THINKING AND ACTING LIKE A SCIENTIST

TEACHER'S GUIDE

Earth Systems: Carbon Feedback

How does an increase in atmospheric Carbon dioxide provide feedback to Earth subsystem processes?

GRADES 9–12

Earth & Space

VAN ANDEL EDUCATION INSTITUTE

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INQUIRY-BASED SCIENCE

Earth & Space

Earth Systems: Carbon Feedback

Grade Level/ Content	9–12/Earth and Space Science
Lesson Summary	In this lesson, students will investigate how and why increasing levels of atmospheric Carbon dioxide can influence Earth's climate.
Estimated Time	4, 45-minute class periods
Materials	Internet access; digital presentation software (optional); presentation board and materials (optional); Investigation Plan
Secondary Resources	NASA Science: Earth System Science NOAA: Climate Monitoring CLEAN: Climate Literacy and Energy Awareness Network Accuweather: Climate Forcings Overview Explaining Climate Change: Climate Feedback Loops Lesson NOAA: Teaching Climate NASA's Global Climate Change: Vital Signs of the Planet Resources New York Times: Alaska's Permafrost is Thawing
NGSS Connection	**HS-ESS2-2** Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
Learning Objectives	• Students will develop an understanding of how feedback loops influence systems. • Students will collect, organize, and analyze atmospheric Carbon dioxide data to understand historical trends. • Students will describe the relationship between the release of carbon (as Carbon dioxide gas) from Earth's geosphere and warming of the atmosphere along with its influence on other Earth systems.

How does an increase in atmospheric Carbon dioxide provide feedback to earth subsystem processes?

Earth's subsystems operate in a delicate balance of matter and energy within and between the lithosphere, hydrosphere, biosphere, and atmosphere. Upsetting or dramatically changing any one of these subsystems can have far-reaching consequences. Climate scientists study related processes in and between Earth's subsystems. As they do, they analyze and coordinate scientific data from various fields of research to model, understand, and predict planet's processes.

One area of interest to students is climate change. It offers numerous examples of how changes in one subsystem can impact other subsystems on Earth. More specifically, how and why does Carbon dioxide, a greenhouse gas, influence climate? Students will use the Internet to research and better understand this phenomena.

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

For this research-based project, students will need the following:

- Internet access
- Investigation Plan
- Digital presentation software (optional)
- Presentation board or materials (optional)

Part 2

INVESTIGATION FACILITATION

Question

Introduce the investigation question.

How does an increase in atmospheric Carbon dioxide provide feedback to Earth subsystem processes?

STUDENT ENGAGEMENT

The discussion of greenhouse gases and the effects of global warming may lead to intense dialogue based upon what students know or have heard from family or media. It may lead to a highly-charged debate. If a student cares deeply about the issue, use it to engage them in a process of thinking critically. Focus on ideas without passing judgement by suggesting that students research these topics using available resources to bring clarity to the topic. Also, remind students that scientists back up what they say with data and sound reasoning based on currently accepted science.

Personal Knowledge

Students capture what they already know about atmospheric carbon, the carbon cycle, global climate change, and related concepts.

- Have student groups brainstorm what they know about each of the following terms: *greenhouse gases, global warming, melting glacial ice, rising sea levels, glacial ice,* and *climate feedback loops*. They may add any terms they feel are relevant.
- Ask groups to write short definitions and examples of each term, and compare with other groups. Initiate a discussion of each term, as needed.
- Have students consolidate definitions and observations in a chart in their journal. If they cannot define or give an example, have them leave a question mark to return to later.
- As students conduct the investigation, remind them to return to this chart to add to it or make edits as necessary.

CONSTRUCTION OF MEANING

Have students create an illustration of the carbon cycle to reference throughout the investigation. Ask them to identify possible points of imbalance while ensuring that students do not have the misconception that all Carbon dioxide is bad or not necessary to support Earth's biogeochemical processes.

Secondary Knowledge

Explore feedback loop concepts with students to provide a framework for understanding processes influenced by atmospheric Carbon dioxide.

Before stepping into feedback loops, highlight Earth's four primary subsystems as the lithosphere, hydrosphere, biosphere, and atmosphere. Explain to students that these systems operate in a delicate balance of matter and energy that is influenced by natural and man-made processes.

Continue this discussion with a look at feedback loops. Scientists separate factors that affect climate change into three feedback loop concepts: forcings, feedbacks, and tipping points.

Nasa's Global Climate Change website is an excellent resource for this information.

- **Climate forcings** are the initial drivers of climate. Examples include solar radiation, greenhouse gas emissions, aerosols, dusts, smoke, and soot.
- **Climate feedbacks** are processes that can either amplify or diminish the effects of climate forcings. A feedback that increases warming is called a "positive feedback." A feedback that reduces warming is a "negative feedback." Clouds, precipitation, the greening of forests, and the amount of ice reflecting sunlight from the Earth (referred to as ice *albedo*) all provide significant climate feedback. For more on this topic, check out Accuweather's quick overview of climate forcings with historical data for a variety of feedback types.

  It's important to focus students on the nature of this positive and negative feedback relative to drivers or forcings of climate. Another way to consider this concept is that positive feedback speeds up processes while negative feedback slows down processes.
- **Climate tipping points** are situations in which climate moves between relatively stable states. A change in ocean circulation, long-term ice loss, and the rapid release of methane from frozen deposits are all potential tipping points.

Consider having your students explore (as a whole class, in small groups, individually, or possibly as homework prior to the start of the lesson), the Climate Feedback Loops lesson from the Explaining Climate Change website.

Prediction

Students communicate an expected outcome in a specific Earth system, based on personal and secondary knowledge.

- Students present their predictions in the format: *I predict that an increase in atmospheric Carbon dioxide will _____ the (insert Earth system name) because _____.*

STUDENT CHOICE

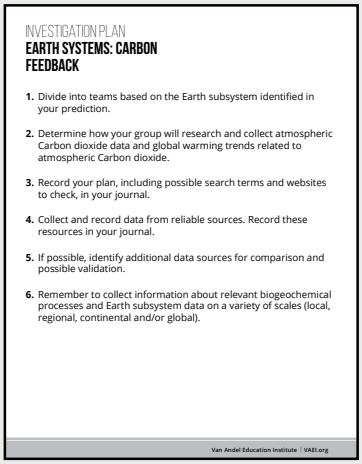
Encourage students to select an Earth subsystem as the basis of their prediction. This can serve as an entry point for their research to get them started with the investigation.

Investigation Plan

Students create a plan to collect atmospheric Carbon dioxide data and explore the warming of Earth's atmosphere along with its influence on other Earth systems.

This is a research-based project, so it will be useful to begin with a discussion of what is considered a reliable Internet resource from which to obtain scientific data. If you feel that students would benefit from general background information on greenhouse gases and the impact of climate change, you may find it useful to direct them to one or more of the videos available through NASA's Global Climate Change: Vital Signs of the Planet Resources webpage or similar resources.

- Group students in teams of 2-3 based on the Earth subsystem included in their prediction.
- Provide each student with a copy of the Investigation Plan.
- Students will determine how to identify and collect atmospheric Carbon dioxide data and global warming trends attributable to atmospheric Carbon dioxide.
- Encourage students to record their plan (possible search terms and websites to target) in their journal.



INVESTIGATION PLAN

EARTH SYSTEMS: CARBON FEEDBACK

1. Divide into teams based on the Earth subsystem identified in your prediction.
2. Determine how your group will research and collect atmospheric Carbon dioxide data and global warming trends related to atmospheric Carbon dioxide.
3. Record your plan, including possible search terms and websites to check, in your journal.
4. Collect and record data from reliable sources. Record these resources in your journal.
5. If possible, identify additional data sources for comparison and possible validation.
6. Remember to collect information about relevant biogeochemical processes and Earth subsystem data on a variety of scales (local, regional, continental and/or global).

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Investigation Plan

CRITICAL THINKING

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

Observation

Students collect and record atmospheric Carbon dioxide data and explore the warming of Earth's atmosphere along with its influence on other subsystems.

- Data should be obtained from reliable sources.
- Students may use data obtained from their research to create their own data charts or they may, in some cases, utilize existing data tables and charts.
- Remind them that they also need to research relevant biogeochemical process and Earth subsystem data on a variety of scales (local, regional, continental, and global).
- If possible, have teams locate related data from an additional source for comparison.

PERSEVERANCE

In some situations, there may be a great deal of data to sift through, or it may take time to find a reliable source with the information students seek. Remind students that science is not always easy and that it often takes a long time for scientists to have enough data to feel confident in drawing a conclusion.

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.

- Have students **evaluate** their data for trustworthiness and note any variations or uncertainties in data collection methods or sources.
- Then, have them analyze their data to find patterns and trends. They may **organize** the data and/or **represent** it visually to construct meaning.
- Have students **interpret** what the identified patterns or trends mean.
- If students are using existing tables or graphs, ensure that they understand the data they are using, how it was obtained, and what it means.
- If two sources of related data are found, ask students to compare the data, and, if possible, synthesize it into one meaningful chart or graph.
- Ensure they have enough data that it can be used as evidence to support a claim.

INTEGRITY

Remind students that scientists must practice integrity and expect it from others. Scientists are required to view data as objectively as possible and not be swayed by what they want to prove or disprove.

Secondary Knowledge

Students use secondary sources to understand the scientific significance of the data they have obtained.

- Use these resources (or your own) to develop students' understanding of climate feedback and change indicators.

  NASA Science: Earth System Science
  NOAA: Climate Monitoring
  NASA: Global Climate Change: Vital Signs of the Planet Resources
  New York Times: Alaska's Permafrost is Thawing

- After reviewing these resources, students should have a better understanding of how climate change indicators like increases in atmospheric Carbon dioxide signal possible changes to Earth's systems. They should also see how some of these changes serve as positive feedback leading to additional climate change.

OPENNESS TO NEW IDEAS

For students who did not expect to find evidence of climate change, it is important to avoid being judgmental or to allow other students to be judgmental of them. Remind all students that to be a good scientist, you utilize a prediction/hypothesis as a starting point for research while being open to new information obtained through research and direct observation.

Explanation

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

- Have students use what they've discovered 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 an increase in atmospheric Carbon dioxide provide feedback to Earth subsystem processes?
- 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.

Claim

Rising levels of atmospheric Carbon dioxide over the last century have positively influenced global climate feedback loops in a variety of ways.

Evidence

In Earth's closed global system, increased levels of atmospheric CO_2 lead to increases in local and global temperatures. In 2016, average global temperatures were 1.78 degrees Fahrenheit (0.99 degrees Celsius) warmer than the mid-20th century mean. The year 2016 was also the third year in a row to set a new record for global average surface temperatures. A NASA video highlighting this data is available online at https://climate.nasa.gov/climate_resources/139.

Reasoning

Investigation: Members of our group researched online to collect atmospheric Carbon dioxide data as well as its impact on Earth's climate system. We were very interested in researching and obtaining data describing increases in global temperatures. We were careful not to let our existing ideas influence our research. Instead, we relied on credible websites, such as NOAA and NASA, for our information and data by digging deeper to find the scientific source of data and reports referenced in mainstream media stories.

Science: CO_2 is a greenhouse gas that traps some heat in Earth's atmosphere that would normally dissipate into space. This trapping of heat serves as a positive feedback on the global climate system in two important ways: increasing temperatures lead to a decrease of ice in the extremes of the southern and lower hemispheres; and, lower levels of continental and ocean ice decrease the moderating influence of the albedo effect that reflects sunlight back into space. Researchers from Woods Hole Oceanographic Institute are beginning to quantify the impact of this positive feedback on the loss of permafrost in Alaska. As the permafrost melts, it opens sources of ancient carbon up for decomposition by bacteria. This decomposition is adding more Carbon dioxide and methane (another greenhouse gas) to the atmosphere adding even more positive forcings to global climate feedback loops.

- Once the explanation is written, have students discuss their results using a Present and Defend.

DISCOURSE

Have students conduct a Present and Defend to develop presentation skills as well as audience participation. Research teams present a summary of their investigation to the class. The class analyzes the information presented and asks clarifying questions, challenges and/or supports the arguments made, and even presents alternative explanations as appropriate. Research teams defend their explanation with evidence and reasoning. Choose between 3 and 5 teams with different investigations (defined by Earth subsystems and related biogeochemical processes) to share their findings.

Evaluation

Students reflect on the investigation.

- Ask students what they learned about climate indicators and Earth's systems through their research.
- Ask students how they would like to extend their research and why.

Part 4

INVESTIGATION ASSESSMENT AND EXTENSION

Application

- Have students apply their learning by thinking of ways the data they obtained in their research could be used to explain other changes in Earth's subsystems, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge; or how the loss of wetlands causes a decrease in local humidity that further reduces wetland footprints.
- Have students theorize whether any of the data they collected and analyzed indicate that Earth has passed a climate tipping point.
- Have students identify whether any of the data they collected and analyzed points to unanticipated or unintended consequences from the use of specific human processes or technologies.
- Encourage students to think of ways that current positive climate feedbacks could be shifted to negative feedbacks through natural processes or man-made technologies.

CRITICAL THINKING

Have students compare the predictions they made before the investigation with the claim, evidence, and reasoning they produced in their explanation. Has their understanding of the climate indicators changed? Have them update their predictions.

Assessment

Evaluate each group's explanation on how well students:

- develop an understanding of how feedback loops influence systems.
- collect, organize, and analyze atmospheric Carbon dioxide data to understand historical trends.
- describe the relationship between the release of carbon (as Carbon dioxide gas) from Earth's geosphere and warming of the atmosphere along with its influence on other Earth systems.

For additional lessons or to customize this lesson, go to www.nexgeninquiry.org.

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INVESTIGATION PLAN

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