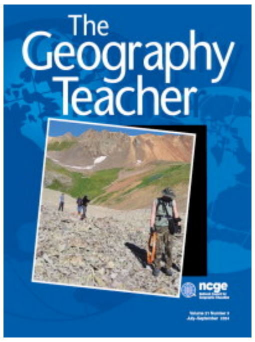

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LESSON PLAN

Dissolved Oxygen and Climate Change

Anna Simon[a], Michael J. Allen[b], Jamie Young[c], Lydia Belser[d], Shelly Carter[e], Michele Sullivan[f], Gretchen Maxwell[g], Gabrielle Hurst[h], and Jennifer L. Whytlaw[i]

[a]AECOM, Virginia Beach, Virginia, USA; [b]Department of Geography and Environmental Planning, Towson University, Towson, Maryland, USA; [c]Old Donation School, Virginia Beach City Public Schools, Virginia Beach, Virginia, USA; [d]James River High School, Chesterfield County Public Schools, Midlothian, Virginia, USA; [e]Central Elementary, Rockbridge County Public Schools, Lexington, Virginia, USA; [f]Mantua Elementary School, Fairfax County Public Schools, Fairfax, Virginia, USA; [g]Westlawn Elementary School, Fairfax County Public Schools, Falls Church, Virginia, USA; [h]W.T. Cooke Elementary School, Virginia Beach Public Schools, Virginia Beach, Virginia, USA; [i]Department of Political Science and Geography, Old Dominion University, Norfolk, Virginia, USA

Lesson Overview

This lesson discusses oceanography, dissolved oxygen, and their connection to climate change. NOAA (2021) shows that 90% of excess heat energy generated by human-caused climate change is absorbed by the Earth's ocean, modifying ecosystems and marine species. Consequences include elevated sea level (Hoffman et al. 2023), increased potential for heavy rain events (Allen and Allen 2019), and changes in dissolved oxygen content (NOAA 2021; USGCRP 2023; NOAA 2024). Students are introduced to the topic through the lens of oceanography, fulfilling standards of learning while also providing opportunities to think critically about issues related to climate change. This exercise also builds on fundamental concepts of biodiversity and considers how climate change influences the spatial distribution of species. The lesson focuses on the topic of dissolved oxygen, but other factors such as salinity and water temperature also modify the distribution and range of species (Jones 2023; NOAA 2024; NASA 2024). Students discuss that ocean water contains gases and how they enter the water. They will view a teacher demonstration to understand how temperature can affect the amount of gas in water and use scientific evidence and reasoning to support a claim.

Target Audience

High school students in grades 10 to 12.

Teaching Time

One 90-minute class period

Essential Question

How do warming waters affect the amount of dissolved gas in the ocean?

Objectives

Explain the relationship between temperature and amount of dissolved gas in water.

Science and Engineering Practices

- Asking questions and defining problems
- Interpreting, analyzing, and evaluating data
- Constructing and critiquing conclusions and explanations
- Developing and using models

Oceanography

- Draw conclusions about the relationship between chemical composition and water quality including dissolved gases, nutrients, and pH levels.
- Predict effects of chemical, organic, physical, and thermal changes from humans on the living and nonliving components of an aquatic ecosystem.

Chemistry

- Investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles.

Prior Knowledge

- Observations and Inferences
- Graph Interpretation
- Water Properties
- Greenhouse Effect

Materials and Equipment

- Student Handout (found at the end of the Lesson Plan)
- Bottle or can containing carbonated drink (seltzer or soda)
- Cup of water (to represent ocean water)
- Lab coat
- Goggles
- Three 1-L bottles of a carbonated drink (seltzer or soda; all the same brand)

CONTACT Michael J. Allen mallen@towson.edu Department of Geography and Environmental Planning, Towson University, Towson, MD, USA.
Supplemental data for this article can be accessed online at https://doi.org/10.1080/19338341.2024.2413948.

- Ice
- Hot plate
- 1000-mL beaker (or larger to fit seltzer bottle inside)
- Towels
- Colored pencils, markers, or crayons
- Reference video: Pauller (2015) How temperature affects gas solubility: https://www.youtube.com/watch?v=wK4reyh86w0&feature=youtu.be

Teacher Note

The lab activity is designed to be completed by the teacher as a demonstration. Please take proper precautions during the demonstration, adhering to best practices outlined by your school or district supervisor.

Safety Precautions

- Perform activity outside and/or at least 6 feet from students.
- Wear a lab coat to prevent clothes from getting wet.
- Wear goggles during the entire demonstration.
- Slip caution: Floor will be slippery, so use caution and a clean surface.
- Hot plate: Use caution and do not touch hot plate surface. Monitor seltzer bottle as it warms up.
- Use caution opening the warm bottle as the cap may fly off. Open with the right side up with the bottle cap aimed at the ceiling.

Pre-Demo Procedure

1. Place one 1-L seltzer bottle in an ice bath for at least 20 minutes.
2. Place one 1-L seltzer bottle on the demo desk to come to room temperature.
3. Place one 1-L seltzer bottle in the 1000 mL or larger beaker with water on a hot plate. Warm the water (DO NOT BOIL) for at least 10 minutes. CAUTION: Monitor heating of the bottle, as it will cause a pressure increase inside of the bottle. If you notice a bulge at the bottom of the bottle, turn the hot plate off and leave the bottle undisturbed.
4. Prepare a workspace to have a clear area away from students but allow enough space for them to make observations. Keep towels nearby.
5. It is important that you do not shake any of the bottles while transferring and opening them. This will affect the demonstration by allowing more gas to come out of the solution than intended.

Activity Procedure

Engage: Discuss and View Map

1. Present students with a bottle of carbonated drink and a cup of "ocean water" and ask what they think they have in common and what is different.
   a. Identify some misconceptions, such as what may be in the water at the microscopic level.
   b. Lead students to determine that ocean water is filled with dissolved gas, similar to the carbonated drink. It mostly contains CO_2, O_2, and N_2. All gases are essential for life in the ocean.
2. Show students a map that represents the amount of dissolved oxygen in the ocean (Figure 1).
   a. Discuss trends with students, and ask how this map would look at different times of the year.
   b. Ask students questions such as the following to guide their thinking:
      i. Does the amount of oxygen change throughout the year? Why?
      ii. How does oxygen enter the ocean water?
      iii. What could be changing the amount of dissolved oxygen available in the water?
      iv. Does it vary from the surface to different depths?

Explore: Demonstrate How Temperature Can Affect Dissolved Gas

Demonstration Procedure

1. Using the student handout (Figure 2), encourage students to establish their hypothesis.
   a. *How will the amount of dissolved gas change when the temperature is changed*?
   b. Discuss student responses before beginning the activity.
2. Review safety precautions with students.
3. Begin demonstration by opening the <u>room-temperature</u> bottle; this will serve as the control.
   a. Students will write down their observations on the handout.
   b. Clean up any mess.
4. Open the <u>cold bottle</u> next.
   a. Students will write down their observations on the handout.
   b. Clean up any mess.
5. Finally open the <u>hot bottle</u>. EXPECT A LARGE "EXPLOSION" AND MESS.
   a. Students will write down their observations on the handout.
   b. Clean up any mess.

Explain: Review and Inform

1. Review observations made by the students and provide an explanation for what is happening and why. Allow students to synthesize the information using their handout.
2. Show Figure 2, which is a map of ocean surface temperatures. Ask students to make comparisons between Figures 2 and 3.
3. Explain to students:
   a. *Seltzer water is water with carbon dioxide pumped in at high pressure that is capped to seal it in. It is assumed that they all contain the same amount of carbon dioxide because they are the same brand and most likely bottled at the same facility.*

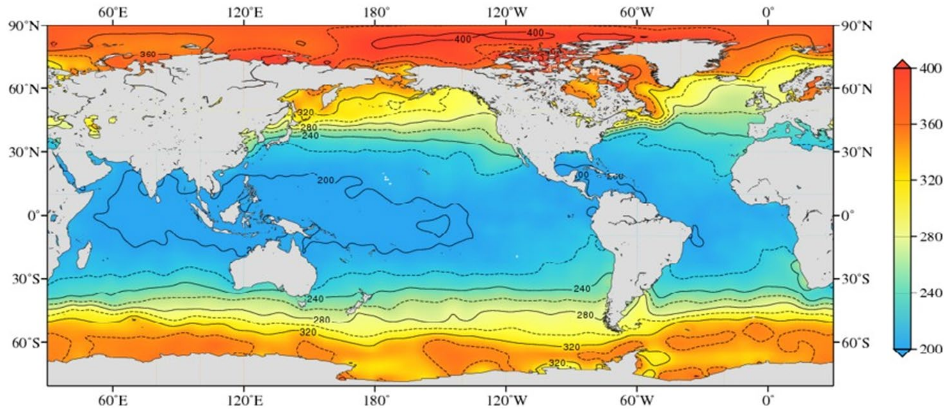


Figure 1. Annual oxygen (μmol/kg) at the surface (World Ocean Atlas; Boyer et al. 2018).

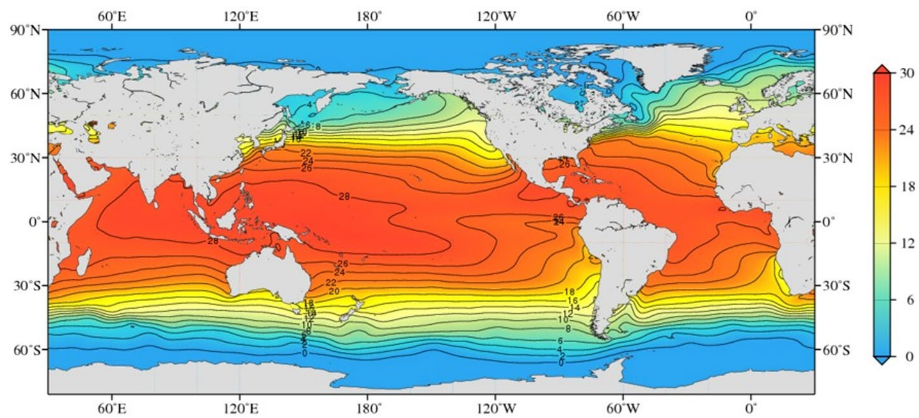


Figure 2. Annual temperature (°C) at the surface (World Ocean Atlas; Boyer et al. 2018).

b. *When the cap is opened, the pressure is released and some carbon escapes as the pressure decreases.*
c. *In the room temperature bottle, we saw a small "explosion" of gas and liquid come out of the bottle. This is because some of the carbon escaped from the liquid and filled the air space between the liquid and the cap. When the cap was opened, the gas rushed out, carrying some liquid with it.*
d. *In the cold bottle, we saw virtually no "explosion" because in cold water, the molecules are moving very slowly and more carbon dioxide molecules can stay within the solution. Gas is more soluble in cold water.*
e. *In the hot bottle, we saw a very large "explosion" because the gas escaped from the warming liquid and filled the air space between the liquid and the cap. When the cap was removed, the gas rushed out, carrying liquid with it. It was a larger explosion than with the room-temperature bottle because more gas escaped. The molecules in warmer water are moving much faster and are unable to hold onto the carbon dioxide molecules. Gas is less soluble in hot water.*
f. *CO_2 is not the only gas that behaves this way; in fact, all the gases dissolved in water behave similarly* (Figure 3).
g. *The solubility of all gases decreases with increasing temperature* (Saylor Academy 2012).

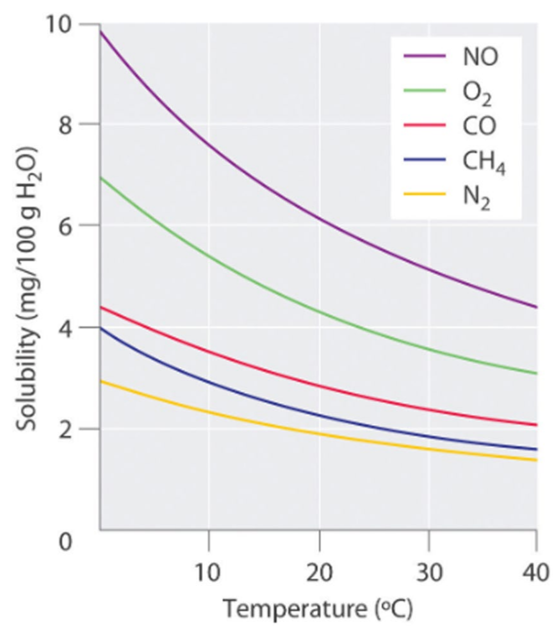


Figure 3. Solubility as a function of temperature (Webb 2021).

Elaborate: Model the Process

1. Have students draw their own model of water and CO_2 on the molecular level inside of one of the bottles before and after opening (see figure on Handout).

a. *Students should represent water molecules and CO_2 molecules together inside the water of the bottle. Depending on the bottle chosen, the relative amount of CO_2 after opening may change and be represented outside of the bottle.*
b. *Have students explain what is happening.*

2. Relate the solubility of CO_2 to the solubility of O_2 by explaining how fish "breathe" oxygen with their gills.
3. Ask students the following: *Power plants situated along a riverbank take up water and heat it to turn turbines to make electricity. Eventually this water needs to be replaced and is pumped back into the river after it cools. Why is it necessary to cool the water first? What is a possible impact of not cooling the water?*

Evaluate

1. Present students with the prompt and graph:
   a. Which ocean is warmer, the Atlantic or Pacific? Use evidence and reasoning from the lab and graph to support your answer.
   ANSWER: The Pacific Ocean is warmer. This is supported by the lower amount of dissolved oxygen levels throughout the water column. The demonstration showed that warmer water has less dissolved gas than colder water.
   b. Some students will answer *the Atlantic Ocean* simply due to the color of the line. Ensure that they read the axes on the graph.

Extension Options

Students can extend their learning by investigating different species and considering how other marine factors such as temperature or salinity may modify species distribution or range. Students may explore the intersection of climate change, habitat disruption, and the human dimensions related to food, economy, demographics, or policy (Jones 2023; NOAA 2023; USGCRP 2023).

Disclosure Statement

No potential conflict of interest was reported by the author(s).

Notes on Contributors

Anna Simon is presently a Geologist II at AECOM in Virginia Beach, Virginia. She previously was a science educator at Renaissance Academy in Virginia Beach, Virginia, for five years. As an alternative education teacher, Anna exposed her students to the community around them through local field trips and scientific inquiry. Anna earned a BS in Geology from Marshall University and a master's degree in Oceanography from the University of Rhode Island.

Michael J. Allen, PhD, is an Assistant Professor of Climatology within the Department of Geography and Environmental Planning at Towson University. He previously served as co-coordinator of the Virginia Geographic Alliance and Geography Program Director at Old Dominion University. In addition to having interests in geographic literacy and climate education, Dr. Allen explores the intersection of weather, climate, and human health. In 2023, he was a U.S. Fulbright Scholar in Serbia.

Jamie Young is a National Geographic-Certified Educator and Geo-Inquiry Ambassador and has more than 20 years of teaching experience in public schools/college. She taught Earth Science for 19 years, and she exposed her students to experiential, place-based learning. She is presently a STEAM educator at Old Donation School in Virginia Beach, Virginia. She integrates climate issues into her coding and engineering design activities. An active member of the Virginia Geographic Alliance, Jamie has both a BS in Criminal Justice and Political Science and a master's degree in Education.

Lydia Belser is a Google-Certified Educator and National Science Foundation Robert Noyce Scholar. With more than 5 years of teaching experience in formal and informal K–12 education settings, Lydia works to further high-quality teaching in underserved areas. She currently teaches oceanography and environmental science at James River High School in Chesterfield County, Virginia. Lydia is a graduate of The College of William & Mary, with a BS in biology and marine science and an MA in Education with a specialization in curriculum and instruction in secondary science.

Shelly Carter, an elementary school educator for more than 10 years, currently teaches preschool in Rockbridge County, Virginia. With a passion for social emotional learning and integrating students' well-being with all academic learning, she incorporates outdoor learning experiences into her curriculum. Shelly earned both a BBA and MAT from James Madison University.

Michele Sullivan incorporates aspects of the natural world into her lessons and emphasizes outdoor learning. For more than 10 years, Michele has been a fifth-grade teacher with Fairfax County Public Schools. As an Eco Teams Leader for Mantua Elementary School, Michele works with students to plant trees on campus and install native, pollinator species in bioretention facilities. Michele earned a BA in Quantitative Economics from Stanford University and an MBA from the University of Virginia's Darden School of Business.

Gretchen Maxwell is an Advanced Academic Resource Teacher in Fairfax County, Virginia. A career switcher, she wanted to implement change by encouraging and advocating for the students in her neighborhood Title 1 school, Westlawn Elementary. She is the daughter, sister, and mother of scientists and loves nothing more than using different pathways to expose students to new experiences outside. Gretchen earned her MS in gifted education from Arkansas State University.

Gabrielle Hurst is a K–6 Gifted Resource Educator in the Virginia Beach City Public School System and Virginia Master Naturalist. These experiences help her incorporate citizen science activities into the classroom. For the last 15 years, her experience has included providing classroom instruction for third and fifth grade and acting as a sixth-grade Advanced Life Science teacher and a Gifted Resource Teacher assisting in grades K–5. She also oversees school garden projects and helps students learn about organic growing, composting, and sustainable acts. Gabrielle earned a BBA in accounting and an MS in Education from Old Dominion University.

Jennifer Whytlaw, PhD, GISP, is an Assistant Professor of Applied GIS in the Department of Political Science and Geography at Old Dominion University. Her research focuses on utilizing geospatial analyses and visualizations to understand how environmental hazard events influence personal understanding of vulnerabilities within communities.

ORCID

Michael J. Allen http://orcid.org/0000-0002-8897-3901
Jennifer L. Whytlaw http://orcid.org/0000-0002-1612-8805

References

Allen, M. J., and T. R. Allen. 2019. Precipitation trends across the Commonwealth of Virginia (1947–2016). *Virginia Journal of Science* 70 (1):4.

Boyer, T. P., H. E. Garcia, R. A. Locarnini, M. M. Zweng, A. V. Mishonov, J. R. Reagan, K. A. Weathers, O. K. Baranova, D. Seidov, and I. V. Smolyar. 2018. World Ocean Atlas 2018. NOAA National Centers for Environmental Information. Dataset. Accessed August 16, 2022. https://www.ncei.noaa.gov/archive/accession/NCEI-WOA18.

Hoffman, J. S., S. G. McNulty, C. Brown, K. D. Dello, P. N. Knox, A. Lascurain, C. Mickalonis, G. T. Mitchum, L. Rivers, III, M. Schaefer, et al. 2023. Southeast. In *Fifth National Climate Assessment*, ed. A. R. Crimmins, C. W. Avery, D. R. Easterling, K. E. Kunkel, B. C. Stewart, and T. K. Maycock, Ch. 22. Washington, DC: U.S. Global Change Research Program. doi: 10.7930/NCA5.2023.CH22.

Jones, N. 2023. As ocean oxygen levels dip, fish face an uncertain future. *Yale Environment 360*. https://e360.yale.edu/features/as-ocean-oxygen-levels-dip-fish-face-an-uncertain-future.

NASA. 2024. Salinity. *Sea Surface Salinity from Space*. https://salinity.oceansciences.org/.

NOAA. 2021. Understanding sound in the ocean, marine life in distress. *NOAA Fisheries*. https://www.fisheries.noaa.gov/insight/understanding-sound-ocean.

NOAA. 2023. How will changes in habitat affect fish in and near the Chesapeake Bay?. *NOAA Fisheries*. https://www.fisheries.noaa.gov/feature-story/how-will-changes-habitat-affect-fish-and-near-chesapeake-bay.

NOAA. 2024. Hypoxia. *National Ocean Service*. https://oceanservice.noaa.gov/hazards/hypoxia/.

Pauller, N. 2015. How temperature affects gas solubility. https://www.youtube.com/watch?v=wK4reyh86w0&feature=youtu.be.

Saylor Academy. 2012. 13.4 effects of temperature and pressure on solubility, general chemistry: Principles, patterns, and applications. Creative Commons Attribution 3.0. https://saylordotorg.github.io/text_general-chemistry-principles-patterns-and-applications-v1.0/s17-04-effects-of-temperature-and-pre.html.

USGCRP. 2023. *Fifth National Climate Assessment*. Edited by A. R. Crimmins, C. W. Avery, D. R. Easterling, K. E. Kunkel, B. C. Stewart, and T. K. Maycock. Washington, DC: U.S. Global Change Research Program. doi: 10.7930/NCA5.2023.

Webb, P. 2021. *Introduction to Oceanography*. Roger Williams University, Creative Commons Attribution 4.0. https://rwu.pressbooks.pub/webboceanography.

Student Handout

Dissolved Oxygen and Climate Change: Student Worksheet

Complete the following tables.

Table 1. Observational hypothesis.

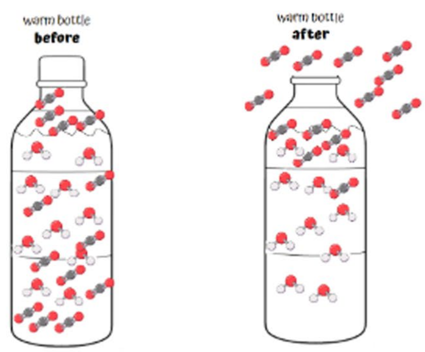
How will the amount of dissolved gas change when the temperature is changed?	
Scenario	My Hypothesis
Increase in Temperature	
Decrease in Temperature	

Table 2. Observations.

What did you see happening when I opened the bottles?	
	Observations
Room Temperature	
Cold-Water Bath	
Hot-Water Bath	

Table 3. Scenario hypothesis.

Which ocean is warmer, the Atlantic or Pacific? Use evidence and reasoning from the lab and graph (see figure) to support your answer. Why is this happening? Describe different scenarios.	
Increase in Temperature	
Decrease in Temperature	



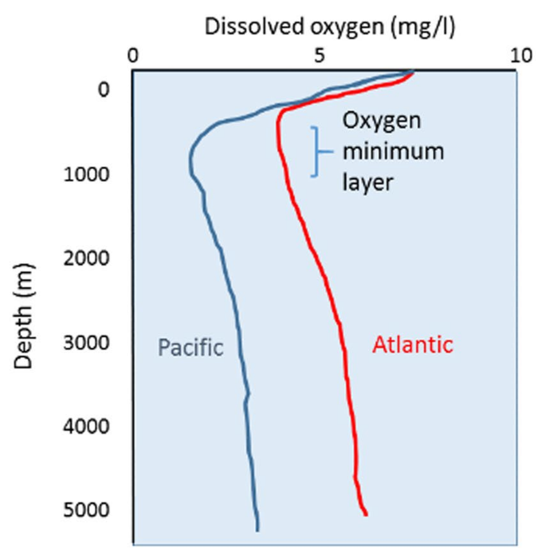


Figure. Dissolved oxygen content for the Atlantic and Pacific Oceans (Webb 2021).