THINKING AND ACTING LIKE A SCIENTIST

TEACHER'S GUIDE

Carbon Cycling

How does carbon cycle through Earth's subsystems?

GRADES 9–12

Earth & Space

VAN ANDEL EDUCATION INSTITUTE

VAEI.ORG

INQUIRY-BASED SCIENCE

Earth & Space

Carbon Cycling

Grade Level/Content	9–12/Earth and Space Science
Lesson Summary	In this lesson, students explore and quantify the movement of carbon through Earth's four systems.
Estimated Time	2, 45-minute class periods
Materials	Investigation Plan, Internet access, materials will vary depending upon the model produced by student groups.
Secondary Resources	Changing the Balance – Carbon Cycle overview The Carbon Cycle Game – Windows to the Universe The Carbon Cycle: Sources and Sinks – NASA's Exploring the Environment Carbon Cycle – Sources and annual flux Quest Soil Interactive – Carbon in the Geosphere NOAA's Carbon Tracker – Carbon in the Atmosphere *Note: Some of these links may be Adobe Flash dependent.*
NGSS Connection	**HS-ESS2-6** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
Learning Objectives	• Students will analyze the movement of carbon and record carbon cycling data from credible online resources. • Students will develop a demonstration or model that quantifies the cycling of carbon through Earth's four systems. • Students will analyze and communicate the details of interrelated biogeochemical processes of their choice.

How does carbon cycle through Earth's subsystems?

What is carbon? Where is it found? Carbon is an essential element that cycles through Earth's non-living and living environments. Carbon is one of the main building blocks necessary to form carbohydrates, lipids, and proteins. Because plants can turn Carbon dioxide into energy and animals use the molecules as a source of energy, carbon is found throughout Earth. In fact, a single atom of carbon could be traced traveling through different environments and organisms, though it may take several years. As it travels through various systems, the carbon atom bonds with other elements to form a wide variety of molecules that perform specialized functions.

There are numerous processes involved in these short and long-term carbon cycles. Students will create a demonstration or build a model that illustrates and quantifies these cycles based on their online research. To close out the investigation, students will apply their understanding to draw conclusions about changes to carbon sources and sinks in one of the four Earth subsystems.

Investigation is based on the Van Andel Education Institute (VAEI) Instructional Model for Inquiry-Based Science. In all investigations:

Students don't know the "answer" they are supposed to get.

Students play a driving role in determining the process for learning.

Teachers and students construct meaning together by journaling.

Students are working as hard as the teacher.

Part 1

INVESTIGATION SETUP

Review suggested Internet resources and/or collect additional ones for use with your students prior to the investigation. Collect materials for possible use by students to create their carbon cycle models.

- Investigation Plan
- Internet access
- Materials will vary depending on how students choose to model or demonstrate the carbon cycle.

Part 2

INVESTIGATION FACILITATION

Question

Introduce the investigation question.

How does carbon cycle through Earth's subsystems?

OPENNESS TO NEW IDEAS

In addition to considering the carbon cycle within a single system, encourage students to consider how each of Earth's four systems impact each other as carbon is cycled on various time scales.

Personal Knowledge

Students capture what they already know about the carbon cycle.

- Have student groups reflect on/brainstorm what they know about each of the following terms, including examples from their daily lives: *carbon cycle*, *Carbon dioxide*, *photosynthesis*, *respiration*, *decomposition*, *hydrosphere*, *atmosphere*, *geosphere*, and *biosphere*. They may add any terms they feel are relevant.
- Ask groups to write short definitions and examples of each term, then compare with other groups. Initiate a discussion of each term within groups, as needed.
- Ask students to consolidate definitions and observations in a chart for their group. If they cannot define or give an example, have them label it with a question mark and leave it for later. Have each group post their chart on the board or in a prominent place for students to reference and revisit as needed.
- As student groups conduct research for the investigation, have them add details or make edits to their group chart.

Secondary Knowledge

Students use secondary sources to understand the processes of carbon cycling between the hydrosphere, atmosphere, geosphere, and biosphere.

Work with students to review the first Internet resources for information on the carbon cycle starting first with the Changing the Balance – Carbon Cycle overview and then The Carbon Cycle Game – Windows to the Universe. Allow time for students to explore both interactives and record notes, key observations, and any surprises from these resources.

Prediction

Students communicate an expected outcome, based on personal and secondary knowledge.

Remind students that they will be investigating carbon flow through Earth's four systems. Ask them to pick one of the four systems as the basis of their prediction.

Suggest that students complete this sentence or a similar sentence when making their prediction:

- *I predict that carbon will primarily move in and out of the _____ system as a result of _____ because _____.*

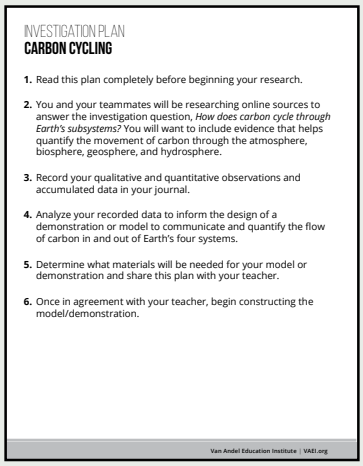
STUDENT CHOICE

Encourage students to choose a specific Earth subsystem that interests them. Students can also choose to display their predictions with a diagram.

Investigation Plan

Students conduct research to determine how carbon moves through Earth's systems.

- Divide the class into teams of between 3 and 4 students.
- Ask teams to follow the Investigation Plan.
- Share with students that they will be researching online sources for evidence to quantify the movement of carbon through all four of Earth's subsystems.
- Remind students that they are researching beyond the scope of their prediction. When it comes to their prediction, encourage them to dig deeper into the biogeochemical interactions that specifically apply to their prediction.



INVESTIGATION PLAN
CARBON CYCLING

1. Read this plan completely before beginning your research.
2. You and your teammates will be researching online sources to answer the investigation question, *How does carbon cycle through Earth's subsystems?* You will want to include evidence that helps quantify the movement of carbon through the atmosphere, biosphere, geosphere, and hydrosphere.
3. Record your qualitative and quantitative observations and accumulated data in your journal.
4. Analyze your recorded data to inform the design of a demonstration or model to communicate and quantify the flow of carbon in and out of Earth's four systems.
5. Determine what materials will be needed for your model or demonstration and share this plan with your teacher.
6. Once in agreement with your teacher, begin constructing the model/demonstration.

Van Andel Education Institute | VAEI.org

Investigation Plan

CRITICAL THINKING

Use the Fair Test checklist to help students think critically about the investigation plan. Help them understand that a good investigation plan must include a test that is repeatable, generates quality data, and minimizes error. The more critically students think about their investigation plan, the more confident they can be in their results.

DISCOURSE

Ensure that all students are participating in the investigation. Ask students to orally share the status of their carbon cycle investigations, problems encountered, and possible solutions.

Observation

Students research and record evidence of the flow of carbon between the Earth's subsystems.

- Evidence will be obtained from a variety of online data sources.
  Excellent targeted resources include the following:
  The Carbon Cycle: Sources and Sinks – NASA's Exploring the Environment
  Carbon Cycle – Sources and annual flux
  Quest Soil Interactive – Carbon in the Geosphere
  NOAA's Carbon Tracker – Carbon in the Atmosphere

Continued

- As students find graphic representations that quantify the carbon cycle, they will be introduced to a variety of units that quantify carbon storage and annual flux, including gigatons (GtC), petagrams or $x10^{15}$ g of carbon. Take a moment to describe how these units are related and encourage all groups to standardize their observations using a common unit.
- Students are also likely to find information about the relative speed of these processes. Encourage them to document observations that shed light on this phenomena.
- Evidence can be recorded as sketches, drawings, or photos. Have them document the online sources of this evidence (data and images) to include in their explanation.
- Remind students to focus on identifying biogeochemical processes and quantifying estimated amounts of carbon sources and sinks. Biogeochemical evidence may include, for example, the chemical reactions for photosynthesis and respiration.

Part 3 INVESTIGATION ANALYSIS AND DEVELOPMENT OF CLAIM

Data Analysis

Students make sense of their data by organizing it and representing it visually.

Have students analyze their data. They may wish to use the Data Analysis prompt as a guide.

- Ensure they have enough data that it can be used as evidence to support a claim.
- Have students **evaluate** their data for trustworthiness by focusing on the source of their collected data and the nature that it was collected and recorded by their team.
- Then, have them analyze their data to find patterns and trends. They should **organize** the data and/or **represent** it visually in a demonstration or model that communicates and quantifies the flow of carbon between all four of Earth's systems. Work with each team to determine what materials are needed to demonstrate or model the carbon cycle.
- Have students identify and **interpret** patterns or trends shown in their demonstration or model.

Explanation

Students write a claim and provide evidence and reasoning to support it.

- Have students use what they've discovered from their analyzed data to write an explanation that answers their investigation question. Students may wish to use the Explanation prompt as a guide. Have them write their explanation in their journal.
- Have students develop a **Claim** to answer the question: How does carbon cycle through Earth's subsystems?
- Then, have them add **Evidence** (the analyzed data) to support their claim.
- Finally, have them add **Reasoning** to their claim. Reasoning should include the information obtained from this investigation as well as science principles they have learned.
- Answers will vary across each group based on their online research. As an example, students could make the following claim supported by evidence:

Continued

Claim

Carbon flows through Earth's four subsystems in a series of interrelated biogeochemical processes that take place on different time scales.

Evidence

I was specifically interested in the role of plants in the biosphere. During photosynthesis, plants use absorbed light energy to convert atmospheric carbon dioxide gas and water from the ground into sugar that contains carbon. The vast majority of photosynthetic activity takes place in saltwater ecosystems (with marine plants responsible for 70% of Earth's oxygen production) as opposed to plants on land (terrestrial plants are responsible for approximately 28% of Earth's oxygen). When marine plants decompose or are eaten, the carbon they contain is reformulated into new compounds. When woody plant structures are burned as an energy source, this carbon is released back into the atmosphere as carbon dioxide gas through the process of combustion.

Reasoning

Investigation: We researched a variety of high quality, reputable online resources include the National Oceanographic and Atmospheric Administration as well as the Climate Literacy and Energy Awareness Network. We carefully made our observations and double-checked the quantities associated with our carbon sources, sinks, and annual fluxes.

Science: Photosynthesis is the process through which green plants convert Carbon dioxide and water into food. It is this food that helps a plant grow, and makes plants producers. The food is sugar, and like all aspects of the plant, it is carbon based.

Evaluation

Students reflect on the investigation.

Have students discuss:

- What surprised me?
- How are the biogeochemical processes that drive the flow of carbon related to other scientific concepts like global warming, species evolution, or habitat loss?
- What would I like to investigate next?

Part 4

INVESTIGATION ASSESSMENT AND EXTENSION

Application

Students demonstrate understanding of the carbon cycle by applying their learning in a specific context.

- Have students apply their learning by focusing in on the biogeochemical processes that served as the basis of their prediction. Students should define the boundaries of their analysis and include all relevant terms and chemical formulas associated with their chosen processes within the carbon cycle.
- Have students theorize whether the carbon cycle is an efficient one. Encourage them to make connections between how carbon and energy flow are both related and different.

CRITICAL THINKING

Have students compare the predictions they made before the investigation with the **claim**, **evidence**, and **reasoning** they produced in the investigation. Has their understanding of the carbon cycle changed? Have them describe what their new prediction would be based upon this investigation.

Assessment

Evaluate each group's explanation on how well students:

- analyzed the movement of carbon and record carbon cycling data from high quality online resources.
- developed a demonstration or model that quantifies the cycling of carbon through the Earth's four subsystems.
- analyzed and communicated the details of interrelated biogeochemical processes of their choice.

INVESTIGATION PLAN
CARBON CYCLING

1. Read this plan completely before beginning your research.

2. You and your teammates will be researching online sources to answer the investigation question, *How does carbon cycle through Earth's subsystems?* You will want to include evidence that helps quantify the movement of carbon through the atmosphere, biosphere, geosphere, and hydrosphere.

3. Record your qualitative and quantitative observations and accumulated data in your journal.

4. Analyze your recorded data to inform the design of a demonstration or model to communicate and quantify the flow of carbon in and out of Earth's four systems.

5. Determine what materials will be needed for your model or demonstration and share this plan with your teacher.

6. Once in agreement with your teacher, begin constructing the model/demonstration.