

Ocean Acidification

How does the movement of carbon between the atmosphere and hydrosphere affect these two global systems?

Unit	Utah SEEd Standard / NGSS Performance Expectation	Estimated Lesson Time:
Carbon Cycle Between Atmosphere and Hydrosphere	Standard ESS.3.5 Develop and use a quantitative model to describe the cycling of carbon among Earth's <u>systems</u> . Emphasize each of Earth's systems (hydrosphere, atmosphere, geosphere, and biosphere) and how the movement of carbon from one system to another can result in changes to the system(s). Examples could include more carbon absorbed in the oceans, leading to ocean acidification, or more carbon present in the atmosphere, leading to a stronger greenhouse effect. (LS2.B, ESS2.D, ESS3.D)	90 min

LESSON OVERVIEW

Learning Objective(s)

Students will plan and carry out an investigation using experiments to identify the cause-and-effect relationships of human interruptions of the carbon cycling between the atmosphere and hydrosphere (Leading to designing a solution to mitigate the effects on the biosphere).

Anchor Phenomenon

Ocean acidification is caused by more carbon dioxide dissolving into the world's oceans. (Crustations being killed by ocean acidification)

Driving Question(s)

Driving question: ***What factors can affect ocean acidification?***

Teachers will guide students to think about the following ideas:

- How does the movement of carbon between the atmosphere and hydrosphere affect these two global systems?
- Potentially discussing how movement between all of the systems affects one another in an extension.

Lesson Level Performance Expectations

- Students will plan and carry out an investigation to develop an understanding of how carbon emissions moving between different reservoirs, such as the atmosphere, the ocean's surface, and the deep ocean, can be the cause of chemical changes to those reservoirs.
- Students will also be exposed to the idea of carbon's involvement in respiration in the biosphere.



3D-RST is supported by the NSF under grant number #DRL-2101383



LESSON SNAPSHOT

LESSON SUMMARY: PRESENT STUDENTS WITH A SCENARIO THAT DESCRIBES THE PHENOMENON OF OCEAN ACIDIFICATION USING A VIDEO AND DATA TO BE EXPLAINED, ALONG WITH A SCIENTIFIC QUESTION. THEN, ASK STUDENTS TO CREATE AN INVESTIGATION PLAN TO STUDY THE SCIENTIFIC PHENOMENON, INCLUDING THE INDEPENDENT AND DEPENDENT VARIABLES, CONTROLS, TOOLS FOR DATA COLLECTION, AND METHODS FOR RECORDING OBSERVATIONS AND MEASUREMENTS. HAVE STUDENTS EXPLAIN HOW THE INVESTIGATION WILL GENERATE RELEVANT EVIDENCE TO ANSWER THE SCIENTIFIC QUESTION, AND THEN CONDUCT THE INVESTIGATION TO COLLECT DATA THAT SERVES AS EVIDENCE TO ADDRESS THE QUESTION.

	Estimated Time	Section Overview	How are students answering the driving question or meeting the learning objectives?
Experience the Phenomenon	Watch Video 3 minutes	Students will watch the video (first 3 minutes only) on the acidification of the ocean water and its effects on the oyster farms in Shelton, Washington.	Driving question: What factors can affect ocean acidification? What is the problem in the North Pacific? (DCI) - Ocean acidification is the problem What is the cause and the effect of the problem? (CCC) - Increased carbon emissions are the cause - Lower pH in the oceans/More acidic water is the effect
Investigate the Phenomenon	60 minutes	Students will plan and carry out an investigation to identify which variables can affect water pH. As they organize and perform their investigation, they will complete the accompanying lab sheet to help guide them through the lab requirements.	Investigate ocean acidification and identify how carbon emissions alter the chemical composition of the water. (SEP) Students will observe cause-and-effect through their investigations. (CCC)
Model the Phenomenon	60 minutes	The students will create a poster of their experiment results, then participate in a gallery walk to share their findings with the class. They will use the data collected during the gallery walk to develop a real-world solution for ocean acidification.	Students will use the results of their investigation (SEP) to create a gallery walk and communicate (SEP) that information to their peers, establishing a real-world connection in which the results they encountered can be observed. They will then use that information about the cause-and-effect (CCC) of other students' data to create a poster. The poster will convey ideas (SEP) for potential solutions (SEP) to a real-world situation where ocean acidification may be occurring.

DISCIPLINARY CORE IDEAS	SCIENCE & ENGINEERING PRACTICES	CROSSCUTTING CONCEPTS
NGSS Appendix E LS2.B: Cycles of Matter and Energy Transfer in Ecosystem ESS2.D Weather and climate ESS3.D Global climate change	NGSS Appendix F Practice 3: Planning and Carrying Out Investigations	NGSS Appendix G Cause and effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
This lesson could be one in a series of lessons building toward the following Performance Expectation(s): Photosynthesis and cellular respiration provide most of the energy for life processes. Only a fraction of matter consumed at the lower level of a food web is transferred up, resulting in fewer organisms at higher levels. At each link in an ecosystem, elements are combined in different ways and matter and energy are conserved. Photosynthesis and cellular respiration are key components of the global carbon cycle. The planet's dynamics are greatly influenced by water's unique chemical and physical properties. The role of radiation from the sun and its interactions with the atmosphere, ocean, and land are the foundation for the global climate system. Global climate models are used to predict future changes, including changes influenced by human behavior and natural factors. Global climate models used to predict changes continue to be improved, although discoveries about the global climate system are ongoing and continually needed.		
Related knowledge and skills from prior grades		
Disciplinary Core Idea: NGSS Appendix E The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. Food webs model how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem. Water cycles among land, ocean, and atmosphere, and is propelled by sunlight and gravity. Density variations of sea water drive interconnected ocean currents. Water movement causes weathering and erosion, changing landscape features. ----- Complex interactions determine local weather patterns and influence climate, including the role of the ocean. Human activities affect global warming. Decisions to reduce the impact of global warming depend on understanding climate science, engineering capabilities, and social dynamics.	Science and Engineering Practices NGSS Appendix F Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.	Crosscutting Concept: NGSS Appendix G In grades K-2, students learn that events have causes that generate observable patterns. They design simple tests to gather evidence to support or refute their own ideas about causes. In grades 3-5, students routinely identify and test causal relationships and use these relationships to explain change. They understand events that occur together with regularity might or might not signify a cause-and-effect relationship. In grades 6-8, students classify relationships as causal or correlational, and recognize that correlation does not necessarily imply causation. They use cause and effect relationships to predict phenomena in natural or designed systems. They also understand that phenomena may have more than one cause, and some cause-and-effect relationships in systems can only be described using probability.

Materials

Link to all materials on the 3DRST website (3drst.byu.edu): <https://3drst.byu.edu/ess-3-5-acidification>

Link to all materials on Canvas Commons: <https://tinyurl.com/3DRSTearth>

Student Materials	Teacher Materials	Lab Materials/Other Resources
- Lab Rubric - Student Handout - Bell work Assignments (four versions)	- Printed (in Color) the Bromothymol pH scale & Relationship Analysis - Acidification Lab Teacher Slides - Ocean acidification video - Acidification Test examples	- Whiteboards or poster boards for the gallery walk - Bromothymol Blue - Universal Indicator (optional) - Clear Plastic Cups - Straws - Water (various types: distilled, tap, pond, etc.) - Hot water - Cold water - Different substrates (Sand, Soil, Limestone, Shells, etc.) - Soluble Substances (Salt, Sugar, etc.) - Timers

LESSON PREPARATION

Material Preparation:

Pre-Lab: The Teacher will need to have student handouts printed and ready for students. Ensure the video is ready to play and the volume is set correctly for the class to see and hear it. Students will need pencils to write in their answers on the student handout.

Lab: Prepare water in a pitcher at room temperature and water in a kettle at boiling temperature. If you do not have a kettle, you could use a hot plate or another method to boil some water. Separate a stack of solo cups for the students to access and a small squeezable bottle of bromothymol blue for each group of students to access. Each student will need a straw and some paper towels to assist with cleaning up. Provide different substrates for students to access if they choose to consider that as a factor for change. Also, provide different soluble substances for students to access if they decide to use them for their experiments.

Required Previous Knowledge:

- The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.
- Food webs model how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem.
- Water cycles among land, ocean, and atmosphere, and is propelled by sunlight and gravity. Density variations of seawater drive interconnected ocean currents.
- Water movement causes weathering and erosion, changing landscape features.
- Complex interactions determine local weather patterns and influence climate, including the role of the ocean.



3D-RST is supported by the NSF under grant number #DRL-2101383



- Human activities affect global warming.

Supports students will need/adaptations:

Reduce the number of possible variables for the experiment. Alternate Student Handout / Lab Sheet provided for students who need adaptations

Vocabulary Definitions:

- **Acidification:** The action or process of making or becoming acidic.
- **Geosphere:** Any of the almost spherical concentric regions of matter that make up the Earth and its atmosphere, as the lithosphere and hydrosphere.
- **Hydrosphere:** All the waters on the earth's surface, such as lakes and seas, and sometimes including water over the earth's surface, such as clouds.
- **Atmosphere:** The envelope of gases surrounding the Earth or another planet.
- **Biosphere:** The regions of the surface, atmosphere, and hydrosphere of the Earth (or analogous parts of other planets) occupied by living organisms.
- **Substrates:** An underlying substance or layer.
- **PH Level:** Quantitative measure of the acidity or basicity of aqueous or other liquid solutions.
- **Reservoir:** A large natural or artificial lake used as a source of water supply.
- **Carbon Sink:** Takes carbon out of the atmosphere.
- **Carbon Source:** Where carbon is pulled from and placed into the atmosphere.
- **Diffusion:** The spreading of something more widely.
- **Molecule:** A group of atoms bonded together, representing the smallest fundamental unit of a chemical compound that can take part in a chemical reaction.
- **Fossil Fuel:** A natural fuel such as coal or gas, formed in the geological past from the remains of living organisms.
- **Combustion:** The process of burning something.

EXPERIENCE THE PHENOMENON/PROBLEM (ENGAGE)

What Students Are Doing	Teacher Tips
- Students will complete the "Acidification Bellringer" to prepare for the lesson. - Students will engage with the phenomenon by watching the video (first 3 minutes only) on ocean acidification found on slide 3 of the PowerPoint. - After watching the video, the students will complete questions 1 & 2 on the student lab sheet. - Once the teacher has prompted the students to, they will model the chemical formula of ocean acidification on question 3 of their worksheet.	Give a bell ringer to the students, but don't let them work too long on this. You can choose any of the available ones depending on your students' ability level. If you have materials for a chemical model, it would be helpful to show the students how it is built. Slides 40 - 42 can be used as a cut-out model that a teacher can use if they do not have a physical model.
What Teachers Are Doing	Teacher Tips



3D-RST is supported by the NSF under grant number #DRL-2101383



- The teacher will hand out the acidification bellringer. There are multiple bell ringers to choose from; simply select one that you believe your class can complete within an appropriate amount of time. You can give them over multiple days if you would like. - This bell ringer will serve as a preassessment and also help prime the students for the lesson. The teacher can inform students of the results of the bellringer at the beginning of the next class. This should be a brief 5- to 10-minute bellringer. - The teacher is starting the lesson by showing students slides 1 and 2 to remind them of the carbon cycle and what the overall unit is about. - The teacher will introduce the phenomenon of ocean acidification by showing students the video on slide 3. Watch the video till 3:00 so they do not get distracted by the upwelling. Slide 4 will prompt students to answer questions 1 and 2 on their worksheet. - Teachers will briefly discuss the chemistry of ocean acidification using slides 5-6. The teacher should pause on slides 7 and 8 to allow students to answer question 3 on their lab worksheet.	Teachers should ensure that all students understand that they are producing CO₂ through cellular respiration. Molecular models can be used to show how CO₂ and H₂O combine to make carbonic acid.
---	--

INVESTIGATE THE PHENOMENON (EXPLORE)

What Students Are Doing	Teacher Tips
- Students identify variables in an experiment that the teacher demonstrates. - Students generate variables for testing (independent variable) on slide 10 before viewing the pre-made ones on slide 11. - Students then engage in pair-share or discussion to identify variables on slides 12-13 with guidance from the teacher. - Students then identify the pH with models on slides 14-15. - Students will use the information in their handouts they have already completed to guide their experiment. By this point, students should have already chosen a variable they want to test in their lab activity. - When they are ready to start, they will select the appropriate type of water based on their choice of variable, substrate type, or solubility, and fill their plastic Solo cup. - The student will then prepare a timer for their variable to make a change as they either blow into the water or test the BB to react to the carbon from the breath. Students then add BB to their water, 5-10 drops or until the color is easily visible, and then start timing as they blow CO₂ into their water samples.	Use about 5-10 pipette drops of Bromothymol Blue solution per regular solo cup. (Use generously to saturate the color) Make sure kids understand the image is of kids blowing into the straw, not drinking out of the straw.



- Students then record the results on their lab worksheets. Students can explore their lab results as needed.	
What Teachers Are Doing	Teacher Tips
- The teacher will use slide 9 to explain the pH scale so students gain background on acids versus bases. - The teacher will use slides 10-11 to introduce the exploration part of the lesson. They should involve the class in a discussion about factors that can cause ocean acidification. - The teacher demonstrates how CO₂ diffusing into the water changes the bromothymol blue indicator from blue to green. This can be achieved in several ways: ○ The teacher demonstrates how a variable can be changed and conducts the test for the students. Prepare four beakers with 100 mL of water and vary a variable, such as blowing into the water for different durations. Have students identify the changed variable (independent – time in seconds) and the measured variable (color change = pH), along with the controlled variables (amount of water, water temperature, etc.) ○ The teacher fills two large zip-lock bags (gallon size). The first with plain air—open the bag and run it through the air to fill it. Pre-fill the second bag with exhaust collected from a stream of car exhaust. Students can help demonstrate with a straw, with one student holding the bag tightly around the straw while the other squeezes the bag to bubble the air into the bromothymol blue solution. Students will observe that the car exhaust causes a noticeable change, while the air does nothing. - Teacher will show slide 10 and have the students come up with lists of independent variables that can affect ocean acidification. - Progress through slides 11-13. Pause on slides 14-15 and have students discuss (pair-share) the variables as a class. - Have students practice identifying pH with slides 16-17. Assign students to A, B, C, or D on slide 18 and estimate the pH based on the color in the cups. - Teacher shows students examples from slides 18-24 - The teacher will then direct students to choose a variable for their lab to test and have them split into lab groups.	Teachers should test their own water source to understand how acidic or basic their water is. This will determine how long students need to blow into the water to see a color change. Ensure that students understand that when choosing a variable, it must make sense in a real-life scenario. Therefore, they will need to explain why they want to test a variable that may be questionable in terms of its validity. You could have the students complete all the sections of the data table before breaking out to get lab supplies. Another option is to have students identify variables they want to test as a class to prevent duplication and ensure more diverse labs are done in class.

MODEL THE PHENOMENON (EXPLAIN)

What Students Are Doing	Teacher Tips
- Students will review slides 18-24 and the lab rubric to identify the information they need to include in their gallery walk posters, as well as the details they should gather from the gallery walk. OR - View slides 27-34 and create a cause-and-effect chart, simplifying it to emphasize cause-and-effect relationships. - Students will then walk around the classroom, analyze the data and conclusions of other students' investigations, and complete the "Gallery Walk" portion of their worksheet (Slide 35). - Once students understand the results of other experiments, they will observe slides 36–39. - They will use slide 39 and the lab rubric as scaffolding to help them complete the real-world application section of the worksheet.	The gallery walk can be conducted on a poster board or a whiteboard, whichever the teacher deems most suitable.
What Teachers Are Doing	Teacher Tips
- The teacher will review slides 18-24 and the lab rubric to determine what information students need to include in their gallery walk posters and what they need to obtain from the gallery walk. OR - The teacher will show slides 27-34 and instruct students on how to create a cause-and-effect board, modified for a simplified demonstration focused on cause-and-effect. This approach is better for shorter time constraints. - The teacher will need to determine the format of the report (written on a whiteboard, poster, etc.) - After sufficient time has passed and students have finished their reports for the gallery walk, the teacher will instruct the students to walk around the room, observing and recording the results of other groups' experiments. - Once the gallery walk is complete, direct students back to their seats. The teacher will then use slides 35–39, as well as the lab rubric, to help students understand what is expected of them to complete the real-world application portion of their lab worksheet.	Be sure to remind students of the rubric regularly so that they can produce high-quality work.

POSSIBLE ADAPTATIONS

This lesson can easily be adapted to fulfil chemistry strand CHEM.3.6 or CHEM.3.8.

This lesson was created by Jamie Carling, Mikell Sanderson, & Jake Morgan



3D-RST is supported by the NSF under grant number #DRL-2101383

