

Anthropogenic Effects on Carbon Flows and Reservoirs

Overview

In this activity, participants continue to explore the carbon cycle as they consider carbon flows between land, ocean and atmosphere reservoirs, including flows caused by human activities. They run two models of the carbon cycle as they play the *Paper Clip Carbon Cycle Game* and use *Carbon Cycle Cards* to gather evidence and describe the flows (processes) that move carbon from one reservoir to another. Finally, they discuss how the design of the activity affected what they learned.

Learning Outcomes

Students will be able to:

- Construct a model demonstrating carbon flows between reservoirs.
- Discuss how human activities increase the amount of carbon stored in the atmosphere.



NGSS Connections

- **Disciplinary Core Ideas:** MS.LS2.B Cycles of Matter and Energy Transfer in Ecosystems; MS.ESS2.A: Earth's materials and Systems; MS.ESS3.C: Human impacts on Earth's Systems; HS.LS2.B Cycles of Matter and Energy Transfer in Ecosystems
- **Science and Engineering Practice:** Developing and Using Models
- **Crosscutting Concepts:** Systems and System Models

Ocean Literacy Principles

- 3.E: The ocean dominates Earth's carbon cycle. Half of the primary productivity on Earth takes place in the sunlit layers of the ocean. The ocean absorbs roughly half of all carbon dioxide and methane that are added to the atmosphere.



This activity was prepared by the Lawrence Hall of Science and Padilla Bay National Estuarine Research Reserve under award nos. NA14SEC0080004 and NA15SEC0080001 from the Environmental Literacy Program of the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of NOAA or the U.S. Department of Commerce.

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Note: This activity has been modified from two separate student activities available in the Ocean Sciences Sequence curriculum, the Paper Clip Game and the Tabletop Carbon Cycle Model. This workshop version was designed for educators to come to a deeper understanding of the carbon cycle, to reflect on what they are learning about the carbon cycle, and how they are engaging to learn the content. This also serves to also to introduce educators to the student activities.

Materials Needed

For the class

- Powerpoint presentation
- Digital Projector
- Whiteboard or flipchart and markers
- Computer
- (Optional): Interactive Carbon Cycle Diagram (two online animations)
 - go to the following urls:
 - <http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68-overview/oss68-resources/unit2>
 - 2.7 Simulation: Interactive Carbon Cycle Diagram
 - <http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68-overview/oss68-resources/unit3>
 - 3.10 Simulation: Change the Flow

For groups of 3-4 participants for the Paper Clip Carbon Cycle Game

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- 1 set of 32 Carbon Cycle Cards
- 1 each of two different game boards labeled: “Paper Clip Carbon Cycle Model #1”, and “Paper Clip Carbon Cycle Model #2”
- 20 paper clips in each of five different colors (See Preparation of Materials below)
- 5 small plastic bags (for paper clips)
- 1 dice
- (Optional): Instructions for Paper Clip Carbon Cycle Game

For every participant (1 copy of each of the following from previous activity)

- Image of Sydney Harbor (or locally-relevant image; used in previous activity))

Preparation of Materials

For each small group of 3-4 participants

1. **Organize paper clips.** Gather 5 different colors of paper clips. Place 10 paper clips of 1 color into a small plastic bag; repeat with the different colors to make 5 bags, each a separate color, for each small group. [Note: if you have enough paper clips, it is helpful to provide 2 bags of each color paper clip for each small group. This allows them to keep Model #1 set up as they run Model #2 which makes the differences between the two models stand out more clearly.]
2. **(Optional) Access two computer simulations.**
 - <http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68-overview/oss68-resources/unit2>
 - 2.7 Simulation: Interactive Carbon Cycle Diagram
 - <http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68-overview/oss68-resources/unit3>
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Session at a Glance

Task	Description	Time (minutes)
A. Activity: <i>Paper Clip Carbon Cycle Game</i>	Participants work in small groups to play two models of the <i>Paper Clip Carbon Cycle Game</i> (modeling the carbon cycle before and after the Industrial Revolution) to help come to a deeper conceptual	30

	understanding of the carbon cycle and explore how the design of experiences support learning.	
B. Reflection: <i>About the Learning Experience</i>	Participants reflect on the carbon cycle activities and discuss what helped them to answer their own questions and come to a deeper understanding. They also discuss the learning goals and how the activities modeled the five foundational ideas of learning.	15

Session Details

A. Activity: *Paper Clip Carbon Cycle Game*

Introduction

1. **Introduce the overall goals of the Activity.** Explain that this activity focuses on the carbon cycle to support a deeper understanding of this complex system, while also thinking about how they are making sense of the concepts. The activity is designed to be played as a game to simulate running a model to help answer questions about the system.
2. **Reflect on learning experience.** Emphasize that although one of their goals is to perform the assigned tasks and get “caught up” in the playing the game (running the models) themselves, another important objective is to reflect on the learning experience. Display the following and emphasize that as they engage with the activity they should think about:
 - What do you think the specific content learning goals are for this activity?
 - Which of the 5 Foundational Ideas on Learning were addressed?
 - What is one piece of science content you are taking away? Were you able to answer some of your questions?
 - What additional questions about the content arise for you as you engage in the activity? Record your questions.
3. **Introduce Paper Clip Carbon Cycle Game.** Explain how to play the game using the following directions. (Optional: distribute **Instructions for Paper Clip Carbon Cycle Game** handout.)

Paper Clip Carbon Cycle Model #1

1. **Describe Game Board.**
 - a. Different-colored circles on the game board represent different carbon reservoirs (e.g. ocean). Arrows represent flows moving carbon between the reservoirs.

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- b. Carbon atoms that belong to each reservoir are represented by different-colored paper clips. All of the paper clips represent identical carbon atoms—the different colors help keep track of which reservoir each carbon atom started in. Each reservoir starts with 10 paperclips.
2. **Introduce Carbon Cycle Cards.** These cards include descriptions of **reservoirs** (blue-edged cards), **flows between reservoirs** (green-edged cards), and **human actions** affecting the carbon cycle (black-edged cards).
3. **Explain how to run the model (play the game), starting with the ocean reservoir.**
 - a. First person rolls the die. The number that comes up on the die will tell you where to move ONE carbon atom (paper clip) from the ocean reservoir. For example, if the first person rolls a five, she will move a single paper clip to the atmosphere reservoir.
 - b. Before moving a carbon atom, the small group works together to find the flow card representative of that flow (e.g. photosynthesis), and then the person whose turn it is shares with the small group how that process moves the carbon from one reservoir to another.
 - c. Take turns rolling the die and moving one paper clip from the ocean reservoir, finding the appropriate flow card and describing the process. Once everyone has a turn in the ocean reservoir, move clockwise to the next reservoir. Continue until you have completed all five reservoirs.
4. **Small groups discuss prompts after running this first model:**
 - a. Which reservoirs increase? Which decrease?
 - b. Which reservoir(s) gained the most atoms from different reservoirs?
 - c. What happens to the total number of carbon atoms on Earth?

Paper Clip Carbon Cycle Model #2

1. **Describe second model, *Paper Clip Carbon Cycle Model #2*.** Since the start of the Industrial Revolution, fossil fuel use has increased significantly. This game board represents the present day carbon cycle and includes a “combustion” flow from the fossil fuel reservoir.
 - a. Set up the game board as before (10 paper clips in each reservoir of appropriate colors). Follow the directions from step 3 above.
 - b. Discussion prompts. After running the second model, discuss the following:
 - i. What difference(s) in results did you notice between the 1st and 2nd model?

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- ii. What are the strengths and limitations of this model?
2. **Monitor activity.** Check in with groups to make sure they understand the directions and are making progress so that they can start on Game board #2 at the 10 minute mark. Remind them that the point of the activity is not to get to the end of the activity, but rather to enter into conversations with their group about the content and design.
3. **Announce time.** After 20 minutes, call time and remind them to write down any questions about the content that arose during the station activity.

Revisit Sydney Harbor (or local ecosystem) carbon cycle sketch

1. **Show slide of Sydney Harbor or local ecosystem (from previous activity) and add to diagram.** Ask participants to work individually to quickly add to their sketch of the image of the ecosystem they started previously, labeling any additional carbon reservoirs and flows they learned about. As they work, instruct them to write down any additional questions that arise for them, and to try to answer any of their original questions.
2. **Turn and Talk.** Have participants share their updated drawings and questions with a partner. Then have partners share their questions and answers with the whole group as you lead a whole group discussion. Encourage others to share their ideas and answers and challenge them to provide evidence and reasoning for their responses. Have volunteers share which of their questions were answered, what helped them answer the question, and what they discovered the answer to be. Encourage participants to share whether they agree or disagree and build on the ideas expressed.
3. **Reorganize materials.** Ask participants to reorganize the game materials, placing them back in the separate bags.

B. Reflection: *About the learning experience*

1. **Small groups discuss learning prompts.** Remind participants that the learning goals affect what learning experiences are offered and how they are designed. Display the following prompts and have participants discuss for ~5 minutes:
 - a. How were you engaging with the materials and content in the activity to learn about the carbon cycle?
 - b. Which of the 5 Foundational Ideas on Learning were addressed?

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- c. What did you learn about the carbon cycle? What do you think the content learning goal or purpose was for the activity?
2. **Lead brief whole group discussion about the learning goal prompt.** Ask participants to share their small groups discussions. Share the following learning goals if participants don't suggest them:
 - *This activity was designed to specifically address the common misconception that Earth is getting more carbon, rather than the normative science understanding that essentially no new carbon is entering the system, but rather it is cycling more quickly between the reservoirs. Human activities have taken carbon which was stored long-term in the fossil fuel reservoirs and caused it to flow much more rapidly than it naturally would into the atmosphere and ocean reservoirs.*
 - *Using the carbon cycle cards provided the opportunity to work together to learn more about the carbon cycle, while also enabling learners to realize what they individually know and don't know about the carbon cycle.*
3. **Quick write – what I want to remember.** Tell participants to spend a minute thinking about the science content they learned from the activity and then individually record anything they want to remember about what they learned and what helped them to learn it. Also have them record any questions they still have.
4. **Optional: Explore the online carbon cycle simulations.** *[Note: This interactive diagram provides additional information to answer questions that arose through small group discussions.]*
 - a. Provide participants with the urls of the two online simulations and have them explore them as individuals or small groups.
 - b. Go to:
<http://mare.lawrencehallofscience.org/curriculum/oceanscience-sequence/oss68-overview/oss68-resources/unit2>
 - i. Scroll down to Session 2.7 & click on Simulation 2.
 - c. Point out how the carbon cycle diagram changes as you click on the different views in the top navigation. Clicking on the arrows within the diagram provides additional information.
 - d. Possible prompts for discussion:
 - i. Find a new way of looking at the carbon cycle, different from how you have viewed it before.

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- ii. What are some of the things you discovered about the carbon cycle looking at it in this new way?
- iii. What questions are you able to answer, and what new ones arise as you investigate the carbon cycle?