1 The Effects of Carbon Dioxide on Climate

Unit Essential Question

How do we know human activity is influencing climate, and what can we do about it?

Introduction

The Sun is the source of energy that the Earth needs to sustain life. But there is a very delicate balance that—as Goldilocks would say—keeps Earth's temperature "just right," so we and other species can be comfortable (usually), grow or get food, and survive. At the heart of this balancing act is a process known as the *greenhouse effect*, in which gases in the atmosphere trap heat from the Sun and create the pleasant climate we experience today. Without these gases, Earth would be a cold, uninhabitable place. However, with too many of these gases in our atmosphere, the Earth is headed in the opposite direction—global temperature is increasing. This task models what happens when solar energy hits the layer of air surrounding the Earth. Students will conduct an experiment to model the effect of carbon dioxide (CO_2)—one of the gases in the atmosphere—on temperature.

Objectives

Students will be able to

Content

- Explain how the amount of greenhouse gases in the atmosphere affects global temperature.

Science and Engineering Practices

- Plan and carry out an investigation to determine the effect of CO_2 levels on temperature.
- Construct an explanation about CO_2 and temperature using experimental evidence.

Equity and Groupwork

- Discuss their findings as a group.

Language

- Write a clear and logical explanation using evidence.

Academic Vocabulary

- atmosphere
- carbon dioxide (CO_2)
- Goldilocks principle
- greenhouse effect
- greenhouse gases
- methane
- nitrous oxide
- temperature

Language of Instruction

- control bottle
- crosscutting
- escape
- "just right"
- presence
- system

Timing

This task can be completed in 4–5 class periods (based on 45-minute periods).

- Part I • Student Lab—Plan and Conduct an Experiment to Model the Effect of Greenhouse Gases on Temperature (2 class periods)
- Part II • Greenhouse Gases and the Goldilocks Principle (1–2 class periods)
- Part III • Connect to the Culminating Project and Assessment (1 class period)

Student Materials

per group

Part I • Student Lab—Plan and Conduct an Experiment to Model the Effect of Greenhouse Gases on Temperature:

- 2 clear 2 L empty soda bottles with labels removed
- Aluminum foil
- 2 thermometers (these should read at room temperature; it is important they are calibrated)
- 250 mL beaker + water
- 2 Alka-Seltzer® tablets (break both in half)
- 150 W light bulb with heat lamp
- Ruler
- Stopwatch (or digital stopwatch on phone, tablet, etc.)

Part II • Greenhouse Gases and the Goldilocks Principle:

- Handout: How Our Earth System Stays Not Too Hot and Not Too Cold (1 per student)

Teacher Materials

Any (or all) of the following:

- "The Effects of Carbon Dioxide on Climate" digital slide presentation
- Video: *Goldilocks and the Greenhouse: Science and Climate Change*: https://www.youtube.com/watch?v=ky0dwKjYmHE
- Images of greenhouses to display

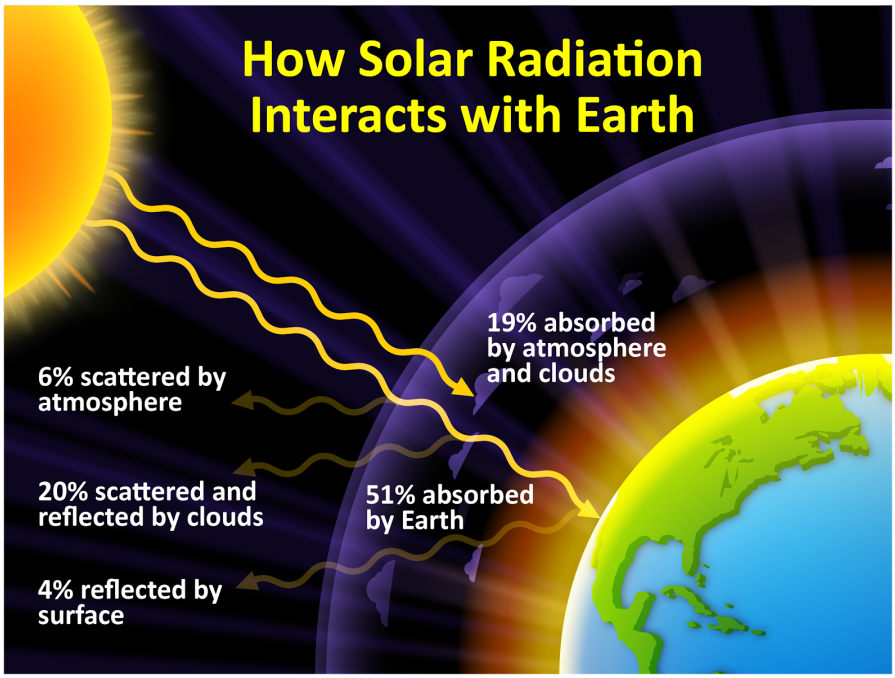
Background Knowledge

The Earth's climate system is driven by energy received from the Sun (sunlight). Some of this energy is reflected back into space, but the rest is absorbed by the land and ocean and re-emitted as radiant heat. Some of this radiant heat is absorbed and re-emitted by the lower atmosphere in a process known as the the greenhouse effect.

The Earth's average temperature is determined by the overall balance between the amount of incoming energy from the Sun and the amount of radiant heat that makes it through the atmosphere and is emitted to space.

When the balance between incoming and outgoing energy is disturbed, the amount of heat within the climate system changes, which affects all those processes that transport heat around the globe. We experience this imbalance as changing weather patterns, the consequences of which can be far reaching because so many human activities have adapted to conditions that have prevailed for long periods of time.

The approximate breakdown of how solar radiation interacts with the Earth is given below.



Source: https://www.ucar.edu/learn/1_3_1.htm

There are many different gases in the Earth's atmosphere. The atmosphere is mostly made up of nitrogen and oxygen, but these gases do not absorb energy. The gases that absorb energy are carbon dioxide, water vapor, methane, nitrous oxide, and fluorinated gases; we call these *greenhouse gases* because they contribute to the warming of Earth. While these gases are necessary for keeping Earth habitable, there is currently too much of these gases in the atmosphere, which causes a warming effect.

When talking about climate change, we most often talk about carbon dioxide rather than the other greenhouse gases because it has caused most of the warming effect. While other gases (like methane) may have more heat-trapping ability, they are far less abundant in the atmosphere and are being added more slowly than carbon dioxide. Carbon dioxide is the most abundant greenhouse gas in the atmosphere (besides water, which cycles quickly), and it remains there longer than the other major heat-trapping gases.

As a greenhouse gas, carbon dioxide absorbs electromagnetic radiation (specifically IR radiation) and resonates (vibrates). Infrared radiation (at lower energy than what was absorbed) is released by the molecule. The increased motion of the molecules is measured as an increase in temperature. The following animation illustrates the absorption, resonance, and release of IR radiation.
http://news.bbc.co.uk/2/shared/spl/hi/sci_nat/04/climate_change/html/greenhouse.stm

People often talk about greenhouse gases as “trapping heat.” Technically, this idea is incorrect because heat is defined as either “thermal energy” (energy due to the motion, mass, and relative position of molecules) or “the transfer of thermal energy from an area of higher temperature to an area of lower temperature.” The more scientifically accurate statement is: Greenhouse gases “absorb radiation, which causes heating.” This is the most scientifically accurate animation of the greenhouse effect that we have been able to find: http://news.bbc.co.uk/2/shared/spl/hi/sci_nat/04/climate_change/html/greenhouse.stm

You can get the latest data on global warming (CO_2 levels, temperatures, etc.) at this site: https://www.co2.earth/global-warming-update

Introduction

For thousands of years, we have been lucky enough to have a global climate that is generally not too hot and not too cold. As Goldilocks would say in the story of the three bears, the temperature was "just right"—at least for survival of the plants and animals on Earth. However, students saw in the Lift-Off Task that global temperatures have been rising over the past century. But why? Students will return to the list of questions they made in the last task.

1. Draw students' attention to the "Climate Change" poster of generated questions from the last task. Ask them as a class to pick out one question related to the task at hand.

   Possible questions: Why has global temperature risen so much in the last century? What does carbon dioxide have to do with temperature? How does the amount of carbon dioxide affect global temperature?

   ELL SCAFFOLD

   If you have not done so yet, have the class pronounce *carbon dioxide* (CO_2) chorally—"C-Oh-Two"—as you record the word on the board or another location. Some ELLs might think the "O" is a zero, since a numeric subscript follows.

   - Have students record the class question in their Student Edition.

2. Explain that today students are going to plan and carry out an experiment to help them answer this question.

   - Tell students to predict the answer to the question the class chose and write their prediction in their Student Edition.

3. To transition to the task, explain that scientists think that carbon dioxide may have an effect on global temperature; that is what students will test today.

Part I • Student Lab—Plan and Conduct an Experiment to Model the Effect of Greenhouse Gases on Temperature

Note: This lab can also be done as a demonstration; however, in either case students should engage in a discussion regarding the procedure.

1. Explain that students will design and conduct an experiment to find out **how changes in CO_2 levels around the Earth affect the global temperature of the Earth**. Of course, they can't just add a bunch of CO_2 to the Earth's atmosphere and see what happens. They have to create an experiment that mimics the larger Earth system.
2. Have students read the experimental question and the list of materials in their Student Edition. Then ask students:
   - How can you mimic the Sun? *[heat lamp]*
   - How can you add in carbon dioxide? *[Alka-Seltzer® tablets; they release CO_2 when mixed with water.]*
3. Read the safety instructions together. Emphasize the experimental question and show students the laboratory materials before they draft the procedure.

4. As a class, discuss and come to agreement about how to plan the experiment to answer the research question.
    - How much water will you add to each bottle? *[Students need to specify a volume. The volume should be the same in both bottles.]*
    - Where should you hang the thermometer in the **control** bottle? *[The thermometer should not touch the water. Make sure you can see the temperature.]*
    - How will you make sure the gas doesn't escape? *[Use aluminum foil to "seal" the top and hold up the thermometer.]*
    - Why do you keep the amount of energy transferred to each bottle the same? *[Keeping the amount of energy added to the bottles the same allows students to compare the temperature changes due to an increase of CO_2. If the amount of CO_2 AND the amount of added energy change, students won't be able to tell which caused the impact on temperature.]*
    - How far will each bottle be from the light source? *[Make sure these are the same.]*
    - How will you measure the temperature of the gas? *[thermometer]*
    - How often will you record the data? *[Students might collect data every 2 minutes; they should show these increments in their data table.]*
5. Check each group's answers and left column (Time) of the data table before they get their lab materials.
6. Have students draw and label their experimental setup and then conduct the experiment.
7. You may want to create a class Excel file and have each group submit their results. The results can then be compared and discussed as a class.
8. After cleanup, have students discuss and share their results in small groups using the questions in their Student Edition as guidance.
    - As they describe their experiment, highlight the crosscutting concept of cause and effect: increased carbon dioxide caused an increase in temperature.

ELL SCAFFOLD

Use a meta-think-aloud about what you notice about students' comments about cause and effect. Spiral back to a previous example that students shared and note how the concept reappears. Emphasize the term *crosscutting* as one that shows how it (in this case, cause and effect) reappears across ideas and examples.

    - **Optional:** You could also elicit background knowledge about temperature being a measure of energy due to the motion of particles (molecules). Since the temperature increased more in the bottle with the CO_2, students can conclude that the CO_2 molecules move more than the other air molecules.
9. Discuss students' results as a class.

Part II • Greenhouse Gases and the Goldilocks Principle

1. In their presentations to the school board, students need to explain why the climate in their area has generally been "just right" because of the amount of CO_2 and other gases in the atmosphere. Toward this end, there are three possible sources of information that you can share with students: a slide presentation, video, and reading. Decide which ones (or all) you want to share with students.

    - Present the digital slide presentation "The Effects of Carbon Dioxide on Climate." Add questions throughout as necessary to measure students' understanding and misconceptions.
    - Show the video *Goldilocks and the Greenhouse: Science and Climate Change*: https://www.youtube.com/watch?v=ky0dwKjYmHE.
    - Have students read the handout How Our Earth System Stays Not Too Hot and Not Too Cold.

    ELL SCAFFOLD

    Point out the use of "too" (spelled with two *o*s) as an adjective, and explain that it means "more than what is needed." To, two, and too are in the top 10 list of the most widely misspelled words in English, and so take this opportunity to illustrate what "too" means in context.

2. If students are using the reading material, have them complete the reading independently and underline definitions. All students should make notes in their Student Edition of any questions they have or connections with prior knowledge.

3. Have students share with their group one connection or question.

Class Discussion

1. Begin the discussion by asking:

    - You have heard and read about the term *greenhouse*. What is a greenhouse? What does it do?

    Show students images of greenhouses, since not all students will will be familiar with them.

2. Have students discuss and answer the questions in their Student Edition.

    - How was the lab that you conducted an example of the greenhouse effect?

      The lab demonstrated the greenhouse effect because the bottle with more carbon dioxide gas increased in temperature more than the bottle with just air. The CO_2 absorbed solar radiation and caused temperature to increase, which represents the greenhouse effect.

    - How do energy-absorbing gases keep the Earth's temperature "just right"? **Draw** and **explain** your answer in the boxes below.

      Students should be able to draw a model of the greenhouse effect and explain how greenhouse gases absorb and radiate heat that keeps the Earth's temperature just right.

    - Why is the Earth's temperature not "just right" any more?

      Excess greenhouse gases make Earth too warm, rather than "just right."

3. Have students write a Claim, Evidence, Reasoning (CER) report of their lab findings, highlighting the crosscutting concept of cause and effect in their claim. A sample student response follows.

    - *Claim: Carbon dioxide caused the temperature inside the bottle to increase more than when carbon dioxide was not present.*
    - *Evidence: In my lab, the bottle that contained the carbon dioxide from the Alka-Seltzer® rose 6° over 18 minutes. The bottle that did not contain carbon dioxide rose only 2° over 18 minutes.*
    - *Reasoning: Both bottles were placed under a lamp to represent heating from the Sun. The carbon dioxide absorbed heat from the lamp, which increases particle motion, thus radiating more heat. This also happens in the atmosphere, when energy from the Sun is reflected off Earth and is absorbed by carbon dioxide in the atmosphere. This causes global warming.*

Class Concept Map

1. Return to the class climate change concept map from the Lift-Off Task.

2. Have students work in groups to brainstorm new words or new connections that they learned in this task that they would like to add to the class concept map.

3. Ask groups to share their ideas aloud in a class-wide discussion, and add their ideas to the class concept map.

4. Some facilitating questions to ask students are:

    - Are there any connections you want to change?
    - Do you want to revise and/or add anything to the description of the relationship between any concepts?
    - Are there more connections you can make between the ideas/concepts already on the map?
    - Do you want to add any new ideas/concepts to the map?

ELL SCAFFOLD

Reinforce the causal relationships being suggested by the class while drawing arrows and eliciting from students why two terms are connected.

5. Highlight any connector words that relate to the crosscutting concept of **cause and effect**. These could be phrases such as “which results in,” “which causes,” “that explains why,” “is due to,” etc.

6. At this point, students should be able to add the connection that increased carbon dioxide leads to increased temperature, which is also known as *climate change* or *global warming*. They might also add terms such as *greenhouse gases* and *greenhouse effect*.

7. Once again, the purpose of this concept map is to promote language development throughout the unit. Allowing students to give names to concepts and to share their ideas about how the concepts are related will help their oral and written language development.

Part III • Connect to the Culminating Project and Assessment

1. Have students independently complete the Task 1 section of the Individual Project Organizer during class.
2. Collect the Individual Project Organizers and assess using:
    - The "Planning and Carrying Out an Investigation," "Analyzing and Interpreting Data," and "Constructing Explanations" rows of the Science and Engineering Practices Rubric
    - A criterion of your choice
3. Return the Individual Project Organizers. Give students time to make revisions based on one of these two options.
    - Have students make changes to their Individual Project Organizer according to your comments. (This could be done for homework, depending upon students' needs and/or class scheduling.)
    - Ask students to exchange their Individual Project Organizer with a partner, and give partners 5 minutes to provide written feedback. Then allow students time to make changes to their work according to the feedback.

ELL SCAFFOLD

Pair ELLs with a student with a higher level of English proficiency, and one who can offer content insight that could strengthen what ELLs wrote. ELLs may need additional time to work on the Individual Project Organizer.

Reflect

At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following two questions in their Student Edition:

1. At the beginning of this task, you made a prediction about why global temperatures are rising. Look back at your prediction. After learning from your lab and your research today, how can you add to your prediction? Use your CER report to help you.
2. In this task, you focused on the crosscutting concept of cause and effect, or how one event can lead to another. Give one example of how this crosscutting concept came up in today's task.

ELL SCAFFOLD

Pair ELLs with a student with a higher level of English proficiency, and one who can offer content insight that could strengthen what ELLs wrote. ELLs may need additional time to work on the Individual Project Organizer.

There are no right or wrong answers. If students are stuck, remind them to look back at their Student Edition and the class concept map. Emphasize that students should not change their initial responses, but rather modify and add to those responses based on what they learned in this task.