



LESSON TITLE

9th -12th

Sheltered Biology
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BIG IDEAS

- **Interconnectedness of Spheres:** The lesson directly connects the **atmosphere** (rising CO₂ levels) with the **hydrosphere** (decreasing ocean pH).
- **Data Analysis as Evidence:** Students use authentic data from NASA and NOAA to identify patterns and trends, rather than just being told the facts.
- **Identifying Cause and Effect:** The core goal is for students to graph and analyze two separate datasets (CO₂ and pH) and infer the causal relationship between them.
- **Real-World Consequences:** The lesson links data analysis to its tangible impact on marine habitats.
- **Science Communication and Advocacy:** The final PSA assessment requires students to translate complex scientific information (causes and consequences) into a persuasive public message and propose solutions.

EDUCATION STANDARDS

Interdependent Relationships in Ecosystems > HS-LS2-6: Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. Students build toward this standard by evaluating claims and evidence from computer simulations, data representations, and video demonstrations regarding the changing conditions affecting ocean pH and coral reef ecosystems (Levels 3, 4, and 5).

Human Sustainability > HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. Students use computer simulations, data maps, and graphs to demonstrate the impact of anthropogenic increases in atmospheric CO₂ on ocean chemistry, marine populations, and ecosystems (Levels 3, 4, and 5).

Chemical Reactions > HS-PS1-6: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium. Students manipulate a computer simulation of the carbonate buffer system to explain that increases in atmospheric CO₂ led to higher hydrogen ion concentrations in seawater. Teachers could slightly modify the student presentations in Level 5, allowing opportunities for students to construct and refine solutions to ocean acidification (Levels 3, 4, and 5).

Earth and Human Activity > (HS-ESS3-5): Analyze geoscience data... to make an evidence-based forecast of the current rate of global... climate change and associated future impacts to Earth systems.

Earth and Human Activity > (HS-ESS3-6): Use a computational representation to illustrate the relationships among Earth's systems and how those relationships are being modified due to human activity.

Ecosystems: Interactions, Energy, and Dynamics >(HS-LS2-7): Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

NGSS Performance Expectation(s)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
<p>Analyzing and Interpreting</p> <p>Using Mathematics and Computational Thinking</p> <p>Constructing Explanations and Designing Solutions</p> <p>Engaging in Argument from Evidence</p>	<p>Ecosystem Dynamics, Functioning, and Resilience</p> <p>Weather and Climate</p> <p>Global Climate Change</p> <p>Chemical Reactions</p>	<p>Cause and Effect</p> <p>Scale, Proportion, and Quantity</p> <p>System and System Models</p> <p>Stability and Change</p>
<p align="center">Common Core State Standards: Standard Connections.</p> <p>Math: MP.2 Reason abstractly and quantitatively.</p> <p>Math: MP.4 Model with mathematics</p> <p>HSN.Q.A.1 Use units to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.</p>		

HSN.Q.A.2 Define appropriate quantities for descriptive modeling.
HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
HSS.IS.A.1 Represent data with plots on the real number line
HSS-1C.A.1. Understand statistics as a process for making inferences and population parameters based on a random sample from the population.
HSS.IC.B.6. Evaluate reports based on data.

ELA: RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author’s claim or a recommendation for solving a scientific or technical problem.

RST. 11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) to address a question or solve a problem.

RST. 11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources or information.

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

ITEEA Standards *N/A*

Other Standards *N/A*

MEASURABLE STUDENT LEARNING OBJECTIVES

DOK 1: Recall & Reproduction

Students will be able to:

- **Define** key vocabulary terms, including ocean acidification, hydrosphere, atmosphere, and pH.
- **Identify** the primary data sources for the lesson (NASA and NOAA) and the variables being measured (atmospheric CO₂ and ocean pH).

DOK 2: Skills & Concepts

Students will be able to:

- **Graph** the provided datasets for atmospheric CO₂ levels and ocean pH levels over time.
- **Describe** the observable trends in each dataset (e.g., "Atmospheric CO₂ levels have increased since...").
- **Summarize** the process of how CO₂ in the atmosphere contributes to changes in ocean chemistry.

DOK 3: Strategic Thinking & Reasoning

Students will be able to:

- **Analyze** the relationship between the CO₂ graph and the pH graph to **infer** a cause-and-effect relationship.
- **Explain** the consequences of ocean acidification for specific marine habitats or organisms, using evidence from the data.
- **Conclude** the interconnectedness of Earth's spheres (atmosphere and hydrosphere) based on their data analysis.

DOK 4: Extended Thinking

Students will be able to:

- **Synthesize** all lesson findings (causes, trends, consequences) to **create** a persuasive public service announcement (PSA).
- **Propose** and **justify** potential solutions to mitigate ocean acidification as part of their advocacy message.

STEM INTEGRATION

Literacy is integrated into this lesson through persuasive and informative writing/speaking. Students must take complex scientific data and conclusions and communicate them into a clear, concise, and compelling message for a general audience. This will develop science communication skills by encouraging students to “own” the knowledge at a deep level—they cannot create an effective PSA if they don’t truly understand the causes, consequences, and

potential solutions. It also enhances literacy skills by giving them power.

NATURE OF STEM

The lesson is designed to move beyond teaching scientific facts and model the scientific process. By addressing the Nature of Science, students take on the role of scientists, analyzing empirical, real-world data from NASA and NOAA to conclude rather than simply repeating facts. This inquiry can only exist due to the nature of technology, which is showcased as the essential tool, including satellites and ocean sensors, that extend human sense to gather this data, demonstrating the co-dependent relationship between scientific questions and technological capabilities. Considering the nature of mathematics, this is framed in the precise language of this inquiry; students use graphing to create a mathematical model, allowing them to clearly visualize and quantify the correlation between atmospheric CO₂ and ocean pH.

MATERIALS NEEDED

Digital Materials:

Datasets – from NASA and NOAA

Microsoft Excell

Student Devices

PSA Creation Tools- Presentation (Google Slides, PowerPoint)

Graphic design tools (canva)

Video Editing software (iMovie, WeVideo, or phone's built-in editor)

In-Class Materials:

Student Handout/Worksheet

Graph Paper

Pencils and Rulers

PSA Art Supplies (poster board, markers, colored pencils, etc)

ENGAGING CONTEXT/PHENOMENON

Hook (dependent upon availability)

Visualize Hook (supports EL and EE Learning) has a gallery walk setup with seashells around the classroom. Some of the shells are healthy, pearly, and strong, and the others are chalky, pitted, and brittle. Whole class discussion: What did you notice that was different about the seashells? What do you think happened to shells 2,4,6 and 8? What do you think is happening to our oceans that could cause this (point to healthy shells on the left) to turn into this (point to the unhealthy shells)? Provide sentence stems/frames for students to respond to the following prompt. Write down one or two ideas.

Video: What Is Ocean Acidification? | A Cartoon Crash Course

Source: The Pew Charitable Trusts

URL: <http://www.youtube.com/watch?v=ogZkV-Yj7Hc>

DATA INTEGRATION

The following data will be integrated into the lessons for students to analyze and think through:

First, we will start with NASA’s “Visualizing Global Carbon Dioxide” to help students connect the atmosphere to the hydrosphere.

Students will observe the movement of atmospheric Carbon, which includes AIRS (Atmospheric Infrared Sounder) <https://wwwb.earthdata.nasa.gov/data/instruments/airs> , and OCO-2(Orbiting Carbon Observatory 2) <https://ocov2.jpl.nasa.gov/science/oco-2-data-center/>

As well as the Global Ocean Acidification Observing Network (GOA-ON) which monitors global ocean acidification. <https://portal.goa-on.org/>

TEACHER BACKGROUND KNOWLEDGE

Teacher background knowledge:

The teacher will need to know the students' trajectory with the topic, based on previously taught middle school standards.

Content-wise, the educator will know the tier 3 and tier 2 vocabulary that will support student understanding.

Tier II (transitional words)	Tier III (Content Specific Words)
Reaction	Absorption
Dissociation	The pH Problem

The teacher will be able to connect human impact, population growth, and ecosystem changes to the hydrosphere and atmospheric carbon dioxide. This will also begin the process of introducing the tools of STEM that will drive the lesson and student understanding.

DIFFERENTIATION OF INSTRUCTION

- One key consideration when differentiating this lesson is knowing who your students are and where they are in key areas of literacy, reading, writing, and speaking. One way that students will differentiate is by using the rubric below.
 - Content For Readiness: Provide a tiered text. One group gets a standard article, while another (e.g., struggling readers or ELs) receives an article with a pre-highlighted main idea and a built-in vocabulary glossary.
 - Process For Learning Profile: When graphing the NASA/NOAA data, give students options: a "Tech Track" to use Google Sheets to create a digital graph, or a "Hands-

on Track" to plot the data manually on graph paper.

- Product For Interest: For the final PSA, give students a choice: create a visual infographic (for artistic students), write a persuasive script (for strong writers), or record a 1-minute video (for tech-savvy students).
- Environment For Readiness: Create a "scaffold station" with sentence stems and analysis questions that students can *choose* to pick up if they get stuck inferring the link between the two graphs. (

REAL-WORLD CONNECTIONS FOR STUDENTS

One of the connections we will link to this study is the impact, as previously mentioned, on coastal communities such as those in California, including changes to ecosystems, increased erosion, and population shifts.

INTEGRATION POSSIBLE MISCONCEPTIONS

One misconception is the acidification of the ocean as it has pH of 7 so it's alkaline. This is a misunderstanding of the term "acidification." The sea is indeed naturally alkaline, with an average pH of about 8.1. Acidification is the process by which pH decreases (moving toward the acidic end of the scale). It does not mean the ocean has become an "acid".

Also, increased CO₂ is suitable for plants, which is dangerous oversimplification. While some simple photosynthetic organisms (such as certain algae or seagrasses) may grow faster with higher dissolved CO₂ levels, this isn't necessarily a good thing.

LESSON PROCEDURE

5E	Details of 5E Lesson Implementation
<u>Engage</u>	<p>Procedure: Visualize Hook (supports EL and EE Learning) has a gallery walk setup with seashells around the classroom. Some of the shells are healthy, pearly, and strong, and the others are chalky, pitted, and brittle. Whole class discussion: What did you notice that was different about the seashells? What do you think happened to shells 2,4,6, and 8? What do you think is happening to our oceans that could cause this (point to healthy shells on the left) to turn into this (point to the unhealthy shells)? Provide sentence stems/frames for students to respond to the following prompt. Write down one or two ideas.</p> <p>Alternative to engage ML and EE students</p> <p>Teacher: As students enter, the teacher has the "Disappearing Shell" demonstration set up on a front table (a seashell or a piece of chalk fizzing in a beaker of vinegar). Alternatively, a short video of this is on loop on the main screen. The teacher greets students and directs their attention to the demo. After a minute or two, the teacher poses three questions for a Think-Pair-Share:</p> <ol style="list-style-type: none"> 1. "What do you observe?" 2. "Why do you infer this is happening?" 3. "What do you predict this might have to do with our oceans?" <p>Student: Students observe the demonstration, think independently, and</p>

	<p>then discuss the three questions with a partner. Several students share their inferences with the whole class, activating prior knowledge about acids, bases, and shells (calcium carbonate).</p> <p>Modifications ELLs: Provide a visual "word bank" on the board with key terms: Observe, Infer, Shell, Dissolve, Acid, Vinegar, Ocean. Use sentence starters for the pair-share: "I observe...", "I infer this is happening because...", "This connects to the ocean by..."</p> <p>Standards Addressed HS-LS2-6, HS-PS1-6</p> <p>Formative/Summative Assessments: Teacher circulates and listens during the Think-Pair-Share. This is a pre-assessment to gauge students' prior knowledge of acids/bases and their initial conceptions about the ocean.</p> <p>Resources</p> <p>Beaker (250ml)</p> <p>White Vinegar</p> <p>Seashell (or piece of chalk)</p> <p>Mimeo Board or Promethon Board</p>
<p><u>Explore</u></p>	<p>Procedure: Students will actively explore data to discover the relationship between atmospheric carbon dioxide and ocean pH.</p> <p>Teacher: Divides the class into "Expert Groups" of 3-4 students (Groups 1, 2, and 3). The teacher provides each group with their specific data packet and "mission."</p> <ul style="list-style-type: none"> • Group 1 (Atmosphere): Gets NASA data on atmospheric CO₂. Mission: "Identify the trend in atmospheric CO₂ over the last 50

years."

- **Group 2 (Hydrosphere):** Gets NOAA data on ocean pH. Mission: "Identify the trend in ocean pH over the last 50 years."
- **Group 3 (Biosphere):** Gets short readings/infographics on shell-building organisms (pteropods, oysters, coral). Mission: "Identify what these organisms need to build their shells and what happens when the water chemistry changes."

Teacher: After 10-15 minutes, the teacher instructs students to "jigsaw" into new "Teaching Groups" (one expert from Group 1, 2, and 3 in each new group).

Student: In "Expert Groups," students analyze their data/reading and become experts on it. In "Teaching Groups," each student "teaches" their findings to their new group members. The group's collective task is to create a concept map or model on a large sheet of paper that answers the question: "**How are all three of our pieces of information connected?**"

Modifications for ELLs: Jigsaw is an excellent strategy. Provide readings for Group 3 with predefined key vocabulary. For data groups, color-code the axes (e.g., "Time is the **blue** axis") and provide a sentence starter for their conclusion: "As the time (x-axis) increases, the CO₂ level (y-axis) ..." ELs will be grouped based on the ELPA 21 scores and their growth areas.

Standards Addressed (HS-ESS3-5)

Formative/Summative Assessments The group-created concept map. The teacher circulates, observing the group discussions and the models, checking for the correct connection (Rising CO₂ → Falling pH → Harm to organisms).

Resources

Handout 1: NASA CO₂ data graph (e.g., the Keeling Curve).

	<p>Handout 2: NOAA ocean pH data graph (e.g., Hawaii Ocean Time-series).</p> <p>Handout 3: Infographics/short readings on coral, pteropods, and oysters.</p> <p>Large poster paper</p> <p>Markers.</p>
<p>-</p> <p><u>Explain</u></p>	<p>Procedure:</p> <p>Teacher: Brings the class back together. Ask 1-2 groups to share their concept map. The teacher then formalizes their findings with a 10-minute mini-lecture, introducing key vocabulary: Ocean Acidification, Carbonic Acid, Carbonate Ions. The teacher shows the chemical equation ($\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$) and explains how the carbonic acid "steals" the carbonate ions that shell-builders need. The teacher explicitly debunks common misconceptions ("It's not an acid yet...").</p> <p>Student: Listens, takes notes, and asks clarifying questions. Students refine their own group's concept map with the new, formal vocabulary.</p> <p>Modifications: Provide a "cloze" notes worksheet for the mini lecture where they fill in the new vocabulary words.</p> <p>Standards Addressed (HS-ESS3-5) and HS-LS2-6</p> <p>Formative/Summative Assessments: Four Corners regarding ocean acidification. Teacher asks, "Check for Understanding" questions (e.g., "So, does 'acidification' mean the ocean is now an acid? [No!]")—review of the refined concept maps.</p> <p>Resources</p> <p>Slides/diagrams showing the chemical reaction.</p> <p>Student notebooks or group concept maps.</p>

Elaborate

Procedure:

Teacher: Poses the question: "Now we know the science. Why does it matter to *people*?" The teacher presents two short case studies (using the articles/videos you found) to the whole class:

1. Arctic Indigenous Communities: Show a quote or short video about the cultural and food security implications of a declining salmon population (which feeds on affected organisms).
2. Pacific Island Nations: Show a map of Tuvalu and explain how the death of coral reefs (from acidification and warming) removes their *only* protection from storm surge and sea-level rise.

Teacher: Facilitates a class discussion: "How is ocean acidification not just an environmental problem, but also a social, cultural, and economic one?"

Student: Reads the case studies. Connects the abstract science (chemistry) to concrete human impacts. Participates in the class discussion, applying their new vocabulary to explain the real-world scenarios.

Modifications ELLs: Pre-teach the words "**culture**," "**tradition**," and "**economy**." Use captioned videos.

Standards Addressed (HS-ESS3-5), (HS-ESS3-6)

Formative/Summative Assessments: The quality of the class discussion. The teacher assesses students' ability to use evidence from the Explore phase to justify their claims about human impact.

Resources:

Curated articles, quotes, or short video clips about:

1. Arctic Indigenous communities.
 2. Pacific Island nations (Tuvalu, Kiribati).
- Projector/Smartboard.

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Evaluate

Procedure: Teacher: Introduces the summative assessment: a 60-second Public Service Announcement (PSA). The teacher provides a clear rubric. The PSA must:

1. Explain the *cause* of ocean acidification (using data).
2. Describe one *effect* on either an ecosystem or a human community.
3. Include one clear *call to action*.

Teacher: As students begin planning their PSAs (individually or in pairs), the teacher hands out the final Exit Ticket for the last 5 minutes of class.

Student: Begins planning the PSA. Before leaving, the student completes and hands in the Exit Ticket. The PSA can be completed in class the next day or assigned as homework.

Modifications: Provide a storyboard template or script outline for the PSA. Allow them to create the PSA in their native language with English subtitles, or as a visual-only infographic.

Standards Addressed HS-ESS3-5, HS-ESS3-6, and HS-LS2-7

Formative/Summative Assessments Exit Ticket. The prompt is: "In two sentences, explain the link between the CO₂ from a car's exhaust pipe and a crab's ability to build its shell." This checks their understanding of the entire lesson's causal chain.

Summative: The final **PSA** (graded with the rubric).

Resources

Rubric for PSA (printed or digital).

Exit Ticket slips (notecards or small paper).

(Optional) Devices for students to record/create their PSAs (phones, tablets, computers).

REFERENCES