Insulating You, Insulating Earth

Examining the Impact of Increased CO_2 on Earth Systems

Description

To explore the effect of increasing CO_2 in the atmosphere, students model the greenhouse effect using their own thermal energy, thermometers, towels, and Mylar blankets.

Phenomenon

Human behavior is changing Earth's atmosphere and affecting the climate.

Objectives

Students will:

- Model the greenhouse effect
- Apply understanding of a model to a real-world phenomenon
- Apply understanding of climate change causes to determine solutions

Grade Level

5 – 8

Time

1 Hour

Materials

- *Insulating You, Insulating Earth* handout [1 per student]
- PowerPoint presentation
- Computer and projector*
- Large "Greenhouse effect" posters [2]
- Large arrow labeled "Sun" [2]
- Large arrow labeled "Earth" [2]
- Set of 2 small arrows [2]
- Large blue arch labeled "Extra Greenhouse Gases" [1]
- Set of 1 "Natural" and 1 "Human Enhanced" labels
- Hand towels [1 per every four students]
- Mylar space/emergency blanket cut into rectangles of approximately 20" x 26" or larger if needed [1 per every four students]
- Thermometers with cable [1 per every four students]
- Stopwatches [1 per every four students]
- Masking tape [approx. 8 inches total per every four students]
- Calculators* [1 per every four students or more if available, optional]

* Not included in kit

Developed by the Asombro Institute for Science Education (www.asombro.org)

Background

An atmosphere of gases surrounds Earth, and it remains near the planet because of gravitational force. The atmosphere is composed mainly of nitrogen, oxygen, argon, and carbon dioxide, and it functions to moderate the climate of Earth.

The greenhouse effect describes the process by which the climate is regulated by greenhouse gases: carbon dioxide, water vapor, ozone, methane, nitrous oxide, and fluorinated gases. Electromagnetic radiation from the sun, mostly at short wavelengths in the form of light, can pass through the atmosphere and is absorbed by Earth. Electromagnetic radiation at longer wavelengths, often called thermal energy, infrared radiation, or heat, is re-radiated from Earth towards space. Unlike solar radiation, most long-wave radiation is absorbed by greenhouse gases (or clouds) and re-emitted in all directions. The long-wave radiation re-emitted downward warms the surface of the planet. The greenhouse effect traps thermal energy near Earth and ensures that it is warm enough to sustain life.

Since the Industrial Revolution, humans have been emitting increasing amounts of greenhouse gases, especially carbon dioxide, methane, and nitrous oxide. The burning of fossil fuels to produce the energy used for transportation, industry, and electricity releases greenhouse gases. This causes more of the re-radiated thermal energy from Earth to be re-emitted back to the planet instead of escaping into space. This enhanced greenhouse effect is causing average global temperatures to increase. With this increase in temperature, Earth is experiencing changes in weather, climate, and ocean systems. The effects include increased droughts in some areas, increased flooding in other areas, melting glaciers and ice, rising sea levels, altered timing of stream flows, and ocean acidification. Through this activity, students are introduced to the underlying cause of global warming. As part of the final discussion, students will begin to brainstorm actions to combat the changes they have observed through these activities. Climate and weather are helpful concepts for students to understand before this activity.

Tips for Entire Class Participation

- Have students work in small groups, so each student is participating directly in the model. Groups of four are ideal, but groups of three or five will work. Small group size is dependent on your class size; there are eight setups in your kit.
- Highlight student roles during the model to ensure each student feels they are contributing.

Preparation

1. Plan to divide students into teams of four. If necessary, teams of three or five would also be acceptable because activity tasks can be combined or divided.
2. Plan locations for the appropriate number of stations needed to accommodate the number of student teams in the group. Stations can be tables and chairs with enough space for three to five students, and no power source is needed.
3. Place masking tape, calculator, stopwatch, thermometer with cable, towel, and a rectangle of Mylar blanket at each station.
4. Draw the "Whole Class" table from page 1 of the *Insulating You, Insulating Earth* handout on the board or prepare to show it with a document camera.
5. Set up greenhouse effect posters and have attachments accessible.
6. Set up a computer and projector and display the PowerPoint presentation.

Teaching Guide

Introduction to New Mexico Climate Champions (~5 minutes)

1. Slide 1: Give students a brief introduction to New Mexico Climate Champions (NMCC), explaining the format and purpose of the program.

2. Slide 2: Tell students that they will have an opportunity to learn about climate change: what is causing it, what are the impacts, and what they can do to help.
    a. NMCC has two parts: making sense of a phenomenon related to climate change and designing solutions to issues that result from climate change.
    b. These two parts are divided evenly. The first half focuses on making sense of a phenomenon related to climate change. The second half focuses on engineering solutions to problems associated with climate change through action projects.
    c. Explain that during the first half, students will participate in hands-on activities that will help them better understand climate change and offer motivation and ideas for their projects as they learn more about how climate change impacts energy processes.
    d. Students will work in groups during the engineering project to plan and implement a New Mexico Climate Champion project in their school or community.
    e. At the end of NMCC, students will present their projects to their community to help others learn more about climate change and how they can take action against it.

Introduction to the Greenhouse Effect (~15 minutes)

1. Slide 3: To start New Mexico Climate Champions, introduce students to the phenomenon they will be investigating in the energy module: human behavior is changing Earth's atmosphere and affecting the climate. This activity explores the changes occurring in the atmosphere and the effects of those changes. The following activities will explore the human behavior responsible for these changes. Students will begin by conducting an investigation into the greenhouse effect.
2. Slide 4: Show students the graph of CO_2 concentration in the atmosphere. Since 1958, scientists at Mauna Loa, on a Hawaiian island in the North Pacific, have been collecting atmospheric data. This graph shows the concentration of carbon dioxide in the atmosphere at Mauna Loa. As you can see in the graph, atmospheric CO_2 has been steadily increasing since measurements began. This rise in CO_2 is the change in the Earth's atmosphere referenced in our phenomenon.
3. Slide 5: This graph shows how global temperatures have changed over time. Ask students what they notice (increasing temperatures). Increasing temperatures are also expected here in New Mexico. Explain that atmospheric CO_2 plays a role in this phenomenon. In today's activity, we will use a model to make sense of how this increase of CO_2 affects Earth systems. Students should be asking as they use this model: How do changes in the atmosphere affect climate on Earth?
4. Divide students into teams of four and place students at stations.
5. Pass out an *Insulating You, Insulating Earth* handout to each student.
6. Slide 6: Instruct students to choose one role for each student in the group.
7. Slide 7: Display this "Setting Up the Model" slide in the PowerPoint presentation as a reference.
    a. The test subject will use masking tape to attach the thermometer to the clothing on their lap. Instruct the student to point the probe toward their hip and attach 2 inches of masking tape to hold the wire down and 6 inches of masking tape to fasten the probe against their thigh approximately halfway down the length of their thigh. Do not cover the probe tip with tape (Figure 1).
    b. Ensure that the thermometer probe is contacting the student's thigh as much as possible. The probe should not be pointed sideways or hanging off of the student's lap.
    c. Have students be sure that the thermometer is reading in °C. To switch to °C, flip the toggle on the back of the thermometer.

Figure 1. Thermometer set up

8. The cable thermometer can take up to five minutes to accurately display the initial temperature of students' laps. Instruct students to watch the temperature casually and note whether it increases, decreases, or stays the same. Now that students have their thermometers in place, take some time to explain the model (see below) and give a short introduction to the greenhouse effect.
9. Explain to the class that they will use a model to explore the greenhouse effect and the impact of increasing CO_2 using a single towel and a towel with a Mylar blanket on top. Tell students that they will first place a towel over the thermometer and parallel to their thighs. They will record the temperature every minute for five minutes. Then, after the thermometer has reacclimated to the test subjects' laps, a second trial will be conducted with the towel and Mylar blanket. They will record the temperature with the towel plus a Mylar blanket every minute for five minutes. Explain that the blanket is made of Mylar, which is a good insulator (and also used for balloons), and it can be used as a blanket in emergencies.
10. Slide 8: Give a short introduction to the greenhouse effect using the "Greenhouse Effect" poster.
    a. We have gases in our atmosphere (called greenhouse gases) that trap thermal energy. Greenhouse gases include carbon dioxide, water vapor, ozone, methane, nitrous oxide, and fluorinated gases. These gases exist in our atmosphere naturally.
    b. Direct the students' attention to the "Greenhouse Effect" (Figure 2) poster and explain the different parts that will be important for the model later. Earth has an atmosphere that allows us to live here. This atmosphere is composed of these gases that trap thermal energy and keep Earth at a habitable temperature.
    c. Add the "Natural" label to the poster. First, we are going to explore the natural greenhouse effect. Have students write that in the blank on Figure 1 on page 2 of their handout.
    d. Add the "Sun" arrow (labeled on the back). Energy from the sun comes through the atmosphere and hits Earth's surface. Some of that energy will be absorbed, and the rest will re-radiate back towards our atmosphere.
    e. Add the "Earth" arrow (labeled on the back). The part of the system that we will investigate is when the re-radiated energy hits the atmosphere and greenhouse gas layers. After the second trial, we will add two more arrows to indicate where the energy is going in this model after hitting the greenhouse gas layer.

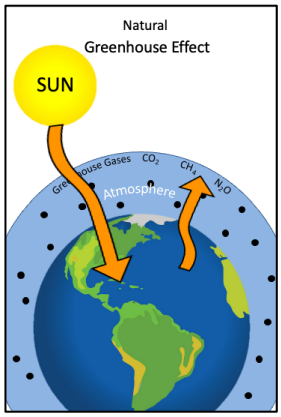

Figure 2. Greenhouse Effect poster with "Natural" label, the "Sun" and "#2" arrows added.

Towel Trial (~15 minutes)

1. Slide 9: Towel Trial - Ask students to read the current temperature of their thermometers and tell you whether it has increased, decreased, or stayed the same since they taped it to their clothing. The temperature should have increased initially and then mostly stabilized.
2. Once the temperature has stabilized, direct each team's data recorder to record the temperature in the lap row of the towel temperature column. The data recorder is the team member responsible for writing down all of the data, but all students must complete the data table.
3. Instruct the materials manager to give the towel to the test subject. The test subject lays the towel over the thermometer and across their lap so that its long side is perpendicular to their thighs. Then they tuck the ends of the towel under their legs if possible; if it does not tuck under, just ensure that it is covering the thermometer.
4. As soon as the towel is in place, instruct the timer to press the start button on the stopwatch.
5. Explain to the timer that they are to call out the time to the data recorder for each minute that passes. Tell students that they should not stop the stopwatch at each minute but rather let the stopwatch continue to keep time as data is collected.

6. Explain to the data recorder that when the timer calls out the time, they are to read the temperature on the thermometer and record it in the corresponding row of the towel temperature column.
7. Tell students to stop recording after 5 minutes. If you would like to extend the data collection time for this activity, have students continue to write temperature data on a separate piece of paper (see the Extensions section).
8. At the conclusion of the measurements, instruct the timer to reset the stopwatch.
9. Quickly ask the test subject to remove the towel from their lap but leave the thermometer attached. The goal is to return the thermometer to approximately the same temperature as the beginning lap temperature in the towel only trial, which can take 2-3 minutes. If it takes too long, students can fan the probe with a piece of paper, but be cautious of fanning it for more than 20-30 seconds, which could result in the temperature decreasing too much.
10. While waiting for the thermometer to stabilize and return to the beginning lap temperature in the towel-only trial, ask students to complete subtraction problem A (Towel Difference) on their handout (between the tables). They fill in the blanks with the temperature of their final measurement (5 min.) and the test subject's lap temperature at the beginning of the trial. They then calculate the difference by subtracting lap temperature from the 5 min. temperature.
11. Ask students to report the temperature differences in the towel trial to the class. Have students record their differences in the table on the board, or they can call them out to you while you write them on the board. Students must then record them in their "Whole Class" table on their handout and calculate the mean.
12. Remind students that we have two arrows to place on the "Natural Greenhouse Effect" poster after the next trial to represent where the energy travels after hitting the greenhouse gas layer. First, we need to investigate what happens when the amount and composition of our greenhouse gases change.

Towel + Mylar Blanket Trial (~15 minutes)

1. Slide 10: Human activity is changing the composition of the atmosphere. This pie chart shows the percentage of each of the greenhouse gases that humans emit through our actions. Carbon dioxide accounts for more than 75% of the greenhouse gases that we release. Emphasize that humans are adding these greenhouse gases in addition to those that already exist in Earth's atmosphere.
2. Slide 11: Humans emit carbon dioxide primarily through fossil fuel combustion, i.e., the extraction and burning of coal, natural gas, and oil, to produce electricity and transportation. Many industrial processes also rely on fossil fuel combustion. The production of mineral products, such as cement, the production of metals, and the production of chemicals can all result in carbon dioxide emissions as well.
3. Tell students what we will explore in the second trial: the effect on temperature after humans have added a lot of CO_2 and other greenhouse gases to the atmosphere. Add the "Human Enhanced" label to the second "Greenhouse Effect" poster and the poster labeled "More Greenhouse Gases." Have students write this in the box on Figure 2 on page 2 of their handout and label the atmosphere on Figure 2 with "More Greenhouse Gases."
4. Add the "Sun" arrow and the "Earth" arrow and explain that these arrows will remain the same between trials because the amount of energy from the sun and re-radiated energy from the Earth will remain (relatively) constant for many millennia. Students will be responsible for adding the remaining two arrows that represent energy re-emitted back towards Earth and energy that escapes into space after the towel plus Mylar blanket trial.

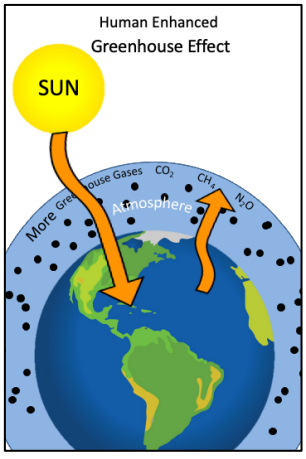

Figure 3. Greenhouse effect poster before the towel and Mylar blanket trial. Students will make their handout reflect this.

5. Slide 12 – Towel + Mylar Blanket Trial - When the thermometer stabilizes at approximately the same temperature as the beginning lap temperature in the towel trial, begin the towel and Mylar blanket trial. Instruct the data recorder to record the beginning lap temperature in the towel and Mylar blanket temperature column in the lap row.
6. Ask the materials manager to give the towel and then the Mylar blanket to the test subject.
7. Instruct the test subject to first lay the towel over the thermometer and across their lap and then place the Mylar blanket on top. Both should be oriented so that the long side is perpendicular to their thighs. Have them tuck both the towel and the Mylar blanket under their legs if possible. If they do not tuck under the student's legs, just ensure they cover the thermometer.
8. As soon as the towel and Mylar blanket are in place, the timer starts the stopwatch.
9. Explain to the timer that they call out the time to the data recorder for each minute that passes.
10. Explain to the data recorder that when the timer calls out the time, they read the temperature on the thermometer and record it in the corresponding row of the towel and Mylar blanket temperature column.
11. Tell students to stop recording after 5 min (unless you would like to extend data collection time).
12. The test subject can remove the Mylar blanket, towel, and thermometer.
13. Instruct students to complete subtraction problem B (Towel + Mylar Blanket Difference) on their handout (between the tables). They fill in the blanks with the temperature of their final measurement (5 min.) and the temperature of the test subject's lap at the beginning of the trial. They then calculate the difference by subtracting lap temperature from the 5 min. temperature.
14. Ask students to report the temperature differences in the towel and Mylar blanket trial to the class. Have students record their differences in the table on the board, or they can call them out to you while you write them on the board. Students must then record them in their "Whole Class" table on their handout and calculate the mean.
15. Have students complete the "Understanding the Model" section on page 3 of their handout.
    a. Students modeled the natural greenhouse effect and the enhanced greenhouse effect.
    b. Ask students to determine which item in the model represented Earth and discuss how it is like the Earth [answer: the lap modeled the Earth because it emits thermal energy].
    c. Ask students to determine which item in the model represented the atmosphere and discuss how it is like the atmosphere [answer: the towel modeled the atmosphere because the towel absorbed some of the thermal energy and re-emitted it back toward the lap, effectively trapping it and keeping the lap warmer].
    d. Ask students to determine which item in the model represented the additional greenhouse gases and discuss how it is like additional greenhouse gases [answer: the Mylar blanket because, once it was added, more of the thermal energy from the lap was re-emitted back to the lap instead of escaping into the room].

Results and Conclusions (~10 minutes)

1. Have students answer results questions 2 – 4 on their handout.
2. Remind students that we have two arrows to place on each of the "Greenhouse Effect" posters. Tell students to use their whole class data table or their results questions to figure out where the energy will go after hitting the greenhouse gas layer. Use guiding questions to elicit a discussion and consensus on which arrows should go where and have two students add the arrows per poster.
3. The posters will have opposite answers (see figures 4 and 5).

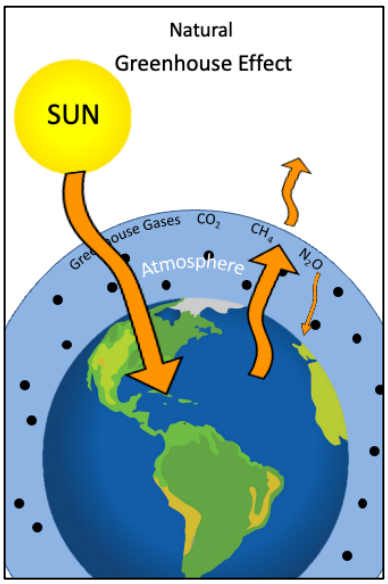

Figure 4. Correct answer for Greenhouse Effect poster after towel trial discussion. Students will make their worksheet reflect this.

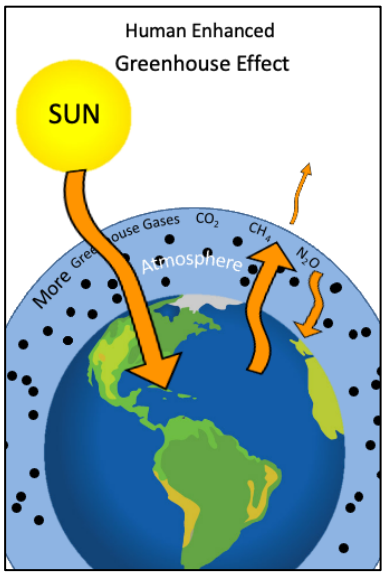

Figure 5. Correct answer for Greenhouse Effect poster after towel + Mylar blanket discussion.

4. Slide 13: The atmosphere influences our climate, and we used this model to represent one aspect of how our climate is changing due to changes in our atmosphere. Climate is the description of the long-term pattern of weather in a particular area. Long-term usually means approximately 30 years. Ensure that students understand that to be considered climate, conditions must be averaged over a long time period. Today's (or even this month's or this year's) weather in your area is not the same as the climate.
5. Slide 14: The climate of Earth is changing. Read the definition for climate change. Tell students that climate change includes global warming (the temperature of Earth is increasing), changes in precipitation patterns, and more severe storms.
6. Slide 15: Remind students that you discussed carbon dioxide levels in the atmosphere earlier and that these are shown in the top graph. Temperature is shown in the bottom graph. Ask students to describe the relationship between CO_2 and global temperature [answer: as carbon dioxide increases, global temperature increases].
7. Have students respond to the conclusion questions 5 and 6 on page 3 of their handout. Begin to discuss actions that we can take in response to climate change.
8. Explain that in our next activity, Energy Audit, students will investigate one human behavior contributing to changes in Earth's atmosphere and climate.

Extensions

1. If you would like to discuss Extension questions 1 – 2 with students, display slide 16.
    a. Slide 16: Scientists used several models to predict global temperatures by the end of the century. This graph displays three global temperature projections, shown by the colored lines. The three lines represent different scenarios for the amount of warming that will occur, which depends on the activities of humans. The amount that the temperature will increase depends significantly on human population growth and the amount of greenhouse gases emitted in this century.
    b. Direct students to look at extension question 1 and the scenario with the highest emissions, shown by the top (red) line of the graph. Emphasize that they should only be considering the top line of the graph. Ask them to estimate the approximate average

temperature increase projected by 2100 (in degrees Celsius) in the highest emissions scenario [answer: approximately 4 °C].

c. Direct students to look at extension question 2 and the scenario with the lowest emissions, shown by the bottom (blue) line of the graph. Emphasize that they should only be considering the bottom line of the graph. Ask them to estimate the approximate average temperature increase projected by 2100 (in degrees Celsius) in the lowest emissions scenario [answer: approximately 2 °C].

2. After students explore the model as outlined, they may have ideas for further research. Students are often interested in what happens under different scenarios. Here are some ideas for additional student-directed inquiry, but feel free to encourage your students to think of more:
    a. Test the model for a more extended time. The temperature differences are more significant, and there is a more pronounced difference between the two trials if you allow the data collection to continue for up to 15 minutes. Record the results on a separate piece of paper. Ask students to determine which variables they will be measuring and how they need to construct their data table.
    b. Add more layers of insulating materials, such as additional towels and Mylar blankets, small blankets, jackets, etc., and conduct the model again.
        i. Record the results on a separate piece of paper. Ask students to determine which variables they will be measuring and how they need to construct their data table.
        ii. Ask students to reflect on how their extension model relates to the natural and enhanced greenhouse effect. For example, some additional insulating materials may not result in increased temperatures because they are not as efficient at insulating as Mylar blankets. This is analogous to adding non-greenhouse gases, such as O_2, to the atmosphere.
    c. Carry out the model on an object that does not generate thermal energy, such as a rock.
        i. Ask students to hypothesize about the temperature change [answer: insulating a rock will not change its temperature because the rock does not have an internal temperature source like a person does. The rock is in energy balance with the surrounding air.].
        ii. Record the results on a separate piece of paper. Ask students to determine which variables they will be measuring and how they need to construct their data table.

This lesson has been adapted for New Mexico Climate Champions from "Insulating You, Insulating Earth" by the Asombro Institute for Science Education and the Southwest Climate Hub. <https://swclimatehub.info/education/download/climate-change-and-water-cycle/day1>