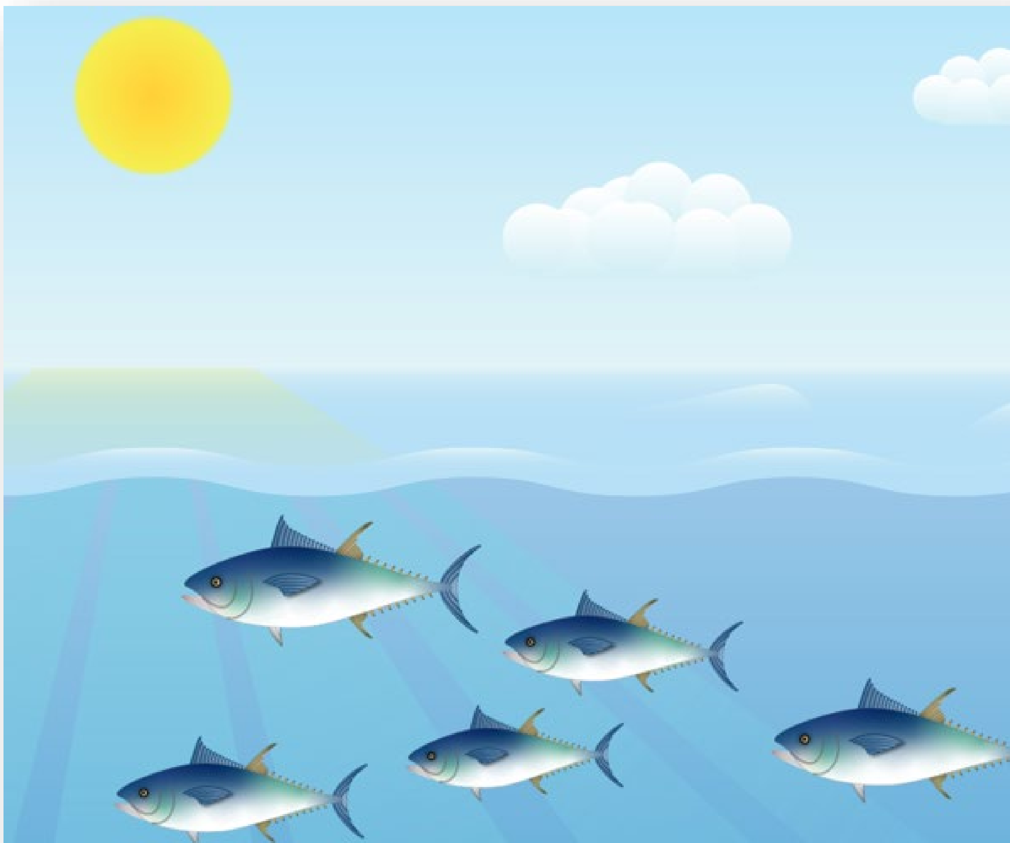
Teachers Guide for using *Ocean Protector* in the classroom



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Introduction

The amount of carbon dioxide (CO_2) in the atmosphere is increasing, due to the burning of fossil fuels and other human activities. How do these changes, as well as other human activities, affect the chemistry of the ocean?

The online program *Ocean Protector* is a game-based learning tool that teaches students about ocean acidification (OA), the effects on humans and marine life, and ways to help minimize the effects. This game-based curriculum integrates current OA data/models from NOAA and scientific literature into a framework of decisions and outcomes that align with Next Generation Science Standards. The program first guides students through learning the background about OA. Following this foundational lesson, students enter the scenario with a given role, such as a fishing boat captain, marine park ranger, scuba tour guide instructor, etc. Students are tasked with making decisions for how to reduce OA impacts on their character and marine life. Students will evaluate and select decisions based on the data provided and their own knowledge, and then they will analyze how their decision influenced OA impacts in real-time. This decision-driven experience helps students construct explanations, reason effectively, and become self-directed learners involving OA science and ocean literacy.

The document provides a background on OA, which is sourced from NOAA Ocean Data Education Project (2019). This background and introduction are followed by a structured lesson plan for using *Ocean Protector*, including sections for Objectives, Background, Materials, and Procedure. Links to complementary material are also listed, including how this material aligns with Next Generation Science Standards and an example of Module Integration.

For more great information on OA and marine science be sure to check out the great resources created by NOAA.

Ocean Acidification Background

The Basics of Ocean and Coastal Acidification

Burning fossil fuels, and other human activities, releases CO_2 into Earth's atmosphere. This not only leads to a warmer Earth (i.e., global climate change, the greenhouse effect), but also changes the chemistry of Earth's oceans. The ocean is a "carbon sink," which means that it removes CO_2 from the atmosphere. The ocean currently absorbs approximately 26% of human-caused CO_2 emissions from the atmosphere. When CO_2 dissolves in seawater, a series of chemical reactions occur resulting in the increased concentration of hydrogen ions. This increase causes the seawater to become more acidic. Ocean acidification refers to a reduction in the pH of the ocean over an extended period of time, caused primarily by uptake of carbon dioxide (CO_2) from the atmosphere. Coastal acidification refers to the same processes resulting from the absorption of atmospheric CO_2, as well as several additional, local-level processes, including the excess input of nutrients from shore (from fertilizers, wastewater, animal manure and more). Coastal acidification generally exhibits more variability over shorter time scales relative to open ocean acidification. Acidification is affecting the entire world's oceans. As the pH of ocean water decreases, there is a resulting decrease in the amount of carbonate ions available for many marine organisms to form their calcium carbonate shells. Oysters, clams, corals, and other shell-building creatures are less able to precipitate the mineral aragonite, which they use to build or rebuild their skeletons. As marine life is impacted, so too are economies that are dependent on fish and shellfish for food.

Carbon Cycling

Carbon cycles naturally between the atmosphere, the land, and the ocean due to multiple processes, including photosynthesis and respiration. Since the industrial revolution, carbon dioxide levels in the atmosphere have increased by 30%. This increase is primarily the result of fossil fuel emissions and deforestation. Some of the excess, human-caused CO_2 is absorbed, like a sponge, by the ocean. As CO_2 dissolves into the ocean, a series of chemical reactions occur that result in the increased concentration of hydrogen ions and the reduction of pH. This process is called ocean acidification. From long-term ocean measurements and observations, we know that ocean surface waters have become 30% more acidic over the last 150 years as they have absorbed large amounts of CO_2 from the atmosphere.

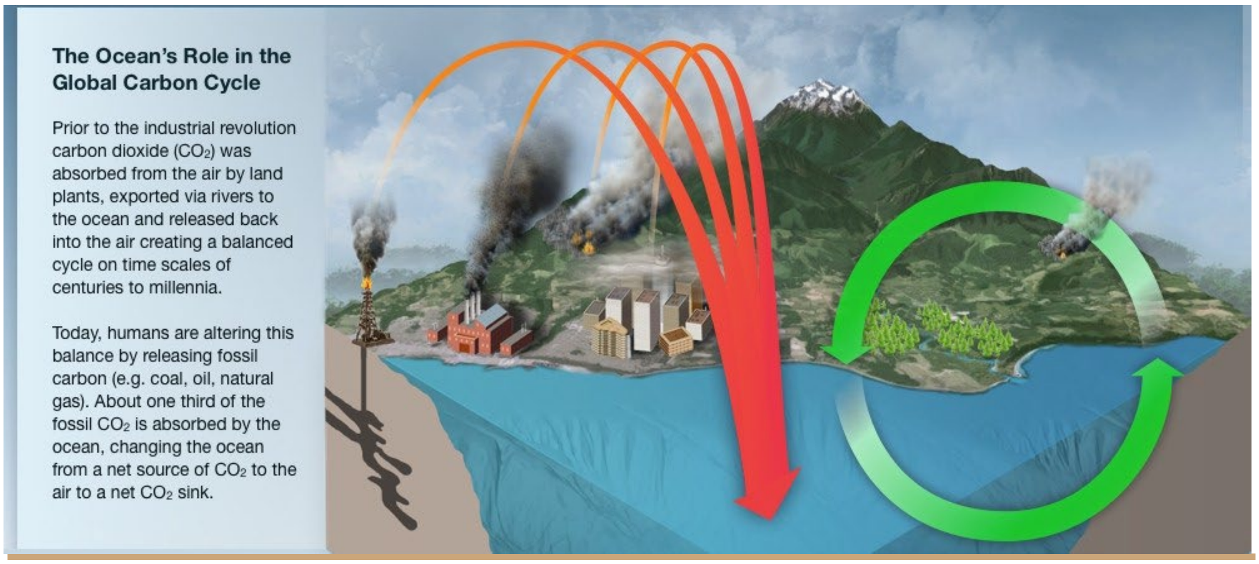


Image credit: Center for Environmental Visualization & NOAA PMEL Carbon Group

Review of pH

pH is the measure of the hydrogen ion concentration in a solution. pH is used to express acidity or alkalinity on a scale of 0 to 14. The pH of pure water is considered neutral and has a pH value of 7. Values above 7 are basic, or alkaline. Values below 7 are acidic. pH is measured on a logarithmic scale, where small changes have increasingly greater effects. A solution with a pH of 5 is ten times more acidified than a solution with a pH of 6 and 100 times more acidified than solution with a pH of 7.

Earth's oceans are naturally slightly alkaline. Historically, the pH of the surface ocean was approximately 8.1. Since the Industrial Revolution, the global average pH of the surface ocean has decreased by 0.11 pH units. This change may not seem like much, but because the pH scale is logarithmic, it represents a 30 percent increase in acidity. For more background information, check out [“A Primer on pH”] from NOAA’s PMEL Carbon Program.

Coastal Acidification

While ocean acidification is caused by the uptake of carbon dioxide (CO_2) from the atmosphere, coastal acidification is a slightly different mechanism. Near the coast, several other factors can contribute to even greater changes in ocean chemistry. The excess input of nutrients from shore (from fertilizers, wastewater, animal manure and more) promote acidification by stimulating algae growth. This in turn leads to intense respiration by animals that eat them, and the respiration drives up the local CO_2 concentration in the water. Along the West Coast of the US, coastal acidification can also be impacted by the process of upwelling. Deep waters that ‘rise up’ during upwelling are naturally enriched with CO_2 because respiration processes dominate in the deep. Deep waters are also enriched with excess (human-caused) CO_2 that was absorbed from the atmosphere when last in contact with the surface. Coastal acidification generally exhibits more variability over shorter time scales relative to open ocean acidification.

References

Center for Environmental Visualization and NOAA Pacific Marine Environmental Laboratory (PMEL) Carbon Group (2022). "A primer on pH," <https://www.pmel.noaa.gov/co2/story/A%2Bprimer%2Bon%2BpH>.

NOAA Ocean Data Education Project (NODE), 2019. 2nd Edition. National Environmental Satellite, Data, and Information Service (NESDIS), National Estuarine Research Reserve System, National Oceanographic Data Center, and the Office of National Marine Sanctuaries, <https://s3.amazonaws.com/ditcr-prod/2022-06/Ocean%20and%20Coastal%20Acidification_TeacherGuide_june_2022.pdf>.

Ocean Literacy Network, (2018). < Ocean Literacy | Understanding the Ocean's influence on you and your influence on the Ocean | Ocean Literacy (coexploration.org)>.

Curriculum Structure and Standards

Scaled Structure

This game-based curriculum incorporates a scaled approach to learning. Each module offers activities at different levels of student interaction, specifically Knowledge and Comprehension, Application and Analysis, and Synthesis and Evaluation. The early levels are directed and linear, which provides important first steps when learning something new. The levels of Application through Evaluation are more student-directed and foster opportunities to design lessons featuring student inquiry. The levels are designed to engage students in increasingly sophisticated modes of understanding and evaluation.

Ocean Literacy

This curriculum module supports the following Essential Principles of Ocean Sciences (Ocean Literacy Network, 2018).

1. The Earth has one big ocean with many features.

    e. Most of Earth's water (97%) is in the ocean. Seawater has unique properties. It is salty, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. Balance of pH is vital for the health of marine ecosystems, and important in controlling the rate at which the ocean will absorb and buffer changes in atmospheric carbon dioxide.

2. The ocean, and life in the ocean, shape the features of the earth.

    d. The ocean is the largest reservoir of rapidly cycling carbon on Earth. Many organisms use carbon dissolved in the ocean to form shells, other skeletal parts, and coral reefs.

5. The ocean supports a great deal of diversity of life and ecosystems.

    f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate, and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy." Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

6. The ocean and humans are inextricably interconnected.

    e. Changes in ocean temperature and pH due to human activities can affect the survival of some organisms and impact biological diversity (coral bleaching due to increased temperature and inhibition of shell formation due to ocean acidification).

Next Generation Science Standards Alignment

This game-based learning program was developed to build data literacy, engaging students in increasingly sophisticated modes of understanding and manipulation of data. You can learn more about how *Ocean Protector* aligns to Next Generation Science Standards here: PDF Link

Module Integration Example

This game-based learning curriculum on ocean acidification can also be integrated into a larger context module. You can see an example of how to integrate *Ocean Protector* into a larger module within a Biology, Chemistry or Environmental Science course here: PDF Link

Ocean Protector Lesson Plan

Objectives

Knowledge and Comprehension

- Learning Objective:
    - Students will understand that rising atmospheric CO_2 contributes to rising CO_2 concentrations in the ocean. Students will learn the likely effect of changes in CO_2 on ocean pH and acidification.
- Question Outcomes:
    - Conventional correct or incorrect answers on these questions, as they form the foundational knowledge and comprehension basis for the subsequent questions. Users will go through these 'tutorial' questions each time the game program is played, which reinforces learning. Ideally students will practice recall when going through this section again and be able to complete it more quickly on subsequent playthroughs. All users will see the same questions.

Application and Analysis

- Learning Objective:
    - Students will apply knowledge by answering questions and analyzing new data to understand the relationship between CO_2, pH, and ocean acidification.
- Question Outcomes:
    - Questions will not have an incorrect answer, and instead each option will have weights that affect the variables of the program. These questions will focus on applying understanding and analyzing ocean acidification decisions. Outcomes will be presented in real-time based on user choice. Many of these questions may be unique to an individual character.

Synthesis and Evaluation

- Learning Objective:
    - Students will continue answering more advanced questions and synthesize ongoing ocean chemistry data and real-time feedback from biologic components to evaluate best decisions to reduce effects of ocean acidification.
- Question Outcomes:
    - Questions will not have an incorrect answer, and instead each option will have weights that affect the variables of the program. These questions will focus on synthesizing and evaluating more in-depth ocean acidification decisions. Outcomes will be presented in real-time based on user choice. Many of these questions may be unique to an individual character.

After completing their individual decisions, teachers can guide students to discuss and evaluate their decisions with classmates and be able to replay the experience. Ideally, this engaging learning experience will foster ocean literacy and stewardship, especially with students from inland communities who may not have engaged previously with these topics or with this form of learning and decision-making.

Background

Note, the game itself will summarize and describe this background information to students and present them with a summary PDF (link here). The following paragraphs within this Background section provides additional details for your convenience which are sourced from NOAA OA Background.

As carbon dioxide (CO_2) dissolves into the ocean, a series of chemical reactions occur that result in the increased concentration of hydrogen ions and the reduction of pH. This process is called ocean acidification. pH is the measure of the hydrogen ion concentration in a solution. pH is used to express acidity or alkalinity on a scale of 0 to 14. Values above 7 are basic, or alkaline. Values below 7 are acidic. pH is measured on a logarithmic scale, where small changes have increasingly greater effects. A solution with a pH of 5 is ten times more acidified than a solution with a pH of 6 and 100 times more acidified than solution with a pH of 7.
Earth's oceans are naturally slightly alkaline. Historically, the pH of the surface ocean was approximately 8.1. Since the Industrial Revolution, the global average pH of the surface ocean has decreased by 0.11 pH units. This change may not seem like much, but because the pH scale is logarithmic, it represents a 30 percent increase in acidity.

While ocean acidification is caused by the uptake of CO_2 from the atmosphere, coastal acidification is a slightly different mechanism. Near the coast, a number of other factors can contribute to even greater changes in ocean chemistry. The excess input of nutrients from shore (from fertilizers, wastewater, animal manure and more) promote acidification by stimulating algae growth. This in turn leads to intense respiration by animals that eat them, and the respiration drives up the local CO_2 concentration in the water.

Coastal and shallow water ecosystems are some of the most productive ecosystems in the world. These areas support important fisheries that we rely on for food. Increases to OA can cause harmful effects on both marine life and the people that rely on those ecosystems for food and jobs.

The game-based learning tool that teaches students about OA, the effects on humans and marine life, and ways to help minimize the effects. Students will evaluate and select decisions based on the data provided and their own knowledge, and then they will analyze how their decision influenced OA impacts in real-time. This decision-driven experience helps students construct explanations, reason effectively, and become self-directed learners involving OA science and ocean literacy.

Materials

Each student will require a computer with an internet connection to access and go through the online *Ocean Protector* program.

Procedure

The game will self-guide students through the following steps as play through *Ocean Protector*. The overall process is summarized in visual form with Flowchart 1.

1. Students will open the program and select "New Game." They will then be prompted to enter a 4-digit number. This number will show on the Google Sheet Analytics page along with a game generated ID. Note, multiple students can use the same number if desired because the game generated ID will be unique.

2. All students will go through the same preface lessons and answer the same questions, setting the groundwork for understanding basic topics. At the end of this introductory material students will be presented with a summary of this information as a PDF

document that they can reference throughout the rest of the game (link here for convenience).

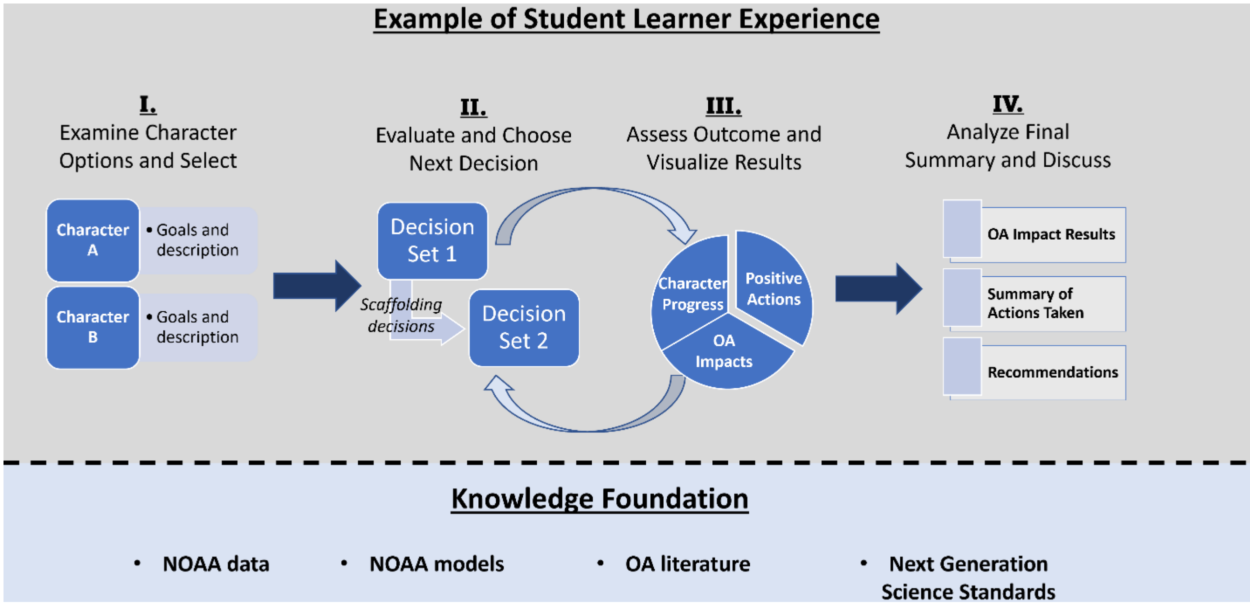
3. Once successfully completed with the prerequisite lesson, students will choose a character role, such as marine park ranger, fishing boat captain, or ocean tour guide. Background information for each character will be provided.

4. The game will then present a set of decisions—with some being more helpful to OA impacts than others. Each decision consists of the following steps:
   a. A new decision will be presented, and students will evaluate and select a choice based on their understanding and cumulative experience within the game.
   b. Once students submit their choice, the program will automatically update OA outcomes and students will observe these outcomes in real-time.
   c. Students will then assess how their decision affects their character and marine life by measuring and recording values for each group. These values will be appended to a times series plot so students can analyze how their choices affect each group over time.
   d. After students complete the data step, the game will then present a summary of the main points to reinforce learning objectives.

   Note, decisions will be engineered to engage students in increasingly sophisticated modes of understanding and help students construct explanations and become self-directed learners.

5. After students complete all decisions, they will be presented with a final summary of their decisions. This summary will show the cumulative effect of OA outcomes on their character and marine life. Adaptive recommendations based on their decisions will also be shown. For example, if students select decisions that are not ideal for reducing impacts of OA, the final summary will provide examples of how students could improve with another playthrough.

6. After completing their individual decisions, students will be allowed to re-run the game to select a different character or try to improve their overall outcome. Students can also discuss and evaluate their decisions with classmates as they replay the experience. Ideally, this engaging learning experience will foster ocean literacy and stewardship.



Flowchart 1. Overall structure and outline for student experience in game-based learning curriculum for *Ocean Protector*.

Assessment

As noted above, the game will provide students with a summary and review that will show how well they accomplished their objectives to reduce OA impacts. As an educator, you may also prefer to view quantitative information regarding student outcomes.

Therefore, analytical data is also presented and saved [at this Google Sheet](). Analytical data does not contain any personal data and only consists of fields for assessing how students are interacting with the game, such as final summary score, time for each stage, choice of each decision, and more. There are multiple sheets within this Google Sheets Document:

1. All_Analytics sheet provides all recently recorded analytical data. This data is mostly useful for NOAA and the game developers for assessing interaction within each stage in the game. Educators can also use this data if they want highly detailed information on student usage.
2. FinalOutcome_Analytics sheet provides a summary score for each playthrough of a student. This data will likely be the most useful for educators, as it provides a short and summarized report of student outcomes. This score is calculated as the following:
    a. number of best decisions from student / total number of possible decisions
    b. 100% means the student chose the most ideal decision each time.
3. Archived_Analytics_<1,…> sheets provide analytical data that is no longer recent and has been archived for long-term storage.

As mentioned, no personal information is collected—if you want to tie specific scores to a specific student you can ask that student to enter a specific 4-digit number at the start of the game and then view that 4-digit ID within the Google Sheet. Alternatively, you can ask students to show you a screen shot of the final summary of the game, and/or you can assign a writing exercise to explain what decisions helped reduce OA impacts and why.