article or something. My grandma trusts the newspaper, but my sister is super into TV and commercials.* *Maybe it could be through a video that can be shared on social media. I know a lot of people my age get their information from social media.* *I think we have to use methods that people are comfortable using and that they trust. People have to trust the information they are receiving to use it.*

Additional Guidance

For this discussion, consider using charts from previous lessons to help draw out ideas from students. If students are uncertain if each group would need different information or different methods of communication, compare two different stakeholder groups from the Community Stakeholders chart to help spur the discussion about stakeholder needs. For example, you might say, *Let's compare the elderly and children. How might they get information that they listen to and trust? Are those methods of communication similar or different? Would they need to know the same information?*

Introduce *Determining Stakeholder Needs*. Project **slide J**. Say, *It sounds like we have to consider how we communicate with our stakeholders and what their needs are.* Distribute *Determining Stakeholder Needs*. Direct students to look at the top of the chart as a class. Emphasize that the handout is intended to help determine what needs to be considered when communicating with certain stakeholder groups. Ask students to think about the stakeholder group(s) that they would want to communicate with about their hazard and identify them using the first column of the first table.

Determine how to communicate with stakeholders. Explain to students that they will have the rest of the class period to consider the needs of their stakeholders. Allow students to complete the handout in partner pairs.

As students are working, distribute *Project Options*. Explain to students that some common methods of communication can be found on this handout that might be relevant for their projects, along with ways that students could create the project and what those projects would require. Tell students that they are welcome to consider these methods listed on *Project Options* as methods of communication for their project, or they can propose another method that works well for their stakeholder group. Instruct students that if they pick something that is not on the list or previously approved to check with the teacher about their selected method of communication.

9. Determine hazard information and begin communication plan.

10 MIN

Materials: *Determining Stakeholder Needs, Hazard Communication Planning, Project Options, Natural Hazards Around the World*

Say, *Yesterday we analyzed what needs our stakeholders had for a communication plan and what type of plan to develop for them. But, we also have a lot of information that we need to communicate. We know that our communication method will depend on the stakeholders, and what we are communicating will depend on the hazard we have each chosen. Let's take a few minutes to look at another tool that can help us determine what might be important to share with our stakeholders.*

Explain part 1 of *Hazard Communication Planning*. Display **slide K.** Distribute *Hazard Communication Planning* to students. Explain to students that this handout will guide them through collecting information about their hazards based upon the areas we identified in our systems model from Lesson 9.

Explain part 2 of *Hazard Communication Planning*. Display **slide L.** Show students part 2 of the handout. In part 2, students will consider how to present the information that is relevant to stakeholders in their communication plan. Remind students that there are suggestions for what to use to create different types of communication plans on *Project Options* that they can think about as they are filling out part 2.

Go over available reference materials.* Project **slide M**. Show students the natural hazard resources using *Natural Hazards Around the World* in the student edition. Explain that most, if not all, of the information they need for the natural hazard will be in the reference deck. Point out that each hazard is organized into different subcategories to make it easier to find information.

- About the ____ hazard: This section provides students with an overview of the natural hazard, when the hazard tends to strike (if seasonality exists), hazard levels, and what kind of damage can result from the hazard.
- Forecast and Detect: This section gives information about how the hazards are/can be forecasted and detected.
- Warn and Communicate: This section explains how the community can be warned of a hazard and how information is communicated with the community.
- Reduce Damage: This section explains what can be done before the hazard by members of the community to reduce damage from the hazard.
- Helpful Resources: The resources found in this section have additional information for students to explore to gather more information about the hazard.

***Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information**

At this point in this final lesson, students will focus on critically obtaining important information from a text adapted for classroom use, alongside some additional resources. They will need to integrate that information and decide how to communicate it to others in a relevant, effective, and/or engaging way. To support this practice, use questions like: *What is the main idea about how this hazard impacts people? Or, What are the three most critical pieces of information to communicate about ______.*

Consider available resources and additional resources needed. Display **slide N**. Give students a list of all the resources available to them as they work on their hazards projects. Some students may be creating a communication plan over the same hazard or for the same stakeholder group. It may be beneficial to allow these students to share ideas as they work on their hazards. Some students may also benefit from developing their communication plan collaboratively in a larger group. Use teacher discretion to determine the best option for students in the classroom.

10. Begin natural hazards communication plan.

85 MIN

Materials: *Determining Stakeholder Needs*, *Hazard Communication Planning*, *Stakeholder Criteria and Constraints Peer Feedback Form*, *Self-Assessment: Giving and Receiving Feedback*, *Peer Feedback Guidelines*, *Obtaining and Communicating Information about Natural Hazards*, computer, variable project materials

Begin compiling information for the communication plan. After orienting students to the handout and resources available, give students time to work through their *Hazard Communication Planning*.* Some students may request extra resources to complete their handouts. One option to help students process information can be found in the "additional resources" section of the *Natural Hazards Around the World*. In addition to this, many states have state-specific disaster information readily available online. Here are some easy-to-access national sites for student-driven research:

- CDC Disasters Resource Page
- EPA Disasters Resource Page
- Ready.gov
- Ready.gov for Kids
- National Weather Service
- (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)

Students may need to investigate additional resources and websites beyond this list to obtain information on their hazard. Emphasize to students that one aspect of this project is gathering reliable information from credible sources. Take a moment to discuss the initial list of sources that have been provided to them and aspects that make those sources reliable (i.e., many are government agencies that collect data and monitor hazards around the country).

Provide work time and review student work.* Once students are finished with both parts of *Hazard Communication Planning*, have students bring the handout to you. Review the handout with students and ask clarifying questions about any areas that seem to be lacking information or are incomplete.

Approve an appropriate project format. Look specifically at the project option chosen by each student. Ask students what method they are going to use to present the information and why they are choosing that method. If students need additional ideas, the teacher reference, *Hazard Communication Project Choice and Platform Information*, can be used by the teacher to help students identify which communication platform or method would help them best communicate their hazard information based upon their personal strengths and classroom limitations. This reference can also be used to gain general information about different popular project platforms that may be used during this project by any student.

***Supporting Students in Developing and Using Stability and Change**

While students work on obtaining information about a hazard, take this opportunity to support students in understanding what parts of the system are in place to protect communities while it is stable and what parts of the system are in place to detect and respond to sudden changes, such as the rapid onset of a natural hazard. In some hazards, communities have more time to prepare and respond. In other natural hazards, such as earthquakes, the onset of the hazard is sudden with no warning. Depending on the hazard under investigation, students should consider how much time people have to prepare and respond with warning.

Provide students with information about how their project will be assessed. Give students a copy of *Obtaining and Communicating Information about Natural Hazards*, which provides guidance on the important considerations for assessing their final product.*

Assessment Opportunity

Building towards:

9.B Critically read scientific texts adapted for classroom use to obtain scientific and technical information related to predicting the locations and severity of a hazard and understanding the response systems designed to mitigate the effects.

9.C Communicate scientific and technical information in writing and/or oral presentations about a system designed to meet the criteria and constraints for communicating with identified stakeholder groups about a natural hazard.

Students are working on these two lesson-level performance expectations over the course of days 1–3.

What to look for/listen for:

- Ideas about obtaining information and communicating about hazards (the causes of the hazard, locations at risk, how to design solutions, and how to respond when it happens).
- Ideas about how effective communication and response plans account for the people living in their community and the resources the community has to respond.
- Ideas about how different communication strategies include educating the community before a natural hazard happens and then also alerting people when the hazard is happening with a variety of different modes of communication.

What to do: Use the Progress Tracker to help students recall ideas figured out from previous lessons, and then apply those ideas to a new hazard and a new community. Use *Obtaining and Communicating Information about Natural Hazards* to help students understand the expectations for their final project.

Prepare for feedback on communication criteria and constraints. When projects have been completed, distribute a copy of *Stakeholder Criteria and Constraints Peer Feedback Form* to students. Direct students to look back at *Determining Stakeholder Needs* and focus on the second and third columns. Remind students that in those two columns they identified their criteria and constraints for communication with their stakeholder group(s). Explain that students will be given a chance to get feedback on how well their communication plans have met the needs of their stakeholder groups.

Project slide O. Point out the column headers to students. Explain that students will use their previously identified criteria and constraints to complete the first column on *Stakeholder Criteria and Constraints Peer Feedback Form* by adding each separate criteria or constraint to its own row on the handout.

***Attending to Equity**

Supporting Universal Design for Learning: This project provides multiple opportunities to support the principles of Universal Design for Learning, including the following:

- Multiple means of *engagement* by *recruiting interest* through student choice and autonomy (i.e., which hazard they investigate; choosing the format for the communication plan); *sustaining effort and persistence* through collaboration and community work together to develop their projects and provide peer feedback; *self-regulation* through selfassessment of one's ability to provide feedback to peers.
- Multiple means of *action and expression* by: providing options for *expression and communication* through student choice of multiple media for communication; and promoting *executive function* by providing support for planning and strategy development.

Engage in peer feedback using the *Stakeholder Criteria and Constraints Peer Feedback Form* handout. Move on to column 2 with students and explain that this column will be used to cite specific places where the communication plan addressed that criteria or constraint. Partners will look through the communication plan and record on the handout where they see evidence of the communication plan clearly using or addressing the criteria or constraint. Explain that column 3 is where students will give feedback about the use of the criteria and constraints within the communication plan, and also provide ideas for how to either incorporate or enhance the criteria and constraints used in the communication plan.

Place students in partner pairs and ask students to trade their *Stakeholder Criteria and Constraints Peer Feedback Form* handouts. Direct students to share their communication plan with their partners. Give time for each partner to complete the peer feedback and instruct students to present that feedback to their partners. Give students time to make any needed enhancements or changes to their projects after the peer feedback has been reviewed.

Share Communication Plans. If time allows, provide students time to present their communication plans to another audience. Audiences can include community members, school administrators, and peers.

As students communicate their projects, peers can use guidance in *Peer Feedback Guidelines* to provide overall feedback on one another's communication plans. Use *Teacher Instructions for Peer Feedback* and student-facing material *Self-Assessment: Giving and Receiving Feedback* to allow students to self-assess how well they give and receive feedback during and after student presentations.

Alternate Activity

Plan for additional time, as needed, for project communication to ensure that students who might need additional time for obtaining information, developing their communication plan, and communicating their project to others have an appropriate amount of time to do so. Additionally, it might be helpful to offer students different modalities for communicating their projects to others, such as silent gallery walks with sticky note feedback, pre-recording audio or video presentations, or live presentations in small groups.

***Supporting Students in Three-Dimensional Learning**
This project is designed to integrate elements of obtaining, evaluating, and communicating information about the likelihood of hazard in a community and using criteria and constraints identified for the community. This project uses a lens of systems and system models as students consider different aspects to forecast, warn, and communicate with stakeholders. As students develop their projects, facilitate three-dimensional learning by encouraging students to seek out information from different sources, evaluate the quality of the information, and decide how best to communicate about levels of risk of a hazard and the systems in place to mitigate the effects. Students should use criteria and constraints for stakeholders to refine the information they choose to communicate.

11. Evaluate our DQB questions and celebrate. 15 MIN

Materials: science notebook, 5 sticky dots, *Family Hazard Plan, Family Hazard Plan: Hazard-specific Information*

Gather at the DQB and mark questions we figured out. Present **slide P** and have students place sticky dots on the class DQB next to the questions that they think we have made progress on.* Then, look for patterns in the sticky dots.

Display **slide Q** if needed. Have the class discuss the answers to these questions as a group. If you have space, make a Takeaways board to record the answers the class comes up with.* Importantly, encourage students to celebrate their accomplishments as they figured out their questions about the anchoring phenomenon, and other related phenomena. Importantly, students might notice that some questions were never figured out. Emphasize for students that sometimes not all questions get answered through initial investigations, and often those questions can be pursued in later units, grades, or on our own.

***Attending to Equity**
It is important to revisit the DQB to ensure students feel as though their questions are valued and recognized. While not all questions will have been addressed (it's more likely that most will be at least partially answered), this helps students see that they have done hard work to help answer many of their own questions.

Alternate Activity

Another option is to have students work either individually or in pairs to answer the questions they posed. This can be done by asking them to write their questions on a sheet of paper and answer the questions in words and/or pictures. To help students feel like they made progress answering their own questions, create a focus on the questions that we have not answered but now feel we could (or partially could) using the ideas we have developed.

As another option, some teachers may start a Wonder board on which questions that have not yet been answered but students are still interested in pursuing are housed. These questions are available for students to pursue independently or as time allows.

If time allows at the end of the unit, provide students with *Family Hazard Plan* as a way for them to create a family or home-specific plan to prepare and respond to a local hazard. This is a good opportunity to get caregivers involved as well by planning for hazards that might impact them as well. Additional information about each natural hazard is also included in the student reference section as *Family Hazard Plan: Hazard-specific Information.*

***Supporting Students in Engaging in Asking Questions and Defining Problems**

Revisiting the DQB at the end of the unit helps students see the progress they have made toward answering the questions that were important to them at the onset of the unit. At that time, students asked questions "that required sufficient and appropriate evidence to answer". Through investigations and individual and whole-group sensemaking, they can now answer many of their initial questions. This final visit to the DQB also allows students to see how their work toward a shared learning goal can help them figure out the phenomenon and also explain other phenomena in the world.

ADDITIONAL LESSON 10 TEACHER GUIDANCE

See *Potential Accompanying Standards* for a complete list of possible connections to ELA and Technology standards. ELA and Technology standard connections will vary based on students' choice of communication plans.

Communities and Cooperation

1 **Radiation from Fukushima! Or Something Else?**
2 **Hazard Map Comparison**
3 **Katrina's Aftermath**
4 **Hazards on Hawaii's Islands**

Literacy Objectives

- ✓ Argue a position on the issue of where a family should move to avoid natural hazards.
- ✓ Distinguish between credible and noncredible sources.
- ✓ Differentiate fact, reasoned judgment, speculation, and opinion.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 8–10.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a well-reasoned paragraph in response to the reading.

Instructional Resources

Student Reader

Collection 4

Science Literacy Student Reader, Collection 4
"Communities and Cooperation"

Exercise Page

EP 4

Science Literacy Exercise Page
EP 4

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 8: Which emergency communication systems are the most reliable in a hazard?
- Lesson 9: How can we model the systems put into place to protect communities?
- Lesson 10: How can we effectively prepare our communities for a natural hazard?

Standards and Dimensions

NGSS

Disciplinary Core Idea ESS3.B: Natural Hazards: Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (MS-ESS3-2)

Science and Engineering Practices: Analyzing and Interpreting Data; Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Cause and Effect; Systems and System Models

CCSS

English Language Arts

RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

RST.6-8.8: Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization. No Core Vocabulary terms are highlighted in the text of Collection 4.

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

landslide **radiation** **topography**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Natural Hazards unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *First, you will read two mock transcripts from online sources. The first consists of a couple of social media posts about radiation coming from Fukushima nuclear reactors. The second is a myth-busting article*
    - *Next, you'll take a close look at some natural hazard maps and read a series of text messages about what city to live in. If this sounds familiar, it should. The texters are members of the fictitious family you met in the Preface to this unit.*
    - *Then, you'll read a simulated journal entry from a FEMA contractor, who describes the damage to homes done by Hurricane Katrina in 2005.*

- *Finally, you'll read an article about how residents of Hawaii deal with tsunamis and other hazards.*
- Distribute Exercise Page 4. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate a well-reasoned paragraph addressed to the family introduced in the Preface of this unit. You'll give the family your best advice about how to solve their problem of deciding where their next home should be.*

Exercise Page

EP 4

- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What did the myth-busting article say about the map used to support a claim that radiation was traveling toward California?	*that it was actually the NOAA map showing tsunameter buoys*
What are two kinds of natural hazards that people moving to Portland, Oregon, should think about?	*earthquakes and landslides*
What are the problems the FEMA inspector found in the parts of New Orleans that were flooded during Hurricane Katrina in 2005?	*The wood frames of houses were rotting, drywall was moldy, flooring was wet and buckled, and there was the danger of breathing spores and bacteria.*
How are roadways an important factor in Hawaiian emergency management?	*People need to take certain roadways to reach higher ground that is outside of tsunami evacuation zones.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
What other kinds of natural hazards should the family choosing to move to Charleston, SC, or Portland, OR, think about?	*wildfires, winter weather, extreme heat, droughts*
What could the FEMA contractors who inspected the Gulf Coast area have done if they had come BEFORE Hurricane Katrina?	*They could have told homeowners what parts of their homes were likely to be damaged and steps they could take to prevent hurricane damage.*
At what point in the "Tsunami Chain of Events" model we developed in earlier lessons would the Hawaiian map of roadways be useful?	*at the endpoint, where the tsunami reaches a shore and floods low-lying communities*

Exercise Page

EP 4

- Refer students to the Exercise Page 4. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
    - *The writing expectation for this assignment is to develop a well-reasoned paragraph that states a claim about what the family introduced in the Preface should do to reduce their risks related to natural hazards.*
    - *Use what you know about Claims-Evidence-Reasoning to help you plan what you will say.*
    - *You may want to refresh your memory of the scenario by rereading the Preface to this unit, called "Put Yourself in This Scene."*
    - *Also, pay special attention to the reading in Collection 4 that features the same characters and situation.*
    - *But don't overlook evidence from other readings, as well as Lessons 8, 9, and 10, that will help you give the best advice to the family.*
    - *The important criteria for your work are that you write a clear claim to answer the question "Where should the family move, and what can they do after they move to reduce the risks related to natural hazards?" and support it with reasoning that uses evidence from this unit.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion. (Friday)

Facilitate class discussion about the reading collection and writing exercise. Students begin the reading activity by thinking critically about online claims related to radiation leaks that might—or might not—have been carried across the Pacific Ocean.

Student Reader

Collection 4

Pages 34–43 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "Radiation from Fukushima! Or Something Else?"	*It has three online posts. Two of them try to persuade readers that radiation from the Fukushima nuclear reactors was about to reach or had already reached the United States. The third post tries to persuade readers that the first two are fake information.*
What could you say to the commenter on the first post about causes, effects, and correlations?	*When they saw a dead dolphin at the same time as radiation MAY be in the ocean, it does not mean that the radiation caused the dolphin to die. It could have been old or had a disease.*
Check out the "Spot the BS" box. Can you detect what kinds of tactics the social media writer is using to influence readers?	*They play to people's emotions by writing about "poor" marine organisms.* *They suggest a conspiracy to hide a danger from the public.* *They also use an image without saying where it came from.*
Take a look at the "Consider the Source" box. Which post do you have more confidence in?	*the final post because the writer gives reputable sources for the scientific information*
What is the general purpose of the second selection, "Hazard Map Comparison"?	*It continues the story introduced in the unit Preface and shows how people use reliable data to make decisions.*
What did the Charleston map data reveal about home locations and flooding risk?	*that some parts of the city have a higher risk than other parts but that any part of the city has some flooding risk*
If the family decided to live in Portland, should they find a brick home or a wood-framed home? Explain.	*They should find a wood-framed home since these are more likely to stay standing during an earthquake. Just make sure the house is firmly attached to the foundation.*
What questions about landslides in Portland should the family investigate?	*Where in the city have landslides occurred?* *How often do they occur?* *What type of house construction is safer in a landslide?* *Can a landslide be predicted so that people can evacuate?*
What is the general purpose of the third article, "Katrina's Aftermath"?	*It compares the damage from wind to homes made of different materials.* *It also describes the hurricane damage to homes from flooding.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—For students who are not aware of online "myth-busting" websites, show them a few that are reliable sources for fact-checking urban legends, rumors, fake news, and the sort. Some focus on science and politics, including facts about pandemics and climate change. Others are more general and include science myths and rumors.

EXTEND—Have students compare the data on the three maps and make some inferences about which evacuation routes have the highest chance of being blocked due to lava flow hazards. For example, if a family lives in Hilo and heads west on the road that goes near volcano Mauna Kea, they would travel through a lava flow hazard Zone 2.

Pages 34–43 **Suggested prompts**	**Sample student responses**
What information provided by the FEMA inspector can be used to design safer homes in the future?	*The upper parts of homes should be anchored to a concrete foundation or slab.* *Homes in flood zones should be built on concrete or brick-and mortar piers.* *Roofs should be attached to houses with heavy-duty straps and anchors.*
When hurricane winds blow a home away, the family that lived there cannot go back. What about homes that are still standing but were flooded? What do the stakeholders have to know about them?	*Families should know that moving back in may be dangerous to their health because of mold, bacteria, and heavy metals.* *Workers who clean up wet homes also have to know about dangers to their health.*
What is the general purpose of the fourth article, "Hazards on Hawaii's Islands"?	*It explains how maps are used to plan for evacuations when the island of Hawaii is threatened by tsunamis and volcanic eruptions.*
What in the article would lead you to infer that it will be difficult to bring in emergency and rescue workers in the event of a tsunami?	*It says that the airport is partly in the evacuation zone. So, if a tsunami caused a lot of damage at the airport, planes carrying emergency workers and equipment might not be able to land on the island.*
How is the topography of the island of Hawaii an advantage when dealing with tsunamis?	*There is plenty of high ground not far from the coast that people can evacuate to.*
Take a look at the "Connection" box. Why would it be important to know the lava flow hazard zones on this map if a tsunami is approaching?	*because if a roadway is blocked by a lava flow, it cannot be used to evacuate in the event of a tsunami warning*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 4, students should write a well-constructed paragraph to make and support a claim answering the question "Where should the family move and what can they do after they move to reduce the risks related to natural hazards?" Students should support their claims with logical reasoning, using evidence from the Preface, the readings in Collection 4, and the activities in Lessons 8, 9, and 10. Look for claims such as:

- The family should move to Charleston but needs to plan for flooding, hurricanes, and heat waves.
- The family should move to Portland but needs to plan for earthquakes, landslides, wildfires, and heat waves.
- The family should move wherever it wants for other reasons, because there are natural hazards everywhere.

Use the rubric provided on the Exercise Page to supply feedback to each student.

Teacher Resources

Table of Contents

Assessment System Overview

Each unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the "Assessment Icon" in the teacher support boxes to identify places for assessments. In addition, the table below outlines where each type of assessment can be found in the unit.

Overall Unit Assessment

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 1	Initial design solutions in science notebooks Driving Question Board	**Pre-Assessment:** The student work in Lesson 1 should be considered a pre-assessment, as it is an opportunity to learn more about the ideas your students bring to this unit. Surfacing these ideas early on can help you to be strategic in building upon and leveraging student ideas across the unit. Students will spend time in Lesson 1 developing their ideas around initial design solutions for detecting tsunamis, warning people, and reducing damage. This is a good place to assess their thinking about what a design solution would need to be able to do to protect communities. You can leverage these ideas when they begin to evaluate design solutions in Lessons 5-7. The Driving Question Board is another opportunity for pre-assessment. Encourage students to generate open-ended questions, such as how and why questions. However, any questions students share, even if they are close-ended questions, can be valuable. Make note of any close-ended questions and use navigation time throughout the unit to have your students practice turning these questions into open-ended questions that can be tested through lesson investigations.
Lesson 4	*Explaining and Forecasting Tsunami Risk* & Scoring Guidance	**Midpoint Formative:** This formative assessment can be used to understand how well students have developed ideas about (1) how tsunamis form, (2) how tsunamis move, and (3) which coastal communities might be at risk for damage. It also introduces students to their first experience evaluating the risk of different communities based on their characteristics. These initial ideas that students have for rating risk can be used and developed as they evaluate design solutions and community risk in Lessons 5-7.
Lesson 10	*Assessing Hazard Risk* & Key for *Assessing Hazard Risk* *Determining Stakeholder Needs*	**Summative:** The final task for the unit challenges students to first investigate general regional patterns in risk for other natural hazards, as well as the risk of each natural hazard for their local community. Using this data and their wonderings about how other natural hazards impact communities, students make decisions about which natural hazards to investigate further to develop education and communication plans.

When	Assessment and Scoring Guidance	Purpose of Assessment
	Hazard Communication Planning & Final Group Product *Stakeholder Criteria and Constraints Peer Feedback Form* & Rubric for *Obtaining and Communicating Information about Natural Hazards*	Groups then develop a communication plan for a hazard in order to prepare a community to respond in the event of the hazard. Through this work, students will focus on obtaining and communicating information to community stakeholders using science ideas from Lessons 2-9. They will identify (1) critical information about how the natural hazard forms, moves, and impacts communities, (2) methods to detect, warn people, and reduce damage, and (3) how people in the community can prepare for, respond during, and recover after a natural hazard. This final assessment serves two broad purposes. The first is to determine how well students can apply science ideas from the unit to another hazard that impacts communities in the US. Use *Obtaining and Communicating Information about Natural Hazards* to assess the final student product. The second purpose is to prepare students themselves to understand which hazards they are at risk for and how they, their family and/or friends, or other communities can prepare and respond in the event the natural hazard occurs in their community. It is important that students see this final product for the unit as not just a "grade" but rather as an opportunity to empower students with a communicating strategy that can protect people and save lives.
After each lesson	Lesson Performance Expectation Assessment Guidance	**Ongoing Formative Assessment:** Use the lesson-level performance expectation table below in this document to see which parts of lessons or student activity sheets can be used as embedded formative assessments.
Anytime after a discussion	Student Self Assessment Discussion Rubric *Engineering Self-Assessment*	**Student Self Assessment:** The student self-assessment discussion rubric can be used anytime after a discussion to help students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week. Initially, you might give students ideas for what they can try to improve for the next time, such as sentence starters for discussions. As students gain practice and proficiency with discussions, ask for their ideas about how the classroom and small group discussions can be more productive. This is not required in any particular lesson for this unit, but it is recommended for use in Lessons 2 or 3, and again in Lessons 5 or 9. Additionally, this unit integrates an Engineering Self-Assessment Tool in Lesson 9 to help students reflect on the aspects of the engineering process they engaged in during Lessons 5-9.
After Students Complete Substantial, Meaningful Work	Peer Feedback Facilitation: A Guide	**Peer Feedback:** There will be times in your classroom when facilitating students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback from others. Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good contexts for using a peer feedback protocol. They do not need to be final pieces of student work, rather, peer feedback will be more valuable to students if they have time to revise after receiving peer feedback.

When	Assessment and Scoring Guidance	Purpose of Assessment
		Peer feedback is usually a formative, not summative, type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities to use as evidence for their feedback. We suggest that peer review happen at least two times per unit. For this unit, peer feedback works best for Lesson 10 as students present the ideas before or during the communication of their final unit products. Ideally, this feedback could be used to revise communication plans, if time allows. Peer feedback can also be used in either Lessons 5 or 7, after students complete their evaluation of design solutions and communication options, respectively. The Peer Feedback Guidelines, located in the "Additional Lesson References" section of the Teacher Edition, is designed to give you options for how to support this in your classroom. It also includes student-facing materials to support giving and receiving feedback along with self-assessment rubrics where students can reflect on their experience with the process.

For more information about the approach to assessment and general program rubrics, visit the Teacher Handbook.

Lesson-by-Lesson Assessment Opportunities

Every lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to Science and Engineering Practice(s), alignment to Cross-Cutting Concept(s), and alignment to the Disciplinary Core Ideas.

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 1	**1.A** Ask questions that arise from careful observations of a sudden natural event that causes damage to communities. **1.B** Apply scientific ideas to design an object, tool, process, or system that detects a tsunami when it starts (cause) and warns people or reduces damage to communities (effect).	**1.A Asking Questions; Stability and Change** **When to check for understanding:** Day 1, after students read about and watch videos of the 2011 Japan tsunami and brainstorm engineering ideas; day 2, when the class discusses related hazards; and day 3, when the class develops the Driving Question Board (DQB). It may be helpful to have students turn in their handouts after day 1 for you to quickly assess their developed engineering designs and then return the handouts on day 2. **What to look for/listen for:** (1) Identification of tsunamis as large waves that cause damage to communities, (2) disagreement or uncertainty about what causes a tsunami, (3) disagreement or uncertainty about why a tsunami possesses such destructive power, and (4) proposed engineering solutions involving technology to mitigate the effects (detect the tsunami, warn of its approach to give people more time to get away from it, and reduce the damage). **1.B Designing Solutions; Cause and Effect** **When to check for understanding:** Day 1, after students compare their initial engineering designs; day 2, when the class evaluates their engineering designs; and day 3, when the class discusses how to design solutions to reduce the impact of natural hazards on communities. It may be helpful to have students turn in their science notebooks after day 1 and day 3 for you to quickly examine their ideas. **What to look for/listen for:** (1) Agreement that though tsunamis may cause devastation, their effects can be reduced by systems that detect, warn people, and reduce damage; (2) agreement that some engineering designs may be more promising or challenging than others; and (3) uncertainty or disagreement about what makes one engineering design more promising or challenging than another.
Lesson 2	**2.A** Use graphical displays (maps) of large data sets to identify spatial and temporal patterns in historical tsunami occurrence. **2.B** Use digital tools, including maps and graphs, to analyze large data sets to identify cause-and-effect relationships between characteristics of related geologic forces and resulting tsunamis.	**2.A Analyzing and Interpreting Data; Patterns** **When to check for understanding:** Day 1, as students interpret the first map showing the spatial distribution of historical tsunami occurrence and related geologic events. **What to look for/listen for:** Students may notice that the locations of tsunamis are similar to the locations of earthquakes in data from the *Unit 6.4: What causes Earth's surface to change? (Everest Unit)*. They should notice that tsunamis occur in oceans or other large bodies of water, and that more have occurred in the Pacific Ocean than elsewhere. Tsunamis are most frequently caused by earthquakes. **2.B Mathematics and Computational Thinking; Patterns** **When to check for understanding:** Day 1 as students use the maps and graphs. **What to look for/listen for:** As students compare recent earthquake data to tsunami-generating earthquakes, their interpretations should include the pattern that earthquakes and tsunamis are related but only some earthquakes cause tsunamis. This helps to motivate looking more closely at what types of earthquakes cause tsunamis.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
	2.C Integrate quantitative and qualitative scientific information to connect cause- and-effect relationships to predict communities at risk for future tsunami occurrence.	**2.C Obtaining, Evaluating, and Communicating Information; Cause and Effect** **When to check for understanding:** Day 2, during consensus building for the cause-and-effect relationship between earthquakes and tsunamis. **What to look for/listen for:** Students integrate information across text, maps, and graphs to establish a cause-and-effect relationship between specific earthquake characteristics and tsunamis (i.e., shallow, strong earthquakes along colliding boundaries cause most tsunamis). They use this information to update predictions for identifying communities most at risk for tsunamis.
Lesson 3	**3.A** Analyze and interpret data from different wave models to identify patterns in how the tsunami wave forms and moves toward shore, changing height (amplitude) as it interacts with the ocean floor. **3.B** Evaluate the limitations and benefits of different wave models for explaining how tsunamis form from a movement in the ocean floor (cause), and how they move and change as they approach the shore (effect).	**3.A Analyze and Interpret Data; Patterns** **When to check for understanding:** On days 1 and 2 when students look at three different wave models from top-view and side-view perspectives. **What to look for:** After examining each model, the class pauses to share what has been figured out about waves and tsunamis. After analyzing all three models, students should be able to identify key ideas, such as how the initial wave forms, moves across the ocean, and then builds as it approaches land. See the *Teacher Guide* for detailed guidance on more specific ideas. **3.B Develop and Use Models; Cause and Effect** **When to check for understanding:** On day 2 while developing the Comparing Different Wave Models chart; on day 3 as students add new science and engineering ideas to the Tsunami Chain of Events poster and Science Ideas chart. **What to look for:** The class develops a chart to capture what was beneficial or helpful and what were the limitations of the wave models. Students should be able to identify the benefits and limitations of each model for explaining how an earthquake causes a tsunami and how the wave moves toward shore. By the end of the lesson, on day 3, students should be able to explain through the class model the chain of events that need to occur for a tsunami to form.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 4	**4.A** Apply scientific ideas to construct an explanation for how sudden changes in the ocean floor during an earthquake lead to the formation of a tsunami. **4.B** Construct an explanation that includes qualitative relationships between variables (distance to epicenter, shoreline topography) that predicts which communities are most at risk for damage as a result of a sudden change.	**4.A and 4.B Constructing Explanations; Stability and Change** **When to check for understanding:** Use *Explaining and Forecasting Tsunami Risk* during the forecasting and resource-prioritization explanation task. **What to look for/listen for:** Students should make connections that a sudden shift in the ocean floor can form a tsunami, which can move quickly across large parts of the ocean and cause damage when it reaches the coastlines. Students should use scientific ideas of how waves move and qualitative variables such as relative distance to the epicenter and local shoreline topography to rank order the risk of four places, determine which place needs immediate action, and determine where tsunami-mitigation funds should be prioritized.
Lesson 5	**5.A** Make an oral argument based on a systematic evaluation process using relevant scientific principles to support or refute the ability of different existing solutions (structure) to mitigate the effects of tsunamis and meet the needs of at-risk communities (function).	**5.A Engaging in Argument from Evidence; Structure and Function** **When to check for understanding:** On day 3, as students build consensus in a Scientists Circle. **What to look for/listen for:** Listen for students to use criteria and constraints to evaluate existing tsunami-mitigation solutions using a systematic process that accounts for community needs and the stated performance of the design solutions. Important ideas include: 1. The design solution must account for relevant scientific principles (e.g., it dissipates the wave's energy), the needs of the community (e.g., economic activity), how well the structure would function for surrounding communities (how well it will function in this scenario vs. its proposed functionality), and its environmental impacts (e.g., on marine life). 2. Clearly defining and prioritizing criteria and constraints is necessary when evaluating and choosing a solution for a given community. 3. Communities have different criteria and constraints, so the evaluation process should also consider impacts on neighboring communities. Students should realize that the proposed performance of a structure in one area may affect other areas in ways that might negate the intended result, such as the seawall at Kamaishi having a negative effect on Ryoishi.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 6	**6.A** Critically read scientific text to understand how a system designed to detect tsunamis follows specific criteria (related to earthquake activity) and constraints (related to signal transmission).	**6.A Obtain, Evaluate, and Communicate Information; Systems and System Models** **When to check for understanding:** In this lesson, students read with a partner about how tsunamis are detected and how warning signals are sent. By detailing the individual parts of the detection system, students have an opportunity to understand how the parts operate in concert with one another, and how specific criteria must be met before a tsunami warning can be sent. **What to look for/listen for:** Using the scientific text, students are able to identify and communicate criteria related to a tsunami detection and warning system (e.g., types of earthquakes and wave movement that trigger the system) and also constraints to the system (e.g., related to signal transmission and maintenance and battery life of sensors).
Lesson 7	**7.A** Integrate written text with multimedia displays of tsunami warning and preparedness systems to clarify additional ways communities at-risk of tsunami can mitigate potential future effects. **7.B** Evaluate communication systems, using a systematic process and agreed-upon criteria and constraints, to determine how well the system (structure) communicates with stakeholders (function).	**7.A Obtaining, Evaluating, and Communicating Information; Systems and System Models** **When to check for understanding:** On day 1, using Part 3 of *Community Stakeholders*. **What to look for/listen for:** Look for clearly identified stakeholders with particular needs for emergency communication, and then look for corresponding criteria and constraints to address those needs. **7.B Arguing from Evidence; Structure and Function** **When to check for understanding:** On day 2, when students complete *Evaluation Matrix* in small groups and then as a class. What to look for/listen for: Listen for agreement about what their assigned communication solution does well and its limitations. Across all groups and as a whole class, listen for ideas about how some communication solutions meet some criteria very well, while others meet other criteria well. The purpose of this work is to better understand how combining multiple forms of communication can address multiple stakeholder needs.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 8	**8.A** Use digital tools and/or mathematical concepts to integrate and synthesize information to compare the reliability of emergency communication systems.	**8.A Mathematics and Computational Thinking: Obtaining, Evaluating, and Communicating Information; Systems and System Models** **When to check for understanding:** As small groups share their ideas on Obtaining Information Notetaking Guide and during the Building Understandings Discussion. **What to look/listen xfor:** • Ideas of how technologies have changed over time, but some technologies are still used today to alert people in a hazard. • Ideas about how technologies use different systems for communication. ◦ wired versus wireless systems ◦ broadcast mechanisms to each individual household versus across an entire area • Ideas for why some signals (i.e. digital) are more reliable than others. • Ideas for what causes some communication technologies to be limited in their ability to warn people.
Lesson 9	**9.A** Construct a system model to represent the interactions of subsystems designed to detect, warn communities, and reduce damage from a tsunami hazard.	**9.A Developing and Using Models; System and System Models** **When to check for understanding:** During the Consensus Building Discuss with the System Model. **What to look for/listen for:** • Parts of a subsystem work together to achieve a particular function and are connected to other parts of the system. • Subsystems are part of a larger system that interact together to meet the goals of the community.

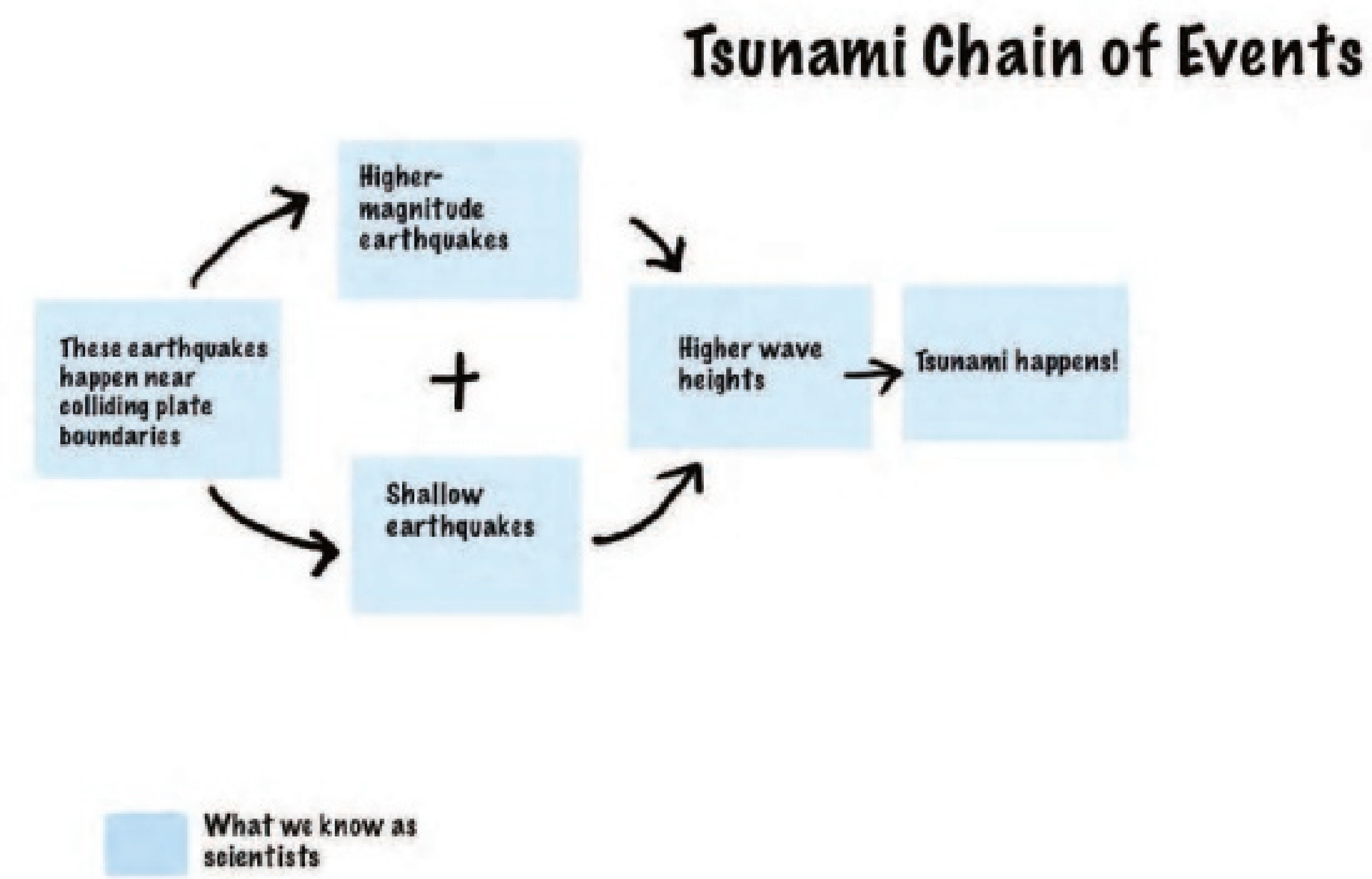
Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 10	**10.A** Use digital tools to analyze patterns in large data sets (maps) of the history of natural hazards in regions and use this information to forecast future risk. **10.B** Critically read scientific texts adapted for classroom use to obtain scientific and technical information related to predicting the locations and severity of a hazard and understanding the response systems designed to mitigate the effects. **10.C** Communicate scientific and technical information in writing and/or oral presentations about a system designed to meet the criteria and constraints for communicating with identified stakeholder groups about a natural hazard.	**10.A Mathematics and Computational Thinking; Patterns** **When to check for understanding:** Day 1, as students complete risk analysis on *Assessing Hazard Risk*. What to look for/listen for: • Students identify general regional patterns for different natural hazards. • Students assess their risk for various natural hazards. • Students identify future risks for local hazards. • Students provide a rationale for why communicating with a community at risk for a natural hazard is important. **10.B & 10.C Obtaining, Evaluating, and Communicating Information; Systems and System Models** **When to check for understanding:** Formatively, on days 2 and 3 when students are working on *Determining Stakeholder Needs* and on day 4 as students complete their final project. **What to look for/listen for:** • Students obtain key information about a local hazard, including where it happens, how severe it can be, how long it can last, and what the major impacts are on people and property (ideas developed in Lessons 1–4). • Students consider how the hazard is detected and ways damage can be reduced (ideas developed in Lessons 5–6 & 9). • Students consider criteria and constraints for developing communication and education plans (ideas developed in Lessons 7–10).

How to Build the Tsunami Chain of Events Poster

The Tsunami Chain of Events poster will be a public representation of different aspects of the unit and will help students pull together science and engineering ideas from Lessons 2-9. Use this guidance to build the poster for each lesson. This is only one example for how to build this causal chain.

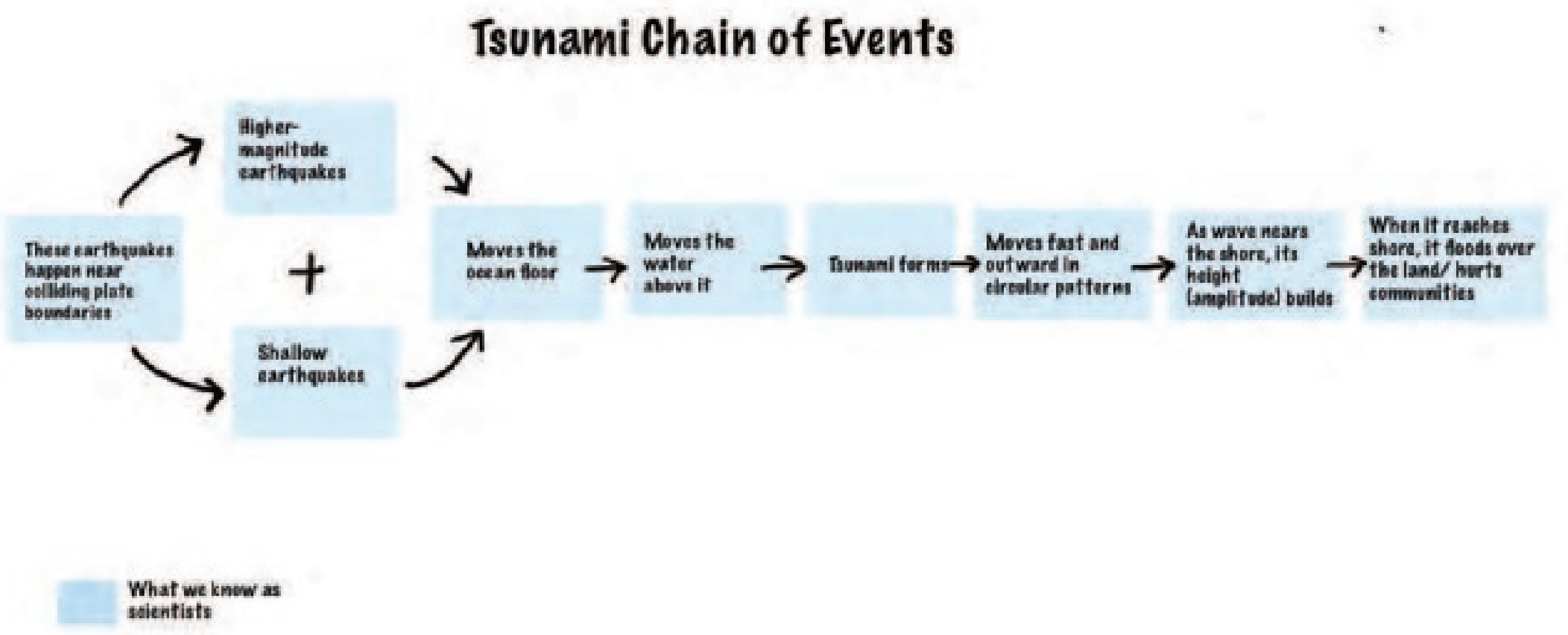
Lesson 2

Build the first causal link between the type of earthquakes that cause tsunamis.



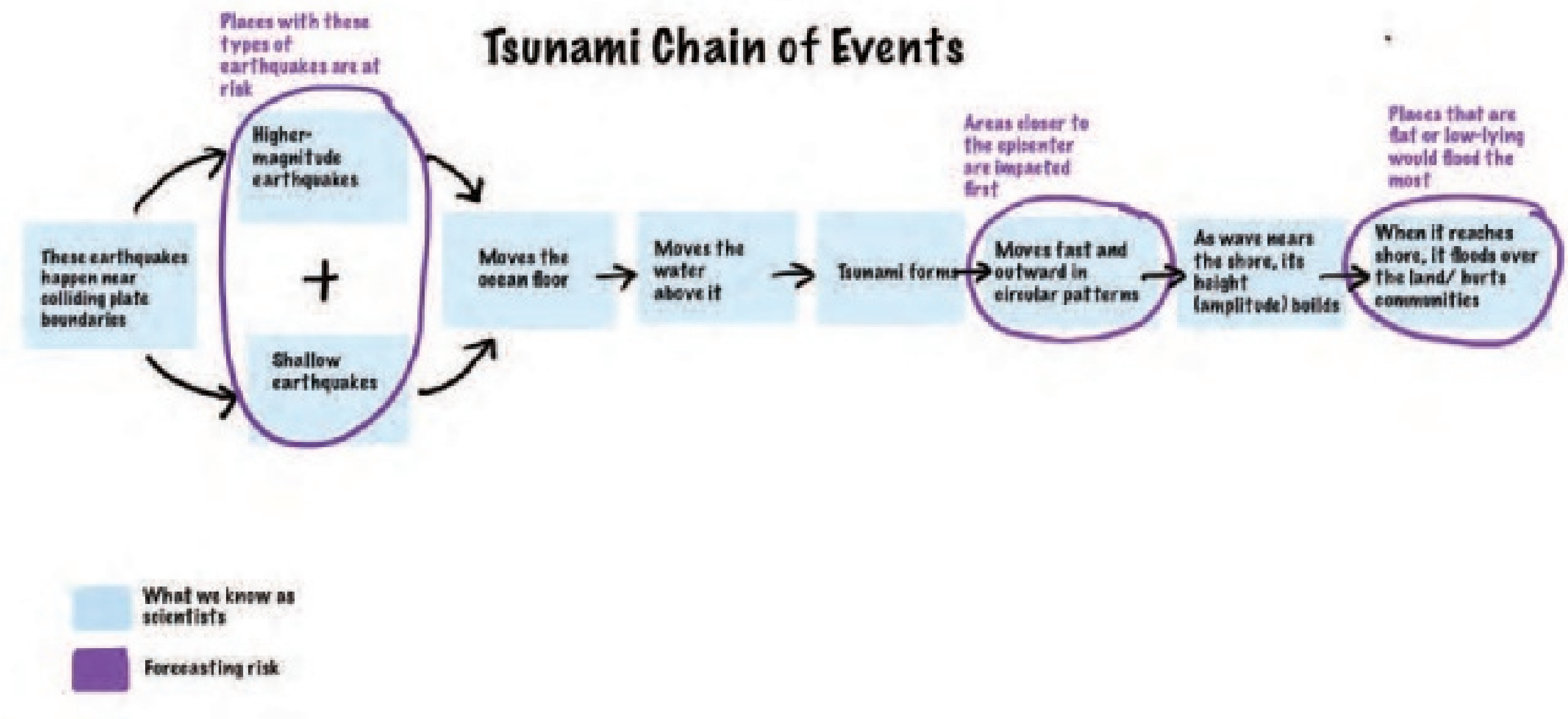
Lesson 3

Add new science ideas to the causal chain. First, remove “Wave Height” and replace it with two new ideas: “Moves the Ocean Floor” and “Moves the Water Above the Ocean Floor.” Exchange “Tsunami happens!” for “Tsunami forms” as now students know how it forms. Then add new ideas for how the tsunami travels and comes onto shore.



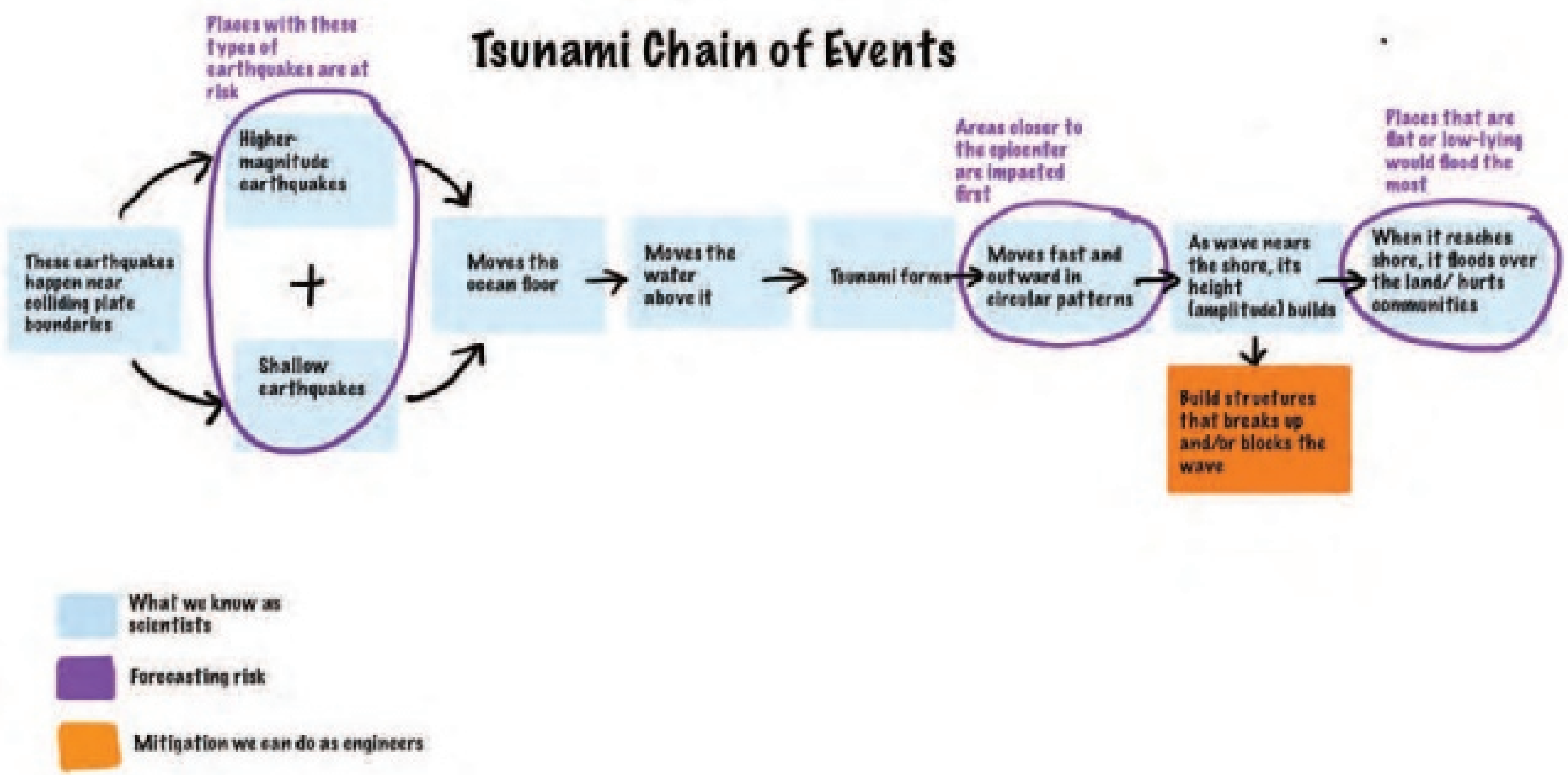
Lesson 4

In a new color, add new ideas about how we can use data to forecast which communities are most at risk of the tsunami hazard.



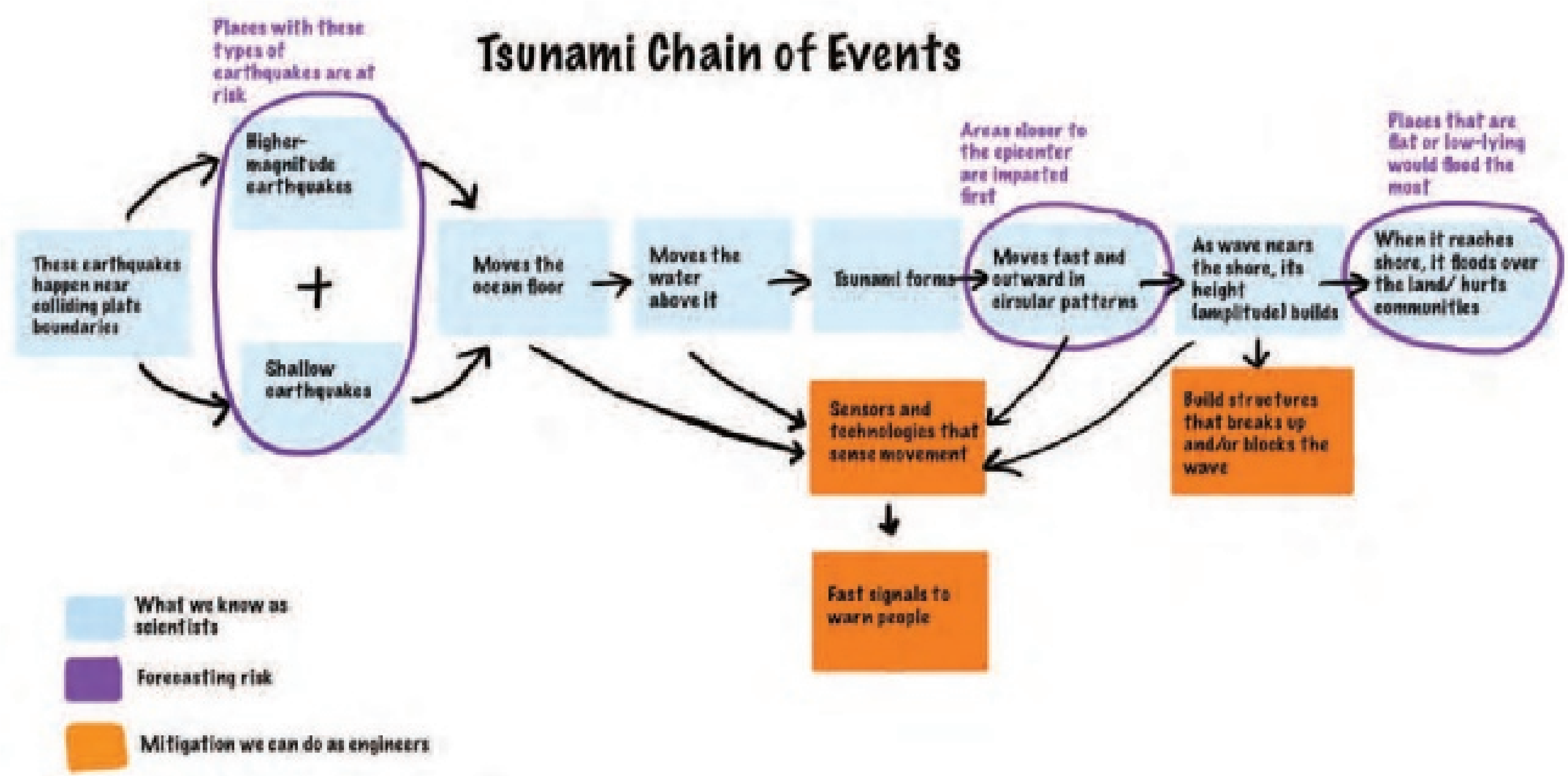
Lesson 5

Start a sticky note in a new color to map on engineering ideas that connect to this Tsunami Chain of Events. Add a new idea about how design solutions are focused on breaking up or blocking the wave.



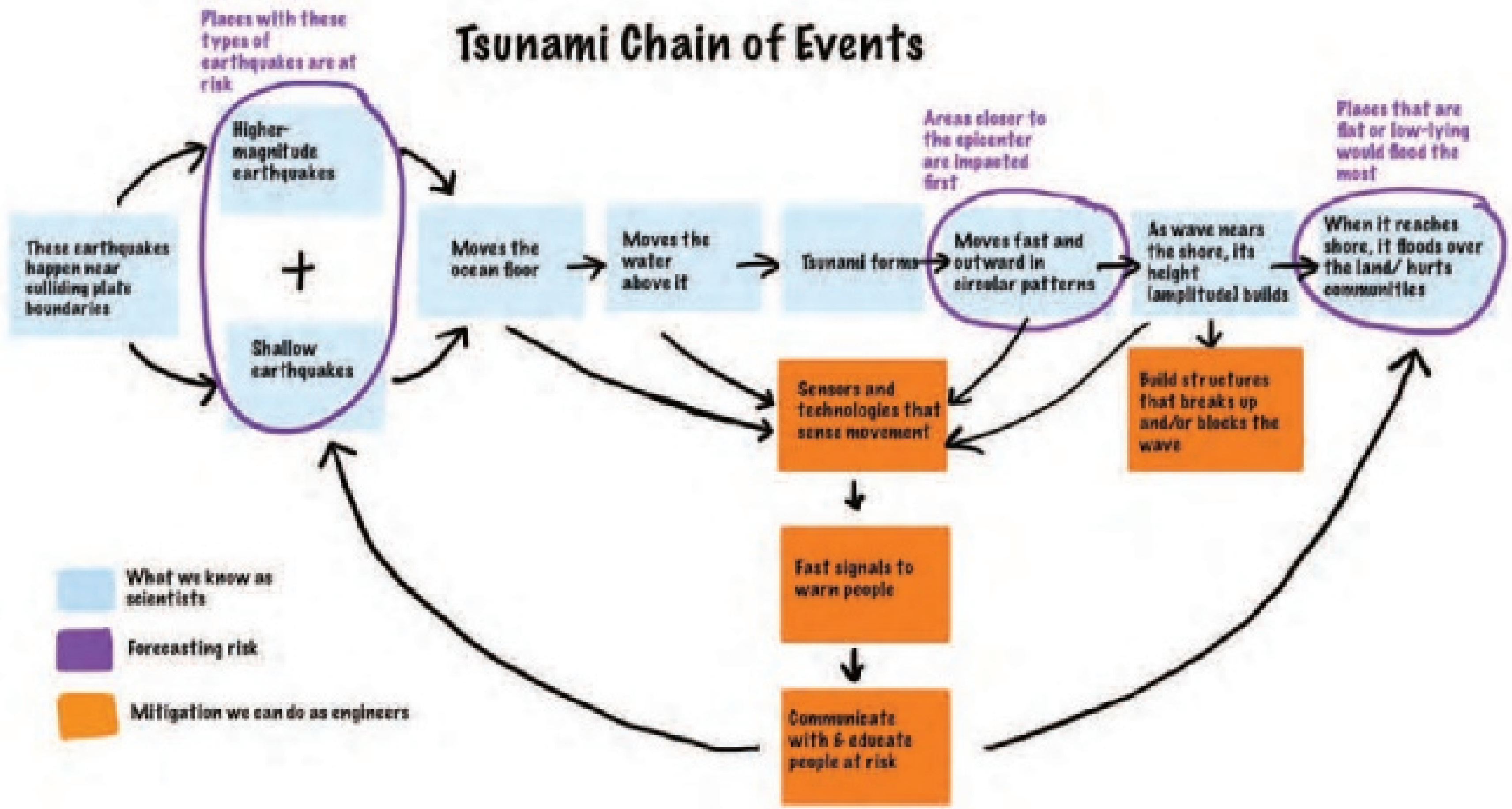
Lesson 6

Add new engineering design ideas for how tsunamis are detected and warning signals sent.



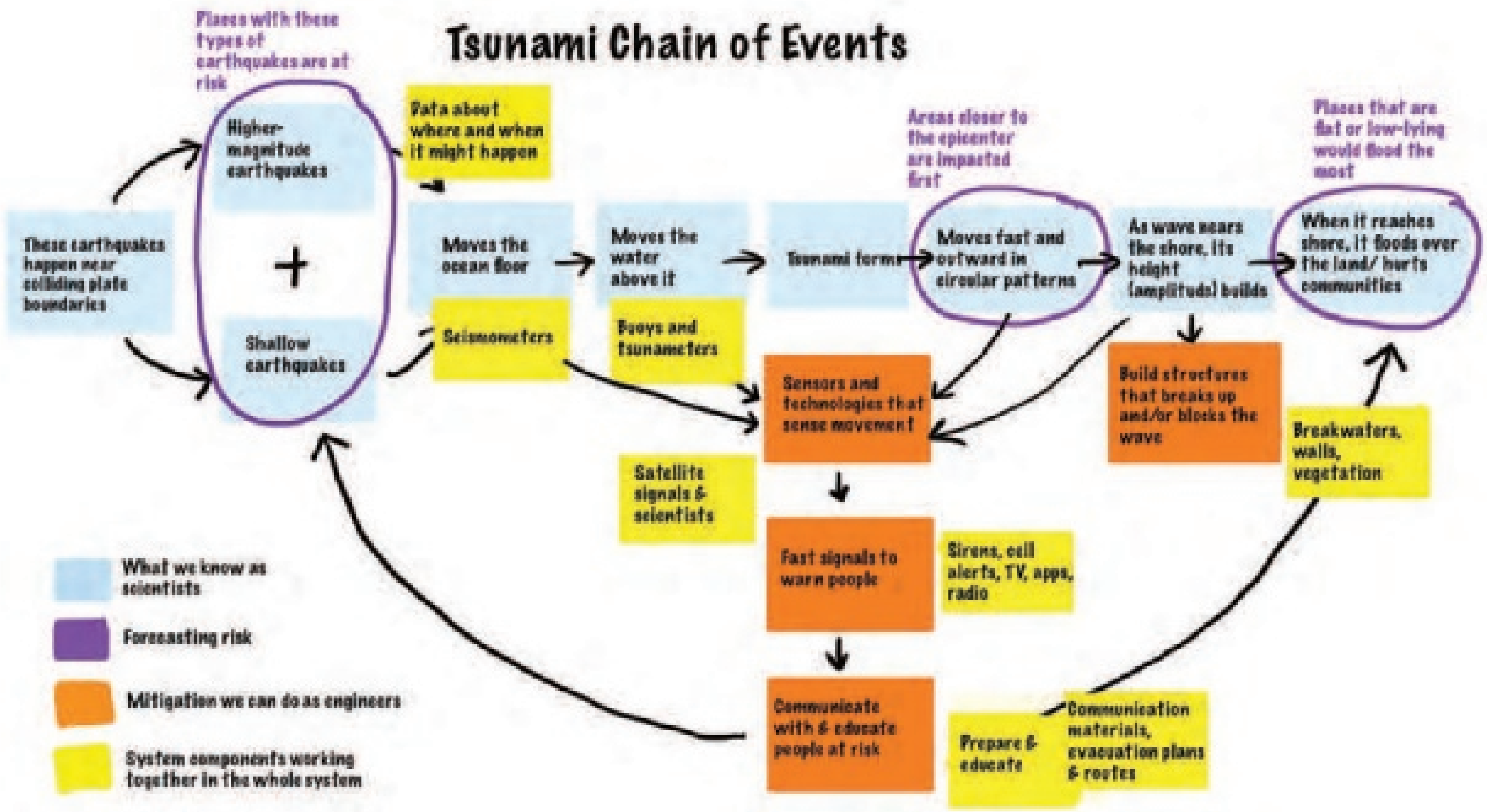
Lesson 7

Add new engineering design ideas for how to communicate warnings during a tsunami, but also how to educate people ahead of time to prepare and respond during a tsunami.



Lesson 9

Add the various design solutions and technologies to the Tsunami Chain of Events to help students see how many different subsystems work together to protect communities.



Name: ______________________ Date: ______________________

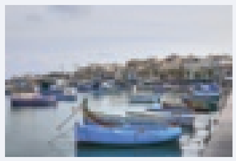
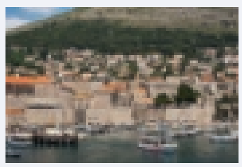
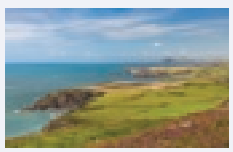
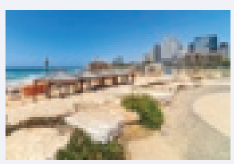
Explaining and Forecasting Tsunami Risk

Part 1. A shallow earthquake of 7.6 magnitude occurs along a colliding plate boundary in the Pacific Ocean. Should authorities immediately send tsunami warning signals to countries that touch the Pacific Ocean? Be sure to explain why you would or would not send the signal to those countries, using the science ideas we figured out about earthquakes and how tsunamis form.

Part 2. When tsunami warnings are issued, they are sent to all the places that could be affected, even though some places are at higher risk than others. The map below shows the location of the earthquake and four places where the tsunami warning will be sent.

2a. Use the map and think about what we know about tsunamis and how they affect places along the coasts. You can take notes and write on this map to show your thinking.

2b. Use the descriptions of each location to rate which places are most at risk for damage to people and property by this tsunami, and how quickly each place will be impacted.

Location and description	Image of location	**Risk for damage** Rank the places by their risk for damage to people and property. *(1 highest - 4 lowest)*	**How quickly impacted** Rank the places by how quickly they will be impacted by the tsunami. *(1 first - 4 last)*
Place A: This is a busy fishing community on the coast. It is flat and right on the water's edge with lots of boats and businesses.			
Place B: This is a large city near the ocean. Most homes and buildings are in the higher elevations of the hills nearby.			
Place C: This is a rural area with not many people along a hilly coast.			
Place D: This is a popular tourist town with hotels on the flat beach and lots of people.			

2c. Based on your rankings in the table, which place do you predict would need to take action the fastest to protect people and property from this tsunami? Explain your choice, considering both the time to impact and possible risk of damage.

Part 3. Using what we understand about forecasting which types of places and communities are most at risk for damage from tsunamis, let's think about the coast of Japan. The map below shows an area called Fudai. This is a hilly region, and the darker areas on the map mean there is a steep incline and higher elevation, while the lighter areas are lower elevations or flatter.

If Japan has limited resources for the next year to help keep people and property safe from tsunami damage, which part of the coast would you predict would be most at risk and prioritize sending resources to? Circle that area on the map and then explain your reasoning.

Scoring Guidance for Explaining and Forecasting Tsunami Risk

Scoring Guidance: The scoring guidance provided below uses a + and ++ notation that can help you identify different ideas that students should (or could) include in their responses.

- If several of the ideas marked with a + are missing from a student's response, this may indicate the student has not mastered the science ideas or may be struggling to bring those ideas together in a written explanation or model. Additional probing of their thinking can provide insight about whether they are struggling with a science practice, science idea, or both.
- If all or almost all of the ideas marked with a + are present in a student's response, this may indicate the student has mastered the science ideas and is able to use them in a written explanation or explanatory model.
- If the ideas marked with a ++ are present in a student's response, this indicates that they are bringing a deeper understanding of the science ideas or a deeper engagement with the practice to their response. Responses should not be marked off if ideas marked with a ++ are not present in their response.

This assessment can be used to evaluate student progress on the LLPEs. The LLPEs are an integration of elements from the three dimensions, so look for these three aspects working together across the students' explanations.

4.A Apply scientific ideas to construct an explanation for how sudden changes in the ocean floor during an earthquake lead to the formation of a tsunami.

4.B Construct an explanation that includes qualitative relationships between variables (distance to epicenter, shoreline topography) to predict which communities are most at risk for damage as a result of a sudden change.

SEPs	DCIs	CCCs
Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events. Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena. Across the written (or oral) tasks, look for students applying ideas and evidence from Lessons 2 and 3 about: • the characteristics of earthquakes likely to cause tsunamis and why, • the point of formation of the tsunami (e.g., the earthquake epicenter), • distance between the origin and the shoreline, and • the topography of the shoreline and the local communities there. Look for how students apply science ideas to support their explanations. Are there patterns in science ideas present or missing from all students' explanations? Students may also bring evidence from the classroom or their experiences to bolster their explanations.	Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (MS- ESS3.B) The tasks on the assessment require students to use ideas about related geologic forces (e.g., earthquakes) and the formation of tsunamis. Additionally, students weigh the risks of different locations based on distance and topography. Finally, look for students to consider how to plan for future protection along the coast of Fudai, Japan, by using those same ideas.	Stability might be disturbed either by sudden events or gradual changes that accumulate over time. The primary crosscutting concept lens on this assessment is that of stability and change, and specifically, how a sudden event can disturb the stability of a region. Look for students to include ideas about which communities are most at risk for a tsunami, particularly as it relates to how quickly they must respond and why.

Optional Student Choice: Allow your students to choose the modality for communicating their thinking. They can explain the phenomenon through written explanation or orally. Guidance is provided based upon a written explanation; however, these same ideas could be communicated orally.

Part 1. A shallow earthquake of 7.6 magnitude occurs along a colliding plate boundary in the Pacific Ocean. Should authorities immediately send tsunami warning signals to countries that touch the Pacific Ocean? Be sure to explain why you would or would not send the signal to those countries, using the science ideas we figured out about earthquakes and how tsunamis form.

Student responses should include:

+ A claim responding to the question, such as: The tsunami warning should be sent out because the types of earthquakes that tend to cause tsunamis are shallow and occur along a colliding plate boundary.

+ An explanatory chain of events that links the type of earthquake to how a tsunami forms, including:

+ When an underwater earthquake at a colliding plate boundary occurs, the ocean floor physically moves, which causes the water above it to move. This movement causes a wave to form in the ocean water above where the earthquake happens. As the wave approaches land and the depth of the ocean decreases, the height of the wave increases. When this large wave reaches the shore, it spreads out onto the land farther than a typical wave would. The bigger the movement of the ocean floor, the bigger the wave that results.

+ These shallow and strong earthquakes tend to cause tsunamis because they can cause greater movement in the ocean floor.

Part 2. When tsunami warnings are issued, they are sent to all the places that could be affected even though some places are at higher risk than others. The map below shows the location of the earthquake and four places where the tsunami warning will be sent.

2a. Use the map and think about what we know about tsunamis and how they affect places along the coasts. You can take notes and write on this map to show your thinking.

2b. Use the descriptions of each location to rate which places are most at risk for damage to people and property by this tsunami, and how quickly each place will be impacted.

There are multiple ways a student could complete the table below. Student responses should be consistent with the following ideas:

+ The higher the elevation of a location or farther from the shoreline, the less likely the waves will reach that location with high impact.

+ Place D and Place A should rank higher risk than Place B and Place C based on elevation and the likelihood of people and property damage at that location.

+ The places closer to the earthquake will be impacted more quickly by the tsunami.

+ Ideal response order is Place D or Place C, Place B, Place A.

+ Damage can be damage to property, or people, or both.

Location and description	Risk for damage	How quickly impacted
	Rank the places by their risk for damage to people and property. *(1 highest - 4 lowest)*	Rank the places by how quickly they will be impacted by the tsunami. *(1 first - 4 last)*
Place A: This is a busy fishing community on the coast. It is flat and right on the water's edge with lots of boats and businesses.	*2*	*4*
Place B: This is a larger city near the ocean. Most homes and buildings are in the higher elevations of the hills nearby.	*3 or 4*	*3*
Place C: This is a rural area with not many people along a hilly coast.	*3 or 4*	*1 or 2*
Place D: This is a popular tourist town with hotels on the flat beach and lots of people.	*1*	*1 or 2*

2c. Based on your rankings in the table, which place do you predict would need to take action the fastest to protect people and property from this tsunami? Explain your choice, considering both the time to impact and possible risk of damage.

Student responses will vary, but their reasoning should include the following key ideas:

+ The place that is closest to the earthquake location will have the least amount of warning time and therefore the least amount of time to evacuate and put protective measures in place.

+ The place with low elevation (or flatter, near to water) and high people activity is likely to experience damage to both people and the surrounding property.

+ Ideal student response: Place D would need to take action the fastest to protect people and property because it is flat and near the water, and lots of people are there. Place A has more warning time to evacuate people and secure property. Place B has lots of people, but they have more warning time, and the homes are higher in elevation. Place C doesn't have many people so fewer people could be injured.

Part 3. Using what we understand about forecasting which types of places and communities are most at risk for damage from tsunamis, let's think about the coast of Japan. The map below shows an area called Fudai. This is a hilly region, and the darker areas on the map mean there is a steep incline and higher elevation, while the lighter areas are lower elevations or flatter.

If Japan has limited resources for the next year to help keep people and property safe from tsunami damage, which part of the coast would you predict would be most at risk and prioritize sending resources to? Circle that area on the map and then explain your reasoning.

Student responses will vary, but their reasoning should include the following key ideas:

+ We need to put tsunami-protecting resources in places that are low, flat, and have people and property, but not in places that are mountainous and where the population isn't at the shore.

+ An ideal student response: We should put resources into protecting the part of the coast where the river goes into the ocean. The area inland from there is flat and has lots of people, so there is a high risk to people and property during a tsunami. There are also people to the east of the town, by the observation deck. We do not need to send resources to protect that part of the coast, though, because the people and property are up on a cliff and a tsunami wouldn't reach them.

Completed Decision Matrix

Evaluating the solution against our criterion and constraints:

Solution	Criterion Break waves	Constraint 1 Impact on boats	Constraint 2 Impact on marine life	Constraint 3 Impact on ocean view	Constraint 4 Cost	Constraint 5 Time to build	Constraint 6 Maintenance
A. **Wall-** Seawall	3	5	4	1	3	3	3
B. **Wall-** Levee or sea dike	2	5	3	4	5	4	4
C. **Wall-** Recurved wall	5	5	4	2	2	3	3
D. **Breakwater-** Tetrapod	4	3	2	4	4	4	3
E. **Breakwater-** Rock armor	3	3	3	4	5	4	3
F. **Breakwater-** Submerged breakwater	4	4	2	5	1	2	4
G. **Natural vegetation-** Mangrove forest	3	5	5	4	4	1	4
H. **Natural vegetation-** Pine forest	2	5	5	3	5	1	4

Questions for Solution Reasoning

Students may be considering different existing tsunami-mitigating solutions as “the best” for a variety of reasons. Here is a set of generic questions to push students’ thinking:

- *What makes this solution better or worse than the others?*
    - *Does this solution meet our criterion? How well does it meet our constraints?*
    - *Is this solution feasible for the people of Ryoishi?*
- *Are there criteria and constraints that you feel are especially important in choosing the best solution for Ryoishi? Why are the ratings for those criterion or constraints more important to consider than others?*
    - *Do you think the criterion and constraints you are valuing would also be the ones most valued by the people of Ryoishi?*
    - *What constraints would be important for Ryoishi, and how well does this solution meet those constraints?*
- *When thinking about certain criteria and constraints being more important than others for Ryoishi, does that change your decision about the best solution for that community?*

Questions about specific design solutions:

This table shows some ways to help students evaluate choices for specific solutions. The questions below can help them compare and evaluate the solutions and develop an argument using evidence to support which solution best meets the relevant criteria and constraints. This table is not exhaustive; it gives examples of what sorts of questions might lead students to consider alternatives to their chosen solution.

Design solution	Student considerations	Questions to extend students’ thinking	Target observations or ideas
Seawall	Ocean views may not be important to the residents. Rated higher on other things than most other solutions.	We think the view may not be important, but are any other criteria or constraints more important than others?	Seawalls are rated lower than other solutions in the ability to break waves. The waves at Ryoishi were high, so Ryoishi may need a design that can break waves more effectively.
			Reevaluate the criterion and constraints based upon Ryoishi’s needs.
Levee or sea dike	Highest-rated overall. Doesn’t cost much compared to the others. Doesn’t require much maintenance.	Even though this is the highest-rated solution overall, Ryoishi experienced higher-than-predicted waves during the 2011 tsunami. Does this solution meet the potential wave heights of future tsunamis that might reach Ryoishi?	Reevaluate the notes considering Ryoishi’s needs, because a levee/sea dike performs worse with higher waves.
		How well does a levee or sea dike meet the need to break up the waves?	Determine that a levee/sea dike does not meet the criteria for the community’s needs as well as other solutions do.

Design solution	Student considerations	Questions to extend students' thinking	Target observations or ideas
Recurved wall	Highest-rated in ability to break waves and in having a low impact on boats.	In the overall ratings, it is the same as a tetrapod. Why would a recurved wall be better than a tetrapod? What makes it better at meeting the criterion and constraints for Ryoishi?	Assess which criteria and constraints to prioritize, and whether the community of Ryoishi would also value them.
		Do you think anything in the description that you read would make a recurved wall less appealing to Ryoishi's residents?	Reevaluate the description, because the cost is high and most recurved walls block marine life's access to the beach. Consider the needs of the community.
Tetrapods	Sounds like it looks cool. Only one rating for tetrapods was below a 3.	Its rating for impact on marine life is lower than most of the other solutions. Is that rating important for Ryoishi's fishermen?	Reevaluate the constraints that are important for the community, because the health of the environment and having easy paths for boats to access fish are both important for fishermen.
		Are some criteria or constraints more important than others? Although tetrapods several 4 ratings, does that make it better than another solution overall? Should we value certain criteria or constraints over others?	Revisit the other constraints to determine whether some should have higher priority than others.
Rock armor	Breaks waves better than a levee/sea dike, and has a decent score on ocean view and cost.	Do other solutions score better than rock armor on certain criteria or constraints that Ryoishi may value?	Reconsider the criterion and constraints, because rock armor does not meet the criterion as well as other designs.
Submerged breakwater	Does OK breaking waves and keeps the ocean view. Doesn't have a high impact on boats and doesn't require a ton of maintenance.	A submerged breakwater performs decently on the ability to break waves, but doesn't score as well as most other solutions on impact on marine life. Is that important for the people of Ryoishi?	Reconsider the criteria and constraints based upon the needs of the community, because Ryoishi may need a design that doesn't harm marine life.
		The submerged breakwater scored really well on ocean view. Is that the most important constraint for Ryoishi?	Reconsider the criteria and constraints based upon the needs of the community, because ocean view may not be as important to Ryoishi as it is other communities.

Design solution	Student considerations	Questions to extend students' thinking	Target observations or ideas
Mangrove forest	Scored very highly for low impact on marine life and low impact on boats—very important to the fishermen of Ryoishi. Does OK with wave protection in smaller tsunamis. A natural solution.	How well does a mangrove forest protect against large tsunami waves?	Reevaluate their materials to determine that this solution only works well for small waves.
		What would make a mangrove forest better or worse than the other natural solution, a pine forest?	Reevaluate their materials to determine that mangrove forests cannot grow well in the region, but pine forests can; however, a pine forest does not meet the criteria as well as a mangrove forest.
			Reevaluate the criteria and constraints based upon the needs of the community.
Pine forest	A natural solution that can grow in the area. Very environmentally friendly and doesn't impact boats at all because it's on land. Has a very low cost and is more friendly to marine life than a levee/sea dike.	The pine forest's overall score is tied with rock armor. What makes it better or worse than rock armor?	Compare the criteria and constraints of both solutions with the needs of the community.
		What would make this solution better or worse than a mangrove forest?	Reevaluate the description to determine that mangrove forests cannot grow well in the region, but pine forests can; however, a pine forest does not meet the criteria as well as a mangrove forest.

Name: ______________________ Date: ______________

Engineering Self-Assessment

Read each statement and circle how well you did it:

1 - I need to work on this, or I did not do it.

2 - OK—this is an area that you did well on but could improve your work.

3 - GREAT—this is an area that you really did well on.

In this unit, I. . .	Student	Teacher
identified a set of criteria for a given problem.	1 2 3	1 2 3
identified a set of constraints for a given problem in a given context.	1 2 3	1 2 3
considered positive and negative consequences on people when solving a given problem.	1 2 3	1 2 3
considered positive and negative consequences on the environment when solving a given problem.	1 2 3	1 2 3
considered how impacts on people and the environment could limit possible solutions.	1 2 3	1 2 3
used a defined process to evaluate a design solution with respect to both criteria and constraints.	1 2 3	1 2 3
prioritized criteria and constraints when evaluating design solutions and identified what tradeoffs are made when choosing one design solution over another.	1 2 3	1 2 3
identified and considered potential stakeholder needs related to each part of the design solution.	1 2 3	1 2 3

Explain your ratings and how you think you may change or improve your engineering work in the future:

Engineering Self-Assessment Rubric

Directions: This rubric provides more scoring detail to help give feedback to students using *Engineering Self-Assessment*. The descriptions in the rubric below offer more detailed descriptions of what a "3" versus a "2" versus a "1" score might look like on the different self-assessment components.

Category	Beginning 1	Developing 2	Mastery 3
Identify criteria	Describe a given problem.	Describe some criteria for an effective design solution.	Document a complete set of criteria for an effective solution focused on a given problem.
Identify constraints	Describe the context where a given problem is relevant.	Describe some constraints for a given context.	Document a complete set of constraints for an effective solution to a given problem in a given context.
Consequences to people of a design solution	Share ideas for how the problem might impact people.	Describe some of the possible positive and/or negative impacts on people in this problem context.	Document positive and negative consequences on people of solving a given problem, including how some solutions positively impact some while negatively impacting others.
Environmental consequences of a design solution	Share ideas for how the problem might impact the environment.	Describe some of the possible positive and/or negative impacts on the environment in this problem context.	Clearly document positive and negative consequences on the environment of solving a given problem, including how some solutions positively impact parts of the environment while negatively impacting other parts.
Impacts on people and the environment limit possible solutions	Share ideas about how impacts on people and the environment might influence a possible design solution.	Identify and describe how impacts on people and/or the environment might serve as a constraint to possible solutions.	Clearly document how specific impacts on people and/or the environment might serve as a constraint for potential solutions, but these impacts might be prioritized when choosing one solution over another.
Using a defined process to evaluate design solutions	Design solution was **not** evaluated using a design matrix.	Design solution was evaluated using a design matrix that includes **some** criteria and constraints or **non-specific** criteria and constraints.	Design solution was evaluated using a design testing matrix that included **all specific** criteria and constraints. Design solution evaluation includes a full analysis of how well the design will detect, warn, or communicate to people and/or reduce the impact of a tsunami wave.

Category	Beginning 1	Developing 2	Mastery 3
Prioritizing criteria and constraints and identifying tradeoffs	The criteria and constraints are **not** prioritized.	The criteria and constraints are prioritized in order to produce or evaluate a design solution. There is a rationale for the priority order.	The criteria and constraints are prioritized and weighted in order to produce or evaluate a design solution for use in a particular context. Tradeoffs are identified. There is a clearly stated rationale, including science ideas for the priority and weighing decisions.
Identify and consider the needs of stakeholders	Stakeholders have not been identified, or their needs have not been included in the evaluation process.	Some relevant stakeholders and their needs have been identified and partially included in the evaluation process.	Relevant stakeholders and their needs have been considered and incorporated into the evaluation process.

Hazard Communication Project Choice and Platform Information

Project Choice Considerations

Below is a list of considerations for each type of project. Think about these options when allowing your students to select their project choice. Consider your devices available, space in your room, and other factors, such as how students are expected to turn in work. Remove any options from the student handout if they do not fall in line with your privacy policies or student expectations. Student privacy policies vary widely by school and district. Remember to check with your student privacy school policies before approving the use of any specific projects, sites, or apps.

Project type	Considerations
Posters, Brochures, Flyers, Billboards, Children's Book, Comic Strip	• This more traditional option can be done without any digital tools • Paper can easily be lost by students without a paper management system • Can be done on a variety of digital platforms as well • Different digital tools have different sharing settings and capabilities
Commercials, Podcasts, Newscasts, Mock Social Media, Jingles, Songs	• Some recording options are easier than others—help students find an appropriate tool based upon their individual strengths • Make sure all students have permission to be recorded if their voices or bodies end up on the project • Recorded items could be shared—check student privacy policies
Infographic, Newspaper Article	• Are more susceptible to copying and pasting • Might require additional sources of data
Website	• Can be done on a variety of platforms • Check sharing settings of any blogs or sites • Check student privacy policies before any sites go live
App	• Could be a draft on paper or an actual app • If students create an actual app, monitor student privacy • Creating an actual app could take more time than a more traditional project format

Potential Project Platforms

Below is an alphabetical list of some widely used project creation platforms along with their pros and cons. This list is not all-inclusive, but it will give an idea of different ways students can demonstrate their learning. Each platform is linked to the Commonsense.org review when available, if you would like further information regarding the digital tool.

Platform	Use	Pros	Cons
Adobe Spark	Adobe Suite has many different applications and uses. Can be used to create the following: • Billboards • Flyers • Posters • Charts • Websites • Children's books • Comic strips • Mock apps and social media pages	• Very versatile • Many different presentation options • Looks professional • Web-based platform	• Meant for ages 13 and up if no school login is available • Check sharing settings against school policies • Choices could be overwhelming to some students • Steeper learning curve than Google platforms
Anamaker	Versatile creation tool Can be used to create the following: • Posters • Billboards • Pages in children's books • Flyers • Social media pages • Commercials • YouTube videos • Instagram stories • WhatsApp stories	• Web-based platform • Easy to navigate • Create a variety of projects	• Check sharing settings against school policies • Only lite version is free with limited features • Need to create login or use Google credentials
Anchor	Simplistic platform used to make podcasts	• Record an actual podcast • Has basic editing functions • Up to 10 can work together on the same podcast • Can import music	• Available on Androids, iPhones, and web based application • Must be 13 years old • Can only share publicly

Platform	Use	Pros	Cons
Auxy studio	Music creation app Can be used to create the following: • Songs • Jingles • Podcasts	• A variety of tools to create sounds, beats, and loop tracks • Can create current-age sounding music	• Only available as an iOS app • Has features to upload content to social media
Book Creator	Digital storybook creation website	• Free to register for the site • Large selection of graphics to choose from • Easy to use • Sharing options available	• Some features require a subscription upgrade • Compatible only with iPad and Chrome
Clips	Video recording and sharing platform Can be used to create the following: • Commercials • YouTube videos • Newscasts • Children's books read aloud • Mock TikTok	• Captions are available in many different languages • Can be easier to use than GarageBand • Can upload any videos or pictures on your iOS device for use	• Requires an Apple ID login • Very easy for students to share work—check with student privacy policies • Only available with iOS apps • No classroom-specific templates
Flipgrid	Video recording and sharing platform Can be used to create the following: • Commercials • YouTube videos • Newscasts	• Teacher can create an account and control accessibility, sharing features • Single videos can be recorded • Web-based platform	• Not a lot of editing is available with Flipgrid • Teacher has to create a class site and distribute codes to students
GarageBand	Video recording and sharing platform Can be used to create the following: • Podcasts • Songs	• Various audio editing options • Easy to trim music and audio files	• Can be too complex for some students • Learning curve involved • Some background music has to be purchased • Only available on iOS

Platform	Use	Pros	Cons
Google Docs	More traditional word processing application Can be used to create the following: • Articles • Create comic strip layout to print and draw • Write lyrics to a song • Write up a script • Brochures	• Easy to use • Familiar to most students • Web-based platform • Different layouts exist on the Google suite for a variety of purposes • Can be shared with select stakeholders	• Limited ability to reformat pages • Charts can be hard to layout or organize in different ways • Text direction cannot be changed
Google Drawings	Online drawing tool similar to Microsoft paint application Can be used to create the following: • Billboards • Posters • Charts • Flyers • Any other simplistic visual product	• Easy to use • Integrates with other Google applications • Can import images from search features • Can be shared with select stakeholders	• Has limited tools to utilize • No pre-made templates or layouts • Simplistic look vs. a more sophisticated look achieved with Adobe tools
Google Slides	Tool traditionally used to create presentations Can be used to create the following: • Posters • Billboards • Pages in children's books • Flyers • Social media pages	• Easy to use • Familiar to most students • Web-based platform • Multiple premade layouts and color schemes • Can be shared with select stakeholders	• Hard to create detailed drawings • Harder to export as a JPG if needed
Movie	Tool traditionally used for creating and editing videos Can be used to create the following: • Commercials • YouTube videos • Newscasts • Children's books read aloud • Mock TikTok	• Easy to use • Templates and layouts available • Allows for voice overs • Would need a webcam or camera to create mock TikTok	• Available only on iOS platforms • Limited video editing available

Platform	Use	Pros	Cons
Keynote	Tool traditionally used to create presentations Can be used to create the following: • Posters • Billboards • Pages in children's books • Flyers • Social media pages	• Similar to Google slides • Has more features than Google slides • Basic graphics and layouts available • Voiceovers can be added but are more difficult to integrate	• Available only on iOS platforms • Harder to share with classmates and stakeholders
Microsoft Powerpoint	Tool traditionally used to create presentations Can be used to create the following: • Posters • Billboards • Pages in children's books • Flyers • Social media pages	• Similar to Google slides • Has more features than Google slides • Basic graphics and layouts available • Easy to record and play audio over slides	• Harder to share with classmates and stakeholders • School needs Microsoft Office license to utilize • Does not function as well on iOS devices
Pikto chart	Application typically used to create infographics Can be used to create the following: • Infographics • Posters • Flyers • Billboards	• Students can create professional looking graphs and charts • Templates available • Controlled sharing settings available	• Basic features are limited • Does require a free login
Pixton	Comic creation tool	• Easy to use • Has a lot of graphics to choose from • Can create multiple frames • Many options to share work • Available for Android and iOS	• Mostly human figures—upgrade is needed for additional characters • Teacher has to create a class site and distribute codes to students

Platform	Use	Pros	Cons
Powtoon	Tool traditionally used to create presentations Can be used to create the following: • Posters • Pages in children's books • Flyers • Commercials • YouTube videos • Newscasts	• Many different presentation formats • Premade templates • Many different ways to share the product • A multitude of images and videos are available to use • Easy to use • May need recording device if doing a newscast • Can upload and use your own videos • Web-based platform	• Students can add pictures and videos from a variety of sources, including Flickr, which may not be supported by some schools • Check with student privacy policies if students use images or likenesses due to the shareability of Powtoon
QuickTime	Traditional recording, video editing, and playback software included on Mac devices. Can be used to create the following: • Commercials • YouTube videos • Newscasts • Children's books read aloud • Mock TikTok • Podcasts • Songs	• Easy to use • Can upload or modify any videos • Can be used to record audio	• Microsoft version is no longer supported by Apple • Comes with macOS • Does not have a lot of standard templates or music to utilize
Scratch or ScratchJr	Coding application designed to introduce K–8 students to basic coding language Can be used to create the following: • Animated commercials • Interactive children's stories	• Unique way to create a children's book or commercial • Interesting for students who like to code • Can easily be shared with others via email • ScratchJr is very simplistic—easy to use	• Involves a coding learning curve for some students • Can take more time than other options • All text—no voice-over option • Only available on Chrome, iOS, and Amazon

Name: ____________________ Date: ____________________

Assessing Hazard Risk

1. Determine the general pattern for places that are most at risk for each hazard and how at risk your local community is. Use this key to circle the risk for your local community. Very High Risk (VH); High Risk (H); Moderate Risk (M); Low Risk (L); Little to no risk (NR)

Hazard	Describe the general patterns of risk for this natural hazard in the United States.	Level of risk of this hazard for my community	Notes: My experiences with or wonderings about this hazard
Wildfires		VH H M L NR	
Thunderstorms		VH H M L NR	
Winter Storms		VH H M L NR	
Hurricanes		VH H M L NR	
Extreme Heat		VH H M L NR	
Droughts		VH H M L NR	
Coastal Flooding		VH H M L NR	
River Flooding		VH H M L NR	
Earthquakes		VH H M L NR	

2. Explain which hazard you and your community are at most risk. Use evidence from the maps to support your explanation. If there are additional sources of data that you would want to study, include those ideas in your explanation.

3. Identify a natural hazard that impacts you in some way or that you feel would be important to investigate. It could be one that affects your community, a community that you are familiar with, or a place you have always wanted to visit. Use evidence from the maps to identify the area at risk for this hazard and explain why the communities in that area need to understand and prepare for this natural hazard.

Potential Accompanying Standards

Different projects will lend themselves to potential standards for ELA, Mathematics, and Technology based upon their modality and presentation style. Use the tables below to help develop any accompanying rubrics or materials for students in your classroom. Consider discussing these standards with colleagues who may also teach these content areas to develop a cross-curricular connection. The list below is not exhaustive and are suggestions, not recommendations. Some states that do not use Common Core standards have similar areas such as reading, writing, speaking, and listening that can be cross-referenced. Consult your own state adopted standards when deciding on any potential additional standards.

ELA Common Core College and Career Readiness Standards Connections

Consider the following Common Core ELA standards for student use. Many standards are applicable to more than one project. Depending on state, this alignment may vary. Consult your state standards documents for further guidance.

Standard	Indicator	Statement
Reading		
Integration of Knowledge and Ideas	CCSS.ELA-LITERACY.CCRA.R.7	Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.
Writing		
Text Types and Purposes	CCSS.ELA-LITERACY.CCRA.W.2	Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.
Production and Distribution of Writing	CCSS.ELA-LITERACY.CCRA.W.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
Production and Distribution of Writing	CCSS.ELA-LITERACY.CCRA.W.6	Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.
Research to Build and Present Knowledge	CCSS.ELA-LITERACY.CCRA.W.8	Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.
Speaking and Listening		
Comprehension and Collaboration	CCSS.ELA-LITERACY.CCRA.SL.2	Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

Standard	Indicator	Statement
Presentation of Knowledge and Ideas	CCSS.ELA-LITERACY.CCRA.SL.4	Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.
Presentation of Knowledge and Ideas	CCSS.ELA-LITERACY.CCRA.SL.5	Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

ISTE Standard Connection

Consider the following technology standards for student use. Many ISTE standards are applicable to more than one project. Depending on the state, this alignment may vary. Consult your state standards documents for further guidance.

Standard	Indicator	Statement
Knowledge Constructor	3b	Students plan and employ effective research strategies to locate information and other resources for their intellectual or creative pursuits.
Computational Thinker	5b	Students collect data or identify relevant data sets, use digital tools to analyze them, and represent data in various ways to facilitate problem-solving and decision-making.
Creative Communicator	6a	Students choose the appropriate platforms and tools for meeting the desired objectives of their creation or communication.
Creative Communicator	6c	Students communicate complex ideas clearly and effectively by creating or using a variety of digital objects such as visualizations, models or simulations.
Creative Communicator	6d	Students publish or present content that customizes the message and medium for their intended audiences.
Global Collaborator	7a	Students use digital tools to connect with learners from a variety of backgrounds and cultures, engaging with them in ways that broaden mutual understanding and learning.
Global Collaborator	7c	Students contribute constructively to project teams, assuming various roles and responsibilities to work effectively toward a common goal.

Teacher Instructions for Peer Feedback

There will be times when helping students give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback. We suggest that peer review happen at least once, but preferably two times, per unit. This document provides options on how to support this in your classroom. It also includes student materials to support giving and receiving feedback, along with self-assessment rubrics with which students can reflect on their experience with the process.

When is a good time to facilitate peer review?

Peer feedback is most useful when complex and diverse ideas are visible in student work and not all work is the same. Student models or explanations are good opportunities to use a peer feedback protocol. They do not need to be final pieces of student work; rather, peer feedback will be more valuable to students if they have time to revise their work after receiving the feedback. It should be a formative, not summative, type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities so they can use these experiences as evidence for their feedback.

What classroom structures can I use for peer review?

Below are three examples of ways to organize peer review in your classroom. You may choose to use all of them as your time or material constraints allow, or you may choose to always use the same structure so your students get familiar with it and become better at it over time.

Sticky Note Peer Review: In this protocol—shared on *Tools for Ambitious Science Teaching*—students use sticky notes to leave questions and comments on posted student work. Time is built in for students to respond to the feedback. Use the self-assessment rubrics in this document at the end of the class period to have students reflect on their experience in this feedback session.

Peer Review with Unit Rubrics: Each unit—and the curriculum overall—has Science and Engineering Practice (SEP)-specific rubrics for teachers to assess student work. You can also use these as a way for students to assess each other's work and give feedback on how to improve. For example, in the first lesson set of Unit 8.2: *How can a sound make something move?* (Sound Waves Unit), students develop models of how objects vibrate to produce sound. We suggest having students use the rubric to give each other specific feedback. You can use this in a gallery walk context or have students exchange models.

Group Review: Ask students to form groups of four and bring their individual models or explanations (or other work) to their group. Review the peer feedback guidelines as a class, giving examples of productive and nonproductive feedback. Then, in pairs, have students provide feedback on the other two pieces of student work. They can use sticky notes or write directly on the work. Make sure to allow time after feedback is exchanged for students to individually revise their models and complete the self-assessment rubrics.

Giving Feedback to Peers

This tool was inspired by the Sticky Note Feedback resource originally developed by Ambitious Science Teaching at: https://ambitiousscienceteaching.org/sticky-note-student-feedback/.

Feedback needs to be specific and actionable.

For feedback to be productive, it needs to be related to science ideas and provide suggestions for improvement.

Here are some examples of productive feedback:

- "Your model shows that the sound source changes position when it is hit. I think you should add detail about how the sound source moves back and forth after it is hit."
- "You said that the drum moves when it makes a sound, but the table doesn't move when it makes a sound. We disagree and suggest reviewing the observation data from the laser investigation."

Here are some examples of nonproductive feedback that does not help other students improve:

- "I like your drawing."
- "Your poster is really pretty."
- "I agree with everything you said."

How to Give Feedback

Your feedback should give ideas for specific changes or additions the person or group can make. Use the sentence starters below if you need help writing feedback.

- "The poster said ____________________. We disagree because ____________________. We think you should change ____________________."
- "I like how you ____________________. It would be more complete if you added ____________________."
- "We agree that ____________________. We think you should add more evidence from the ____________________ investigation."
- "We agree/disagree with your claim that ____________________. However, we do not think the ____________________ (evidence) you used matches your claim."

Receiving Feedback from Peers

The purpose of receiving feedback is to get ideas from your peers about things you might improve or change to make your work more clear, more accurate, or better supported by evidence. It can also help you to communicate your ideas more effectively to others.

When you receive feedback, you should take these steps:

- Read it (or listen to it) carefully. Ask someone else to help you understand it, if necessary.
- Decide if you agree or disagree with the feedback, and say why you agree or disagree.
- Revise your work to address the feedback as needed.

Self-Assessment: Giving Feedback

How well did you give feedback today?

Today, I ...	YES	NO
Gave feedback that was **specific and about science ideas.** **Shared a suggestion** to help improve my peer's work. **Used evidence from** investigations, observations, activities, or readings to support the feedback or suggestions 1 gave.		

One thing I can do better the next time I give feedback is:

Self-Assessment: Receiving Feedback

How well did you receive feedback today?

Today, I ...	YES	NO
Read the feedback I received carefully. **Asked follow-up questions** to better understand the feedback I received. **Said or wrote why I agreed or disagreed** with the feedback. **Revised** my work based on the feedback.		

What is one piece of feedback you received?

What did you add or change to address this feedback?

Obtaining and Communicating Information about Natural Hazards

This assessment can be used to assess student progress on the LLPEs. The LLPEs are an integration of elements from the three dimensions, so look for these three aspects working together across the student explanations. The rubric is designed to integrate aspects of the elements of these dimensions to ensure the task is three-dimensional.

<table>
<tr><td colspan="3">9.B Critically read scientific texts adapted for classroom use to obtain scientific and technical information related to predicting the locations and severity of a hazard and understanding the response systems designed to mitigate the effects.

9.C Communicate scientific and technical information in writing and/or oral presentations about a system designed to meet the criteria and constraints for communicating with identified stakeholder groups about a natural hazard.</td></tr>
<tr><th>SEPs</th><th>DCIs</th><th>CCCs</th></tr>
<tr><td>8.1 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).

8.5 Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations.

In this final summative task, students will apply multiple aspects of SEP 8 Obtaining, Evaluating, and Communicating information. They should:
• identify key science ideas relevant to their chosen hazard,
• cross-check science and technical ideas and evidence across multiple sources,
• integrate data and evidence from multiple forms of media, and
• demonstrate evidence of careful communication of these ideas to an identified stakeholder group.</td><td>ETS1.A: The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

ETS1.B: There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

Students will develop stakeholder criteria and constraints for an effective communication plan and then apply those ideas to their final product. The more precisely they define the criteria and constraints, the more effective their communication plan is likely to be. Scientific principles about the hazard and how the system is designed to prepare, warn, and help people respond will be a key aspect to look for in student products. The rubric below can then be used by students as part of a systematic peer feedback process to evaluate student products for how well they meet criteria and constraints.</td><td>Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.

The primary crosscutting concept lens on this assessment is system and system models. As students develop a communication plan and final product, they will communicate different aspects of a hazard system designed to prepare, warn, and help people respond in a hazard.</td></tr>
</table>

Optional Student Choice: Allow your students to choose the modality to communicate their thinking. Some students may benefit from silent gallery walks with sticky note feedback, small group live presentations, or pre-recorded audio or video presentations.

Category	1	2	3
Obtain information about the natural hazard.	Identifies where the hazard happens and possible damage that can result.	Identifies where the hazard happens, the possible damage that can result, and who could be at risk.	Identifies where the hazard happens, who is at risk, possible damage that might result, and how different locations and populations may be affected differently.
Obtain information about components of a system designed to detect, warn, and reduce damage.	Identifies general information about the detection and warning system, and/or solutions to reduce damage.	Identifies how some of the components of the system work together to detect, warn about, and/or reduce damage to communities.	Identifies in detail the specific components of the system and describes how each component works together to detect, warn, and reduce damage.
Obtain information about community stakeholders criteria and constraints.	Identifies a general group of community stakeholders for the communication plan.	Identifies different stakeholder groups and 1–2 criteria and/or constraints and/or addresses them in the plan.	Identifies different stakeholder groups and clearly outlines criteria and constraints and addresses those in the plan.
Obtain information from reliable sources and evaluate its credibility.	No sources are included.	Sources are included, but little to no information is provided about the credibility of the source.	Sources and evidence of their credibility are included.
Communicate information to stakeholders about the natural hazard and how to prepare for the natural hazard.	Shares information about the natural hazard and some information about how to prepare.	Shares detailed information about the natural hazard and some information about how to prepare for the hazard.	Shares detailed information about the natural hazard and tailors information about how to prepare for the hazard to specific stakeholder group(s).
Communicate information to stakeholders about how to respond during and after a natural hazard.	Shares some information about what to do during a natural hazard.	Shares information about how to respond during and after a natural hazard.	Shares level of detail appropriate to the project type about what to do during and after a natural hazard with options for action tailored to specific stakeholder groups.
Information is accessible to a targeted group of stakeholders.	Final product communicates basic information to stakeholders.	Final product uses everyday language along with symbols and images to communicate information.	Final product thoughtfully pairs symbols, images, and text in a way that communicates important ideas to stakeholder group(s) in everyday or easy-to-understand language.
Additional category:			
Additional category:			

Name: ____________________ Date: ____________________

Obtaining and Communicating Information about Natural Hazards

Category	1	2	3
Obtain information about the natural hazard.	Identifies where the hazard happens and possible damage that can result.	Identifies where the hazard happens, the possible damage that can result, and who could be at risk.	Identifies where the hazard happens, who is at risk, possible damage that might result, and how different locations and populations may be affected differently.
Obtain information about components of a system designed to detect, warn, and reduce damage.	Identifies general information about the detection and warning system, and/or solutions to reduce damage.	Identifies how some of the components of the system work together to detect, warn about, and/or reduce damage to communities.	Identifies in detail the specific components of the system and describes how each component works together to detect, warn, and reduce damage.
Obtain information about community stakeholders criteria and constraints.	Identifies a general group of community stakeholders for the communication plan.	Identifies different stakeholder groups and 1–2 criteria and/or constraints and/or addresses them in the plan.	Identifies different stakeholder groups and clearly outlines criteria and constraints and addresses those in the plan.
Obtain information from reliable sources and evaluate its credibility.	No sources are included.	Sources are included, but little to no information is provided about the credibility of the source.	Sources and evidence of their credibility are included.
Communicate information to stakeholders about the natural hazard and how to prepare for the natural hazard.	Shares information about the natural hazard and some information about how to prepare.	Shares detailed information about the natural hazard and some information about how to prepare for the hazard.	Shares detailed information about the natural hazard and tailors information about how to prepare for the hazard to specific stakeholder group(s).
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Additional category:			
Additional category:			

LESSON 10: ANSWER KEY 1

Assessing Hazard Risk

Scoring Guidance: The scoring guidance provided below uses a + and ++ notation that can help you identify different ideas that students should (or could) include in their responses.

- If several of the ideas marked with a + are missing from a student's response, this may indicate the student has not mastered the science ideas or that the student may be struggling to bring those ideas together in a written explanation or model. Additional probing of their thinking can provide insight about whether the student is struggling with a science practice or science idea, or both.
- If all or almost all of the ideas marked with a + are present in a student's response, this may indicate the student has mastered the science ideas and is able to use them in a written explanation or explanatory model.
- If the ideas marked with a ++ are present in a student's response, this indicates that the student is bringing a deeper understanding of the science ideas or a deeper engagement with the practice to their response. Students should not be marked off if ideas marked with a ++ are not present in their response.

This assessment can be used to assess student progress on the following LLPE. The LLPE is an integration of elements from the three dimensions, so looking for these three aspects working together across the student work.

9.A Use digital tools to analyze patterns in large data sets (maps) of the history of natural hazards in regions and use this information to forecast future risk.		
SEP	**DCI**	**CCC**
5.1 Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.	Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events (MS-ESS3.B).	1.4 Graphs, charts, and images can be used to identify patterns in data.
Students use digital interactive maps to explore hazard risk data across nine different hazards that affect the United States. Students will use the digital tool to look at the larger pattern of risk for a hazard (e.g., what parts of the United States are most or less at risk). Then they can zoom into their local county level to assess localized levels of risk for each hazard.	The focus of this assessment task is on comparing the varying historical levels of risk of nine different hazards to determine which locations are more or less at risk. Students use this risk evidence to explain which hazards they are at risk for and provide a rationale for why communication to certain communities at risk is important.	Look for how students use maps to identify general regional patterns in risk as well as their own local pattern of risk. Regional patterns of risk include identifying places at greater and lesser risk.

1. Determine the general pattern for which places are most at risk for each hazard and how at risk your local community is.

Hazard	Describe the general patterns of risk for this natural hazard in the United States	Level of risk of this hazard for my community	Notes: My experiences with or wonderings about this hazard
Wildfires	Places in the western half of the United States are more at risk than the eastern half of the United States, except for Florida, which has higher levels of risk. There are some smaller pockets of risk, but the highest risk is generally in the west.	This column varies based on location. Check the level of risk for your communities to create a localized key for this column.	This column varies based on student experiences or wonderings. Look for how students incorporate these experiences or curiosities into their responses for Questions 2 and 3 below.
Thunderstorms	Communities in the midwestern and southern United States are most at risk, from Texas to Chicago and then to Florida. The western and northernmost parts of the United States are not really at risk.		
Winter Storms	The western and northern part of the United States are most at risk, and some places in the Rocky Mountains, Appalachian, and Sierra Nevada mountains. The southern part of the United States is not really at risk for winter storms.		
Hurricanes	Communities along the Gulf Coast and Atlantic Ocean are most at risk of hurricanes, but communities in the rest of the United States are not at risk for this hazard.		
Extreme Heat	Places at highest risk are around the center of the United States near Missouri, Kansas, Arkansas, and Oklahoma, and the southwest around Arizona, and a small area near Philadelphia. Most of the west and northeast is at a lower risk.		
Droughts	Most of the western United States is at a very high risk of drought, except for the northwest corner. There is also an area in Georgia at higher risk, but most of the eastern United States is at a lower risk.		
Coastal Flooding	All counties along the Pacific and Atlantic Coasts are at moderate to very high risk of coastal flood. Counties not on the coast are not at risk.		
River Flooding	Places in the northeast, central, and southwest are all at risk for river flooding. There are places all over the United States that are at risk though. The lowest risk is found in the northwestern United States.		
Earthquakes	The western United States is most at risk, and also the area between St. Louis, Memphis, and Nashville in the center of the United States. There is some risk in the northeastern parts of the United States. The rest of the United States is at little or no risk of earthquakes.		

2. Explain which hazard you are at most risk for in your local community. Use evidence from the maps to support your explanation. If there are additional sources of data that you would want to study, also include those ideas in your explanation.

+ Student identifies all hazards that have moderate to high levels of risk. Students cite the exact level of risk for their local county based on the data from the map (answers will vary based on location).

+ Student asks for additional data, such as: frequency of the hazard in their area, how severe or strong or fast it can happen, or more details about time of year it may occur.

++ Student asks questions about the integrity or source of data on the maps, such as: where did the data come from, is it a reliable source, what time period does the data represent, etc.

3. Identify a natural hazard that impacts you in some way or that you feel would be important to investigate. It could be one that affects your community, a community that you are familiar with, or a place you have always wanted to visit. Use evidence from the maps to explain the area that is at risk for this hazard and provide a rationale for why you think the communities in that area need to understand and prepare for this natural hazard.

+ Students clearly identify a natural hazard from the data set.

+ Student clearly identifies a community matched to a moderate or high level of risk and provides information for why this place is chosen.

+ Student clearly identifies the level of risk that warrants a communication plan for a community. Communities at moderate risk to very high levels of risk need communication plans. Communities at little or no risk do not necessarily need communication plans.

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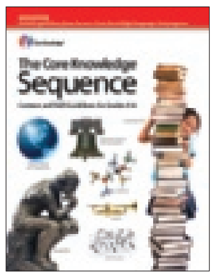

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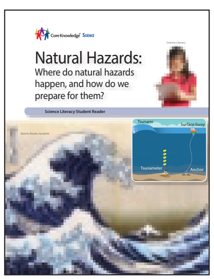

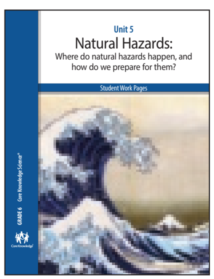

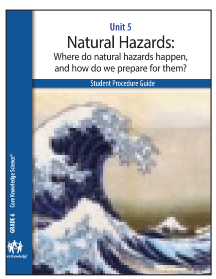

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