

Data Analysis Lesson Plan

Lesson Title: Climate Change: How do increasing levels of CO₂ impact the health of our oceans?

Author: Danielle Neubauer

Topic: Climate Change, Ocean Chemistry, Ocean Acidification, Analyzing Data Sources, Human Impact on the Environment

Targeted Grade Level: High School, Grades 9-10

Time Needed: 3-4 Class Blocks/80 Minute Periods (can be adapted for shorter periods)

Subject Integration: Science, Math, & Technology

Justification for Data Integration:

Students will observe and analyze authentic data sourced directly from NOAA (atmospheric CO₂, oceanic CO₂, and ocean pH levels) that will act as a precursor to the cause-and-effect relationship between increasing atmospheric CO₂ levels and ocean acidification. Students often learn about increasing atmospheric CO₂ in science class but may not directly connect this phenomenon as the cause of decreasing pH of the world's oceans. Integrating authentic data will help engage students in a lesson about data interpretation and analysis, emphasizing the Nature of Science tenet that *Scientific Knowledge is Based on Empirical Evidence*. Analyzing data will help students to make reliable claims about patterns of change related to ocean acidification and to help them examine how ocean chemistry, marine populations and ecosystems are changing in response to increases in atmospheric CO₂.

Connections to STEM:

Science: Students will practice using observations and data to construct explanations about natural phenomena, analyze data and identify trends and patterns, and make predictions about future outcomes.

Math: Students will use algebra to calculate the percent change in CO₂ levels over the last 36 years.

Engineering: Students will research solutions to mitigate the effects of ocean acidification on vulnerable marine organisms.

Standards

NGSS Performance Expectations:

HS-LS2-6 (Interdependent Relationships in Ecosystems): 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.

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

HS-PS1-6 (Chemical Reactions): Refine the design of a chemical system by specifying a change in conditions that would

produce increased amounts of products at equilibrium.		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
<p>Analyzing and Interpreting Data Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Builds toward HS-ESS3-6 and LS2-6.</p> <p>Using Mathematics and Computational Thinking Use computational representations of phenomena to support claims and/or explanations. (HS-ESS3-6)</p> <p>Constructing Explanations and Designing Solutions Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. Builds toward HS-LS2-6.</p> <p>Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS1-6).</p>	<p>Ecosystem Dynamics, Functioning, and Resilience</p> <p>HS-LS2-C: A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability (HS-LS2-6).</p> <p>Weather and Climate</p> <p>HS-ESS2.D: Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere (HS-ESS3-6).</p> <p>Global Climate Change</p> <p>HS-ESS3.D: Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities (HS-ESS3-6).</p> <p>Chemical Reactions</p> <p>HS-PS1.B: In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present (HS-PS1-6).</p>	<p>Stability and Change Much of science deals with constructing explanations of how things change and how they remain stable (HS-PS1-6; HS-LS2-6).</p> <p>Cause and Effect Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Builds toward HS-ESS3-6</p> <p>System and System Models When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models (HS-ESS3-6).</p>
Common Core State Standards:		

Math:

CCSS.MATH.CONTENT.7.RP.A.2.B

Identify the constant of proportionality (unit rate) in tables, graphs, equations, diagrams, and verbal descriptions of proportional relationships.

ELA/Literacy :

RST.11-12.1Cite 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. (HS-ESS3-5)

RST.11-12.2Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (HS-ESS3-5)

Measurable Student Learning Objectives:

Students will be able to:

- Develop an understanding of how carbon moves between land, oceans, and the atmosphere is key to understanding how our climate will continue to change.
- Read and interpret graphs of atmospheric and ocean CO₂. Students predict the likely effect of changes in CO₂ on ocean pH.
- Use data and models to understand the relationship between ocean carbon dioxide and pH.
- Analyze ocean chemistry data to compare coastal and ocean acidification.
- Examine carbonate data in a coastal ecosystem and will explain the relationships between global increases in CO₂, ocean pH, and the effects on vulnerable marine organisms.
- Design their informational brochure to answer research questions

Possible Misconception:

Since many organisms use carbon dissolved in the ocean to form shells, other skeletal parts, and coral reefs, then more dissolved CO₂ in the ocean is beneficial.

When carbon dioxide dissolves in seawater, the water becomes more acidic and the ocean's pH decreases. Even though the ocean is immense, enough carbon dioxide can have a major impact. In the past 200 years alone, ocean water has become 30 percent more acidic—faster than any known change in ocean chemistry in the last 50 million years.

Lesson Procedure:

5E Model	5E Objectives
----------	---------------

Engage

Procedure: Day 1 (80 minutes)

1. Carbon Cycle Pre-Activity
 - a. *Teacher:* show the NASA video below [Keeping Up with Carbon](#) and explain that understanding how carbon moves between land, oceans and atmosphere is key to understanding how our climate will continue to change.
 - b. *Students:* complete part 1 of their [activity sheet](#), “Pre-Activity Prep”
 - c. *Students:* share out portions of their KWL chart
 - d. *Teacher:* create a class-sized KWL chart on chart paper with a selection of student answers

2. *Students:* work in pairs or a group of three to complete part 2 of the activity sheet, “Global Carbon Cycle Interactive”
 - a. *Students:* work with their partner to create a flow chart demonstrating the two carbon pathways they chose.

Students must adhere to these two rules:

 1. You must start in a carbon store/reservoir of your choice and identify a complete carbon pathway that takes you back to the same carbon stores/ reservoir.
 2. At least one of your two carbon pathways must go through part of the ocean.

The flow chart must include the following:

 1. Names of the carbon stores/reservoirs the carbon moves through.
 2. Arrows indicating the processes that move carbon between reservoirs.
 3. Label each process.
 4. Label each carbon store/reservoir as belonging to the Biosphere or Geosphere
 5. Forms of carbon compounds found in each carbon store and indicate whether each is a solid(s),liquid(l), or gas(g). (examples: carbohydrate(s), calcium carbonate(s), CO₂ (g))
 - b. *Teacher:* circulate and address clarifying questions for students as they make their flow chart

3. Wrap-up: Students will share their flow charts with the class (1-2 minutes per group)

Formative Assessments: Part 3 of activity sheet “HW Summary Questions”

Standards Addressed: HS-LS2-6 (Interdependent Relationships in Ecosystems)

Modifications: Options for completing work (independent, pair, whole-class discussion); visual aids on worksheet

Resources:

Chart Paper (1 sheet per group)

Colored Pencils/Markers

	<p>Projector, Laptops, Internet Access Video Link: "Keeping Up with Carbon Carbon on the Move! Activity Sheet (adapted from Earth Labs "Carbon on the Move" Activity): Google Doc Link Carbon Cycle Interactive Link</p>
Explore	<p>Procedure: Day 2 (40 minutes)</p> <ol style="list-style-type: none">1. Review HW from Day 1 Carbon on the Move! Activity:<ol style="list-style-type: none">a. <i>Students</i>: meet in groups to discuss their answers to the HW.b. <i>Teacher</i>: circulate from group to group, listening to student answers.c. <i>Teacher</i>: invite groups to share out HW answers.2. <i>Students</i>: investigate how a carbon dioxide-rich atmosphere can change the water existing below it.<ol style="list-style-type: none">a. <i>Teacher</i>: passes out lab sheets, assigns lab groups, reviews safety precautions, and demonstrates lab set-up either using lab equipment or by drawing the set-up on the board. Lab materials should be set up/ laid out prior to students entering class.b. <i>Students</i>: review the procedure individually and teacher will address general questions about the lab before students break out into groups.3. <i>Students</i>: carry out the investigation in groups and complete the data table and conclusion questions on their lab sheet.<ol style="list-style-type: none">a. <i>Students should observe a color change in cup A from blue to yellow, indicating a decrease in pH.</i>b. <i>Students should observe no color change in cup B, as this is the control.</i>c. <i>Students should observe that the surface layer of the liquid in cup A changes first and then, after some time, the CO₂ will diffuse throughout the rest of the liquid, changing the color.</i>4. Wrap-Up: Walk & Share Activity<ol style="list-style-type: none">a. <i>Students</i>: choose one partner from a different lab group to participate in the Walk & Share.b. Pairs of students will have 3-4 minutes to walk around the classroom or do a lap around the floor/school building engaging in a discussion about their lab conclusion.<ol style="list-style-type: none">i. if this is the first time students are engaging in a Walk & Share activity, teacher should review expectations for behavior, especially if giving students permission to walk around the school building.c. Students will bring their lab sheets on the walk.d. Bring student back together to discuss their answers to the conclusion questions as a whole class. (5 minutes)<ol style="list-style-type: none">i. Students should begin to formulate that the causes and effects of ocean acidification are examined by investigating changes in pH and atmospheric CO₂. <p>Modifications: pictures of the experiment set-up to accompany the written procedure; mixed grouping for lab groups;</p>

Walk & Share brain-break.

Standards Addressed: HS-PS1-6 (Chemical Reactions)

Formative Assessment: teacher will collect and review lab conclusion questions

Resources:

Photocopies of the [Ocean Acidification lab](#) (adapted from Exploratorium Science Snacks "[Ocean Acidification in a Cup](#)")

Lab Materials (see lab for list)

Explain

Procedure: Day 2 (40 minutes)

1. *Teacher:* explains that students will analyze climate data from NOAA to investigate how rising atmospheric CO₂ contributes to rising CO₂ concentrations in the ocean.
 - a. *Teacher:* will show the video clip: [Charles Keeling \(1928-2005\) and NOAA's Mauna Loa Observatory](#)
 - b. *Teacher:* present slides to establish the background for why climatologists collect CO₂ data from Mauna Loa, Hawaii
 - c. Within the slides are practice graphs for students to analyze in preparation for today's activity
 - i. *Students:* complete the Warm-Up activity by answering the analysis questions on their [worksheet](#)
 - d. *Teacher:* after 5 minutes gather the class for a whole-class review of their answers
 - i. **Students should observe natural fluctuations in CO₂ levels due to seasonal change**
 - ii. **Increasing CO₂ levels in the winter months and decreasing CO₂ levels in the spring due to increased photosynthesis**
2. *Teacher:* explain to students that they will now analyze three more graphs: 1-Year Changes, 2-Year Changes, and 1958-Present Changes in CO₂
 - a. *Students:* work in groups of 3-4 to complete pages 1 & 2 of their [activity packet](#)
 - b. *Teacher:* circulates to address clarifying questions and to help students
3. *Teacher:* will lead a whole-class discussion focused on student observations and explanations of patterns observed in the data analysis. Teacher will record student answers on chart paper/whiteboard.
 - a. Are the CO₂ levels the same as they were the previous year?
 - b. What pattern(s) did you observe in the 2-year CO₂ Change graph?
 - c. What do you think is causing this pattern?
 - d. What pattern(s) did you observe in the 1958-Present CO₂ Change graph?
 - e. What do you think is causing this pattern?
 - i. **students should observe that the 2-Year lows and highs are slightly higher than the previous year**
 - ii. **students should observe patterns of rising CO₂ levels (2-year and 1958-present graphs)**
 - iii. **students should be able to explain the rise in CO₂ levels is not due to natural fluctuations in CO₂ levels, rather it is due to the burning of fossil fuels**
4. *Teacher:* asks students to think about the demo from the beginning of class.
 - a. How do rising atmospheric CO₂ levels affect oceanic CO₂ levels? **increased due to diffusion of CO₂ gas into the surface of the oceans**
 - b. Based on what you observed during the demo, what other effect does rising levels of oceanic CO₂ have on the ocean? **decreases pH of the ocean (ocean acidification)**

Extend

Procedure: Day 3 (40 minutes)

- 1) *Teacher:* Show the video: [Acidifying Waters Corrode Northwest Shellfish](#). Teacher will elicit student responses to the following question: How is ocean acidification is already affecting oysters and other shellfish in the Northwest?
- 2) *Teacher:* Explains to students that they will research how ocean acidification affects marine life.

Teacher: Provides background information:

- a) Many species in the ocean form calcium-based shells/structures e.g. corals, mussels, sea urchins, barnacles, clams. Increased acidity makes it harder for these calcified features to form, meaning many of these species are growing slower/thinner shells. This could lead to many issues including:
 - May be more vulnerable to predation as adults
 - Reefs that usually provide habitat for fish are not growing
 - Larvae do not grow properly (predated before adulthood means no reproduction)
 - Loss of food source for other species up the food web (including humans!)
- 3) *Students:* will choose a case study organism to research (ex. mussel/oyster/clam/coral) and complete their research in the template.

Standards Addressed: RST.11-12.2

Formative Assessments: Conference with each student to give feedback about their research

Resources:

Video: [Acidifying Waters Corrode Northwest Shellfish](#).

Copies of [Research Template](#)

Students will need access to a laptop

Evaluate	<p>Procedure: Day 3 (40 minutes)</p> <ol style="list-style-type: none">1. <i>Teacher:</i> Explains that students will create an informational brochure about ocean acidification and its potential effects on their chosen marine organism.2. <i>Teacher:</i> will distribute and explain project guidelines and assessment rubric.3. <i>Students:</i> will begin creating their brochure in class; teacher can circulate to address clarifying questions as they pop up4. <i>Students:</i> complete the brochure at home and present it to the class in one week. <p>Standards Addressed: RST.11-12.1, RST.11-12.2</p> <p>Summative Assessments: Project rubric/graded assessment</p> <p>Resources</p> <p>Copies of Project Rubric 8.5 x 11 Paper (at least 1 per student) Colored Pencil/Markers</p>
-----------------	---

Sources:

Data:

- NOAA Earth System Research Laboratory, Global Monitoring Division, [Recent Monthly Average Mauna Loa CO₂](#)
- [Daily Keeling Curve updates of CO₂ concentrations at Mauna Loa Observatory, Hawaii](#) posted on the Scripps Institution of Oceanography website.

Videos:

- NASA's [Keeping Up with Carbon](#)
- NOAA's [Charles Keeling \(1928-2005\) and NOAA's Mauna Loa Observatory](#)
- NOAA's [Acidifying Waters Corrode Northwest Shellfish](#)

Modified Activities: Portions of these activities were integrated into the lesson plan, modified to fit within the time constraints of each day's lesson

- [Earth Lab's Carbon on the Move](#)
- Exploratorium Science Snacks "[Ocean Acidification in a Cup](#)".)