Great Lakes in Perspective

Activity A: How well do you know the Great Lakes?

Many people, including a large proportion of those who live close to the Great Lakes, do not have a basic understanding of the individual characteristics of and the differences between the lakes. Since it is difficult to understand many of the Great Lakes issues such as global warming, pollution, and water use without a basic understanding of the lakes, this activity is designed to help visualize the differences in the volume, length of shoreline, human population distribution, and fish populations of the Great Lakes. These categories are visually represented so that students can put the lakes in perspective with each other. This activity could be used as an introductory activity to the study of other Great Lakes issues.

OBJECTIVES

In this activity, students will develop a perception of the differences between the Great Lakes regarding their water volumes, length of shoreline, human population distribution, and the amount of fish harvested from each lake.

PROCEDURE

1. In this activity the students will work in groups. Each student should be assigned to a base group and an expert group.
   
   **Expert Groups**
   
   There should be a total of five expert groups, one assigned to each lake. Each expert group studies one lake and members become "experts" on that lake.

   **Base Groups**
   
   The base groups should have five (or more) people in them; in this group students from the different expert groups come together to share their knowledge. There must be at least one member from each expert group (in other words, a representative from each lake) in each base group so that every lake has a spokesperson.

2. After group assignments have been made, the students begin by gathering in their base groups. These groups should each be situated around a cluster of desks or in an open area. The base groups then make their best guess about the following characteristics of the Great Lakes:

   **Shoreline**
   
   Give each group one of the prepared sets of five strings (See Using the Data Step 1). The groups should try to

Earth System Understandings

This activity relates to #3 (science methods and technology) and #4 (interactions). Refer to the introduction of this book for a full description.

Materials

Each base group (of five students) will need:

- A set of five labeled strings as described in step one of Using the Data
- 100 squares of blue paper
- One sheet of paper cut into five strips (1 strip for each lake)
- Twenty "fish" (they could be washers, corn kernels, or peanuts...)
- A pen or pencil

Each of the five expert groups will need:

- Access to a map of the Great Lakes
- A copy of the Great Lakes Data (other resource books are optional)

Teacher's Note

An easy way to divide the students into base groups and expert groups may be to divide them into groups of five students (base groups) and have each member of those groups choose a lake (which hasn’t already been chosen by a member of their group), thus creating the expert groups.
arrange their labeled strings to form a model of the outline of
the Great Lakes (without referring to an actual map).

**Water volume**

Have each group of students distribute their 100 squares of blue
paper among the lakes. The 100 squares together represent all
of the water contained in the lakes. If a group thinks that the
water is divided equally among the lakes, then they would put
20 blue squares into each lake.

**Human population**

Have each group cut five strips of paper which will be placed
along the shoreline of the lakes (one for each lake). Tell the
students the total population of people living in the Great Lakes
watershed (31.7 million). The students should then divide that
number between the Great Lakes. For instance, if they think
that about half of the people in the Great Lakes watershed live
on Lake Superior then they would write 16 million on a strip of
paper and place it next to the Lake Superior coastline. The goal
is not for the students to get the number correct but for them
start thinking about where people are located around the lakes.
Instead of writing actual numbers on the strips of paper, the
lakes could be ranked from 1-5 for most population to least
population.

**Fish**

Try to predict the amount of fish taken from each lake for human
food. Give each group 20 "fish." These 20 fish represent all of the
fish taken out of the Great Lakes. If the students think, for
instance, that almost all of the total fish come from Lake Superior,
then they should put 18 or 19 fish in that lake.

3. After the base groups have made their guesses, the students move
into their expert groups. These five groups, each assigned to one of
the lakes, look at all the data available on their lake so that when the
students move back to their base groups they will be able to correct
the guesses that their base group made. You may either give them
the correct percentages or have the students figure them out.

4. Students return to base groups to correct their models and discuss
the review questions.

**Review questions**

1. What was the most surprising thing about this activity? Discuss why.
2. Which guesses were not close to the correct answers?
   What reasoning led the group to its wrong decisions?
3. Why do the majority of the people live around Lake Erie?
4. Why don’t the length of coastline and the amount of water correspond?
5. How did the groups work out differences of opinion in order
to come to common agreement?
EXTENSIONS

1. As a class or individually, pick a question pertaining to the Great Lakes (for instance: “Which lake on a map of the Great Lakes is Lake Huron?” or “Which of the Great Lakes has the largest human population living in its watershed?”) and have the students ask the question to a variety of people either around the school or in their communities. This may lead to interesting discussions concerning the possibility that the voting public may make uninformed decisions.

2. Each group of students could try to find an additional set of data about the Great Lakes such as average depth, fish populations, average water retention time, level of pollution, etc. to present to the class or to lead the class through, as with the other data sets.

USING THE DATA

These notes should help with interpreting the Great Lakes Data chart and with setting up the experiment.

Shoreline

In order to make strings that depict the relative lengths of shoreline of the Great Lakes, use the relative length data in the shoreline section. Any unit of measurement may be used as long as it is used consistently. The measurement units will depend on the amount of space available for the lesson. For instance, if the lesson will be taught outdoors, a large unit of measurement may be used such as meters. In this case the Lake Superior string would be 3.0 meters long. Make sure each string is labeled with a piece of tape.

Water volume

The student groups each have 100 blue squares that represent all of water in the Great Lakes combined. To find how 100 squares should be distributed, look at the relative volume section in the volume category. It lists 54 for lake Superior. This means that 54 of the squares should be in the Lake Superior string model (over half of the water is in Lake Superior).

Human population

The total population data figures are rounded off in the section Population to the nearest 0.5 million. The students attempt to guess the numbers in this category. It is interesting to realize that Lake Superior has only 0.5 million people living near it. This is less than 2 percent of the total population of the Great Lakes watershed.

Fish

The row labeled "amount of fish if the total number was 20" of the chart indicates the number of pounds of fish that would come from each lake if the total number of pounds from all the lakes was 20. Each base group of students should be given (or make) 20 "fish" so that they can make their best guess as to how the fish should be distributed in their string bordered "lakes."
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<th></th>
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<td></td>
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* Measured at Low Water Datum

**REFERENCES**


Activity B: How great are the Great Lakes?

When we consider the VALUE of something, we put a price, literally or figuratively, on its importance to us. Certain things have a measurable value, like the price of fish fillets or the cost of a bag of salt mined from under the lakes. Those people who don’t like fish or who don’t use salt will naturally place a low value on these items and will avoid their purchase. On the other hand, they may enjoy sailing and invest large amounts of money in a boat and dockage fees. Value is a personal judgment.

Some commodities have an artificially applied value based on perceived importance. For instance, lakefront hotel rooms often cost more per night than identical rooms facing inland. Fast, flashy cars cost more than economy cars equally capable of transporting people from place to place.

Still other things have no price tags at all but clearly have value to some people: a quiet place to walk on the beach, a golden sunset, the sight of an eagle overhead. A glass of pure drinking water is a thing of great value in most of the world. In most parts of North America we take drinking water for granted.

**PROCEDURE**

1. Have students individually brainstorm as complete a list as possible of valuable aspects of the Great Lakes. Bring the individual lists to the class and compile a composite list for all to see.

2. Did the students consider personal, industrial, lifestyle, and aesthetic values as well as things that can be bought because of the lakes? Discuss.

3. For each valuable thing on the list, have the students tell how the value is measured and by whom. Do any students NOT see value in some of the things on the list? Discuss.

4. In small groups and then with the class, have students select the Desirable Dozen; those 12 things they consider most valuable about the Great Lakes. Discuss differences in the choices, but allow all possibilities to be accepted.
FOLLOW-UP

This activity tends to generate deep thought and personal searching. In a portfolio entry or essay, encourage individual students to explore their own set of values and how they would make trade-offs to keep those things they consider most valuable.

Share your classes’ list of values with other students in the region. Send it to the Great Lakes Information Network to be shared on the Education Bulletin Board! Mail to GLIN Systems Operator, CICnet, 2901 Hubbard Ave., Ann Arbor, MI 48105, or send electronic mail to glin.education@great-lakes.net, and all the readers of the bulletin board will share it.
Global Climate Change

Over the past 20 years, much attention has been focused on the potential climatic effects of rising levels of atmospheric greenhouse gases, such as carbon dioxide, methane, and CFCs. Human activities as well as natural factors increase the levels of these gases in the atmosphere. A great deal of research has been done during the past two decades regarding the potential global significance of the increased greenhouse gas concentrations. In addition to receiving attention by the scientific community, global temperature fluctuations and other notable climate variations are causing a great deal of concern for average citizens worldwide. Advances in computer and communication technologies have allowed people to access and share large amounts of global climate information. The media have been an important part of this communications revolution, keeping the public informed on environmental issues. The information that we receive, however, can be conflicting and confusing.

Against a backdrop of controversy, government policy makers must decide whether or not to take action to reduce greenhouse gas emissions. Some policy makers argue that scientists do not agree on the problem, and therefore, they oppose any specific timetables for combating global warming. Others call for the establishment of specific targets to cut the production of human made greenhouse gases, principally carbon dioxide and methane.

A key to understanding the global warming debate is to understand how predictions are made. By recognizing the strengths and weaknesses of predictions based on one data record, for instance, in observing temperature trends, the debate over global warming can become easier to understand.

Earth Systems Understandings

This activity focuses primarily on ESUs #3 (science methods and technology), #4 (interactions), and #5 (change through time). Refer to the introduction of this book for a full description of the understandings.

Scenario Reference

Introduction: Understanding climate models.

Materials

- Global and the Great Lakes region temperature data sets provided
- Graph scale provided
- Colored pencils
- Masking tape
Activity A: Is the globe warming?
Is there evidence in the Great Lakes region?

Objectives

After completing this activity, students will be able to:

- Critically interpret graphic data.
- Evaluate and discuss the difficulties inherent in interpreting and forecasting long- and short-term trends.
- Analyze data, draw conclusions about whether there is evidence of global warming, and defend their conclusions.

Procedure

In preparation, cut apart the sections of the Global Temperature and Great Lakes Temperature lists (p. 9 and p. 12) so each group will see only one segment of each. Make a copy of the graph scale for each team to graph its data.

1. Have students read Ohio Sea Grant’s Global Change Scenarios “Introduction: Understanding Climate Models.”

2. Divide the class into five groups that will work separately. Each group will receive a copy of one global temperature data set (28 years) and colored pencils. Students should graph their set of data on the scale provided. As they observe how readings fluctuate from year to year, students can theorize whether there is any evidence that the global temperature was rising, falling, or remaining constant during the period they are studying. They should be able to back up their conclusions with data from their sample graphs.

3. The students then project what the graph of global surface air temperature will be 30 years into the future (from the last year of their graph), based on the trends and periodicities they observe in their individual data set. This should be drawn on the right side of the graph in a different color.

4. Repeat the exercise (Steps 2–3) using temperature data from the Great Lakes. Plot the data on the same graph sheets used for the global data, but this time using new colors so that four different colors appear on the graph. Have the class agree to use similar colors. How do Great Lakes temperature variations compare with those of the whole world? Did they always show parallel trends? How does the complete regional graph compare to the global graph?

(Procedure continues on page 14.)
## Global Annual Temperature Anomaly Data (°C)

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<th>Year</th>
<th>Temperature Anomaly</th>
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To The Teacher: Give one set of data to each group of students.

Teacher's Page: Graph of Global Annual Temperature Anomaly Data
Graph for Global and Great Lakes Temperature Activity

Temperature Anomalies (°C)
### GREAT LAKES ANNUAL MEAN TEMPERATURE ANOMALY DATA (°C)

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To The Teacher:
Give one set of data to each group of students.

Teacher's Page: Graph of Great Lakes Mean Temperature Anomaly Data

GREAT LAKES ANNUAL TEMPERATURE ANOMALIES

TEMPERATURE ANOMALY (°C)

YEAR

© The Ohio State University, 1995
5. Each group, beginning with the first (1854-1881) temperature chart, should present their data, along with predictions for average global and Great Lakes temperatures 30 years in the future. Compile the graphs of each group into a single graph to show the class. The first group hangs its graph on the front wall. The next group then covers the previous group’s predictions with the actual data. Some teachers create a data timeline along the classroom wall or in a hallway. Students can compare their estimates with the actual data.

**Questions for Discussion**

1. Groups should consider their predictions and answer the following:
   a. How much data do we need to plot a trend?
   b. Were weather collection methods the same for all data sets being reviewed? (e.g., how were weather data collected in 1885?)
   c. Even if the data are old, do they have value?
   d. Besides measurement techniques, what other factors may influence the reported data?

2. In 1995 the Intergovernmental Panel on Climate Change established predictions about future global warming. Their results are based on a scenario of “business as usual,” in which no changes are made in government regulations about greenhouse gas emissions. The predictions are that, as a result of enhanced greenhouse warming, the global mean temperature will rise 1.0 to 3.5°C by the year 2100 with a best estimate of 2°C. How do predictions made in the class compare with these predictions?

3. Based on information in the background readings, discuss what factors are involved in “global climate change” besides just temperature. What kinds of data should scientists combine into a model to get a more complete picture of the Earth System changes involved in global warming?

**A teachable moment for graph scales!**

Have students compare the two bar graphs on overhead transparencies. The Y-axis of the global temperature graph extends from 0.5°C to -0.5°C, while the Y-axis of the Great Lakes temperature graph extends from 2.5°C to -2.5°C. What we are experiencing is an error of scale. Plotting the two sets on the same axis, one for global and one for the Great Lakes, shows the true magnitude of the variation!

Sometimes people who report science choose their graph scales in such a way that data are distorted vertically. They can then claim that the trend is “not as great as it was feared,” or is “even worse than anyone imagined.” Students should be alert to how data are portrayed in the media, so they can become wise consumers of science information.
**Review Questions**

1. How reliable were the five sets of predictions in Activity A? Discuss the implications of basing conclusions on limited data and the patterns that could be inferred from considering each of these subsets.

2. How much data is needed to make reliable predictions? What kinds of data might be combined for a more reliable picture of global climate change?

3. Thinking back to your history classes, can you recall any events, inventions, or discoveries that may have contributed to increased temperatures?

4. Were the data used in this exercise collected by experimentation? Sometimes we learn about “the” scientific method and assume that the only way to do science is by experiments. Often in reality, more can be learned about Earth Systems through historical data that are mainly descriptive. To the following list add some observable data about the Earth Systems or the Great Lakes in particular that might be classified as:

   **Historical/Descriptive**
   - Phosphorus loading to each lake over the years
   - Amount of toxin in birds in different regions
   - Lake level changes
   - Flood periods

   **Experimental**
   - It may be difficult to find experimental data!
   - Fish-growing experiments based on Great Lakes fishes

**Answers to Review Questions**

1. In trying to make predictions or conclusions based on limited data, it is hard to see the “whole picture.” As the Great Lakes graph shows, conditions are more variable over short distances than when averaged worldwide. Also, trends are difficult to determine when data are only available from a limited time period. For instance, flooding may have been prevalent in a specific region over a period of 2-3 years. In looking at a graph of floods for a 10-year period, one might conclude that floods occur in an area two or three years out of every 10, when actually they occur only two or three out of every 10 years.

2. In order to make a reliable prediction, data should be obtained from as many years as possible using both human records and proxy data (data from which other information can be inferred, such as tree rings and fossil pollen as indicators of past climate conditions). In doing so, the researcher can better generalize data to a longer time frame. If just a few years of data are used, the researcher must list the limitations of data from a short time span.

3. Several events occurred after the late 1800s that created greater levels of pollution, including the levels of greenhouse gases. For example, the industrial revolution occurred in the late 1800s. Additionally, the automobile, invented in 1885, began to be mass produced in 1913. WWI may have had effects also — either directly from fires and other factors, or indirectly from technological developments during the war.
EXTENSIONS

1. Local temperature variation may be different than either regional or global variation. Obtain local temperature data and plot this on a similar graph. How does it compare to the other data? What factors could cause differences between the data sets?

2. Working in groups, do research on the history of legislation regarding atmospheric conditions, such as those banning CFCs. Do you feel that these laws have had an effect? Explain your answer.

3. Do library research on the phenomenon of El Niño and its effects on global temperature.

4. Review the data provided on greenhouse gas concentrations (Activity B), and the changes in their levels over time. What relationships do you see between changes in global temperature and the levels of these gases?

Global and Great Lakes temperature data can be downloaded in the following manner:

tftp ediac.esd.ornl.gov
Name: anonymous
Password: YOU@your e-mail address
Guest login ok, access restrictions apply.
ftp> cd /pub/trends93
ftp> dir
tftp> cd temp
ftp> get glakes721 (or use "ftp> get jones606" for global anomalies)
ftp> quit
tftp> Goodbye
Access to CDIAC's anonymous FTP area is also available on the Internet: CDP@ORNL.GOV

REFERENCES


Activity B: How are data from varying sources applied in problem identification?

We study concentrations in gases in the Earth's atmosphere to observe atmospheric changes: carbon dioxide is a by-product of the use of fossil fuels and a result of deforestation; methane is produced by cattle, rice fields, landfills, and naturally occurring wetlands; chlorofluorocarbons are made by people for use in refrigerators, air conditioners, foam, and insulation. When we observe changes in the concentrations of gases in the Earth's atmosphere and changes in global temperature, we are not necessarily attempting to prove a cause-and-effect relationship. Instead, we observe phenomena to see if different sets of data are following a similar trend, and we try to see what we can learn from this information. Studies of the Earth's history can also give us information about climate change. By studying bubbles of ice age air within glaciers and ice caps, scientists propose that there was less carbon dioxide and methane during colder times. Lower concentrations of the gases lessened the greenhouse effect and helped the Earth to stay cooler. Sometimes we can observe trends through collecting data over many years. In addition to the distant past, we have current measurements, as shown in the graphs used in the following activity.

**Objectives**

This activity will allow students to:
- Observe how the atmospheric levels of four greenhouse gases have changed over time.
- Consider the relationship between the greenhouse gases and global temperature.

**Procedure**

The accompanying graphs represent the concentrations of four greenhouse gases — methane, nitrous oxide, CFC11 and carbon dioxide — with the changes in their levels over time. Discuss as a class or in small groups the following questions:
1. What is the apparent relationship between changes in global temperature (from Activity A) and the four gases?
2. What are the levels of these gases?
3. At what approximate date did the levels of the gases start to increase? Was this related to temperature?
4. Construct a hypothesis as to what you think may have caused these changes. How might such a hypothesis be tested?
Table 1. Major greenhouse gases

<table>
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<tr>
<th>Gas</th>
<th>Assumed Concentration in 1880</th>
<th>Concentration in 1990</th>
<th>Projected Concentration in 2030</th>
<th>Annual Growth Rate as of 1990*</th>
<th>Emissions from Human Activity in 1985</th>
<th>U.S. Share of Emissions in 1985</th>
<th>Contribution to Warming 1880-1990*</th>
<th>Major Sources*</th>
<th>Life Spans*</th>
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<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>260-290 ppm</td>
<td>353 ppm</td>
<td>440-450 ppm</td>
<td>0.3%/yr</td>
<td>0-9 billion metric tons C*</td>
<td>20%</td>
<td>66%</td>
<td>Fossil fuel</td>
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<td>Methane (CH₄)</td>
<td>1.2 ppm</td>
<td>1.72 ppm</td>
<td>2.5-2.6 ppm</td>
<td>0.9%/yr</td>
<td>330 million metric tons CH₄*</td>
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<td>15%</td>
<td>Rice fields, cattle, Landfills, Fossil Fuel Production</td>
<td>7-10 yrs</td>
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<td>Nitrous Oxide (N₂O)</td>
<td>290 ppb</td>
<td>310 ppb</td>
<td>310 ppb</td>
<td>0.25%/yr</td>
<td>4-10 million NE*</td>
<td>3%</td>
<td>140-</td>
<td>Nitrogenous fertilizers, Deforestation</td>
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<td>4%/yr</td>
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§Impact on warming over the next three decades of reducing U.S. EPA's (1990) projected annual emissions of each gas by an amount equal to 20 percent of 1985 levels. Expressed as a fraction of the impact of reducing projected annual carbon dioxide emissions by 20 percent of 1985 levels.
NE = no estimates.
*Drawn from The Greenhouse Trap, by Francesca Lyman, et. al., World Resources Institute, 1990.

Reproduced from Reporting on Climate Change: Understanding the Science, with permission from the Environmental Health Center of the National Safety Council.

Figure 1. Concentrations of greenhouse gases
GLOBAL CLIMATE CHANGE 19

REVIEW QUESTIONS

1. We know that certain processes cause increased gas concentrations in the atmosphere. What steps can be taken to reduce these levels?
2. Does the warming trend appear to be consistent with the rise in gas concentrations? What kind of information can be obtained from our observations?

EXTENSIONS

Often students are given data to construct into a table or graph and are familiar with the origin of that data. Another important skill is to be able to interpret someone else's data. The data table in this activity gives students the chance to interpret what the figures mean. Examples are the following questions:

1. Why are the greenhouse gases in different units? CFCs seem to be occurring in small concentrations compared to CO₂ or N₂O. Is CFC at a lower concentration more of a concern than other gases in greater volumes? Does the table answer this question or is more research needed?
2. How could some of the data be displayed graphically?
3. Do research to compare the U.S. share of emissions shown in the data table with the U.S. share of world population. Students can discuss the comparison. Do the values parallel each other? Why or why not?

REFERENCES


Activity C: How do greenhouse gases affect heat absorption?

The Earth’s climate depends on the amount of solar radiation received and the atmospheric abundance of clouds and greenhouse gases. The main greenhouse gases are carbon dioxide, methane, chlorofluorocarbons, nitrous oxide, water vapor, and ozone. Much of the high-energy, short-wavelength radiation from the sun passes through the Earth’s atmosphere and hits the surface of the Earth. The energy that is not reflected off the surface is absorbed and re-radiated into the atmosphere, where much of it is absorbed by the greenhouse gases. This is known as the greenhouse effect.

Figure 1. The greenhouse effect (adapted from Houghton, et. al., Climate Change: The IPCC Scientific Assessment, 1990)

In Activity B it became clear that certain gases have been increasing in concentration in the atmosphere on a timeline concurrent with increasing global temperature. In the following activity you will simulate a portion of the greenhouse system using carbon dioxide. The concepts studied in this activity include: greenhouse gases, greenhouse warming, the greenhouse effect, thermal equilibrium, and experimental variables.
OBJECTIVES

After completing this activity, each student will be able to:

- describe the components of the greenhouse effect
- explain the effect of CO₂ on the absorption of heat in the atmosphere.

PROCEDURE

1. Before the activity begins, the apparatus should be assembled by the teacher. Lubricate the bottom one-third of each thermometer with glycerine or other lubricant. Hold one of the thermometers with several layers of paper towels and gently push the thermometer through the hole in one of the rubber stoppers. Push until about 10 cm of the thermometer has passed through the other end of the stopper.

CAUTION: DO NOT FORCE THE THERMOMETER THROUGH THE HOLE. THE THERMOMETER MAY BREAK AND CAUSE INJURIES.

Make sure that you push the bulb end of the thermometer toward the small end of the stopper and through the opening. Repeat with the other thermometer and rubber stopper.

2. Wipe off the excess glycerine and then tape a small piece of white paper over one side of the bulb of each thermometer. The purpose of this paper is to shield the bulbs from the heat source. Make sure you affix the paper so that you can read the scale accurately.

3. Place 1 CO₂ cartridge in the empty cream whipper. Activate the cream whipper and “pour” the CO₂ from the cartridge into one of the 1-liter bottles. Make sure to empty the whipper completely.

4. Stopper the bottle containing CO₂ with one of the stopper/thermometer assemblies. Seal it with stopper grease or parafilm. Stopper the other 1-liter bottle in the same way. This bottle will have air in it. Label the first bottle “CO₂” and the second bottle “AIR.”

Earth Systems Understandings

This activity focuses on ESUs 2 (stewardship), 3 (science methods and technology), and 4 (interactions). Extensions address ESUs 5 (change through time), 6 (Earth as a subsystem), and 7 (careers and hobbies). Refer to the introduction of this book for a full description of each understanding.

Scenario Reference

Introduction: Understanding climate models.

Materials Per Team

- 2 clear, empty, 1-liter plastic pop bottles
- cream whipper with one CO₂ cartridge
- 2 thermometers
- infrared radiation source (heat lamp)
- 2 #4 rubber stoppers with 1 hole in each
- 2 sheets of white paper
- transparent or masking tape
- parafilm or stopper grease
- thin book, sponge or piece of wood
- glycerine or other lubricant
- graph paper
- a meter stick

STRESS SAFETY: STUDENTS SHOULD WEAR GOGGLES AND PROTECT THEIR HANDS WHEN INSERTING THERMOMETER IN STOPPERS.
5. On a white piece of paper lay the two bottles down together on their sides. Support the necks of the two bottles with a thin book, sponge, or piece of wood. It is important that the pieces of paper you taped to the bulbs of the thermometers are on top and will shield the bulbs from the infrared heat source. Make sure that you can read the scale of each thermometer without moving the bottles.

6. Place the infrared heat source 0.5 m above the two bottles. Make sure that both bottles are equidistant from the heat source.

7. On your own paper, record the temperatures in each bottle before adding the heat lamp. Then turn on the infrared source and record the temperatures in the two bottles at 2-minute intervals for a total of 16 minutes. (You should have eight readings in addition to your original reading.)

8. At the end of 16 minutes, lower the infrared source to 0.25 m above the bottles and continue to record the temperatures in the two bottles at 2-minute intervals for another 16 minutes. (You should now have 16 readings in addition to your original reading.)

9. After you have completed recording the temperatures for a total of 32 minutes, turn off the infrared heat source and feel the two bottles to see if you can detect a difference in temperature.

10. Draw a line graph to show how the temperatures in the two bottles changed over time. Use a solid line for the temperatures from the bottle that contains air, and a dashed line for the temperatures from the bottle that contains CO$_2$.

**Evaluation**

1. What part of the greenhouse effect system does the infrared source represent?

2. What part of the greenhouse effect system is being represented by the 1-liter bottles?

3. Why was it necessary to shade the bulbs of the thermometers with pieces of white paper?

4. When the heating of the bottles was completed, which bottle felt warmer?
5. In which bottle did the temperature increase faster? Explain why.

6. Was the rate of temperature increase for each bottle the same throughout the first 16 minutes? Explain why or why not. Keep in mind what the different parts of the apparatus represent.

7. How many times more heat energy was striking the two bottles after you lowered the infrared source to 0.25 m? How did this affect the temperatures in the two bottles?

8. Was the rate of temperature increase for each bottle the same during the second 16 minutes? Explain why or why not. Keep in mind what the different parts of the apparatus represent.

9. Is the pattern of change of temperature in each bottle the same? Explain why or why not.

10. How would you know when the apparatus is in thermal equilibrium?

11. Is Earth's atmosphere in thermal equilibrium at present? Explain.

12. Explain how the presence of CO₂ and other “greenhouse” gases in the atmosphere affect the heating of the atmosphere from an infrared source.

13. Explain fully how this activity relates to the greenhouse effect in Earth’s atmosphere.

14. In this activity, what variables help to determine the temperature of the gases in the bottles?

15. Choose one of the variables (Question 14) other than the distance between the infrared heat source and the bottles, and describe how you would repeat the activity to determine how that variable affects the temperature in the bottles.

16. If human activity continues to add CO₂ and other greenhouse gases to Earth's atmosphere through burning of fossil fuels, deforestation, and other practices, predict how the average temperature of the atmosphere will change in the future.

Answers (continued)

5. The bottle containing the CO₂ should, because CO₂ absorbs infrared radiation more effectively than air.

6. Refer to the slopes of the lines. The temperature of the CO₂ should increase faster. Both lines flatten out as the system approached thermal equilibrium.

7. Four times – inverse square law. They should both increase.

8. The temperature of the CO₂ should increase faster than the temperature of the air.

9. Possibly not. The temperature of the CO₂ is likely to increase faster than the temperature of the air. After a certain time, both lines should flatten out.

10. The temperature in the bottles no longer increases.

11. Global warming appears to be occurring, which suggests that the atmosphere is not in thermal equilibrium.

12. Greenhouse gases transmit short-wave radiation from the Sun, but absorb long-wave radiation from the Earth. These gases absorb thermal radiation, thereby trapping it in the atmosphere.

13. Answers should address how increased amounts of greenhouse gases cause warming of the Earth’s atmosphere.

14. Variables include, but are not restricted to: the strength of the heat source; the opacity of the plastic bottles; the distance between the bottles and the heat source; the concentrations of gases in the bottles; and the types of gases in the bottles.

15. Answers will depend on the variable chosen, but could include factors such as size of bottle, type of material comprising the bottle, heat source used, gas injected, etc.

16. Based solely on the factors listed, the temperature should be expected to increase.
There has been an increase in the amount of CO₂, N₂O, and other greenhouse gases in Earth's atmosphere in the last 150 years. This increase has been measured and recorded in a variety of ways. Much of it has been attributed to such human activities as deforestation and the burning of fossil fuels. The current rate of increase of CO₂ in the atmosphere is 0.5 percent per year. At this rate, computer models predict that the average global temperature could go up 3–5°C by the year 2050.

**TOPICS FOR DISCUSSION**

1. Have students explain why the initial temperatures in the two bottles were not the same. Discuss what would have to be done to make them the same.

2. What are the important aspects of the apparatus that determine at what temperature thermal equilibrium is reached — include discussion about the size of the bottle, the concentrations of gases in the bottles, and the opacity of the plastic.

3. How “real” is the lab setup? There is a major difference between concentrations of greenhouse gases in the bottle(s) and in Earth's atmosphere. Discuss how an increase of just 2 or 3°C in the atmosphere could cause agricultural belts to migrate. (See *Science*, November 3, 1995, p.731.)

4. Have the students create a concept map illustrating the process of heat absorption in the atmosphere and the consequences that it could produce on the various Earth systems and human society.

**EXTENSIONS**

1. Earth is more than 4 billion years old. When did the atmosphere develop around the planet? Determine what role this played in the evolution of life. If the amount of greenhouse gases in the atmosphere continues to increase, what impact would this have on all the life systems and the planet?

2. Venus is a planet whose orbit around the sun is closest to Earth's orbit. It has experienced greenhouse warming for many thousands of years and has a mean surface temperature of 480°C. How did the atmosphere form? Could this happen to Earth if the gas composition of the atmosphere alters? Support your answers with evidence.

3. The National Oceanic and Atmospheric Administration (NOAA) is one organization that monitors changes in the oceans and atmosphere of the planet. Many scientists, such as meteorologists, oceanographers, atmospheric scientists, etc., focus on different areas in their work. Select one of these scientists and investigate the type of training required for his/her career.
4. The demand for energy will continue to grow as the human population increases. To tackle the problem of the greenhouse effect, gases such as CO$_2$, CH$_4$, and N$_2$O cannot continue to be pumped into the atmosphere. What alternative energy sources can be used to meet this increasing demand for energy? Select one of these energy sources and explain its advantages and disadvantages in relation to environmental impact. Also investigate how the public perceives this energy source. Support your answers with evidence.

REFERENCES


VIDEO

*After the Warming*. 1990. A co-production of Maryland Public TV, Film Australia, Wiseman (UK), Electric Image (UK) in association with Principal Film Company Ltd. (UK).
HELPFUL DEFINITIONS (VOCABULARY)

Greenhouse effect: “The trapping by atmospheric gases of outgoing infrared energy emitted by Earth. Part of the radiation absorbed by the atmosphere is returned to Earth’s surface, causing it to warm” (Graedel and Crutzen, 1993, 430). Principal greenhouse gases are H$_2$O vapor, CO$_2$, O$_3$, CH$_4$, N$_2$O, CF$_2$Cl$_2$, and CFC$_1$.

Thermal equilibrium: Balanced temperature regime achieved when the amount of heat leaving and entering a system are equal.

TEACHER BACKGROUND INFORMATION


This journal comprises several articles surrounding the issue of global warming. It contains figures, photographs and discussions of modeling, policy, temperature, agriculture, and climate–related phenomena.


The section concerning the atmosphere of Venus documents how the atmosphere developed and how the greenhouse effect on the planet evolved. Diagrams of this process, while small, are an excellent representation and could easily be enlarged. They could also be placed on transparencies. This would be a good way of allowing students to envision the process that may occur on Earth, should global warming (or an enhanced greenhouse effect) occur.


This is a superb article that deals with the complete topic of global warming. Specifically, pages 72–77 concentrate on the influence of greenhouse gases on the process of global warming. Excellent illustrations and charts help to create an understandable account of the scientific processes involved.
Activity D: Why don’t all scientists agree that global warming is in progress?

One of the tricky questions that scientists wrestle with is highlighted by a study of the variability of the weather. It is clear even from a short-term study that weather is constantly changing! How then can we sort out real climate change from simple variability?

Imagine trying to listen to a radio station that is full of static. The noise prevents you from getting a clear radio signal. The same is true for climate: noise (natural variability) may prevent us from detecting the signal that global climatic change is in progress. This is why it is extremely important to study weather patterns as far back as records go. As an example, Reader’s Digest ran an article questioning global warming based on fifteen years of data whereas the New York Times, a month later, ran an article based on 1994 temperature data stating that global warming was occurring. Neither fifteen years nor one year of data can be sufficient. Many years of data are needed so that trends can be detected and people will know enough to detect a signal denoting climate change.

Think about it: the decade of the 1980s included the five warmest years in this century. In the ’90s, major hurricanes and great floods created memorable weather history for the U.S. Are these events part of the noise, or are they a signal that the climate is changing?

In addition to the uncertainty about how much the Earth will warm under global warming, there is an ongoing debate among scientists, politicians, and policy makers whether there will be global warming and whether it is already in progress. Both sides have supporting data, including highly technical devices for measuring temperature, and both groups of experts can sound very convincing.

In this activity, students watch a videotaped debate about global warming or read articles with conflicting claims. Their task is to analyze the complex issues that arise when scientists disagree.
PROCEDURE

Watch the videotape as a group, and/or assign the articles for homework reading. Divide the class into groups of four or five people for discussion. Here are suggested discussion questions.

1. What are the most believable points presented by each side of the debate?

2. What references are given by each side? Do you feel the references are credible?

3. Are the two sides interpreting the same data in different ways, or do they have different data sets? Where were the data obtained?

4. Do you feel that in either of the views, fear is used? That is, do you think either side is using scare tactics to convince the audience?

5. Can your group reach a consensus as to which view you believe is correct? Or, are able to find some truth to each argument? Present your decision to the class. Explain why you have reached this decision.

6. Suppose an energy-use policy is being proposed, how much data would be sufficient as a basis for policy?

REVIEW QUESTION

After a public outcry demanding a remedy for global warming, you, as a governor of a Great Lakes state, must weigh the opinions of the two sides of the global warming issue and define a likely state policy that would lessen the effect of global warming. What side would you take? What are the strongest points that would defend your side of the issue? Explain the steps of your plan to resolve the public’s understanding of the issue of global warming.