SeaGlide_TEAM	Ocean Acidification	Lesson #8 (60 minutes)

Description:

Scientists are already working on ways to reduce Carbon Emissions that lead to Ocean Acidification. One example is Sailors For the Sea Ocean Water, a Citizen Science project. In Sailors For the Sea, scientists give sailors instruments called OSMOs (Ocean Sailing Microbial Observatory) that collect real-time data about the ocean's microorganisms. Ocean Acidification causes these microorganisms to no longer function and even die, creating a major loss in oxygen production for the entire planet. By collecting data during travels, scientists are able to determine the rate at which the ocean is increasing in pH and where the increased acidity is coming from. What are some ways you can make a difference and reduce the rate of Ocean Acidification?

Students will be able to:

- Connect microscale Acid-Base reactions to large-scale to the Earth's water system
- Discover a mechanism for climate change
- Understand the chemical process by which Carbon Dioxide (CO_2) gas leads to increased Hydronium (H^+) ions in ocean waters
- Investigate and develop solutions to decrease rising acidification levels in ocean water
- Explain how organisms are impacted by ocean acidification and therefore climate change

Students will understand:

As they learned prior to this lesson, acid-base reactions are essential to a foundational understanding of chemistry. However, due to the nature of chemistry, students often forget that small reactions can have major impacts on the planet earth. In this lesson, students discover that Carbon emissions from fossil fuels contribute to the ocean becoming increasingly acidic. Through inquiry and experimentation, students discover that an increased level of Hydronium ions can lead to devastating effects within the ocean food chain. However, students learn of possible solutions through Citizen Science, including those that can be applied to their own lives to reduce the rate of ocean acidification.

Key Definitions & Concepts: [1]

- **Ocean acidification**: the ongoing decrease in the pH of the Earth's oceans, caused by the uptake of carbon dioxide (CO_2) from the atmosphere
- **pH**: a logarithmic scale used to specify the acidity or basicity of an aqueous solution
- **Ecosystem**: a biological community of interacting organisms and their physical environment
- **Sustainability**: avoidance of the depletion of natural resources in order to maintain an ecological balance

Standards: [Copied from: 2]

HS-ESS2-5: Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

- Students will be actively contributing and observing a science experiment that examines how decreased pH, and therefore increased acidity, can affect living organisms. Since the experiment only changes the acidity of the water solution, students understand how one property of water can impact global ecosystems.

HS-ESS3-3: Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

- Through the Ocean Acidification experiment, students are observing the effects that increased acidity has on an important part of organisms. Students also learn how the population decline of an organism leads to the rapid decline in an ecosystem's success. Since humans rely on oceans for various resources, the loss of ocean diversity eventually leads to the decline in human populations.

Background Information

Prior Knowledge:

- Atoms are made of a nucleus, composed of protons and neutrons, that is surrounded by an electron cloud.
- Moles and how to calculate the molarity of a solution given the volume and number of moles.
- Acids and bases in daily life
- What is an ion and how they're formed.
- pH scale and the range associated with acids and bases.
- Balancing chemical reactions

Science Practices: [Copied from: 3]	**Core Ideas: [Copied from: 4]**	**Cross Cutting Concepts: [Copied from: 5]**
● Using Mathematical & Computational Thinking ● Planning & Carrying Out Investigations	● Human Impacts on Earth Systems ● The Role of Water in Earth's Surface Processes	● Stability & Change ● Influence of Science, Engineering, & Technology on Society & the Natural World ● Science is a Human Endeavor

Possible Preconceptions/Misconceptions:

Students will experience difficulty understanding how Carbon Dioxide gas contributes to increased levels of Hydronium ions in ocean waters based on the diagram on the worksheet *Ocean Acidification Experiment*. Students are not fully expected to understand the process by which Carbon Dioxide is converted to Carbonic Acid and broken down into Bicarbonate ions. The chemistry behind ocean acidification may be too advanced for students; however, they should be expected to learn that the process of forming and breaking complex molecules leads to the release of Hydronium ions, and therefore an increased level of acidity in the ocean.

	Lesson Plan - 5E(+) Model	

Engage: [6]

The instructor will present the video of Bill Nye to students about climate change and ocean acidification. While watching the video, the instructor will have students to recall information that they learned about ocean acidification by completing the *Bill Nye, the Science Guy!* worksheet. The worksheet is designed to guide the students through the video and to test their understanding about why and how acidification occurs in the Earth's climate. The worksheet ends with a question that prompts the students to bridge their understanding of acidification from a conceptual standpoint to a chemical equation. This worksheet will provide the students with foundational knowledge pertaining to ocean acidification and its process. This activity should take up to 10 minutes.

Explore:

Part I: Introduction

The instructor will begin by explaining the chemical process by which CO_2 contributes to ocean acidity (reference the diagram on the worksheet *Ocean Acidification Experiment* as necessary). From the engagement video and previous lessons, students may know the mechanism by which this happens, but not how it impacts organisms directly. The instructor should guide students towards identifying that increases in CO_2 contributes to rising H^+ ions in the ocean. This concept can be most easily seen by the chemical equation of ocean acidification and will provide an introduction for how ocean ecosystems can be affected. This discussion should take less than 5 minutes.

Part II: *Benchmark Lesson*: Ocean Acidification Experiment [7]

The instructor will then explain the procedures and protocol for the experiment. This should include the following: healthy and safety guidelines, classroom rules, etc. The instructor will then distribute the worksheet titled, *Ocean Acidification Experiment*, and the lab materials. Students will work in small groups of two to three to complete a lab activity where they take on a role as an ocean biologist. They will explore the effects of increased water acidity on shell production in clams and sea snails. Through this experiment, students observe the chemical process of chalk, which shares the same chemical structure as clam shells and sea snail shells, being broken down by the acidic conditions. Students are able to visually test and observe how an organism's method of defense is impacted by ocean acidification due to climate change. During the experiment, students will be recording observations and making predictions based on these observations. The instructor should allot 30 minutes for this activity.

Part III: *Investigation Lesson*: Ocean Acidification Analysis

After students finished both completing the experiment and recording their observations at the designated times, they will be prompted to answer questions that extend their understanding of ocean acidification to its effects on ecosystems. On the second page of the *Ocean Acidification Experiment* worksheet, students will individually complete the analysis questions. Students will need to critically think about how the loss of these organisms will impact the food chain. This activity will require students to employ both critical thinking and an application of fundamental acid-base chemistry to living organisms and their environment. Students are expected to complete this analysis within 8 -10 minutes.

Explain:

Throughout the exploration of this lesson, students will engage in discussions and activities that seek to discover their understanding of the topic at-hand as it relates to ocean acidification. The experiment and worksheets are designed to help students bridge understanding gaps while providing them with the opportunity of individuality and uniqueness of their responses. Students are expected to formalize their answers throughout the entirety of the lesson via the worksheets, the experiment and the exit ticket.

Elaborate: [8]

Following the *Ocean Acidification Experiment and Analysis*, the instructor will inform students about Citizen Science, if they are unfamiliar. Once they learn what it is, the students will learn about a Citizen Science project focused on obtaining data while out on the ocean. The Citizen Science project can be found through this link: Sailors For the Sea Ocean Watch | Citizen Science. The instructor will ask students to take the knowledge that they just learned and apply it to their own lives by proposing the question, "How can you help reduce Carbon emissions to decrease the rate of ocean acidification?" The students are expected to use the Citizen Science project as a guide and to apply practices and solutions discussed in the Citizen Science project to their own lives. This will help students become more conscientious of their own contributions to climate change and how they can be addressed. The instructor should allot 10 minutes for this exercise.

Evaluate:

Throughout the entirety of this lesson, there will be both formal and informal evaluations. The informal evaluations occur throughout the exploration via leading and open-ended questioning, as well as through the open class discussions. The informal evaluations will allow for the teacher to gauge surface-level understanding of the students. By surveying the students during completion of the worksheets and activities, teachers will be able to hear and to address any misconceptions or misunderstandings as necessary. The formal evaluations of this lesson are the lab experiment and the exit ticket. The exit ticket prompts the students to identify the chemical formula for how Carbon Dioxide contributes to ocean acidification, then calculate the max pH that an ocean organism can handle. The instructor should allow students the last 5 minutes of class to complete the exit ticket.

Enrich: [9]

Instructors can differentiate this lesson by introducing chemical equilibrium of hemoglobin in blood cells. The hemoglobin in blood cells are used to carry oxygen using a hemoglobin oxygen complex. This will help to introduce complex forming reactions and is viable to discuss since this topic perfectly bridges a connection between biology and chemistry. This topic can also be a substitute for ocean acidification if the instructor so chooses. In a biochemistry classroom, covering chemical equilibrium of hemoglobin in blood cells would be a more useful activity for students to complete. The associated article can be accessed through the following link: Hemoglobin and Oxygen Equilibrium.

All associated documents are attached below

Reference *Annotated Bibliography* on the very last page of this packet

Name: _____ Date: _____

Bill Nye, the Science Guy! [6]

1. In the demonstration involving a thermometer:
    a. What happened to the water level?

    b. Based on your knowledge of matter, what is happening to the molecules of water?

2. Bill Nye relates the thermometer demonstration to the ocean. Explain what is happening to the molecules in the ocean as the ocean temperature increases.

3. In the next demonstration, the news anchor pours vinegar into a glass with red cabbage juice in it.
    a. What happens to the liquid?

    b. How about when the news anchor blows air into the other glass with red cabbage juice in it? Why is this happening?

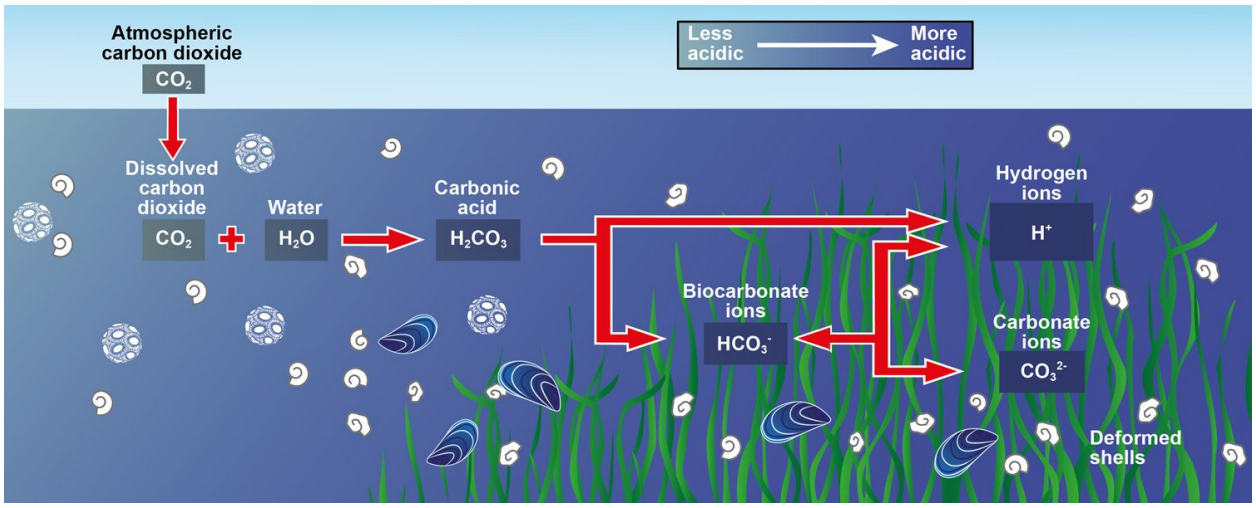
4. Based on the video, apply your understanding of chemical equations to ocean acidification.
    a. What is the reactant?

    b. What is the product?

    c. Write the chemical equation for ocean acidification below.

Name: _____ Date: _____

Ocean Acidification Experiment [7]



Introduction:

To understand the effects of ocean acidification, we are going to be doing an experiment with chalk, which is made of the same material (Calcium Carbonate) that clam and snail shells are made of. Clams and snails are primary consumers, which means they are the second level of the food chain that eats producers like algae. As an ocean biologist, you know that these organisms are necessary food sources for animals higher up in the food chain and are greatly affected by ocean acidification because it makes it makes shell development difficult. It also breaks down shells that are already formed, which will be observed using chalk. You will perform an experiment, mimicking the effects of ocean acidification on organism shells, in order to chemically understand how ocean acidification impacts ocean life.

Materials:

- Chalk (white or colored)
- Water
- Sea Salt
- Distilled White Vinegar
- 3 Clear Containers

Directions:

1. Label three cups: Freshwater, Saltwater, and Acidic Water
2. Place equal amounts of freshwater in the Freshwater and Saltwater cups, and distilled white vinegar in the Acidic Water cup
3. Measure and mix 5 tbsp. of sea salt in the Saltwater cup
4. Place equal amounts of chalk in each cup
5. Observe the chemical reaction. Is the same thing happening in each cup?
6. Answer questions on the back

Observations:

Time Elapsed:	10 Minutes	20 Minutes	30 Minutes
Freshwater			
Saltwater			
Acidic Water			

Questions:

1. Using prior knowledge, predict the results for the experiment. What will happen to the chalk?

$$CaCO_3 + HCO_3^- + H^+ \rightarrow (HCO_3)_2Ca \rightarrow HCO_3^- + Ca^{2+}$$

2. Above is the chemical reaction when Calcium Carbonate interacts with Bicarbonate ions. Chalk is made of the same material as Clam and Snail shells are made of ($CaCO_3$). How does the increased level of Hydronium ions (H^+) affect shell production?

3. Based on your answer above, how will this affect the impact the food chain? Use specific examples and include the ideas of primary, secondary, and tertiary consumer in your answer.

Name: _____ Date: _____

Sailors For the Sea Ocean Watch [8]

Introduction:

Scientists are already working on ways to reduce Carbon Emissions that lead to Ocean Acidification. One example is Sailors For the Sea Ocean Water, a Citizen Science project. In Sailors For the Sea, scientists give sailors instruments called OSMOs (Ocean Sailing Microbial Observatory) that collect real-time data about the ocean's microorganisms. Ocean Acidification causes these microorganisms to no longer function and even die, creating a major loss in oxygen production for the entire planet. By collecting data during travels, scientists are able to determine the rate at which the ocean is increasing in pH and where the increased acidity is coming from. What are some ways you can make a difference and reduce the rate of Ocean Acidification?

Directions:

Working in groups of two to three, come up with as many methods and practices to reduce the acidity of the ocean. Think practically and how you can change what you/your family/community can do to make a difference. Write them down in the section below.

To Reduce the Rate of Ocean Acidification, I can…

-
-
-
-
-
-

Name: _____ Date: _____

Exit Ticket

1. Write the chemical equation for how ocean acidification.

2. Ocean biologists often do experiments testing the organisms and how their ocean environments affect their ability to sustain themselves. An example of these organisms is clams. While clams have hard shells, these shells ($CaCO_3$) are still very susceptible to changes in pH. Recall the experiment conducted during class. Explain (1) how clam shells are affected by ocean acidification and (2) how this impacts the ecosystem.

Name: _____ Date: _____

Exit Ticket

1. Write the chemical equation for how ocean acidification.

2. Ocean biologists often do experiments testing the organisms and how their ocean environments affect their ability to sustain themselves. An example of these organisms is clams. While clams have hard shells, these shells ($CaCO_3$) are still very susceptible to changes in pH. Recall the experiment conducted during class. Explain (1) how clam shells are affected by ocean acidification and (2) how this impacts the ecosystem.

Name: _____Answer Key_____ Date: _____

Bill Nye, the Science Guy! [6]

1. In the demonstration involving a thermometer:
    a. What happened to the water level?

       The water level rose.

    b. Based on your knowledge of matter, what is happening to the molecules of water?

       As the temperature of the water molecules increase, they expand and increase the amount of space they take up.

2. Bill Nye relates the thermometer demonstration to the ocean. Explain what is happening to the molecules in the ocean as the ocean temperature increases.

   The water molecules that make up the ocean are expanding, making the ocean levels rise.

3. In the next demonstration, the news anchor pours vinegar into one glass with red cabbage juice in it.
    a. What happens to the liquid?

       When vinegar was added, the liquid turned pink.

    b. How about when the news anchor blows air into the other glass with red cabbage juice in it? Why is this happening?

       When carbon dioxide was added, the liquid turned pink as well.

       This is because the carbon dioxide is increasing the acidity of the water, just as adding vinegar does.

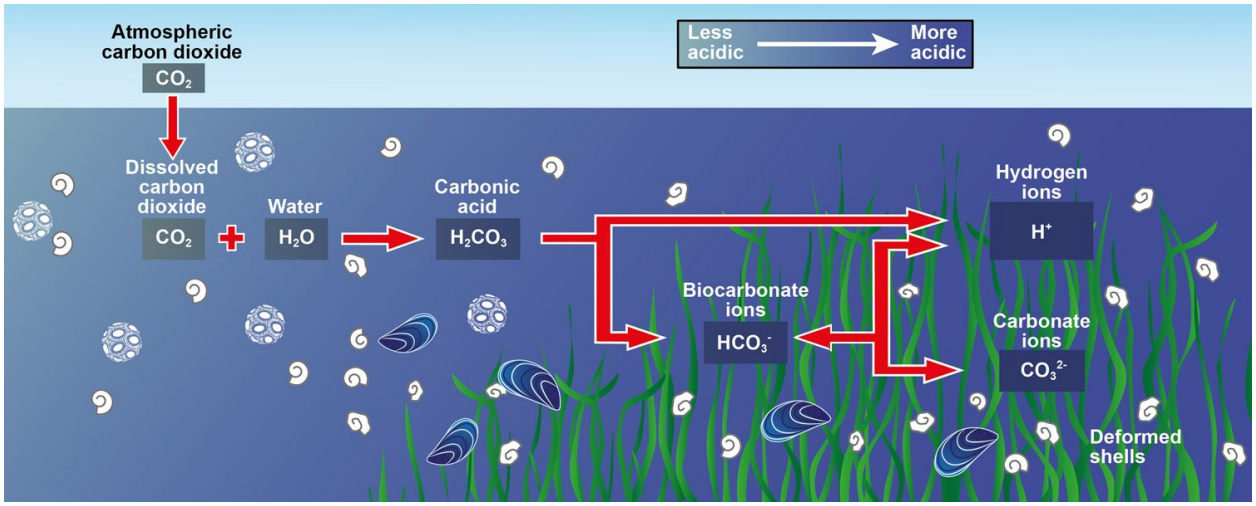
4. Based on the video, apply your understanding of chemical equations to ocean acidification.
    a. What is the reactant? CO_2 + Ocean Water
    b. What is the product? Carbonic Acid and $H^{\pm}$
    c. Write the chemical equation for ocean acidification below.

       CO_2 + Ocean Water → Carbonic Acid → $H^{\pm}$

       Expect something similar to the above. This is based on student interpretation

Name: _____Answer Key_____ Date: _____

Ocean Acidification Experiment [7]



Introduction:

To understand the effects of ocean acidification, we are going to be doing an experiment with chalk, which is made of the same material (Calcium Carbonate) that clam and snail shells are made of. Clams and snails are primary consumers, which means they are the second level of the food chain that eats producers like algae. Sometimes they eat each other and other invertebrates. These organisms are necessary food sources for animals higher up in the food chain and are greatly affected by ocean acidification because it makes it makes shell development difficult. It also breaks down shells that are already formed, which will be observed using chalk.

Materials:

- Chalk (white or colored)
- Water
- Sea Salt
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- 3 Clear Containers

Directions:

Label three cups: Freshwater, Saltwater, and Acidic Water
Place equal amounts of freshwater in the Freshwater and Saltwater cups, and distilled white vinegar in the Acidic Water cup
Measure and mix 5 tbsp. of sea salt in the Saltwater cup
Place equal amounts of chalk in each cup
Observe the chemical reaction. Is the same thing happening in each cup?
Answer questions on the back

Observations:

Time Elapsed:	10 Minutes	20 Minutes	30 Minutes
Freshwater	*Answers will vary based on students' observations*	*Answers will vary based on students' observations*	*Answers will vary based on students' observations*
Saltwater	*Answers will vary based on students' observations*	*Answers will vary based on students' observations*	*Answers will vary based on students' observations*
Acidic Water	*Answers will vary based on students' observations*	*Answers will vary based on students' observations*	*Answers will vary based on students' observations*

Questions:

1. Using prior knowledge, predict the results for the experiment. What will happen to the chalk?

   Answers will vary based on student prior knowledge and understanding of the experiment.

$$CaCO_3 + HCO_3^- + H^+ \rightarrow (HCO_3)_2Ca \rightarrow HCO_3^- + Ca^{2+}$$

2. Above is the chemical reaction when Calcium Carbonate interacts with Bicarbonate ions. Chalk is made of the same material as Clam and Snail shells are made of ($CaCO_3$). How does the increased level of Hydronium ions (H^+) affect shell production?

   An increase in Hydronium ions will lead to the production of Calcium Bicarbonate ($(HCO_3)_2Ca$. However, due to its instability, Calcium Bicarbonate breaks down into Bicarbonate and Calcium ions. This essentially causes shells that have already formed or are currently forming to break down.

3. Based on your answer above, how will this affect the impact the food chain? Use specific examples and include the ideas of primary, secondary, and tertiary consumer in your answer.

   As shell production decreases, so too does the population of organisms that have shells. Being primary consumers, organisms like clams and sea snails consume the photosynthetic producers in the ocean. A decline in clam and sea snail populations would lead to an increase in photosynthetic producers, as well as a rapid decrease in the number of secondary and tertiary consumers that benefit from consuming clams and sea snails.

Name: _____Answer Key_____ Date: _____

Sailors For the Sea Ocean Watch [8]

Introduction:

Scientists are already working on ways to reduce Carbon Emissions that lead to Ocean Acidification. One example is Sailors For the Sea Ocean Water, a Citizen Science project. In Sailors For the Sea, scientists give sailors instruments called OSMOs (Ocean Sailing Microbial Observatory) that collect real-time data about the ocean's microorganisms. Ocean Acidification causes these microorganisms to no longer function and even die, creating a major loss in oxygen production for the entire planet. By collecting data during travels, scientists are able to determine the rate at which the ocean is increasing in pH and where the increased acidity is coming from. What are some ways you can make a difference and reduce the rate of Ocean Acidification?

Directions:

Working in groups of two to three, come up with as many methods and practices to reduce the acidity of the ocean. Think practically and how you can change what you/your family/community can do to make a difference. Write them down in the section below.

To Reduce the Rate of Ocean Acidification, I can…

- Answer depend on the students' response. Expect some of the following: using renewable energy sources when possible, riding a bike instead of driving a car, reducing the usage of electrical appliances, etc.

Name: _____Answer Key_____ Date: _____

Exit Ticket

1. Write the chemical equation for how ocean acidification.

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow HCO_3^- + H^+$$

2. Ocean biologists often do experiments testing the organisms and how their ocean environments affect their ability to sustain themselves. An example of these organisms is clams. While clams have hard shells, these shells ($CaCO_3$) are still very susceptible to changes in pH. Recall the experiment conducted during class. Explain (1) how clam shells are affected by ocean acidification and (2) how this impacts the ecosystem.

   (1) As the pH of the water increases from Carbon Dioxide, shell production becomes increasingly more difficult since Calcium is removed from the shell. A shell supported with Calcium allows for the organisms to survive predation. Hence, decreasing amounts of Calcium leads to decreasing amounts of shellfish in the ocean.

   (2) Being primary consumers, organisms like clams and sea snails consume the photosynthetic producers in the ocean. A decline in clam and sea snail populations would lead to an increase in photosynthetic producers. This means that the photosynthetic producers would experience little to no predation, and thus would lead to an increase in algae production. Also, a decline in shellfish populations leads to a rapid decrease in the number of secondary and tertiary consumers that benefit from consuming clams and sea snails. This would cause the ocean food chain to fall apart, leaving only photosynthetic producers and no consumers.

Annotated Bibliography

[1] Mason, M. (n.d.). What is Environmental Science? Retrieved from https://www.environmentalscience.org/

This website was used for research and inspiration purposes. This reference aided in the completion of definitions. This reference was neither adapted nor excerpted.

[2] Nsta. (n.d.). Access the Next Generation Science Standards by Topic. Retrieved January 18, 2019, from https://ngss.nsta.org/AccessStandardsByTopic.aspx

This website was used in each lesson in the Water Chemistry & Biology module to select proper national set standards for science subjects that each lesson is centered around.

[3] Nsta. (n.d.). Science and Engineering Practices. Retrieved January 18, 2019, from https://ngss.nsta.org/PracticesFull.aspx

This website used in every lesson in the Water Chemistry & Biology module to find Standards for Science and Engineering Practices that are applicable in each lesson.

[4] Nsta. (n.d.). Disciplinary Core Ideas. Retrieved from https://ngss.nsta.org/DisciplinaryCoreIdeasTop.aspx

This website was used in each lesson in the Water Chemistry & Biology module to select appropriate disciplinary core ideas set forth by the NSTA that are at the center of each lesson.

[5] Nsta. (n.d.). Crosscutting Concepts. Retrieved from https://ngss.nsta.org/CrosscuttingConceptsFull.aspx

This website was used in each lesson in the Water Chemistry & Biology module to selecting appropriate crosscutting concepts set forth by the NSTA that apply to each science lesson.

[6] *Bill Nye Explains Climate Change, Acidification With Simple Science Experiments*[Television broadcast]. (2017, April 23). In *TODAY*. New York City, New York: NBC.

This resource was used for research and content inspiration. This reference aided in the completion of the Engagement activity and associated half-sheet. This reference was neither adapted nor excerpted. Videos by Bill Nye the Science Guy are useful in phenomenon demonstration or topic review.

[7] Plymouth Marine Laboratory Staff. (n.d.). Ocean acidification. Retrieved March, 2019, from https://www.pml.ac.uk/Research/Research_topics/Facing_the_challenge_of_new_pollutants/Ocean_acidification

This reference was used for excerption purposes. This reference aided in the completion of the activity worksheet. Also, the image depicting the process of ocean acidification and its associated chemical reactions was excerpted. It was used in the exploration: part two benchmark portion of the lesson. This resource was useful in demonstrating the complex chemistry behind ocean acidification in a diagram. It was used and expanded upon to apply to an inquiry-based experiment in the lesson.

[8] Lauro, R. (2014, June). Citizen Science for Cruisers. Retrieved March, 2019, from http://www.sailorsforthesea.org/programs/ocean-watch/citizen-science-cruisers

This reference was used for research and content inspiration. This reference aided in the completion of the Elaboration portion of the lesson. This reference was neither adapted nor excerpted. Citizen Science is a great resource to engage students in important research and data collection like scientists in the field.

[9] Abithira. (2013, May 07). Hemoglobin Equilibrium. Retrieved March, 2019, from https://fmss12ucheme.wordpress.com/2013/05/07/hemoglobin-equilibrium-2/

This reference was used for research and content inspiration. This reference aided in the Enrichment portion of this lesson. This reference was neither adapted nor excerpted.