Smithsonian | **SCIENCE** *for Computational Thinking*

Protecting Whales

GRADE 3

developed by

Smithsonian
Science Education Center

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Protecting Whales
Teacher Guide

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Smithsonian Science Education Center

The Smithsonian Science Education Center (SSEC) is an education organization within the Smithsonian Institution. The SSEC's mission is to transform K–12 Education Through Science™ in collaboration with communities across the globe. The SSEC promotes authentic, interactive, inquiry-based K–12 STEM teaching and learning; ensures diversity, equity, accessibility, and inclusion in K–12 STEM education; and advances STEM education for sustainable development. The SSEC achieves its goals by developing exemplary curriculum materials and digital resources; supporting the professional growth of K–12 teachers and school leaders; and conducting outreach programs through LASER (Leadership and Assistance for Science Education Reform) to help schools, school districts, state education agencies, and ministries of education throughout the world implement inquiry-based science education programs.

Smithsonian Institution

The Smithsonian Institution was created by an Act of Congress in 1846 "for the increase and diffusion of knowledge . . ." This independent federal establishment is the world's largest museum, education, and research complex and is responsible for public and scholarly activities, exhibitions, and research projects nationwide and overseas. Among the objectives of the Smithsonian is the application of its unique resources to enhance elementary and secondary education.

Smithsonian Science for Computational Thinking (SSfCT) is a freely available curriculum developed by the Smithsonian Science Education Center. This transdisciplinary curriculum integrates science, technology, engineering, and math (STEM) and computational thinking (CT). Using a phenomenon-and problem-driven pedagogy, students work to define and solve real-world problems and/or explain phenomena. This STEM+CT curriculum, which includes a literacy component, is aligned to the Next Generation Science Standards, the Computer Science Teachers Association K–12 Computer Science Standards, the ISTE Standards, and the Common Core Mathematics Standards.

Thank You for Your Support

This lesson plan was made possible through partnership with Department of Defense (DoD) STEM, whose mission is to Inspire, cultivate, and develop exceptional STEM talent through a continuum of opportunities to enrich our current and future DoD workforce poised to tackle evolving defense technological challenges by a diverse and sustainable STEM talent pool ready to serve our Nation and extend the DoD's competitive edge. For more information, visit dodstem.us.

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Dear Educator,

Thank you for using *Smithsonian Science for Computational Thinking* to integrate computational thinking into your science, technology, engineering, and math (STEM) classrooms.

Computational thinking is increasingly recognized as a fundamental approach to problem-solving that can be applied beyond computer science to other disciplines. This approach involves decomposing or breaking down a problem into parts; creating and using sequences of steps called algorithms; organizing and analyzing data to identify meaningful patterns; and developing and using models, including simulations, of natural and designed systems. Computers can do these things. But humans can as well.

Smithsonian Science for Computational Thinking provides high-touch to high-tech opportunities for 3rd through 5th grade students to develop and use computational thinking as part of three-dimensional phenomenon- or problem-driven learning experiences. The work that students do is driven by explaining a phenomenon or defining and/or solving a problem. The use of phenomena and problems motivates students and leads to deeper and more transferable knowledge. Students who spend their time explaining phenomena and solving problems related to real-world situations also develop an understanding of the need for and value of the science and engineering in their community. This is fundamental to STEM.

Making computational thinking an integral part of education is central to the Federal STEM Strategic Plan. As the Plan notes:

> *Although the concept was developed in computer science, computational thinking is increasingly seen as a set of broadly valuable thinking skills that helps people solve problems, design systems, and understand human behavior, and that can be learned at a very young age without involving computer coding. In an increasingly technological and complex global economy, computational thinking needs to be an integral element of all education, giving every learner the capacity to evaluate information, break down a problem, and develop a solution through the appropriate use of data and logic (1).*

Computational thinking is also an integral part of K–12 standards, including the K–12 Computer Science Framework, the National Educational Technology Standards, the Next Generation Science Standards (NGSS), and other state standards based on *A Framework for K–12 Science Education* (2). Using mathematics and computational thinking is one of eight essential science and engineering practices in NGSS. Additionally, aspects of computational thinking are integrated into the practices of designing and building models, planning and carrying out investigations, and data analysis and interpretation, as well as the crosscutting concept of patterns.

Smithsonian Science for Computational Thinking takes a "high-touch to high-tech" approach to teaching computational thinking. It brings object-driven, phenomena-based, problem-based learning together with digital learning so they complement one another. *Smithsonian Science for Computational Thinking* integrates STEM and computational thinking (STEM+CT) so all students can improve their digital literacy—with and without access to computers and other high-tech devices.

I am immensely grateful to the Department of Defense Office of STEM for their support of this project. I am also grateful to my talented Smithsonian colleagues, Dr. Sarah Glassman, Melissa J. B. Rogers, and Hannah Osborn who developed these units under the direction of Laurie Rosatone. I also want to thank the external subject matter experts who contributed to this guide—for their perspectives and technical support in ensuring the information in this guide is accurate.

I hope that your students enjoy engaging in the high-touch to high-tech lessons of *Smithsonian Science for Computational Thinking*. Thank you for all that you do to advance STEM education.

Best,

Dr. Carol O’Donnell, Director
Smithsonian Science Education Center

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Series Pedagogy

Phenomenon- and Problem-Driven Learning

Phenomena are observable events in the universe, for example a fossil of an ocean organism that is found on top of a mountain (3). An engineering problem is a situation that people want or need to change, such as a town not having access to enough freshwater for both farmland and industry. Whether familiar or unfamiliar, all phenomena and problems allow students to draw on their prior knowledge and experiences to come up with an initial explanation or solution. Students can then complete a series of activities to collect evidence. As students collect evidence, they build on their initial ideas through an iterative process of critique and revision (4). This iterative sensemaking process leads to revised explanations of phenomena, definitions of problems, or solutions to problems (5).

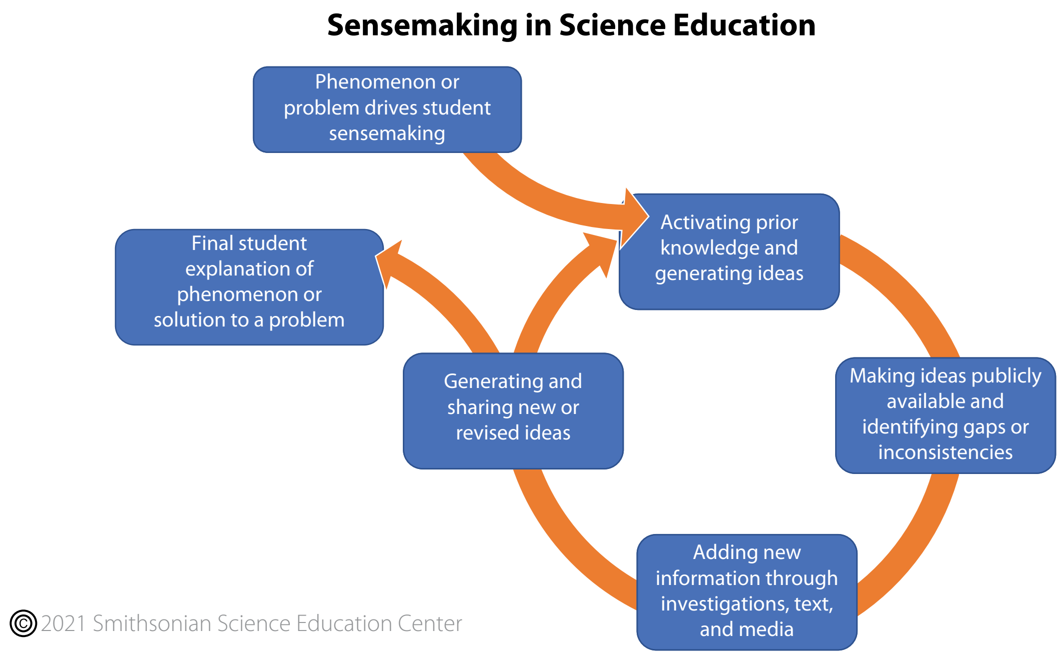


Figure 1: Students engage with new information through investigations, text, and media.

Computational Thinking

Computational thinking has been defined as a conceptual foundation that can be applied in practice to solve problems effectively and efficiently, with or without computers (6). Computational thinking includes (7, 8):

- breaking down complex problems into more manageable sub-problems (decomposition)
- finding patterns within problems and solutions and reviewing how the solution transfers to similar problems (abstraction), which includes
  - data collection and analysis
  - pattern recognition
  - modelling
- using a sequence of steps (algorithms) to solve problems
- determining if a computer can help us more efficiently solve those problems (automation)

There are parallels between the science and engineering practices and crosscutting concepts students develop as part of STEM learning and many aspects of computational thinking and foundational computer science knowledge. These include organizing and visualizing data to identify patterns to support claims and explanations; developing, testing, and improving procedures; working collaboratively and taking on specific and varied roles; and evaluating, ethically using, and communicating information.

Computational thinking as defined above is not described in one single set of standards (7-9). We have identified points within their learning where students are engaged in elements of the Next Generation Science Standards (10) and computational thinking practices described in the Computer Science Teachers Association standards (11) and ISTE student standards (12). The following chart shows how computational thinking overlaps across these standards.

Based on the amount of overlap between the science practices and computational thinking, STEM time is a great place to incorporate computational thinking into an already full instructional day.

CSTA 1B (grades 3-5)	**ISTE Student Standards**	**NGSS grades 3-5**
Data and Analysis	1.5a Computational Thinker 1.5b Computational Thinker	Planning and Carrying Out Investigations (SEP) Data Analysis and Interpretation (SEP) Using Mathematics and Computational Thinking (SEP) Engaging in Argument from Evidence (SEP) Patterns (CCC) Cause and Effect (CCC)
Algorithms and Programming	1.4c Innovative Designer 1.5a Computational Thinker	Defining Problems (SEP) Developing and Using Models (SEP) Planning and Carrying Out Investigations (SEP) Using Mathematics and Computational Thinking (SEP) Constructing Explanations and Designing Solutions (SEP) Engaging in Argument from Evidence (SEP) Obtaining, Evaluating, and Communicating Information (SEP)
	1.3b Knowledge Constructor	Obtaining, Evaluating, and Communicating Information (SEP)
	1.5c Computational Thinker	Defining Problems (SEP) Developing and Using Models (SEP) Systems and System Models (CCC)

Figure 2: Computational thinking practices appear in CSTA, ISTE, and NGSS standards.

Unit Overview

Unit Storyline

Problem: Whales are found injured and killed.

How students work toward solving the problem:

Task	Time
Task 1: Initial Ideas Students share their initial ideas about the problem of whales getting injured and killed.	20 minutes
Task 2: Whale Life Game Students use a model to begin to learn about humpback whales so they can better understand the problem of whales getting injured or killed.	35 minutes
Task 3: Analyze the Whale Life Game Students analyze their data from the model and explain that an increase in shipping traffic, fishing gear, and plastics in the ocean causes more whales to be injured or killed today compared with 250 years ago.	25 minutes
Task 4: Revised Ideas Students revisit the problem of whales getting injured or killed to update their ideas about the cause of the problem. The class decides to focus on the problem of whales getting injured or killed by ship strikes.	20 minutes
Task 5: Whale Fluke Sort Students organize and sort photos from whale observations to begin to understand where whales live at different times of the year.	40 minutes
Task 6: Modeling Whale Movement Students use the data from Task 5 to develop a model to reveal the annual migration pattern of the humpback whale.	40 minutes
Task 7: Adding Ship Traffic Data Students revise their models from Task 6 to include the location of heavy ship traffic.	15 minutes
Task 8: Revised Ideas Students revisit the problem of whales getting hit by ships to explain that the Los Angeles and San Francisco areas of California are likely areas for whales to get hit by ships.	15 minutes

Task 9: Research Solutions Students do further research to better understand the problem of humpback whales getting hit by ships and possible solutions.	20 minutes
Task 10: Propose a Solution Students propose a solution and/or suggest additional research that needs to be done to reduce the number of whales that are injured or killed by ship strikes.	30 minutes
Task 11: Testing Solutions Students use a computer simulation to compare multiple solutions to the problem, based on how well they decrease the number of whale ship strikes, maintain the amount of goods delivered, and minimize cost.	45 minutes

Unit Alignment to Standards

Students develop and use part or all of the following standards in this unit. The standards students use are called out at point of use throughout the tasks.

Orange text indicates an NGSS disciplinary core idea, green text indicates an NGSS crosscutting concept, blue text indicates an NGSS science and engineering practice, and **bolded black text** indicates a CSTA or ISTE standard. Italicized text within the disciplinary core ideas indicates parts of the core ideas students do not use.

Next Generation Science Standards Elements

Disciplinary Core Ideas

LS2.C When the environment changes in ways that affect a place's physical characteristics, *temperature, or availability of resources*, some organisms survive and reproduce, *others move to new locations, yet others move into the transformed environment,* and some die.

LS4.C *Populations live in a variety of habitats, and* change in those habitats affects the organisms living there.

LS1.B Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles.

ETS1.B Research on a problem should be carried out before beginning to design a solution. *Testing a solution involves investigating how well it performs under a range of likely conditions.*

Crosscutting Concepts

Patterns

E1 Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products.

E2 Patterns of change can be used to make predictions

E3 Patterns can be used as evidence to support an explanation

Cause and effect

E1 Cause and effect relationships are routinely identified, tested, and used to explain change.

Science and Engineering Practices

Developing and using models

E4 Develop and/or use models to describe and/or predict phenomena.

Using mathematics and computational thinking

E2 Organize simple data sets to reveal patterns that suggest relationships.

Engaging in argument from evidence

E4 Construct and/or support an argument with evidence, data, and/or a model.

Unit Overview

Designing solutions

E4 Apply scientific ideas to solve design problems.

E5 Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.

Obtaining, evaluating, and communicating information

E6 Communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts.

Computer Science Teachers Association K-12 Computer Science Standards

Data and Analysis

CSTA 1B-DA-06 Organize and present collected data visually to highlight relationships and support a claim.

CSTA 1B-DA-07 Use data to highlight or propose cause-and-effect relationships, predict outcomes, or communicate an idea.

ISTE Student Standards

Computational Thinker

ISTE 1.5.b 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.

Assessment Map

Multiple moments have been identified within this unit during which student learning can be assessed. For each moment, we have identified the assessment as a pre-assessment or a formative assessment.

During pre-assessments students have an opportunity to provide their initial explanation of a phenomenon or their initial definition of or solution to a problem. The phenomena and problems in each unit are purposely chosen because students need to understand key concepts in order to explain or solve them. Reading, viewing, and/or hearing students' initial ideas provides an opportunity to understand what students already know about these concepts.

Following the pre-assessment, subsequent tasks require students to develop and use their skills and knowledge in progressively complex ways. Each identified task incorporates at least two NGSS, CSTA, or ISTE standards. Within multiple tasks, teachers are provided a table of indicators they can refer to as they assess students. Teachers can use this table to identify the extent to which students are meeting the lesson objectives and areas where they need additional support. Analysis of student work using these indicators can be used to inform future lesson planning as well as to provide specific, actionable feedback for students. For some assessable moments, suggestions for supporting all students are provided within the table and or at point of use within the Task.

Assessable Moment and Objectives	Evaluating this Assessable Moment
Task 1: Initial Ideas	
Class Discussion **Objective** Provide initial ideas about what caused the injury and death of the whales. **Standards** NGSS LS2.C NGSS Cause and effect E1	Pre-assessment Students' initial ideas are a pre-assessment. It is an opportunity to learn what students might already know about problems in the whales' environment that might injure or kill them.
Task 3: Analyze the Whale Life Game	
Whale Life Game Review sheet **Objective** Use a model to explain how a change to a whale's environment affects the whale's ability to survive and to predict what would happen if whales stopped reproducing. **Standards** NGSS LS2.C NGSS LS4.C NGSS LS1.B NGSS Cause and effect E1 NGSS Developing and using models E4	Formative Assessment Students should use the data collected from the Whale Life Game (a model) to explain that the increase in ship traffic, fishing nets, and plastic in the ocean can injure and/or kill whales, leading to fewer whales. Students should use evidence from the How Has the Whale's Environment Changed? chart and the How Many Whales? chart to support their explanations. If students are not sure how to answer the questions or how to support their explanations, ask them what happened in the game and what the evidence on the charts means. Students should also use the model to explain that if whales did not reproduce, the whole whale population would eventually be gone.

Assessable Moment and Objectives	Evaluating this Assessable Moment
Task 5: Whale Fluke Sort	
Whale Migration sheet Discussion **Objective** Use evidence from the whale data sort **to support ideas about** the location of the calving ground and feeding ground and the time of the year that whales travel between these locations. **Standards** NGSS LS1.B NGSS Engaging in argument from evidence E4 CSTA **1B-DA-06**	Formative Assessment As students are completing the Whale Migration sheet, listen for students to use evidence from the data table **to support their ideas** about the location of the calving ground and feeding ground and when whales migrate between the two locations.
Whale Fluke Sort Discussion **Objective** Use similarities and differences in patterns to organize whale data to **reveal which observations are of the same whale.** **Standards** NGSS Patterns E1 NGSS Using mathematics and computational thinking E2 CSTA **1B-DA-06**	Formative Assessment Students should notice similarities and differences between the whales' flukes such as the amount of white on the fluke and specific white patterns on the fluke. If students only notice the more obvious differences, such as "these flukes are all mostly white and these fluke are all mostly black," encourage students to look more carefully at specific white shapes in specific places and see if they can match them to other whale flukes. If students try to match two flukes that do not match by saying that they think the two pictures are opposite sides of the fluke, tell students to assume that all images are the same side of the fluke.

Assessable Moment and Objectives	Evaluating this Assessable Moment
Task 6: Modeling Whale Movement	
Whale Movement Model **Objective** Develop a model **based on whale data to reveal** an annual migration pattern of the humpback whale. **Standards** NGSS LS1.B NGSS Patterns E2 NGSS Developing and using models E4 CSTA **1B-DA-06** CSTA **1B-DA-07** ISTE **1.5.b**	Formative Assessment Students should develop a model that shows which whales are located in which location during each month of the year. Students can model the data exactly or make inferences about where their whale was during the months it was not observed.
Task 7: Adding Ship Traffic Data	
Whale and Ship Movement Model **Objective** Develop a model **based on whale and ship traffic data** to reveal the locations that are likely to have ship strikes on whales. **Standards** NGSS Developing and using models E4 NGSS Using mathematics and computational thinking E2 ISTE **1.5.b**	Formative Assessment Students should **represent the whales' annual pattern of migration and the high ship traffic areas**. If students struggle because they are looking for more specific directions, remind students that the purpose of the model is **to figure out where whales are likely to get hit by ships**. They should aim to make a model that will help them figure that out.

Assessable Moment and Objectives	Evaluating this Assessable Moment
Task 8: Revised Ideas	
Your Ideas About the Problem and Solution sheet **Objective** **Use the visual model** of the whales' pattern of movement and the ships' pattern of movement as evidence to support a claim about where whales are likely to get hit by ships and to inform a solution to the problem. **Standards** NGSS Patterns E2 NGSS Engaging in argument from evidence E4 CSTA **1B-DA-06** ISTE **1.5.b**	Formative Assessment Students are likely to identify the San Francisco and Los Angeles areas of California as two areas where ship strikes are a problem because those are locations where many ships travel and many whales are observed. It is okay if students make other claims, as long as they support them with evidence. If students do not provide evidence to support their claim, ask students, "Why do you think that?" Encourage them to write down their evidence. Encourage students to **use what they learned from the data to inform an updated solution**.
Task 10: Propose a Solution	
Our Solution sheet **Objective** Apply scientific ideas **from data** and from text to design a solution to decrease the number of whales getting injured or killed by ship strikes. **Standards** NGSS LS2.C NGSS Constructing explanations and designing solutions E4 ISTE **1.5.b**	Formative Assessment Students' solutions should incorporate what they learned about locations where ships strikes are likely to be problematic as well as information from *Whales and Ships: Sharing the Ocean*. If students propose a solution that does not incorporate what they learned, remind them to review what they learned about whales and possible solutions from the models they used and developed. It is okay if students propose a solution that does not seem reasonable but that does incorporate what they have learned so far about the problem. For example, students could say that an underwater wall should be built to keep whales from going into certain areas. This might seem unreasonable to someone who has additional information about the scope of that project, but because students do not have that information, this is a reasonable solution based on what they know at this point.

Assessable Moment and Objectives	Evaluating this Assessable Moment
Task 11: Testing Solutions	
Testing Solutions sheet Revised Solution sheet **Objective** Construct an argument about the best solution to reduce the number of whale ship strikes using evidence obtained from comparing solutions with a model. **Standards** NGSS Constructing explanations and designing solutions E5 NGSS Engaging in argument from evidence E4 ISTE **1.5.b**	Students should use evidence from the Whale Protection Corps simulation to support their solution. They can also use evidence from the *Whales and Ships: Sharing the Ocean* reading.

Materials Management and Safety

Materials

In this unit, students use a model and then develop multiple models. The unit is written so that students work in groups of three. Group size should be modified to fit your classroom and students.

In the unit, each group of three students will play the Whale Life Game in Task 2. The game includes a Whale Life Game Board and three spinners. To play the game, students will need a Whale Life Game Board and two of the three spinners. The Whale Life Game Board and the three spinner cards should be printed on a color printer, if possible, but they can be printed on a black and white printer. The paper fasteners, paper clips, and chipboard are used to construct the spinners. Chipboard is used to construct most cereal and other prepared food boxes. Directions to construct the spinners are in the Preparation section of Task 2.

The story, *Whales and Ships: Sharing the Ocean*, and the optional story, *Up Close with a Marine Scientist*, should also be printed on a color printer if possible.

Materials, in Order of Use	**How Many?**
Computer or tablet with Internet access	1 for the teacher 1 per group of two students
Projector for digital media	1
Chart paper	
Whale Life Game Board	1 per group of three students
Calving Ground Spinner	1 per group of three students
250 Years Ago Feeding Ground Spinner	1 per six students
Modern-Day Feeding Ground Spinner	1 per six students
Paper fasteners	2 per group of three students
Paper clips	2 per group of three students
Chipboard	Enough to cut out two 13 cm diameter circles for each group of three students.
Glue stick	1 for the teacher
Scissors	1 for the teacher
Whale Data card set	1 set per group of three students
Sticky notes, two colors	
Objects to represent whales in a model (game pieces, paper clips, erasers, stuffed animals)	1 per student
Whales and Ships: Sharing the Ocean	1 per student
Up Close with a Marine Scientist (optional)	1 per student
Markers (optional)	
Colored pencils (optional)	

Student Sheet Guidance

Distribution information for sheets students will need access to during the unit.

Sheet Name	Number of Copies
Whale Life Game	1 per group of three students
Whale Game Pieces	1 per group of three students
Whale Life Game Review	1 per student
Where Are the Whales?	1 per group of three students
Whale Migration	1 per group of three students
Whale Map	1 per group of three students
Whale Model Directions	1 per student
Los Angeles, San Francisco, and Mexico signs	1 per group of three students
Your Ideas About the Problem and Solution	1 per student
Researching the Problem and Solution	1 per student
Our Solution	1 per group of three students
Testing Solutions	1 per student
Revised Solution	1 per group of two students

Safety

Students may be upset by looking at images of dead and injured whales. Tell students before showing the images that they are going to see images that might cause them to be sad. Students may be upset by thinking or talking about injured animals. Students can take a break from looking at the pictures or thinking about injured animals if either is too upsetting.

Task 1: Initial Ideas 20 minutes

Background Information

In this unit students investigate the problem of humpback whales getting hit by ships. Humpback whales are one species of whale. There are 14 distinct humpback whale populations around the world. This unit focuses on the population off the coast of Mexico that migrates to the west coast of California in the warmer months. This population of humpback whales is threatened, which means it could become endangered. Four of the populations are endangered, which means they are in danger of extinction. Nine of the populations are not at risk.

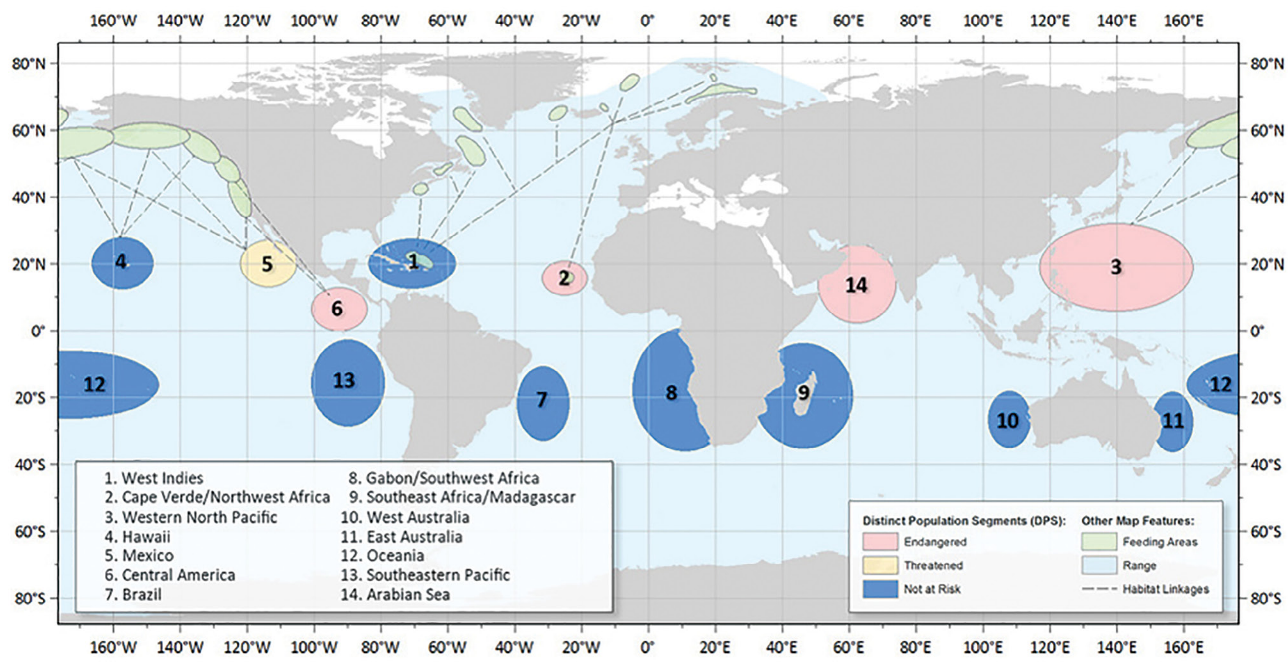


Figure 1.1: Each humpback whale population spends part of the year in one location and part of the year in another location.

Worldwide, many species of whales are endangered or threatened. An estimated 2.9 million whales were killed by commercial whaling in the 1900s. This greatly decreased global whale populations. In 1982, the International Whaling Commission established a ban on commercial hunting. This has helped some whale populations avoid extinction and other whale populations recover. No modern whale species has gone extinct. Although at least ten populations of whales are estimated to have less than 500 individuals remaining. And the population of gray whales in the North Atlantic became extinct in the 18th century.

Whales continue to face many problems that threaten their survival. Whales are hit by ships. This is especially a problem in locations with high vessel traffic and high whale population density. In the past 40 years, the amount of cargo carried by ships across the ocean has increased 25 times. Whales can also get caught in fishing lines. Active fishing gear is a problem, but so is abandoned fishing gear that is not being used. And whales can swallow plastic in the ocean. Large pieces of plastic can injure whales. Scientists predict that very small pieces of plastic, called microplastic, can also be problematic to whales.

In this task, students encounter the problem of whales getting injured or killed. Students share their initial ideas about the cause of the problem.

Preparation

1. @ Navigate to **ScienceEducation.si.edu/whales**. Open the Humpback Whale video and the Whale Problem file and have them ready to share with the whole class.
2. Write the heading "What Is the Problem?" on a blank piece of chart paper and "What Do We Want to Know?" on another piece.

Procedure

1. Play the Humpback Whale video so it is accessible to the whole class.
2. Ask students to turn to a shoulder partner and discuss what they observed. Invite students to share what they observed with the class. Confirm for students that the animals in the video are whales. Tell them that they are a type of whale called a humpback whale.
3. Tell students that you have some images you want to share with them. Tell students that some of the images are sad. Project the Whale Problem file so it is accessible to the whole class. Figures 1.2 through 1.5 show the images in the file. Do not share background information about the images with students at this time.

Figure 1.2: This right whale died from propeller wounds.

Task 1

Figure 1.3: This humpback whale was injured from a ship strike.

Figure 1.4: This humpback whale was found dead with a severely injured tail, likely caused by fishing gear.

Figure 1.5: This whale was injured by a ship strike.

4. Ask students to turn to a shoulder partner and share what they observe in the images. Invite students to share what they observed with the class. Record student's ideas on the What Is the Problem? chart.
5. Ask students if this reminds them of anything from their own life. Use the following guiding questions to help students think of similar experiences.
   - Have you ever been injured? What happened?
   - Have you ever seen an animal injured? What happened?

Teacher Tip

Students may be upset by thinking/talking about injured animals or times when they were injured. Students can take a break if it is too upsetting.

Task 1

6. Have students turn to a shoulder partner to discuss what they think caused the injury and/or death of the whales. Update the What Is the Problem? chart with students' ideas. This is an opportunity to learn students' initial ideas. Do not correct students' ideas at this point.

What Is the Problem?
The whales are injured
Some of the whales look dead
Maybe they crashed into something
Maybe the whale got in a fight
Maybe the whale got hit by a boat

Figure 1.6: Sample answers when students share their initial ideas about observations of injured and dead whales.

LS2.C Students provide initial ideas about aspects of the environment that might cause whales to die.

Cause and effect Students provide initial ideas about what caused the whales' injury and death.

7. Ask students what they would like to learn more about so they can better understand the problem and start to think about solutions to the problem. Record students' ideas on the What Do We Want to Know? chart.

What Do We Want to Know?
Where do whales swim?
What could hurt whales?
What is dangerous for whales?

Figure 1.7: Sample questions when students share their initial ideas; record all students' ideas at this point.

8. Tell students that they are going to have a chance to learn more about humpback whales so they can better understand the problem and start to think about possible solutions.

Task 2: Whale Life Game 35 minutes

Background Information

Most humpback whales spend spring, summer, and fall in cold, nutrient-rich waters. This is where they consume most of their food for the year. They spend the winter in a warmer area where they breed and give birth. Female whales are pregnant for 12 months. They breed one year and give birth the next year. Female whales give birth to a baby whale about every two to three years, starting between the ages of 6 and 10.

In this task students use a model to begin to learn about humpback whales so they can better understand the problem of whales getting injured or killed. Later, students will develop their own model to better understand the problem. Both scientists and engineers frequently use models. Models are representations that are in some way analogous to the thing they represent. Models can take many forms, including a sketch, a diagram, a physical object, an equation, or a computer simulation. In this task, the model is a game that simulates the life of a humpback whale.

Task 2

Preparation

1. @ Navigate to **ScienceEducation.si.edu/whales**. Open the Whale Life Game Directions file and have it ready to share with the whole class.
2. Make sure the What Is the Problem? and What Do We Want to Know? charts are accessible to all students.
3. Make one copy of the Whale Life Game and Whale Game Pieces sheet for each group of three students.
4. @ Navigate to **ScienceEducation.si.edu/whales**. Make one color copy of the Whale Life Game Board for each group of three students.
5. @ Navigate to **ScienceEducation.si.edu/whales**. Access the Whale Life Game Spinners. Make one color copy of the Calving Ground Spinner for each group of three students. Make one color copy of the Modern-Day Feeding Ground Spinner for half of the groups (see Figure 2.2). Make one color copy of the 250 Years Ago Feeding Ground Spinner for the other half of the groups (see Figure 2.5). Here are the directions to make a spinner:

- Cut out a circle 13 centimeters in diameter from a piece of chipboard (see Figure 2.1).

Figure 2.1: Cut a circle from a cereal or cracker box.

- Cut out a spinner and glue it onto the chipboard.

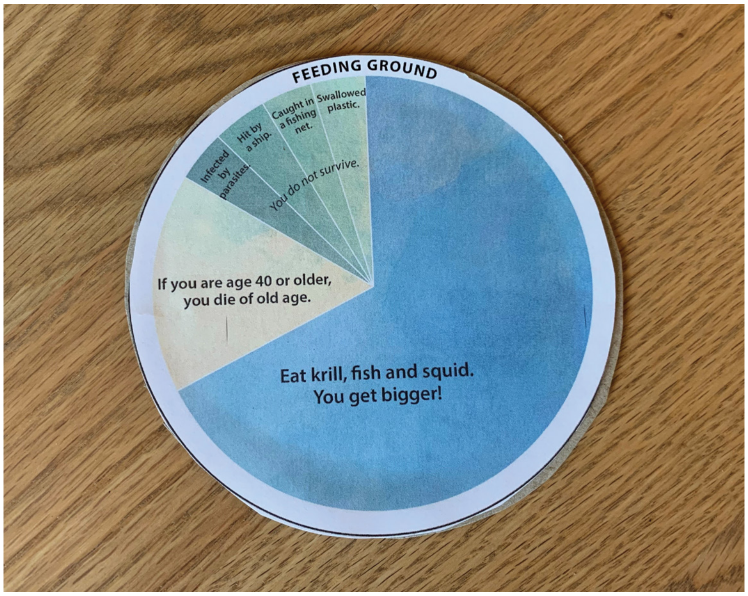


Figure 2.2: This is the Modern-Day Feeding Ground Spinner.

- Put the paper fastener through the paper clip (see Figure 2.3).

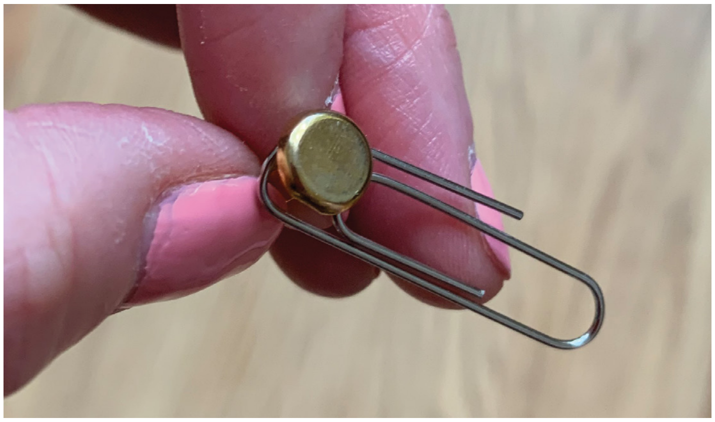


Figure 2.3: This is a 33 mm paper clip. Other sizes will work too.

- Push the paper fastener through the middle of the spinner.
- Open the paper fastener so there is a space between the round top of the paper fastener and the spinner (see Figure 2.4). This will enable the paper clip to spin freely.

Figure 2.4: If the paper fastener is too tight, the paper clip will not spin.

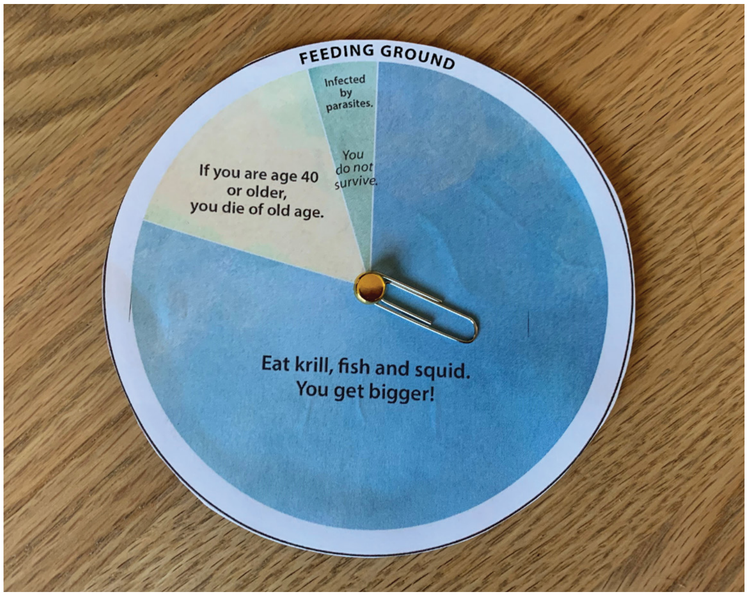


Figure 2.5: This Is the 250 Years Ago Feeding Ground Spinner.

6. Label the back of the Feeding Ground Spinners either "Modern Day" or "250 Years Ago."

Procedure

1. Tell students that you have a game they can use to learn more about the life of the humpback whale. Tell students that the game is a model. A model is a representation that is similar, but not exactly like the real thing. It is important that a model includes parts that are useful for the purpose of the model. The purpose of this model is to learn more about humpback whales to better understand and solve the problem of humpback whales getting injured and killed.
2. Direct students to look at the What Is the Problem? and What Do We Want to Know? charts. Invite students to share the type of information they are hoping will be included in the model. Record students' ideas on the What Do We Want to Know? chart.
3. Tell students that they will use the model in groups. Organize students into groups of three. Hand out one Whale Life Game and one Whale Game Pieces sheet to each group. Give each group one Whale Life Game Board and one Calving Ground Spinner. Give half the groups a 250 Years Ago Feeding Ground Spinner and half of the groups a Modern-Day Feeding Ground Spinner.
4. Project the Whale Life Game Directions file. Project the first slide, which is the game board. Tell students that each year whales migrate between their calving ground and feeding ground. The calving ground is where baby whales are born. Whales spend about 4 months of the year in the calving ground. The feeding ground is where whales eat most of their food for the year. They spend about 6 months of the year in the feeding ground.

5. Project the second slide. Each group will start the game with eight whales. They will cut out eight Whale Game Pieces. The Whale Life Game sheet shows the starting age for each of the eight whales. Students will keep track of the age of each of their whales on this activity sheet.
6. Project the third slide. Tell students to start the game by putting all eight Whale Game Pieces in the Calving Ground. The group will spin the Calving Ground Spinner one time for each of their whales. This will tell them something that happens to each whale while they are in the Calving Ground. Students can create their own system to keep track of which whale they are spinning for with each spin. Tell students that if one of their whales has a baby, they will cut out another whale and add it to the Calving Ground.
7. Project the fourth slide. Students will also add a whale to the Whale Life Game sheet. Each newborn whale should be given the next unused number.
8. Project the fifth slide. Tell students that if one of their whales dies, they should remove that Whale Life Game Piece from the Whale Life Game Board. They should also mark it on the Whale Life Game sheet. They should no longer spin the spinners for the whales that die.
9. Project the sixth slide. Next, all whales migrate to the Feeding Ground. The group will spin their Feeding Ground Spinner for each whale. No baby whales are born in the feeding ground, but some whales might die. Point out that once the whales migrate back to the Calving Ground, one year has passed.
10. Project the seventh slide. Before entering the Calving Ground, students make each of their living whales one year older on the Whale Life Game sheet.
11. Show students how to use the model by spinning the Calving Ground Spinner for several whales and recording what happens to each whale. Point out that there is nothing to write down if the whale survives.
12. Have students aim to play the game for 10 years of the model. If some groups play faster than others, the game can be stopped at the end of any year after 5 years.
13. Figures 2.6 and 2.7 show examples of completed Whale Life Game sheets based on the model from 250 years ago and the present-day model. The model from 250 years ago is likely to end with fewer whales compared to the present-day model, but it will not always end with fewer whales.

Teacher Tip

One student in the group can spin the spinner, one student can record information on the Whale Life Game sheet, and one student can move the game pieces on the board. All students should check that the correct data is recorded.

Task 2

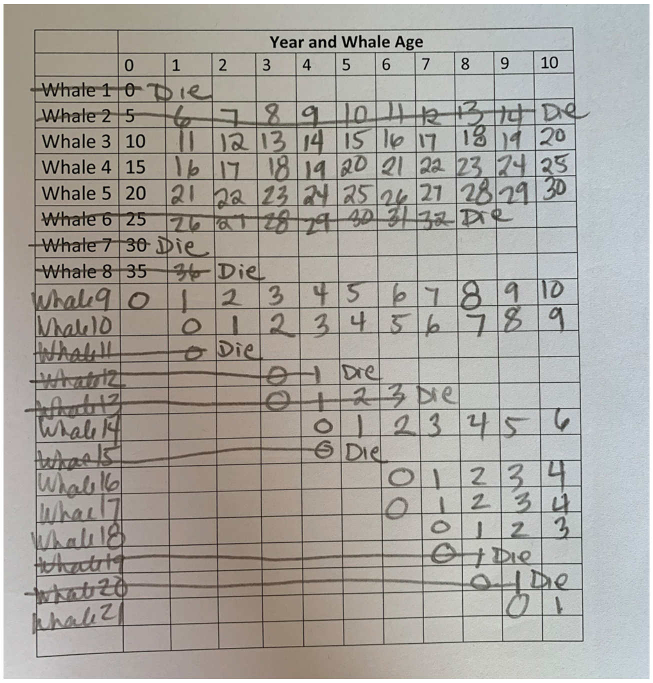


Figure 2.6: An example of a Whale Life Game sheet using the model from 250 years ago.

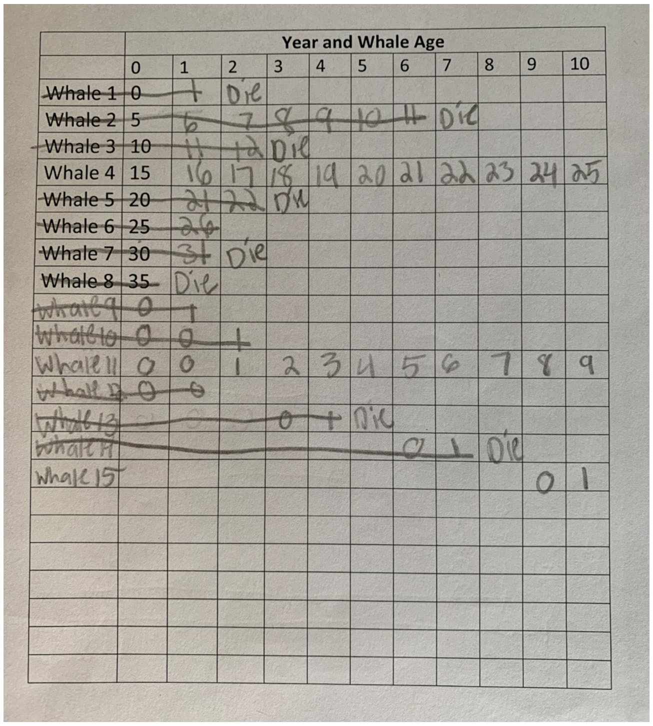


Figure 2.7: An example of the Whale Life Game sheet using the modern day model.

14. Save Whale Game Pieces 1 through 4 for each group so they can be used again in Tasks 6 and 7.

Task 2

<u>Task 3: Analyze the Whale Life Game</u> 25 minutes

Background Information

In this task, students record their data from the two models they used in Task 2. They learn that half the class used a model of the humpback whale's modern environment and half the class used a model of the humpback whale's environment 250 years ago. These two time periods were purposely chosen for this task to avoid the time period of active whale hunting in the late 1800s and early 1900s. Whaling had a major impact on whale survival rates, but that is not part of the work students are doing to solve the problem of whales getting hit by ships.

Students use their data from the model to explain that an increase in shipping traffic, fishing gear, and plastics in the ocean has caused more whales to be injured or killed today compared to 250 years ago. Using a model to describe a phenomenon is part of the practice of developing and using models at this grade level.

Preparation

1. @ Navigate to **ScienceEducation.si.edu/whales**. Open the Whale Environmental Problems file and have it ready to share with the whole class.
2. Prepare the following charts on the board or on chart paper.

How Has a Whale's Environment Changed?

250 Years Ago	Today

Figure 3.1: Students will use their model to record information about a whale's environment 250 years ago and today.

How Many Whales?

250 Years Ago	Today

Figure 3.2: Students will record the number of whales at the end of the game for each model.

3. Make one copy of the Whale Life Game Review sheet for each student.

Procedure

1. Tell students that some groups used a model to represent the whale's present-day environment and some groups used a model to represent the whale's environment 250 years ago. Tell students to look on the back of their Feeding Ground spinner to see which model they used. The two different spinners were created to model what a whale's life was like 250 years ago and today.
2. Invite one student from each group to record one way in which a whale interacted with their environment on the correct side of the How Has a Whale's Environment Changed? chart.
3. Invite one student from each group to record how many whales they had at the end of the game on the correct side of the How Many Whales? chart.
4. Have students discuss the following questions with their shoulder partner:
   - How has the humpback whale's environment changed from 250 years ago to today?
   - How has this change affected the humpback whale species?
5. Project the Whale Environmental Problems file. Use these images to give students more context about the problems affecting whales today compared to 250 years ago.
   - One problem is whales getting hit by ships. Tell students that the amount of shipping traffic in the oceans has been increasing for a long time and continues to increase.
   - Another problem is whales getting tangled in fishing gear. People trying to catch certain animals, such as fish, crabs, and lobsters, leave their fishing gear in the ocean and come back for it later. Whales can get tangled in active fishing gear or fishing gear that was forgotten about a long time ago. (The picture shows abandoned fishing gear being recovered.)

- Tell students that there are both large pieces of plastic in the water and very tiny pieces of plastic. Swallowing large pieces of plastic can injure whales. Scientists think many smaller pieces of swallowed plastic can build up over time and cause problems for whales as well.

6. Hand out the Whale Life Game Review sheet to each student. Have students answer the questions.

LS2.C Students identify that environmental changes from 250 years ago to today have caused more whales to die compared to 250 years ago.

LS4.C Students identify that changes such as ships, fishing nets, and plastic affect whales living in the ocean.

LS1.B Students predict that the whale species would no longer exist if whales do not continue to reproduce.

Cause and effect Students identify that changes in the environment, such as increases in ship traffic, fishing nets, and plastic in the ocean, can kill or injure whales.

Developing and using models Students use a model to explain how a change to a whale's environment affects the whale's ability to survive and to predict what would happen if whales stopped reproducing.

7. If students struggle to describe how the whale's environment has changed, encourage them to find differences between the whale's interactions with their environment 250 years ago and today on the How Has the Whale's Environment Changed? chart. Students can also directly compare a 250 Years Ago Feeding Ground Spinner to a Modern-Day Feeding Ground Spinner to see how they are different.
8. If students struggle to explain how the change in the environment affected the population of whales, encourage students to compare the number of living whales at the end of the 250 Years Ago model and the Modern Day model.

Task 4: Revised Ideas 20 minutes

Task 4

Background Information

Abstraction is a computational thinking practice. It means reducing complexity to make systems or problems easier to think about. Abstraction involves focusing on important details and deleting or ignoring unimportant details. Students use abstraction throughout this unit. In this task, students apply important details from the Whale Life Game to help them better understand the problem of whales getting injured or killed. Students update their ideas about what caused the problem. The class decides to focus on the problem of whales getting injured or killed by collisions with ships.

Preparation

1. @ Navigate to **ScienceEducation.si.edu/whales**. Open the Whale Problem file and Boat Propeller video and have them ready to share with the whole class.
2. Make sure the What Is the Problem? and What Do We Want to Know? charts are accessible to all students.
3. Write the heading "How Can We Protect Whales from Ship Strikes?" on a blank piece of chart paper.

Procedure

1. Project the Whale Problem file to remind students of the problem they are trying to solve.
2. Direct students' attention to the What Is the Problem? chart. Tell students that when solving a problem, they want to focus on important details of the problem and ignore unimportant details. This is called abstraction. Have students think about what they learned from the game that is important to the problem in the images. Invite students to share new ideas about the cause of the problem. Students may want to add all the problems they learned about using the game, or, based on details in the images, they may want to focus on the problem of ship strikes.

What Is the Problem?
The whales are injured
Some of the whales look dead
Maybe they crashed into something
Maybe the whale got in a fight
Maybe the whale got hit by a boat
The whale got caught in a fishing net
The whale was injured by swallowing a piece of sharp plastic

Figure 4.1: Students update their ideas about what caused the problem they saw in the images.

3. Direct students to look at the Whale Problem file. Tell students two of the injuries and one of the deaths were likely caused by a collision with a ship. Play the Boat Propeller video. Tell students that the two injuries with a pattern were likely caused by a whale moving while repeatedly being hit by a propeller.
4. Tell students that they are going to focus on one problem causing whales to get injured or killed: getting hit by a ship.
5. Ask students if the problem of ship strikes reminds them of problems for other animals. This might be similar to the problem of pets, wildlife, cows, or horses getting hit by cars.
6. Give a sticky note to each student. Have students write an idea about how they might be able to decrease the number of whales that are injured or killed by ships. Have students add their sticky note to the How Can We Protect Whales from Ship Strikes? chart.
7. Skim students' ideas as they are adding them to the chart. Invite students to share their ideas. Share any common ideas or unique ideas with the class. Figure 4.2 shows examples of ideas that students might share.

How Can We Protect Whales from Ship Strikes?
Find out where whales are and keep ships away from those areas
Add sensors to ships
Add cameras to ships
Make a wall between where whales can go and where ships can go
Teach whales how to stay away from ships

Figure 4.2: Sample responses; record all ideas, even if they don't seem realistic.

8. Direct students to look at the What Do We Want to Know? chart. Change the question to read, "What Do We Want to Know to Protect Whales from Ship Strikes?" Ask students what else they want to know about whales and ships to better understand why this is happening and think of possible solutions. Record students' ideas on the chart. If students don't suggest it, suggest that they might want to learn more about where whales' swim and where the most ships are located. Add these ideas to the chart. Tell students that they will continue to explore this in the upcoming tasks.

What Do We Want to Know to Protect Whales from Ship Strikes?
Where do whales swim?
What could hurt whales?
What is dangerous for whales?
Where are the most ships?
Can ships see if they are near a whale?
How can we make a sensor to see whales?

Figure 4.3: Sample responses; record all student ideas.

Task 4

Task 5: Whale Fluke Sort 40 minutes

Background Information

Raw data cannot be used to support a claim or solve a problem unless it is organized in a way that reveals patterns and relationships. Computers can store large amounts of data and can be programmed to sort and present data in different ways to reveal different relationships. Whether people sort and organize data or computers sort and organize data, the underlying decisions about how to organize, sort, and present data are human decisions. In this task, students are presented with raw data: photos from observations of whales from different times and places. Students organize and sort the data to begin to further understand patterns in whale movement. Organizing data to highlight a relationship is a computational thinking practice.

The whale's tail is called the fluke. Whale flukes are like a human fingerprint. They are unique to each individual and therefore can be used to identify whales. In this task students look at photographs of whale flukes taken by citizen scientists and uploaded to the project Happywhale. Students first organize the data to reveal where whales have been observed throughout the year. Students use their organized data to support their ideas about the pattern of humpback whale migration. This is an example of using evidence to support an argument.

Then, students use similarities and differences in the unique patterns, colorations, and markings of the whale flukes to identify which observations are of the same whale. Sorting based on similarities and differences in patterns is part of the patterns crosscutting concept at this grade level.

The whales students observe in this task are part of a population of whales that primarily migrate between Mexico, which is their calving ground, and California, which is their feeding ground.

Preparation

1. @ Navigate to **ScienceEducation.si.edu/whales**. Open the Whale Map file and have it ready to share with the whole class.
2. @ Navigate to **ScienceEducation.si.edu/whales**. Prepare a Whale Data card set for each group of three students.
    - Make a copy (in color, if possible) of the Whale Data card set.
    - Cut each sheet into two cards.
    - Secure each card set with a paper clip or in an envelope or a plastic bag.
3. Make one copy of the Where Are the Whales? sheet for each group of three students.

Procedure

1. Tell students that there are people all over the world who observe whales and share online pictures of those whales and the location where they took the picture. Tell students that they can learn more about where humpback whales are at different times of the year by looking at this data.
2. Hold up one Whale Data card. Tell students that each group is going to get 16 Whale Data cards. Each card is going to show a picture of a whale's tail and the date and location the picture was taken. Tell students that the whale's tail is called the fluke.
3. Direct students to look at the Whale Map file. Tell students that the map shows the locations where the whales in this set of data were observed. The map shows the west coast of North America. Tell students that San Francisco and Los Angeles are both in the state of California.
4. Organize students into groups of three. Give each group a Whale Data card set.
5. Tell students that it might be useful to see the big picture of where whales are at different times of the year. Hand out a Where Are the Whales? sheet to each group of students. Have students count how many whales are in each location during each month of the year. Students can do this by organizing their cards by location, organizing their cards by month, or going through each card one by one and counting with tally marks on their sheet. Figure 5.1 shows a completed Where Are the Whales? sheet.

Task 5

Where Are the Whales?

	Mexico	Los Angeles	San Francisco
January	1		
February	2		
March	2		
April			
May			1
June			
July			2
August		1	1
September			1
October		2	1
November			1
December	1		

Figure 5.1: A completed Where Are the Whales? sheet: In this data set, humpback whales were observed in Mexico in December through March and in California in May through November.

6. Once students finish sorting their data, give each group a Whale Migration sheet. Figure 5.2 shows a completed Whale Migration sheet. Circulate around the room while students complete the Whale Migration sheet. If they get stuck on question 1, suggest that they work on questions 2 through 5 and then go back to question 1. Ask students to explain why they answered questions 2 through 5 as they did. Listen for students to use the whale data to support their ideas.

Whale Migration

1. What patterns do you notice in this data?

   Between December and March, all the whale observations were in Mexico. Between May and November, all the whale observations were in Los Angeles and San Francisco.

2. Most whales spend about 6 months in the feeding ground and 4 months in the calving ground. Where is the feeding ground?

   California

3. Where is the calving ground?

   Mexico

4. When do whales travel from the calving ground to the feeding ground?

   April

5. When do whales travel from the feeding ground to the calving ground?

   November

Figure 5.2: A completed Whale Migration sheet: Students might say that the whales migrate to the feeding ground in March, April, or May. Students might say that they migrate to the calving ground in November or December.

LS1.B Students describe migration in the humpback whale's life cycle.

Patterns Students identify patterns of changes in humpback whale location over the course of the year.

Engaging in argument from evidence Students use evidence from the whale data sort to support their ideas about the location of the calving ground and feeding ground and the times of the year whales travel between these two locations.

CSTA 1B-DA-06 Students use data they have organized visually to support claims about whale migration.

7. Bring the class together. Discuss the Whale Migration sheet. Continue to ask students to provide evidence to support their ideas.
8. Tell students that they can check some of their ideas about whale migration if they can track how an individual whale moves over the course of a year. Ask students if they noticed anything in the card set that makes them think some of the pictures are of the same whale. Students may or may not have noticed that the whale flukes have patterns on them and that some of the cards show flukes with the same patterns.
9. Tell students that each whale's fluke is unique to that whale. People can identify whales by their flukes. Tell students that some of the images on the cards are of the same whale. Tell students that if they can find multiple observations of the same whale, they can see how that whale moved over the year.
10. Tell students to observe the whale flukes and try to put all the flukes that belong to the same whale together.
11. Give students 10 to 15 minutes to observe the cards and organize them into groups that belong to the same whale. Circulate around the room as students sort their cards. Ask students why they matched certain cards together. Listen for students to talk about similarities and differences in patterns to justify their choices. At some point tell students that all the observations are of just four whales.

Patterns Students use similarities and differences in patterns in images to group the flukes of the same whales together.

Using mathematics and computational thinking Students organize the whale data set to reveal which observations are of the same whale.

CSTA 1B-DA-06 Students organize data visually to reveal which observations are of the same whale.

12. Once students have their cards sorted, have them choose a name for each whale. Have students label each set of pictures with the whale's name, using a sticky note.
13. As groups finish organizing their cards, use the key in Figure 5.3 to check their sort. Use a different color sticky note to mark any cards that are not sorted correctly. Tell students to double-check those cards.

Mostly white fluke: 1, 4, 11, 14

Mostly black fluke with many white circles and streaks: 2, 6, 10, 12, 15

Mostly black fluke with a white line on the left: 3, 7, 9

Mostly black with a feather-shape above a circle on the upper right side: 5, 8, 13, 16

Figure 5.3: The upper left corner of each card has a number. The key above shows the numbers of the cards that show the same whale.

14. Once students have their cards correctly sorted by whale, have students organize the observations of each whale chronologically, starting in January. Figure 5.4 shows all the cards sorted by whale and then organized chronologically.

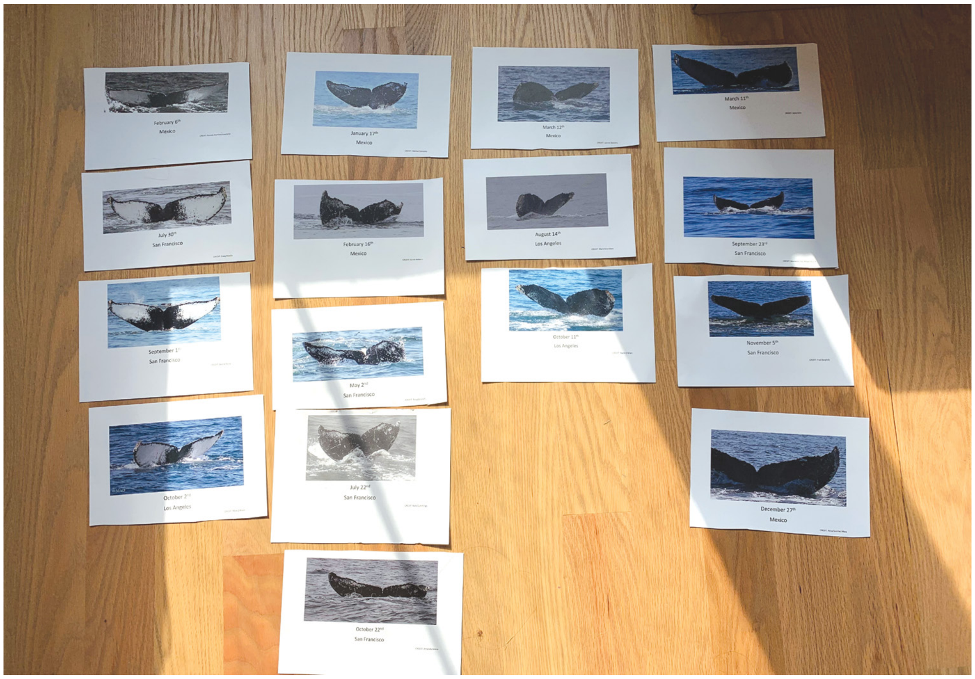


Figure 5.4: These are the Whale Data cards sorted by whale and organized chronologically.

15. Student groups will use their sorted cards in Task 6. Have students save their sorted cards with a paper clip, plastic bag, or envelope. Have groups use a sticky note to write their names on their card set.

Task 6: Modeling Whale Movement 40 minutes

Background Information

In this task, students continue to organize and present data visually to reveal relationships. Students use the general migration pattern they identified in Task 5 to predict the migration of individual whales. Using patterns of change to make predictions is part of the patterns crosscutting concept at this grade level. Students further develop the practice of modeling as they develop their own model to show where whales are located at different times of the year. And they use the computational thinking practice of abstraction as they make models that show details that are important to the problem and ignore details that are unimportant to the problem.

Students physically model whales and/or ships in this task, as well as in Task 7. The act of physically modeling an agent is helpful for students to later understand more complex computer models (13) like the one they will encounter in Task 11.

Task 6

Preparation

1. @ Navigate to **ScienceEducation.si.edu/whales**. Open the Whale Map file and have it ready to share with the whole class.
2. Make sure the What Do We Want to Know? chart is accessible to all students.
3. Make one copy of the Whale Map sheet, and one copy each of the Los Angeles, San Francisco, and Mexico sheets for each group of three students.
4. Make one copy of the Whale Model Directions sheet for each student.
5. Be prepared to give students objects to represent whales in their model. These can be the Whale 1 through Whale 4 Whale Game Pieces that students used in Task 2, paper clips, erasers, sticky notes, or stuffed animals.
6. Make sure that each group from Task 5 has access to their Where Are the Whales? sheet, their sorted Whale Data cards, and their Whale Migration sheet.
7. Have a Whale Life Game Board ready to share with the class.

Procedure

1. Direct students to look at the What Do We Want to Know? chart. Remind students that they want to know where whales swim.
2. Hold up a Whale Life Game Board. Remind students that they used a model to learn more about where whales are at different times of the year. Now they have more information about where specific whales have been observed at different times of the year. They can use this data to make their own model.

3. Project the Whale Map so it is accessible to all students. Remind students that the map shows the locations where the whales in their data set were observed.
4. Organize students into the same groups they were in for Task 5. Tell students that each group will make their own model of the whales' movement. They should make a model that shows details that are important to the problem and ignores unnecessary details. They can draw a model, act out a model on the paper map (see Figure 6.2), or physically act out a model in the classroom.
5. Point out that students have data for four whales. Each student will model the movement of one whale. If students are in a group of three, this means that one whale will not be included in the model. This is okay.
6. Give each group their completed Where Are the Whales? sheet, their sorted cards from Task 5, and their completed Whale Migration sheet. Show students that they can use a Whale Map sheet to make a smaller model or they can use the Los Angeles, San Francisco, and Mexico sheets to make a bigger model. Show students that they can use objects to represent whales or they can be the whales.
7. Give each student a Whale Model Directions sheet. Suggest that each student write where their whale will be at different times of the year. Figure 6.1 shows an example of a completed Whale Model Directions sheet.

Whale Model Directions

Month	Direction
January	Mexico
February	Mexico
March	Mexico
April	migrate
May	San Francisco
June	San Francisco
July	San Francisco
August	San Francisco
September	San Francisco
October	Los Angeles
November	migrate
December	Mexico

Figure 6.1: A completed Whale Model Directions sheet: Students will make predictions about where they think their whale was during some months of the year.

Task 6

CSTA 1B-DA-07 Students use data from some whales to predict likely migration patterns of other whales.

8. If students struggle to do this task, tell them to start by using the data from the cards to identify where they know their whale was during certain months. Then have students use the Where Are the Whales? sheet and the Whale Migration sheet to help them figure out where they think their whale was during other months of the year.
9. Give students 15 to 20 minutes to work together to use their sorted data to model the whales' movements.

LS1.B Students use migration patterns based on multiple whales to predict the likely movement of one whale.

Patterns Students use migration patterns based on multiple whales to predict the likely movement of one whale.

Developing and using models Students develop a model using data to show where whales are located over the course of a year.

CSTA 1B-DA-06 Students organize and present data to reveal an annual migration pattern of the humpback whale.

ISTE 1.5.b Students represent data in various ways to facilitate solving the problem of whales getting injured or killed by ship strikes.

Figure 6.2: Student models might include moving objects on their map that represent whales.

Task 6

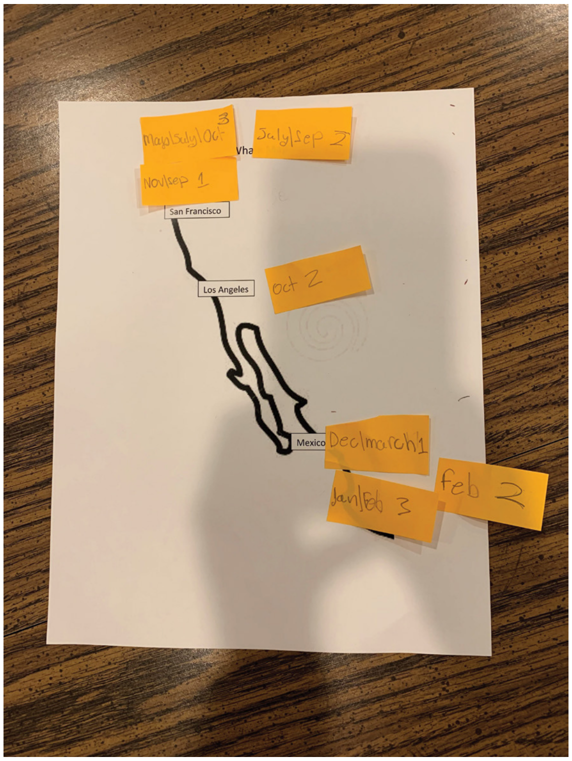


Figure 6.3: Or students might make a static model that shows where whales are at different times of the year.

10. Invite groups to share their model with another group.

Task 7: Adding Ship Traffic Data 15 minutes

Background Information

The San Francisco and Los Angeles areas of California both have heavy ship traffic. They are also common locations for humpback whales. In Task 7 students revise their models from Task 6 to include the location of heavy ship traffic.

Preparation

1. @ Navigate to **ScienceEducation.si.edu/whales**. Open the Ship Traffic Data file and have it ready to share with the whole class.
2. Make sure the What Is the Problem? and What Do We Want to Know? charts are accessible to students.

Procedure

1. Direct students to look at the What Is the Problem? and What Do We Want to Know? charts. Remind students that they are focusing on the problem of whales getting injured or killed by ship strikes. Ask students to talk to their shoulder partner about what else they would like to add to their model that might help them to better understand and begin to solve the problem. Invite students to share their ideas with the class. If students don't mention it, suggest that they could add the movement of ships to their model.
2. Organize students into the same groups they were in for Tasks 5 and 6. Project the Ship Traffic Data file. Tell students that the map shows the number of ships in different locations over one year. Have each group discuss what they think the colors on the map represent. Invite students to share their ideas. Make sure students understand what each color represents in terms of relative volume of ship traffic. For example, students should understand which color represents the most ships and which color represents the least ships.
3. Have each group discuss their ideas for adding ships to their model.
4. Give students 5 to 10 minutes to work together to create a new model that shows the whale movement and the ship traffic movement. Students can make a real-time model with ships and whales moving. Or they can draw on the map to show places where whales and ships are commonly found.

Developing and using models Students further develop a model using ship traffic data to show where whales and ships are located over the course of a year.

Using mathematics and computational thinking Students organize the whale and ship traffic data to reveal where whales are most likely to have the biggest problem with ships striking whales.

ISTE 1.5.b Students organize and present data to reveal the areas that are most likely to have the biggest problem with ships striking whales.

5. Circulate around the room while students are working on their models. If students are struggling to make a good model, ask guiding questions to help them out.
   - What do you observe on the map about ship traffic data?
   - Where are the most ships?
   - How could you show what you observed on the map in your model?
6. Invite groups to share their model with the class. If needed, give groups time to update their model with ideas they learned from other groups.

Task 8: Revised Ideas 15 minutes

Background Information

In this task students revisit the problem of whales getting hit by ships. Students use the practice of engaging in argument from evidence when they make a claim about where the most whales are getting injured or killed by ships and support it with evidence. Using data from the card sort and models, students are likely to explain that the Los Angeles and San Francisco areas of California are the most likely areas for whales to get hit by ships. Students have a chance to brainstorm more solutions.

Preparation

1. Make sure the How Can We Protect Whales from Ship Strikes? chart is accessible to all students.
2. Make one copy of the Your Ideas About the Problem and Solution sheet for each student.

Procedure

1. Tell students they are going to use what they learned by modeling whale and ship data to think more about the problem and how they might be able to decrease the number of whales that are injured or killed by ships.
2. Give each student a Your Ideas About the Problem and Solution sheet and have students complete it. If students do not provide evidence to support their claim, ask students, "Why do you think that?" Encourage them to write down their evidence.

Patterns Students use the whales' pattern of movement and the ships' pattern of movement as evidence to support an argument about where ships striking whales is likely to be the biggest problem.

Engaging in argument from evidence Students use a data model as evidence to support an argument that the Los Angeles and San Francisco areas of California are likely to have the most ship strikes.

1B-DA-06 Students use their data model to support a claim about where the most whales are getting injured or killed by ship strikes.

ISTE 1.5.b Students use data to inform their updated solution to the problem of whales getting injured or killed by ship strikes.

3. Direct students to look at the How Can We Protect Whales from Ship Strikes? chart. Invite students to share additional ideas about how they could protect whales from ship strikes.

Task 9: Research Solutions 20 minutes

Background Information

Scientists and engineers research a problem and possible solutions before designing a solution. In this task students do further research to better understand the problem of humpback whales getting hit by ships and possible solutions.

Humpback whales cannot breathe underwater. They need to swim to the surface so they can breathe air through their blowhole. Unfortunately, ships are also at the surface. Humpback whales can stay underwater for up to 45 minutes. Findings from research suggest that if large ships decrease their speed to 10 knots (12 mph) or less in areas with large numbers of whales, it decreases the number of ships striking whales. When ships go slower, whales may be able to avoid collisions. One study documented a blue whale that was able to change its direction and avoid a ship moving at less than 10 knots (14).

People on an individual ship may not see or hear a whale in time to avoid hitting it. But people can share data to create real-time maps that can help ships avoid whales. Further, some communities have created areas that ships should avoid. Scientists use whale observation data to determine whales' pattern of movement in order to recommend times and areas that large ships should avoid.

Preparation

1. @ Navigate to **ScienceEducation.si.edu/whales**. Make one color copy of *Whales and Ships: Sharing the Ocean* for each student. Students will read parts of the story in pairs in this task and have the full story for reference in Task 10.
2. Make one copy of the Researching the Problem and Solution sheet for each student.

Procedure

1. Tell students that it can be useful to do research to help develop a good solution. Tell students that they are going to research more about why whales get hit by ships and some possible solutions.
2. Give each student a copy of *Whales and Ships: Sharing the Ocean* and a copy of the Researching the Problem and Solution sheet. Tell students there are four sections to the story: Ship Speed, How Do Whales Breathe?, Shipping Traffic and Whales, and How Can We "See" Whales?
3. Using the groups from Tasks 5, 6, and 7, assign one student from each of those groups to read one of the first three sections of the story. Reorganize students into pairs so that each student is reading their assigned section with a partner who has the same assigned section. Tell students that in the next task they are going to share what they learned from their section with the other students in their group from Tasks 5, 6, and 7.

4. Have students partner read their section of the story. Have one student read aloud while the other student follows along. Then have students switch roles and read it again.

Teacher Tip

Have students highlight or underline important parts and/or make notes on the story.

5. Have students discuss what they learned and how it might help them solve the problem of whales getting injured or killed by ship strikes. Have students record their ideas on the Researching the Problem and Solution sheet.

ETS1.B Students do further research on the problem of whales getting injured or killed by ship strikes.

Obtaining, evaluating, and communicating information Students obtain information from text to inform the solution to the problem of whales getting injured or killed by ship strikes.

6. Have pairs that finish early read the last section of the story (How Can We "See" Whales?) and update their Researching the Problem and Solution sheet.

Teacher Tip

@ Navigate to **ScienceEducation.si.edu/whales**. Have students read *Up Close with a Marine Scientist* to learn more about marine scientist Sarah Mallette and a Navy-funded research project to help protect whales.

Task 9

Task 10: Propose a Solution 30 minutes

Background Information

In this task students work in a group to apply what they have learned throughout the unit to propose a solution and/or suggest additional research that needs to be done to reduce the number of whales that are injured or killed by ship strikes. Student may want to create areas with slower ship speeds or areas ships should avoid going. Students may want to do additional research about the Los Angeles and San Francisco areas of California to learn more details about where whales and ships are found in those areas.

There is not a single (or even best) solution to a given problem. Engineers rely on the criteria they developed when they defined the problem to determine which solution best fits the need. That means engineers must often develop and test multiple solutions before selecting and optimizing the final solution. In the next task students will have the opportunity to test multiple solutions to see how they affect the number of whales hit by ships and the amount of good delivered.

Preparation

1. Make one copy of the Our Solution sheet for each group of three students.
2. Make sure each student has their completed Researching the Problem and Solution sheet.
3. The following sheets will also be helpful to students: Where Are the Whales?, Whale Map, and Whale Migration.

Procedure

1. Organize students into the same groups as in Tasks 5, 6, and 7.
2. Have each student use their Researching the Problem and Solution sheet to share what they learned from their section of the story with the rest of the group. If no one in the group had a chance to read the last section (How Can We "See" Whales?), have students read that section of the story now.
3. Give each group an Our Solution sheet and their Where Are the Whales?, Whale Map, and Whale Migration sheets.
4. Have students work together to propose a solution to decrease the number of whales getting injured or killed by ship strikes.

Teacher Tip

Have extra copies of the Whale Map sheet available in case students want to share their solution on a map.

5. Encourage students to think about additional research that can be done for their solution. For example, students might suggest collecting more whale data to see where whales are in the Los Angeles or San Francisco areas of California.

LS2.C Students develop a solution to change a place's physical characteristics to increase the number of whales that can survive and reproduce.

Designing solutions Students apply scientific ideas about whale migration and whale behavior to design a solution to decrease the number of whales getting injured or killed by ship strikes.

ISTE 1.5.b Students use data to inform a solution that will decrease the number of ships striking whales and/or suggest collecting more data to identify more specific locations that need a solution to the problem of ships striking whales.

6. Have students post their solutions and research ideas around the room.
7. Have students use the displayed sheets to learn about other groups' ideas.
8. Bring the class together to discuss possible solutions and ideas for additional research.

Task 11: Testing Solutions 45 minutes

Background Information

A computer can store and process much more data than people can. Because a data-based computer model enables a user to visualize more data than a human-created model, a computer model may be able to reveal additional relationships that might be important to understanding a phenomenon or solving a problem.

In this task students use the Whale Protection Corps (pronouced "core") simulation to see more details about where whales and ships are likely to be found along the west coast of North America. Students can use the Whale Protection Corps simulation to test possible solutions. Students can create areas that require slower ship speeds. Students can create areas that ships should avoid. Students can decide to contribute to and access real-time whale data. By running the simulation with different solutions in place, students can see how their solution will affect the number of ships striking whales and the amount of goods delivered. Students complete this task by constructing an argument about the best solution to reduce the number of whale ship strikes.

Preparation

1. @ Navigate to **ScienceEducation.si.edu/whales**. Open the Whale Protection Corps simulation and have it ready to share with the whole class.
2. @ Navigate to **ScienceEducation.si.edu/whales** on each student device and access the Whale Protection Corps simulation.
3. @ Navigate to **ScienceEducation.si.edu/whales**. Copy a Testing Solutions sheet for each student.
4. Make one copy of the Revised Solution sheet for each group of two students.

Procedure

1. Organize students into groups of two.
2. Give each student a Testing Solutions sheet.
3. Have students use the Whale Protection Corps simulation to view whale and ship data and test different solutions.
4. Have students complete the Testing Solutions sheet.

Designing solutions Students generate and compare multiple solutions to a problem based on how well they decrease the number of ships that strike whales, maintain the amount of goods delivered, and minimize cost.

ISTE 1.5.b Students use a digital tool to analyze data to facilitate solving the problem of whales getting injured and killed by ship strikes.

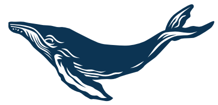
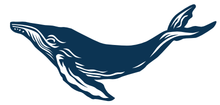
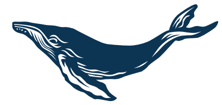
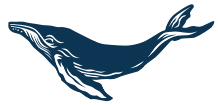
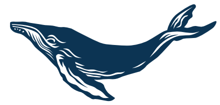
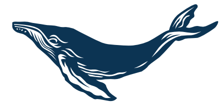
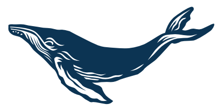
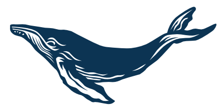
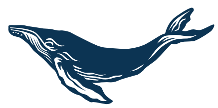
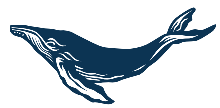
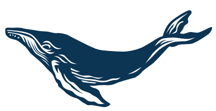
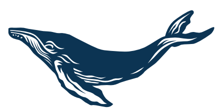
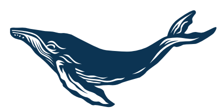
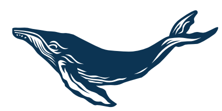
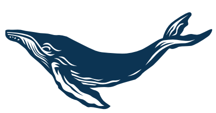
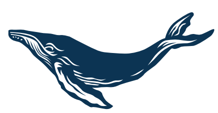
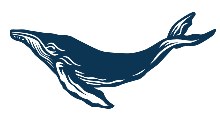
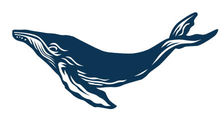
5. Hand out a Revised Solution sheet to each group of students and have them complete it.

Engaging in argument from evidence Students use evidence from a model to support a claim about the merit of their revised solution.

Whale Life Game

	Year and Whale Age										
	0	1	2	3	4	5	6	7	8	9	10
Whale 1	0										
Whale 2	5										
Whale 3	10										
Whale 4	15										
Whale 5	20										
Whale 6	25										
Whale 7	30										
Whale 8	35										

Whale Game Pieces

Whale 1 	**Whale 2** 	**Whale 3** 	**Whale 4** 
Whale 5 	**Whale 6** 	**Whale 7** 	**Whale 8** 
Whale 9 	**Whale 10** 	**Whale 11** 	**Whale 12** 
Whale 13 	**Whale 14** 	**Whale 15** 	**Whale 16** 
Whale 17 	**Whale 18** 	**Whale 19** 	**Whale 20** 
Whale 21 	**Whale 22** 	**Whale 23** 	**Whale 24** 

Whale Life Game Review

1. What is different about the whale's environment today compared to 250 years ago?

2. How has that change in the environment affected whales? What is your evidence?

3. What would happen if you played the game again without the *Have a Baby* space on the spinner?

Where Are the Whales?

	Mexico	Los Angeles	San Francisco
January			
February			
March			
April			
May			
June			
July			
August			
September			
October			
November			
December			

Whale Migration

1. What patterns do you notice in this data?

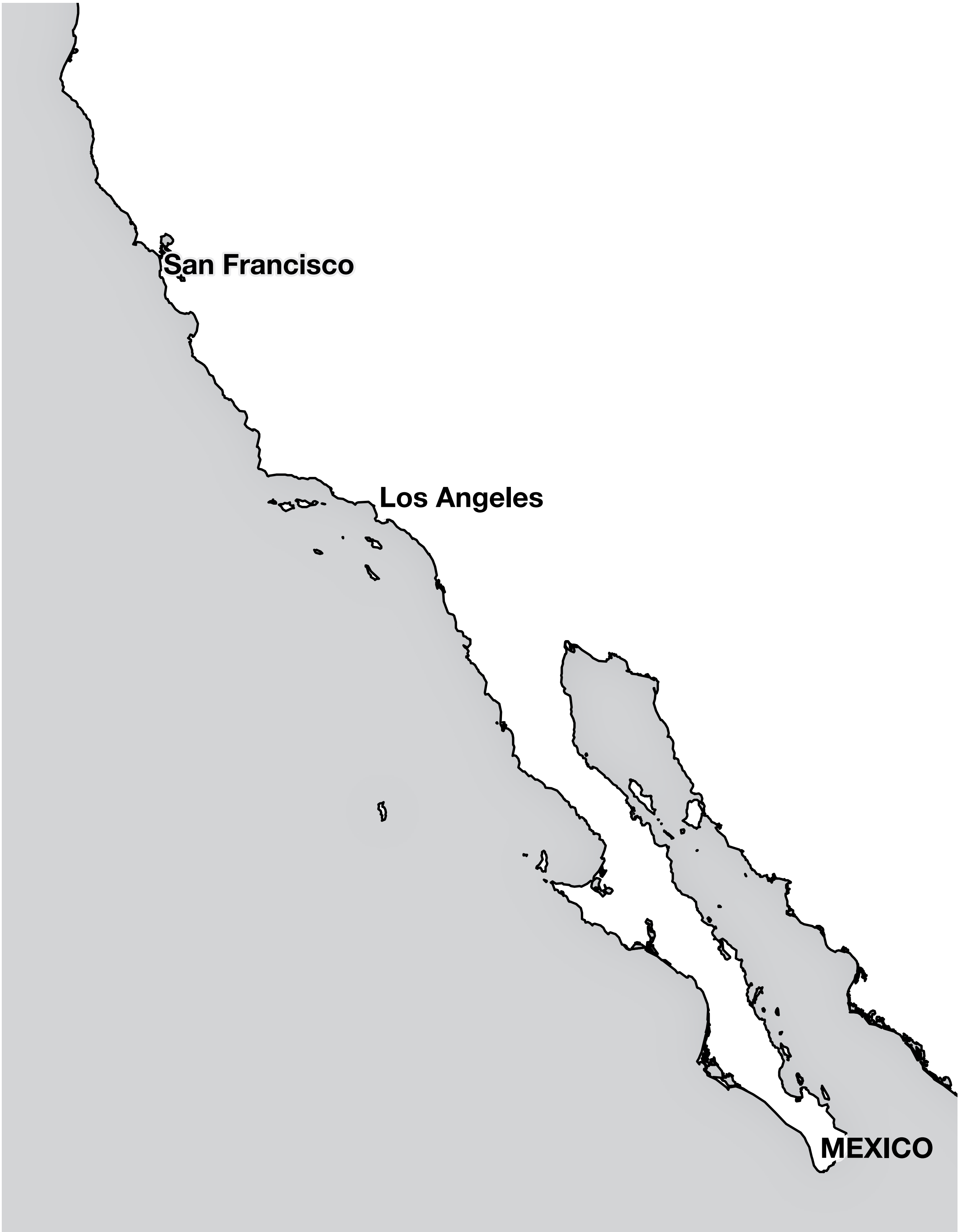
2. Most whales spend about 6 months in the feeding ground and 4 months in the calving ground. Where is the feeding ground?

3. Where is the calving ground?

4. When do whales travel from the calving ground to the feeding ground?

5. When do whales travel from the feeding ground to the calving ground?

Whale Map



Student Sheets

Whale Model Directions

Month	Direction
January	
February	
March	
April	
May	
June	
July	
August	
September	
October	
November	
December	

Los Angeles

Student Sheets

San Francisco

Mexico

Your Ideas About the Problem and Solution

1. Where are the most whales getting injured or killed by ships? What is your evidence?

2. How can you decrease the number of whales getting injured or killed by ships?

Student Sheets

Researching the Problem and Solution

Problem: Whales are injured or killed from getting hit by ships.

1. What did you learn that could help solve this problem?

Our Solution

Problem: Whales are injured or killed from getting hit by ships.

Describe your solution below.

1. Our solution:

2. What additional research should be done for your solution?

Revised Solution

Problem: Whales are injured or killed from getting hit by ships.

1. What is the solution you recommend? Why?

Student Sheets

References

1. Committee on STEM Education of the National Science and Technology Council. 2018. *Charting a Course for Success: America's Strategy for STEM Education*. Office of Science and Technology Policy. Retrieved from https://www.energy.gov/sites/default/files/2019/05/f62/STEM-Education-Strategic-Plan-2018.pdf.
2. National Resource Council. 2012. *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press. Retrieved from https://doi.org/10.17226/13165.
3. Moulding, B., R. Bybee, and N. Paulson. 2015. *A Vision and Plan for Science Teaching and Learning: An Educator's Guide to a Framework for K–12 Science Education, Next Generation Science Standards, and State Standards*. Salt Lake City, UT: Essential Teaching and Learning PD, LLC.
4. Odden, T.O., and R. Russ. 2019. Defining Sensemaking: Bringing Clarity to a Fragmented Theoretical Construct. *Science Education* 103, no. 1: 187-205.
5. Short, M.E. 2021. *Making Sense of Student Sensemaking*. Retrieved from https://landing.carolina.com/smithsonian-students-sensemaking-whitepaper.
6. Wing, J.M. 2010. Research Notebook: Computational Thinking—What and Why? *The Link*. Carnegie Mellon University School of Computer Science. Retrieved from https://www.cs.cmu.edu/link/research-notebook-computational-thinking-what-andwhy.
7. Shute, V.J., C. Sun, and J. Asbell-Clarke. 2017. Demystifying computational thinking. *Educational Research Review* 22: 142-58. Retrieved from https://doi.org/10.1016/j.edurev.2017.09.003.
8. Yadav, A., H. Hong, and C. Stephenson. 2016. Computational thinking for all: Pedagogical approaches to embedding 21st century problem solving in K–12 classrooms. *TechTrends* 60, no. 6: 565-568. Retrieved from https://doi.org/10.1007/s11528-016-0087-7.
9. Weintrop, D., E. Beheshti, M. Horn, K. Orton, K. Jona, L. Trouille, and U. Wilensky. 2016. Defining Computational Thinking for Mathematics and Science Classrooms. *Journal of Science Education and Technology* 25: 127–47.
10. NGSS Lead States. 2013. *Next Generation Science Standards: For States, by States*. Washington, DC: The National Academies Press.
11. Computer Science Teachers Association. 2017. *CSTA K-12 Computer Science Standards.* Retrieved from https://www.doe.k12.de.us/cms/lib/DE01922744/Centricity/Domain/176/CSTA%20Computer%20Science%20Standards%20Revised%202017.pdf.
12. Brooks-Young, Susan. 2016. *ISTE Standards for Students: A Practical Guide for Learning with Technology.* Arlington, VA: International Society for Technology in Education.
13. Sengupta, P., A. Dickes, A. Voss Ferris, A. Karan, D. Martin, and M. Wright. 2015. Education Programming in K-12 Science Classrooms: Introducing students to visual programming as a pathway to text-based programming. *Viewpoints* 58, no. 11: 33-35.
14. Szesciorka, A.R., A.N. Allen, J. Calambokidis, J. Fahlbusch, M.F. McKenna, and B. Southall. 2019. A Case Study of a Near Vessel Strike of a Blue Whale: Perceptual Cues and Fine-Scale Aspects of Behavioral Avoidance. *Frontiers in Marine Science* 6: 761. doi:10.3389/fmars.2019.00761.