Long Term Data Sets

Duration:
1 class

Objectives:
Students will:
- Discuss the benefits of long-term data sets and studies
- Use a long-term data set to plot graphs and examine patterns
- Extrapolate what future climates may be like
- Use empirical data to discuss how human activity is affecting the planet

Vocabulary:
Carbon Dioxide
A greenhouse gas found in the atmosphere in small amounts; it is released naturally into the environment and through human related activities.
Atmosphere
The gaseous layer surrounding the earth consisting of nitrogen, oxygen, and many trace gases, held in place by the earth's gravitational force

British Columbia PLO's:
Math 6, 7, 8
Social Studies 6, 7, 8

Background:
In this activity the students will use actual data from the Mauna Loa Observatory from 1958 to the present to graph CO_2 in the atmosphere. Using their graphs they will analyse any patterns observed, predict future CO_2 values and discuss how this long-term data set has contributed to our understanding of abrupt climate change. This activity can be used after an introduction to climate change, as the students should have a basic understanding of the topic.

Long-term data is invaluable in studying and understanding how organisms will respond to present-day abrupt climate change in the context of long-term climate variability.

One study that has been very useful in determining how CO_2 has increased over the last century was started in the mid 1950s at the Mauna Loa Observatory. Located on the big island of Hawaii, Mauna Loa – a shield volcano – is the largest volcano on the planet. The observatory sits on the north flank of the volcano looking over at Mauna Kea. Its remote location in the Pacific Ocean and high altitude of 3,397 meters makes it an ideal position to study the atmosphere.

Although the Mauna Loa Observatory examines a variety of subjects, in the last decade it has become well known for studying atmospheric CO_2. The long-term data set of atmospheric CO_2 from the observatory was one of the first pieces of evidence scientists used to explain how humans were impacting the climate. Increasing levels of CO_2 over the last half-century show a steadily uprising curve that has become known as the Mauna Loa curve or the Keeling curve (after Charles Keeling who was a pioneer in the monitoring of CO_2 in the atmosphere). CO_2 levels are now being used as a major indicator of global warming, and a movement has begun in most parts of the world to reduce CO_2 emissions.

Materials:
- Class set of *Ocean News* article *The benefits of long-term data*
- Access to the Mauna Loa data set or printouts of the spreadsheet
- BBC News article for students
- Images of Mauna Loa
- Graph paper
- Pencils
- Rulers

Procedure:

1. Place a picture of Mauna Loa up on the overhead or screen when the students walk into the classroom (see resource section).
2. Ask the students what the benefits of long-term data sets are? Get them to Think-Pair-Share.
3. With the students, create a list of why long-term studies are important. Have them list any long-term studies that they know of (i.e. bird counts, temperature studies, fish catch data). Note: they may even come up with the Mauna Loa CO_2 data set since it was featured in the movie *An Inconvenient Truth*.
4. Read the *Ocean News* article *The Benefits of Long-Term Data* as a class or as individuals.
5. Using information from the Mauna Loa Observatory, the class will plot data in order to assess climatic patterns and trends. Measurements at Mauna Loa are taken every month. The Mauna Loa data set might be too much to handle for many small graphs so it will need to be examined, discussed and possibly streamlined beforehand.
6. As a class, decide what data to use; the goal should be to simplify the graph but to still get a clear picture of what is happening. Plot at least one month from summer and one from winter for each year in order to observe seasonal patterns.
7. The students can graph the data by hand or use a computer. The data can be used from the website or from the accompanying excel spreadsheet.
8. If you have internet access in the classroom go to the live web cam page for the Mauna Loa Observatory and have a look at what the current weather conditions are like while the students are working on their graphs.
9. If time is limited, the students can complete the graph for homework and the lesson can be continued the next day.
10. Once the graphs are complete, get the students to answer some of the discussion questions in small groups. Place the plotted Mauna Loa graph (see the resource section) on the overhead for comparisons. Their graphs should show similar trends and patterns.
11. Get the students to extrapolate what the CO_2 levels might be like in 10 years? 20 years? 100 years? Discuss why extrapolations are only estimates. Ask the students to consider what might affect the curve over the next few decades or centuries to make their extrapolations inaccurate. Discuss (1) what is currently being done to reduce emissions globally, (2) carbon sequestration, and (3) increased fossil fuel consumption in some parts of the world.
12. To put the data in a larger context (after the discussion questions are taken up), show the students the atmospheric CO_2 values covering the last several millennia. What can we learn by looking at these even longer data sets? How was this data collected?
13. Have the students read the news article *Ice Cores Unlock Climate Secrets*. This can be done individually or out-loud with members of the class taking turns reading.
14. Discuss where this historical data comes from (ice cores). Ask the class to explain the difference between long-term data sets and historical data (data collected over a long-term versus data implied from current studies that look at data recorded naturally in a medium scientists can study and gather information i.e. archaeological information, ice cores, tree trunk cores etc).
15. To end the activity, get the students to write a short entry in their notebooks on the importance of using both long-term data sets and historical data to improve our understanding of the natural world.

Discussion:

- How is atmospheric carbon dioxide measured?

- Why is it important for carbon dioxide data to be taken in a remote location?
- Why does the data show a small oscillation pattern within the larger shape?
- What is the overall trend in CO_2 levels since the 1950s?
- What predictions for the future can we make using the graph?
- Why is it difficult to extrapolate future values of CO_2 at this time?
- What other data would be useful in determining atmospheric changes and how they relate to climate change?

Extension and Resources:

- A great photo of Mauna Loa www.summitpost.org/mountain/rock/151296/mauna-loa.html
- Mauna Loa at night image www.3dnworld.com/users/65/images/MaunaLoav1.1.jpg
- Mauna Loa data in spreadsheet taken from cdiac.ornl.gov/ftp/ndp001/maunaloa.co2
- Live web cam at the Mauna Loa Observatory www.mlo.noaa.gov/livecam/livecam.html
- Good source of background information on Mauna Loa and the carbon dioxide data www.eoearth.org/article/Mauna_Loa_curve
- Plotted Mauna Loa data in a graph for students to see and use to make comparisons. www.globalwarmingart.com/wiki/Image:Mauna_Loa_Carbon_Dioxide_png
- This Global Warming Art website has great images of CO_2 values over the last few decades to the last few millennia www.globalwarmingart.com/wiki/Image:Carbon_Dioxide_400kyr_Rev_png
- BBC News article *Ice Cores Unlock Climate Secrets* http://news.bbc.co.uk/1/hi/sci/tech/3792209.stm

Teaching Activity: Analyzing Greenhouse Gases and Temperature Over Time

Background. Locked in the Earth's polar ice sheets is a record of past climate stretching back at least 150,000 years. Studies of ice cores provide scientists with a rich archive of information on past temperatures, precipitation and atmospheric composition and circulation. The annual accumulation of precipitation on the ice sheets is preserved with little or no melting , except in coastal areas, and is gradually compacted into solid ice . Ice cores can therefore provide continuous atmospheric and climate records, reaching back several hundreds of thousands of years. Paleoclimatologists who study ice cores do so in the hope that ".....studies of the past may hold they key to the future....." Studies of the climatic response to natural variations in carbon dioxide and atmospheric dust (continentally derived or volcanic), for example, may help scientists understand the effects of the buildup of carbon dioxide and other gases in the atmosphere as a result of man's activities.

The longest and most complete ice core records have been obtained from the central regions of two great ice sheets in Antarctica (Vostok Research Station) and Greenland (Camp Century and Dye 3). However, studies of cores from other parts of the Arctic and high altitude sites in equatorial regions (Quelccaya Ice Cap, Peru) have increased the geographical coverage and have provided important data for interpretation.

Ice cores preserve information on atmospheric composition and climate in three distinct chemical forms:

- the **stable isotope composition** of the ice itself (determined primarily by climatic factors);
- the **soluble and insoluble materials** from biogenic, marine, continental, volcanic and extraterrestrial sources (salts, particulates and heavy metals);
- **air bubbles** in the ice containing samples of the atmosphere at the time the ice was formed;

In the process by which snow is transformed into glacier ice, air is trapped in bubbles in the ice. The air that is trapped in these bubbles preserves a record of the composition of the atmosphere at the time of their final isolation. The trapped air provides scientists with a look at the history and development of the atmosphere over the last 150,000 years. Of particular interest have been the measurements of carbon dioxide and methane, which have shown significant variations linked to temperature. In addition, studies of both the Antarctica and the Greenland ice have shown that carbon dioxide levels prior to 1850 were on average, between 270 and 290 parts per million by volume (compared with a time have been noted in both cores and suggest that while present day increases are the result of human activities, fluctuations in the past, preceding industrial perturbations, were possibly dependent on climatic fluctuations.

In addition to atmospheric gas concentrations, ice cores afford scientists data regarding the temperatures at various points in the Earth's past. Using the oxygen isotope ratio of ^{18}O and ^{16}O, it is possible to form a picture of what past climatic conditions were like. We know from the ratio of ^{18}O ($H_2{}^{18}O$) to ^{16}O ($H_2{}^{16}O$) in present precipitation that a lower value of ^{18}O corresponds to colder temperatures and vice versa. Likewise, a lower than normal level of ^{18}O would indicate that relatively cold conditions were present. When the levels of ^{18}O are higher than normal, climate was undergoing a warm period. One of the most interesting results of this study has been the ability to designate the onset of glacial and interglacial periods over the past 150,000 years. Oxygen isotope ratios in ocean sediment cores have also been used to determine ocean temperatures and paleo-sea levels.

Polar ice sheets are excellent storehouses of information for deciphering the history of our global atmosphere and paleoclimate. Long records extending back hundreds of thousands of years may eventually be recovered from the polar ice sheets; at present the oldest record from the polar ice sheets extends back over 250,000 years from the Greenland core and over 150,000 from the Vostok, Antarctica core. These cores are providing paleoclimatologists, and atmospheric modellers with the information necessary to understand the underlying causes of climatic change, whether it is natural or human induced.

Important Terms: Carbon dioxide, methane, ice core, ice ages, cyclical change, raw data, thermal, isotope, $^{18}O/^{16}O$, ratios, glacial, interglacial;

Objectives:

- Students will learn about changes that have taken place in greenhouse gas and average annual temperatures within the recent past (To 160,000 years ago);
- Students will make graphs of actual research data;
- Students will find trends as illustrated by the graphed data and draw valid conclusions;

Materials: Raw data (temperature / atmospheric gases), pencil / paper, graph paper, colored pencils, ruler;

Procedure:

1) Divide the class into small research teams (2-3 students each).
    - Explain that each group will be assigned a position in research dealing with global issues, in this case global climate change;
    - A research scientist has given their group some raw data and within the week they will have to analyze and present that data and report on it at an international conference;
2) Discuss the data (in general) with the class, what it is, where it comes from, and types of graphs available to illustrate the data;
3) Have students plot the values and make a graph for the temperature and another for the greenhouse gas their group was assigned.
    - Upon completion of the graphs, students should continue the trend indicated in the curve of the graph for another 50 years;
4) Each group should discuss their findings and develop a conclusion for their graphs. (Note: **A set of Guide Questions is included with the packet.)**
    - Students should each produce a detailed, written explanation of their conclusion;
5) A spokesperson from each group should be selected to present their findings to the class;
6) Discuss results with the class and analyze the accuracy of the type of graphs they chose.

*****Note: Each student in the group will be responsible for turning in a completed graph of the atmospheric gases and temperature data and a conclusion of the raw data provided to them.**

GUIDE QUESTIONS

1) What data did your group graph?
2) What time period did your data cover?
3) In what unit of measurement is the data presented?
4) What does the data indicate happening over time?
5) What can you predict about future amounts?
6) What does the temperature data show?
7) How far back in time does the data extend?
8) What do the dips in the temperature graph indicate? The rises?
9) Do you see any correlation between the temperature and the gas concentrations? Explain.

RAW DATA A:

Carbon Dioxide Concentrations (in ppmv*), Mauna Loa, Hawaii

Year	ppmv	Year	ppmv
1958	314.8	1974	330.4
1959	316.1	1975	331.0
1960	317.0	1976	332.1
1961	317.7	1977	333.6
1962	318.6	1978	335.2
1963	319.1	1979	336.5
1964	319.4	1980	338.4
1965	320.4	1981	339.5
1966	321.1	1982	340.8
1967	322.0	1983	342.8
1968	322.8	1984	344.3
1969	324.2	1985	345.7
1970	325.5	1986	346.9
1971	326.5	1987	348.6
1972	327.6	1988	351.2
1973	329.8		

*ppmv = Parts per million by volume.

Methane Gas Concentration

Atmospheric Greenhouse Gas Affected by Human Activities

Year	ppm*	Year	ppm*
1850	0.90	1975	1.45
1879	0.93	1976	1.47
1880	0.90	1977	1.50
1892	0.88	1978	1.52
1908	1.00	1979	1.55
1917	1.00	1980	1.56
1918	1.02	1981	1.58
1927	1.03	1982	1.60
1929	1.13	1983	1.60
1940	1.12	1984	1.61
1949	1.18	1985	1.62
1950	1.20	1986	1.63
1955	1.26	1987	1.65
1956	1.30	1988	1.67
1957	1.34	1989	1.69
1958	1.35	1990	1.72

*ppm = Parts per million.

Nitrous Oxide

Atmospheric Greenhouse Gas Affected by Human Activities

Year	ppbv*	Year	ppbv*
1750	283.0	1880	289.5
1760	283.5	1890	290.0
1770	284.0	1900	291.0
1780	284.5	1910	292.0
1790	285.0	1920	292.5
1800	285.5	1930	293.0
1810	286.0	1940	294.0
1820	286.5	1950	295.0
1830	287.0	1960	297.0
1840	287.5	1970	299.0
1850	288.0	1980	305.0
1860	288.5	1990	310.0
1870	289.0		

*Values of N_2O concentration are in parts per billion by volume (ppbv).

CFC (chlorofluorocarbon)[1] Production

Atmospheric Greenhouse Gas Affected by Human Activities

Year	Amount[2]	Year	Amount
1955	100	1975	350
1957	120	1977	360
1959	140	1979	330
1961	150	1981	325
1963	150	1983	320
1965	200	1985	340
1967	225	1987	300
1969	290	1989	305
1971	320	1991	310
1973	375		

** Values in kilotons per year

RAW DATA B:

Temperature Deviation Over Time[1]

Year	Temp. Deviation	Years BP[2]	Temp. Deviation	Years BP[2]	Temp. Deviation
1880	−0.25	200	0.01	80,000	−0.35
1885	−0.27	1,000	0.01	85,000	−0.30
1890	−0.26	5,000	0.02	90,000	−0.43
1895	−0.29	10,000	0.03	95,000	−0.52
1900	−0.20	15,000	−0.83	100,000	−0.36
1905	−0.38	20,000	−0.90	105,000	−0.40
1910	−0.35	25,000	−0.80	110,000	−0.68
1915	−0.33	30,000	−0.82	115,000	−0.64
1920	−0.30	35,000	−0.70	120,000	−0.19
1925	−0.15	40,000	−0.60	125,000	−0.09
1930	0.00	45,000	−0.75	130,000	0.03
1935	−0.10	50,000	−0.60	135,000	0.10
1940	−0.05	55,000	−0.45	140,000	−0.21
1945	0.05	60,000	−0.80	145,000	−0.75
1950	−0.03	65,000	−0.82	150,000	−0.90
1955	−0.01	70,000	−0.70	155,000	−0.82
1960	0.05	75,000	−0.70	160,000	−0.70
1965	−0.05				
1970	0.00				
1975	−0.05				
1980	0.15				
1985	0.18				
1990	0.21				

[1]For the purposes of this exercise, the mean average temperature from 1950 to 1980 is used as a baseline for comparative purposes. Note the 5-year average deviation values for the past 100 years, then the change to a 5,000-year spread for average deviation values. The values beyond 100 years were taken from ice core readings made by a USSR team of scientists working for years in the Vostok, Antarctic station.

[2]Years BP = years before present.

Student Activity Sheet: Analyzing Greenhouse Gases and Temperature Data Over Time

Background: The data presented on the following pages was collected from ice core research on atmospheric gases long before global climate change became a serious concern. In the past, scientists interested in a particular gas either made or bought the right equipment for their investigations, found a suitable to study the gas and then spent several months setting up, calibrating and checking the data. Eventually, enough raw data accumulated and required analysis. You will be working with that type of data.

Definition of Terms:

Raw data : Numbers that have not yet been organized or analyzed into meaningful results;

Graph: A diagram that represents the numerical difference in a variable in comparison with other variables;

Parts per million (billion) by volume : Either ppmv or ppbv; the number of molecules of a specific gas in a total volume of 1 million (1 billion) molecules of air;

Task: You will be playing the roles of a researcher in a research institution that addresses global change issues. A research scientist has just given you some raw data on atmospheric gases and temperature over time. Within the week there is to be a major international conference on global change which depends upon this material. Your task is to analyze it by then. The data needs to be presented in a meaningful and useful way. Working within your group with other members, your task is to organize, analyze and present the findings of their data.

Materials: Raw data tables, pencils/paper, graph paper, ruler, colored pencils;

Procedure:

1) Plot the values and make two (2) line graphs with the raw data that you are responsible for. (One greenhouse gas and temperature data)
   - X-axis: Year
   - Y-axis ______Concentration in ppm (ppb)

2) When you complete the graphs, continue the trend shown on each for another 50 years.

(NOTE: Make a prediction on how you would expect the graph to look with 50 years more data.)

3) Develop a conclusion for your graph using the Guide Questions provided by your teacher. If another group in the class is working on the same data, get together with them and compare the accuracy of both graphs and conclusions.
   (Example: The data on this graph shows.........)

4) Share your findings with the class.
   - Choose one member of the group to be the spokesperson.

*****NOTE: Each student in the class will be responsible for turning in a completed graph of each data set and a conclusion of the raw data provided to them.

May 9, 2006

Shivering and Unsung, Scientists Monitor the Arctic Year After Year After Year

Lesson is below this article

By ANDREW C. REVKIN

On April 22, two divers from the University of Washington entered a manhole-size opening in the veneer of floating sea ice around the North Pole.

For the fifth year in a row they descended into the blue-green 29-degree water in pursuit of the least glorious, and perhaps most important, facet of earth and ocean science: the collection of basic information on conditions in the same place year after year.

Their task was to retrieve a two-mile-long strand of instruments that for a year had been anchored to the sea floor recording shifting currents, temperatures, salinity, ice thickness and other vital signs. Now, after an acoustic signal released it from the anchor, the strand was bunched in a tangle of floats and Kevlar line under the ice.

The divers are part of a team of nearly two dozen researchers who have been trying to establish the first continuing record of changing ocean conditions near the

North Pole.

After this retrieval of a year's worth of data, the team would drop fresh instruments and a new anchor.

Such monitoring, whether in unremarkable places or at the ends of the earth, is unsung and underfinanced, but it has resulted in some of the most important discoveries about how the world is changing under the increasingly global influence of humans, many scientists say.

First came revelations about acid rain and the destruction of the ozone layer, with atmospheric monitoring over Antarctica revealing the surprising seasonal "hole" that etched the issue into the public consciousness in the 1980's.

In the same way, quotidian efforts by Charles D. Keeling of the Scripps Institution of Oceanography in San Diego to measure levels of atmospheric carbon dioxide — month after month, year after year, decade after decade — provided the first clear evidence that humans were sharply increasing the concentration of this heat-trapping greenhouse gas.

Ralph Keeling, also at Scripps and the son of Charles Keeling (who died last June), has been trying to sustain his father's carbon dioxide monitoring project in a time of shrinking budgets.

Although such work may seem inconsequential or boring to some outsiders, he said, it has its own special feeling of urgency. "To keep up with the latest pulse of the planet in a warming world is quite exciting, similar to watching the charts of an unstable patient in the emergency room of a hospital," Dr. Keeling said.

Trends in the Arctic so far have been reflected in readings of sea ice thickness and the area it covers, taken by satellites and nuclear submarines.

While satellites have helped track increasing summer retreats of the ice over three decades, they cannot reveal the temperature, salinity and currents of the layered ocean below.

Declassified information collected by submarines has shown that the ice has also been thinning but the data are limited to corridors used in the cold war.

Glaring gaps persist in the data, and as a result scientists have had difficulty putting the recent big changes in air, ice and ocean conditions in the far north into context.

The team that sets up what it calls the North Pole Environmental Observatory each spring is content to add one new data point each year to the big picture, right near the North Pole.

Every such point counts because global-scale puzzles, like determining how accumulating greenhouse gases will alter climate and the oceans, are clearest when assessing the "balance of evidence," not specific findings in one place.

As with a pointillist painting, the picture is revealed only when a large array of dots is regarded as a whole.

The challenge with monitoring the central Arctic Ocean is finding ways to take measurements precisely and consistently in a place where nothing is consistent — where the only unchanging thing is the seabed below the ice, 10 Empire State Buildings deep. But the crunching, shifting frozen surface is in constant flux, often drifting up to 400 yards an hour.

The researchers have endured such conditions since 2000, and the National Science Foundation has agreed to spend more than $1 million a year to support the project through 2008, because the top of the world is an important crossroads for currents and flowing ice that can help reveal bigger patterns as the Arctic Ocean responds to warming.

There is no way, yet, to place instruments on the ice or sea floor that phone home year after year as they might do from a mountaintop or Antarctica. Although that continent has one of the harshest environments on earth, it is — beneath its ice sheets — solid ground so scientists can settle in for the long haul with no need to plunge into frigid depths.

Nonetheless, the North Pole research team has stuck with it. The project was complicated this year by a fresh array of challenges, including unusual warmth and wind, thick fog and fragmented ice.

In past years, the scientists usually enjoyed at least the illusion of being on a solid surface, with their man-made hole being the only open water for more than a thousand yards around.

This time, said James Johnson, a University of Washington engineer who helped design the instrument chains, they were essentially camped on an ice raft not much larger than a football field that was surrounded by patches of black, steaming water. As the days passed, the ice beneath them became progressively laced with disconcerting cracks, Mr. Johnson said.

Independent sea ice experts at the National Snow and Ice Data Center in Boulder, Colo., said the weaker ice, the fog and the open water seen by the team at the North Pole were consistent with their latest measurements of the overall conditions on the Arctic Ocean. They have measured big retreats in the floating ice in recent summers, including a modern record in 2005, and the ice did not rebuild in recent months as it usually does in the deep freeze and long nights of the Arctic winter, said Mark C. Serreze, a senior scientist at the center.

In April the divers, who spent 42 minutes under the ice, faced challenges they had not encountered before. Among other issues, the instruments and attached floats were tangled amid ridges of broken ice under some ice floes.

One diver, James Osse, said his knife, usually a pro forma accessory on these expeditions, suddenly became a vital tool as he was forced to hack through a cat's cradle of line.

"And it was actually sharp enough to cut something, which was surprising but fortunate," he said.

Mr. Osse is an engineer back at the university in Seattle, and there he has devoted much of his time in recent years to devising automated winged probes that he hopes will soon make his Arctic scuba work obsolete.

The probes are meant to glide thousands of feet into the depths and surface, then glide and surface again and again, transmitting data each time they surface, staying at sea for up to seven months.

There have been only preliminary tests of such gliders beneath sea ice, where they cannot surface and must keep track of their position using underwater beacons instead of the global positioning system network.

For at least a few more years, then, someone will have to continue diving under the North Pole ice to get the job done.

The New York Times
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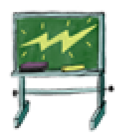


MAY 9, 2006, 1:29 AM

It's Up In the Air!

By MARCELLA RUNELL and YASMIN CHIN EISENHAUER

Note: This lesson was originally published on an older version of The Learning Network; the link to the related Times article will take you to a page on the old site.

Teaching ideas based on New York Times content.

- See all lesson plans »

Overview of Lesson Plan: In this lesson students will conduct a scientific experiment that reveals what types of particles are in the air at their school. Students will then report on these results and write letters to Steven Johnson, the Administrator for the Environmental Protection Agency.

Author(s):
Marcella Runell, The New York Times Learning Network
Yasmin Chin Eisenhauer, The Bank Street College of Education in New York City

Suggested Time Allowance: 1 hour

Objectives:
Students will:
1. Examine a variety of tools used to collect scientific data.
2. Read and discuss the article, "Shivering and Unsung, Scientists Monitor the Arctic Year After Year After Year" to learn about the importance of repetitive scientific research.
3. Conduct an experiment on air quality and report the findings to the class.
4. Write letters to the Administrator for the Environmental Protection Agency offering suggestions on how to improve the air quality in their school community.

Resources / Materials:
-student journals
-various data collection devices
-copies of experiment
-copies of the scientific method found online at the University of California, Riverside's Department of Physics (http://physics.ucr.edu/~wudka/Physics7/Notes_www/node6.html#SECTION02121000000000000000)
-pens/pencils
-classroom board
-copies of article, "Shivering and Unsung, Scientists Monitor the Arctic Year After Year After Year" found online (http://www.nytimes.com/learning/teachers/featured_articles/20060509tuesday.html)
-six sheets of 8″ x 10″ (205 x 255 millimeters, or mm) piece of shoebox cardboard or stiff paper from a file folder for each group in the class
-six pieces of sticky material, enough for each group in the class. Sticky labels or transparent tape work fine. Each piece should be about 1-1/2″ x 3-1/2″ (40 mm)
-one light string per collector, 12″ (300 mm) long
-six magnifying glasses
-microscopes

Activities / Procedures:

1.WARM-UP/DO-NOW: As students enter the classroom, have a variety of data collection tools available for their review including, but not limited to: cotton swabs, thermometer, tweezers, flasks, camera, pencil and paper, and other data collection tools you can access. In their journals, students respond to the following prompt (written on the board or copied into a handout prior to class)

"What do these objects have in common? How can each be used to gather scientific data? Can you name other items, not seen in this display, that can be used to collect information?" Students should then discuss as a class why accurate data collection is central to scientific understanding.

Explain to students that they will be reading an article about the importance of repetitive scientific research and the significance of scientific processes to collect data.

2. As a class, read and discuss the article, ""Shivering and Unsung, Scientists Monitor the Arctic Year After Year After Year" found online at: (http://www.nytimes.com/learning/teachers/featured_articles/20060509tuesday.html) a. What happened on April 22, 2006?

b. What was done for the fifth year in a row?

c. What was the task?

d. To what team do the divers belong and what is their mission?

e. What will the team do after this year's retrieval?

f. What revelations have been made since the team started doing this research?

g. Who is Charles D. Keeling of the Scripps Institution of Oceanography?

h. Who is Ralph Keeling and what has he been trying to do?

i. What have trends in the Arctic been revealing?

j. What are the limitations when using satellites?

k. What are examples of global-scale puzzles?

l. What presents a challenge when monitoring the Arctic Ocean?

m. Why was the project complicated this year?

n. Who is James Johnson and what did he report about this year's research?

o. What happened in April that impacted the research?

p. Who is Mr. Osse and what was his contribution to the research?

3. After reading the article on scientific research as it connects to global warming, explain to students that they will be conducting a scientific experiment on air quality. Air quality and air pollution are commonly cited as important factors in the creation of global warming. This experiment will enable students to monitor air quality in their school community and compose

a report that will be presented to students of the same class, the following year.
First, have students briefly discuss the nature and causes of air pollution. As defined by the Environmental Protection Agency, “Air pollution comes from many different sources such as factories, power plants, dry cleaners, cars, buses, trucks and even windblown dust and wildfires. Air pollution can threaten the health of human beings, trees, lakes, crops, and animals, as well as damage the ozone layer and buildings (http://www.epa.gov/ebtpages/air.html).
In order to research air quality, students should divide into small groups. Have them follow the steps used in the scientific method (copied on handouts for easier access) found online at the University of California, Riverside’s Department of Physics (http://physics.ucr.edu/~wudka/Physics7/Notes_www/node6.html#SECTION02121000000000000000) as they are conducting their research.
Students will complete the following experiment (copied on handouts for easier access). This experiment is a modified version of an experiment found online at the Howard Hughes Medical Institute Web site (http://www.hhmi.org/coolscience/airjunk/nosep2.html) as part of an experiment called “Specks, Flecks and Particles in the Air.” After students have conducted their experiments and written their reports, they should briefly present the results of their findings to the class. Ideally students should wait 24 hours between the data collection time and the reporting time, however a shorter data collection time may also yield results.
Note to teachers: You may want to create a sample “collector” for students to use as a visual guide while they conduct their experiments.
Directions for the experiment:
1. Create a pattern page. Air irritant collectors can be made in any shape, but the size of a luggage tag is recommended. A sample is available at http://www.hhmi.org/coolscience/airjunk/nosep2.html
2. Each group should cut out six collectors using the pattern from the created page.
3. Fold each collector and cut out the inside window. Then flatten the collector.
4. Write the location, starting date, and time on each collector.
5. Cover the window on the collector with the sticky label or tape. Put the sticky side up or out.
6. Hang the six collectors in designated school locations such as the: cafeteria, locker room, bathroom, classroom, school yard, library

7. Create a hypothesis about what type of air particles you expect to find in each location. Record your hypothesis so that you can determine whether you have successfully proven it.
8. If possible, wait a couple of days, then take the collectors down. Write the ending time and date on each. However, if time is prohibitive, try to wait several hours. Remember not to touch the sticky part of the tag or it will contaminate your results.
9. Investigate your findings with a magnifying glass or a microscope.
Some irritants you might find include: dust, pollen, mold, sand, skin flakes or animal dandruff. You can find pictures of these types of air particles at (http://www.hhmi.org/coolscience/airjunk/nosep4.htm) to see if it matches your results using the microscope.
Students will record their findings in a two-part report. Part A of the report will be done in class. In part A, groups should restate their hypotheses and whether they were able to prove them based on their findings. Part A should also include all data available including date, time, and any special consideration used when taking the samples.
Individually, students should complete the following assignment (written on the board for students to copy): “Part B of the research report should offer a detailed explanation of your findings to be shared with future students. Discuss how they might be affected by your results. As noted in the article, “Shivering and Unsung, Scientists Monitor the Arctic Year After Year After Year,” it is important to conduct research repetitively. This experiment may also be used to inspire ongoing data collection efforts in your school community.
4. WRAP-UP/HOMEWORK: Students should write letters to the appropriate authorities, such as, the Administrator for the Environmental Protection Agency, Steven Johnson, about their findings and offer suggestions as to how the situation involving air pollution in their school might be improved.

Further Questions for Discussion:
-What are other factors that influence air quality?
-Are there certain places that are better suited for people with respiratory problems?
-What kind of research should be done to help improve air quality?

Evaluation / Assessment:
Students will be evaluated based on initial journal responses, participation in class discussions, thoughtful and creative input in group experiments and

reporting, and well-crafted letters to the Administrator of the Environmental Protection Agency.

Vocabulary:
mundane, veneer, descended, glorious, facet, retrieve, strand, anchored, salinity, acoustic, Kevlar, quotidian, unremarkable, unsung, atmospheric, consciousness, oceanography, atmospheric, carbon dioxide, sustain, inconsequential, unstable, declassified, corridors, accumulating, pointillist, array, endured, frigid, illusive, disconcerting, amid, floes, expedition, devising, automated, obsolete, beacon, transmitting

Extension Activities:
1. Monitor the weather reports for the next two weeks. Create your scientific data collection by monitoring weather patterns, temperature highs and lows, as well as historic highs and lows. Create a flow chart of the weather patterns.
2. The article mentions the North Pole as being a crucial site for understanding global warming. Conduct a research report on the North Pole. Find out why the region is critical to ongoing scientific projects.
3. The article also mentions oceanography as a career. Find out what schools offer oceanography programs and become an expert on this endeavor.
4. President Bush has created an award for young environmental activists called P.E.Y.A. (Presidential Environmental Youth Awards). Write an article for your school newspaper profiling some of the award winners.
5. Visit the Web site, http://airnow.gov, and find out what the air quality counts are for your community. Create a poster that highlights the daily air quality counts and make it available in your classroom.
6. Conduct an investigation on current household products and the chemicals used in them that might be harmful to the environment. Make a brochure of this information for distribution in your school.

Interdisciplinary Connections:
Civics- Create an illustrated timeline citing the environmental legislation of various United States Presidents. Highlight past and present legislation that has been helpful and/or harmful to the environment.
Fine Arts- The article mentioned "Pointillism" as an art form. Seurat was a famous artist who practiced this type of art. Research the origin and history of the technique. Create a piece of artwork mimicking this style of painting.
Mathematics- The article compares the depth of the water to the size of the Empire State Building. Find out how large the Empire State Building is, and create a word problem using this measurement to describe the size of your city

or town.
Teaching with The Times- Scan The Times over a specified period of time (one week or longer) for articles about environmental policy in the United States and around the world. Clip each article you find and write a summary analyzing the main trends. How does United States environmental policy respond to, differ from or contradict the findings of environmental groups? Post the articles and summaries on a bulletin board or in a binder in the classroom. To order The New York Times for your classroom click here.

Other Information on the Web:
The Learning Network's Global Warming special section (http://www.nytimes.com/learning/globalwarming) offers lesson plans, articles, crosswords, and much more, including an opportunity to ask Times reporter Andrew C. Revkin questions about the Arctic and global warming.
Plain Text Guide to the Clean Air Act (http://www.epa.gov/oar/oaqps/peg_caa/pegcaain.html) presents the statute in clear, simple language, and provides definitions of the various pollutants regulated by the E.P.A.

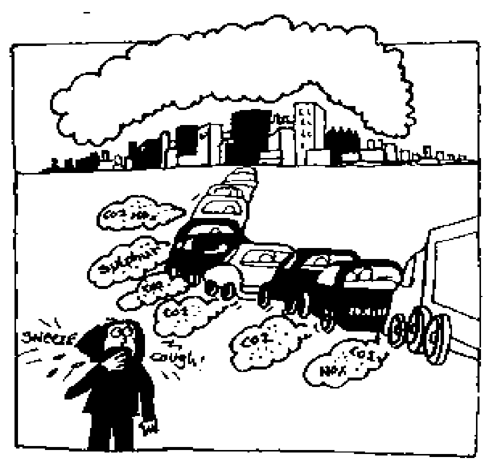
Academic Content Standards:
Grades 6-8 Science Standard 14-Understands the nature of scientific knowledge. Benchmark: Understands that questioning, response to criticism, and open communication are integral to the process of science Science Standard 15- Understands the nature of scientific inquiry. Benchmarks: Understands the nature of scientific explanations; Knows that scientific inquiry includes evaluating results of scientific investigations, experiments, observations, theoretical and mathematical models, and explanations proposed by other scientists Science Standard 16- Understands the scientific enterprise. Benchmark: Knows ways in which science and society influence one another Geography Standard 8- Understands the characteristics of ecosystems on Earth's surface. Benchmarks: Understands the distribution of ecosystems from local to global scales; Understands the functions and dynamics of ecosystems; Understands ecosystems in terms of their characteristics and ability to withstand stress caused by physical events; Knows changes that have occurred over time in ecosystems in the local region; Knows the potential impact of human activities within a given ecosystem on the carbon, nitrogen, and oxygen cycles; Understands the life cycle of a lake ecosystem from birth to death Geography Standard 14- Understands how human actions modify the physical environment. Benchmarks: Understands the environmental consequences of people changing the physical

environment; Understands the ways in which human-induced changes in the physical environment in one place can cause changes in other places Geography Standard 18- Understands global development and environmental issues. Benchmark: Understands how the interaction between physical and human systems affects current conditions on Earth Language Arts Standard 1- Demonstrates competence in the general skills and strategies of the writing process. Benchmarks: Uses style and structure appropriate for specific audiences and purposes; Writes expository compositions Language Arts Standard 4- Gathers and uses information for research purposes. Benchmarks: Uses a variety of resource materials to gather information for research topics; Organizes information and ideas from multiple sources in systematic ways

Grades 9-12 Science Standard 14-Understands the nature of scientific knowledge. Benchmark: Knows that scientific explanations must meet certain criteria to be considered valid Science Standard 15- Understands the nature of scientific inquiry. Benchmark: Knows that conceptual principles and knowledge guide scientific inquiries (historical and current scientific knowledge influence the design and interpretation of investigations and the evaluation of proposed explanations made by other scientists) Science Standard 16- Understands the scientific enterprise. Benchmark: Knows that creativity, imagination, and a good knowledge base are all required in the work of science and engineering Geography Standard 8- Understands the characteristics of ecosystems on Earth's surface. Benchmarks: Understands how relationships between soil, climate, and plant and animal life affect the distribution of ecosystems; Knows ecosystems in terms of their biodiversity and productivity and their potential value to all living things; Knows the effects of biological magnification in ecosystems; Knows the effects of both physical and human changes in ecosystems Geography Standard 14- Understands how human actions modify the physical environment. Benchmark: Understands the global impacts of human changes in the physical environment Geography Standard 18- Understands global development and environmental issues. Benchmark: Understands contemporary issues in terms of Earth's physical and human systems Language Arts Standard 1- Demonstrates competence in the general skills and strategies of the writing process. Benchmarks: Writes compositions that are focused for different audiences; Writes compositions that fulfill different purposes; Writes expository compositions Language Arts Standard 4- Gathers and uses information for research purposes. Benchmarks: Determines the validity and reliability of primary and secondary source information and uses information accordingly in reporting on a research topic; Identifies and defends research questions and topics that may be important in the future

TEACHER BACKGROUND INFORMATION
CALCULATING YOUR CARBON FOOTPRINT

Your ***carbon footprint*** is a representation of the effect you, your family or school, have on the climate in terms of the total amount of greenhouse gases you produce (measured in units of carbon dioxide). Many of your actions generate carbon emissions, which contribute to accelerating global warming and climate change. By measuring your carbon footprint through such tools as the ***The Global Warming Wheel Card*** from the U.S. Environmental Protection Agency, you can get a better sense of what your individual impact is and which parts of your lifestyle deserve the greatest attention. Armed with such information you can more readily take effective action to shrink your carbon footprint, thereby minimizing your personal impact on the climate.



For example, when you drive a car, each gallon of gasoline you burn produces carbon in the form of carbon dioxide. Depending on the fuel efficiency of your vehicle and the miles traveled, a gasoline-powered car can easily generate its own weight in carbon dioxide each year. The average American is responsible for about 20 tons of carbon dioxide emissions each year, a far greater per capita number than that of any other industrialized country. In fact, the US, with less than 5% of the world's population, accounts for more than 20% of the world's total greenhouse gas emissions. You can reduce your carbon footprint by driving a more efficient car, or driving less. You can also plant trees or help preserve forests to offset your emissions, since trees are a sink for carbon.

The carbon footprint calculator estimates CO_2 emissions for energy use and transportation, and for organizations paper use, because these types of activities are responsible for a significant percentage of U.S. emissions, and are measurable based on readily available information. Your total carbon footprint would account for the energy used to produce all the products and services you consume, as well as all your other activities, and would be substantially larger. Home energy use and transportation represent approximately 40% of all U.S. emissions, so for an average person the emissions from these two activities would have to be multiplied by 2.5 to determine the person's total carbon footprint.

Ecological Footprint

There are many other ways to visualize our individual and overall human impact on the environment. Some environmental and government groups feature a broader concept than the carbon footprint -- the ecological footprint, which is an estimate of how much land and water is needed to produce all the resources an individual consumes, and dispose of all the waste and pollution he or she generates. Because of increasing population and levels of consumption and pollution, human beings are leaving bigger and bigger ecological footprints - at a rate that is increasingly harmful to the planet.

For example, ***Redefining Progress*** estimates that the typical American uses 25 acres to support his or her lifestyle, almost five times more than is sustainable. This non-profit group provides tools to calculate your own ecological footprint, and links to many other such calculators. More information on ecological footprints is provided by ***Sustainable USA*** and the British group, ***Best Foot Forward.***

SafeClimate typically quotes greenhouse gas units in terms of carbon dioxide (1lb carbon dioxide = 0.2729 lbs of carbon), as well as converting other greenhouse gases into units of carbon dioxide based on their relative global warming potentials. This standardized approach simplifies things and makes for easier and more meaningful comparisons.

INSTRUCTIONAL ACTIVITY
CREATING A PERSONAL CARBON CALCULATOR

GOAL: Students understand their contributions to greenhouse gas emissions by collecting and analyzing their home energy use.

OBJECTIVES: Students will…

- Build a personal emissions calculator
- Gather information on their daily habits
- Evaluate their daily habits
- Determine their personal contribution to greenhouse gas emissions

MATERIALS (Determine by class size):

- Copies of "What Is A Carbon Footprint?"
- Copies of Personal Emissions Calculator – Student Sheet
- Copies of wheel pieces
- Glue sticks
- Scissors
- Brads or paper fasteners
- Optional: Highlighters in a variety of colors
- Optional: Calculators
- Optional: Copies of **Ecological Footprints of Nations** (1999 Data)

ALIGNMENT TO NATIONAL SCIENCE STANDARDS:

- ✓ Unifying Concepts and Processes (K-12)
  - Consistency, change, and measure
- ✓ Science as Inquiry, Content Standard A (9-12):
  - Abilities necessary to do scientific inquiry
  - Understandings about scientific inquiry
- ✓ Life Science, Content Standard C (9-12):
  - Interdependence of organisms
  - Matter, energy, and organization in living systems
  - Behavior of organisms
- ✓ Earth and Space Science, Content Standard D (9-12):
  - Energy in the earth system
- ✓ Science in Personal and Social Perspective, Content Standard F (9-12):
  - Personal and community health

- Environmental quality
- Science and technology in local, national, and global changes

PROCEDURE:

1. Pass out "What Is A Carbon Footprint" to each student. Allow them time to read while you pass out other materials.

2. Review the information on "What Is A Carbon Footprint".

3. Pass out the **Personal Emissions Calculator – Student Sheet**, wheel pieces, glue sticks, scissors, and brads to each student.

4. Have them follow the directions on the student sheet to create their personal emissions calculator.

5. Allow students time to build the wheel and calculate their personal emissions.

6. Ask each student to share their personal emission total and write their totals as a list on the board.

7. Pass out calculators or have students do addition manually to determine the class average emission total.

8. Compare this to the national average listed on the wheel they created and to the averages of other countries using the "**Ecological Footprints of Nations** "(1999 Data) .

9. Now have students use the "What Can I Do" side of the wheel to determine different ways they can help reduce emissions.

OPTIONAL HOMEWORK: Each student should write a commitment statement outlining how he or she will help reduce emissions.

EXTENSION: Students can use **Monthly Electricity Use - Common Household Appliances** to identify exactly where they expend the most energy.

***Adapted from Environmental Protection Agency's "Climate Change, Wildlife and Wildlands"**

PERSONAL EMISSIONS CALCULATOR - STUDENT GRID

SECTION 1: Complete the grid below. You will have to use your family's electric bill, natural gas bill, and an adult's input on car use. You should be able to *guesstimate* the waste disposal section. Remember that it is important to be honest when completing this grid. You will be assessed on the accuracy of your information. If you cannot find some of the information, your teacher can help you.

HOME HEATING	TRAVEL	WASTE DISPOSAL	ELECTRICITY USE
In the box below, write how much money your family spends on natural gas or fuel gas on average each month.	In the box below, write roughly how many miles your family puts on their car(s) on average per week.	In the box below, write how many items your family recycles (for example, plastics, aluminum, etc.).	In the box below, write how much money your family spends on electricity on average each month (check your electricity bill).

SECTION 2: After you make your personal emissions calculator, fill in the pounds of CO_2 your family emits each year (this will be the number in the small box of your personal emissions calculator). Add the first four numbers to calculate your total emissions.

HOME HEATING	
ELECTRICITY USE	
WASTE DISPOSAL	
TRANSPORTATION	
TOTAL EMISSIONS	

*Adapted from Environmental Protection Agency's "Climate Change, Wildlife and Wildlands"

PERSONAL EMISSIONS CALCULATOR - STUDENT SHEET
ASSEMBLY INSTRUCTIONS

1. Cut out the two large circles & two large rectangular pieces.

2. Cut out the two little rectangular windows on each of the large rectangular pieces.

3. Put glue on the backs of both circles and put them together to make the "wheel" of the wheel card, making sure that you align them so that the four labels that run along the outside of each circle (Waste Disposal, Home Heating, Electricity Use, and Transportation) line up with the corresponding labels on the other side. The Waste Disposal label on one side should line up with the Waste Disposal label on the other side, and so on.

4. Lay the rectangular piece entitled "What Can You Do?" upside-down on the table with the larger of the two cutouts closer to you. If you lift up the edge of the rectangular piece and see the words "Global-Warming—What Can You Do?" right side up, you've done it correctly.

5. Put the glued-together wheel on top of the rectangular piece, with the side that has all the questions (such as "On average, how much does your household spend on electricity each month?") facing up.

6. Lay the other rectangular piece entitled "What's Your Score?" on top of the wheel, with the smaller of the two cutouts closer to you.

7. Find the "belly button" on the pasted-together wheel and the two large rectangular pieces. Push a paper fastener ("brad") through the "belly button" to hold all the pieces together.

8. Glue the large rectangular pieces in all four corners just enough to hold the rectangles together but allowing the wheel to turn freely.

9. Highlight each line inside the windows in a different color to make it easier to read.

10. Using the information from your grid, calculate your personal emissions and fill in the last line on your grid worksheet.

11. Work with the class to figure your class emission average.

12. Use the "What Can You Do" side of the card to determine how you can help reduce emissions.

*Adapted from Environmental Protection Agency's "Climate Change, Wildlife and Wildlands"

PERSONAL EMISSIONS

MONTHLY ELECTRICITY USE COMMON HOUSEHOLD APPLIANCES

(HEATING AND LIGHTING NOT INCLUDED)

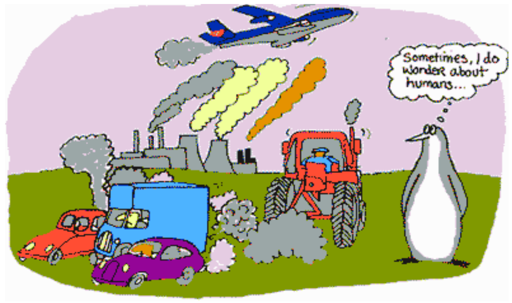
APPLIANCE	PEAK POWER (W)	APPROXIMATE MONTHLY USE KWH	MY HOME USE (ESTIMATE)
Blender	350	1	
Broiler	1450	8	
Coffee maker	900	10	
Clothes dryer 5 load per week	5000	83	
Dish Washer hot water not incl.	1200	120	
Electric Blanket	180	12	
Food freezer $(15ft)^3$	340	90 (manual defrost)	
Food freezer $(15ft)^3$	450	150 (auto defrost)	
Electric Food Disposal "garbarator"	450	3	
Electric Frying Pan	1200	15	
Electric Hand Iron	1000	12	
Microwave Oven	1400	16	
Radio/CD/Stereo	110	9	
Electric Range	180	70	
Self-cleaning unit (on range)	4000	4	

Refrigerator with freezer	330	60 (manual defrost)	
Refrigerator with freezer	600	140 (auto defrost)	
Toaster	1200	5	
TV (bw solid state)	55	10	
TV (color solid state)	200	36	
Vacuum Cleaner	630	4	
Washer (hot water not incl.)	500	8	
Water bed (heater)	370	150	
Water heater	4500	400	
		TOTAL (kWh)	
Conversion Chart - kWh to CO2		TOTAL (CO_2) (kg)	

ECOLOGICAL FOOTPRINTS OF NATIONS (1999 DATA)

		(in global acres per capita)		
COUNTRY	POPULATION (IN MILLIONS)	ECOLOGICAL FOOTPRINT (PER PERSON)	CURRENT CAPACITY (PER PERSON)	ECOLOGICAL DEFICIT (IF NEGATIVE)
WORLD	6,210.1	6.0	4.7	(-1.3)
Argentina	37.9	7.5	16.5	9.0
Australia	19.7	18.7	36.1	17.4
Austria	8.1	11.7	6.9	(-4.8)
Bangladesh	134.0	1.3	0.7	(-0.6)
Brazil	174.5	5.9	14.9	9.0
Canada	31.2	21.8	35.2	13.3
Chile	15.6	7.7	10.5	(-2.8)
China	1,284.2	3.8	2.6	(-1.2)
Denmark	5.4	16.2	8.0	(-8.2)
Egypt	66.2	3.7	1.9	(-1.8)
Finland	5.2	20.8	21.3	0.5
France	59.3	13.0	7.1	(-5.9)
Germany	82.2	11.6	4.3	(-7.3)
India	1,053.4	1.9	1.7	(-0.2)
Indonesia	217.3	2.8	4.5	1.7
Italy	57.7	9.5	2.9	(-6.6)
Japan	127.2	11.8	1.7	(-10.0)

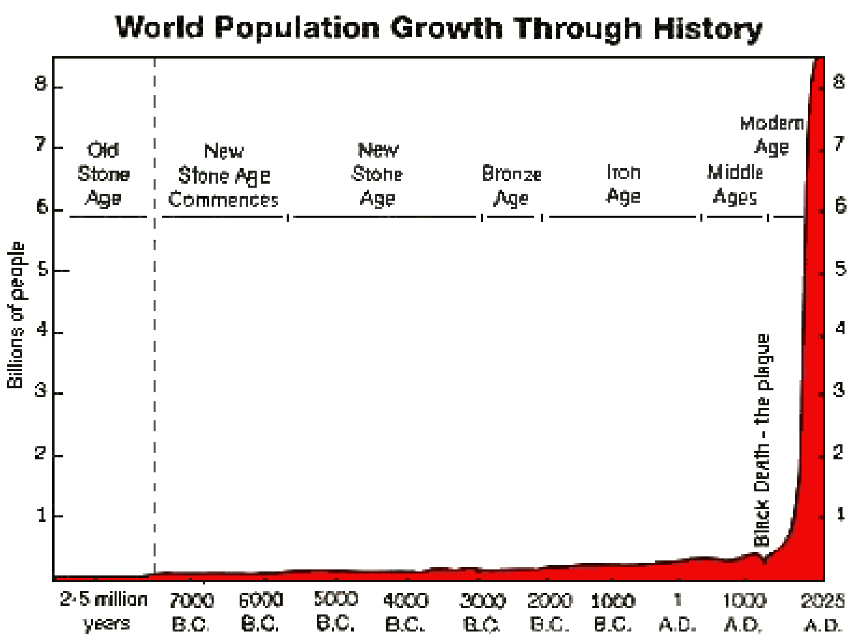
Korea Republic	48.1	8.2	1.8	(-6.4)
Malaysia	24.4	7.8	8.4	0.6
Mexico	100.8	6.2	4.2	(-2.1)
Netherlands	16.1	11.9	2.0	(-9.9)
Norway	4.6	19.6	14.7	(-4.9)
Pakistan	144.8	1.6	1.0	(-0.6)
Philippines	78.3	2.9	1.4	(-1.5)
Poland	38.6	9.1	4.0	(-5.1)
Russia	144.2	11.1	12.0	0.9
South Africa	44.2	10.7	6.0	(-4.7)
Spain	39.5	11.5	4.4	(-7.1)
Sweden	8.9	16.6	18.1	1.5
Switzerland	7.3	10.2	4.5	(-5.7)
Thailand	61.7	3.8	3.4	(-0.4)
Turkey	67.2	4.9	3.0	(-1.8)
United Kingdom	60.2	13.2	4.1	(-9.1)
United States	288.3	24.0	13.0	(-10.9)



TEACHER BACKGROUND INFORMATION

CONNECTING POPULATION GROWTH AND CLIMATE CHANGE

The increase in the size of a population (such as the human population) is an example of ***exponential growth.*** The human population grew at the slow rate of less than 0.002 percent a year for the first several million years of our existence. Since then the average annual rate of human population has increased to an all-time high of 2.06 percent in 1970. As the base number of people undergoing growth has increased, it has taken less and less time to add each new billion people. It took 2 million years to add the first billion people; 130 years to add the second billion; 30 years to add the third billion; 15 years to add the fourth billion; and only 12 years to add the fifth billion. We are now approaching the seventh billion!



Bacteria multiply by division; one bacterium divides and becomes two; the two become 4; the 4 becomes 8 and so on. Assume that for a certain type of bacteria the doubling time is 1 minute, Suppose one bacterium is placed in a bottle at 11:00 Am. When the bottle is observed at noon, it is full. This is a simple example of exponential growth in a finite environment, mathematically similar to the exponentially growing human population and its increasing consumption of out finite natural resources. Keep this in mind when considering the following questions about the bacteria:

- At what time was the bottle half full? Answer: 11:59AM

- If you were an average bacterium, at what time would you first realize that consider: At 11:55AM when the bottle was only 3% filled and 97% empty, would you be likely to perceive the problem?

- Suppose that at 11:58Am some far-sighted bacteria realize that they are running out of space. With a great expenditure of effort and funds, they launch a frantic search for new bottles. They look offshore and in the arctic and at 11:59 AM they discover 3 new empty bottles. Great sighs of relief come from all the worried bacteria!

- The discovery quadruples the total space resource known to the bacteria. Surely this will solve the problem so that the bacteria can be self-sufficient in space!

- How long can the bacterial growth continue in the quadrupled space resource? Answer: Two more doubling times (minutes)

The following chart documents the last minutes in the bottles:

THE EFFECT OF THE DISCOVERY OF NEW BOTTLES

TIME	EFFECT
11:58 AM	Bottle #1 is 25% full
11:59 AM	Bottle #1 is 50% full
12:00 Noon	Bottle #1 is full
12:01 PM	Bottles #1 and 2 are full
12:02 PM	Bottles #1,2,3 and 4 are full

Quadrupling the resource extends the life of the resource by only 2 doubling times. When consumption grows exponentially, enormous increases in resources are consumed in very short times!

Like the bacteria, the human population is growing, using resources and expelling their by-products at an exponential rate. The maximum population the Earth can sustain at some reasonable average living standard for its inhabitants is called the ***carrying capacity.*** The human population today is over 6 billion. The question is: Can we adequately provide the minimal needs for 7 billion people without sacrificing the quality of our environment? Raising their consumption of natural resources to anything approaching that in developed countries may be impossible. Therefore, the population issue, along with many others, must receive our most serious consideration as we plan for the years ahead. If we do not control our global population, natural forces will do it for us.

Be fruitful and multiply... Now divide.

INSTRUCTIONAL ACTIVITY

STAND UP AND BE COUNTED!

OVERVIEW: All population growth, from bacterial division to human procreation are models of exponential growth until natural resources become scarce or diseases or competition start taking a heavy toll. Since the first humans walked the planet, humans have changed ecosystems as they searched for food, fuel, shelter and living space. However, with the start of the Industrial Revolution in the late 1700s, the human influence on the global ecosystem has been seriously increased. A burgeoning human population has modified Earth's ecosystems through advancements in technology and rampant resource consumption. Human destruction of habitats and species through direct harvesting, pollution, atmospheric changes, and other factors is threatening current global stability, and, if not addressed, ecosystems will be irreversibly affected.

OBJECTIVES: Students will:

- develop a model of the exponential nature of population growth.
- consider the population growth of plant and animal species and the resultant stresses that contribute to natural selection.

MATERIALS/ EQUIPMENT

Each group of three or four students will need:

- Approximately 2,000 small, uniformly shaped objects (kernels of corn, dried beans, wooden markers, plastic beads)
- 10 paper cups or small beakers
- A 250-ml or 400-ml beaker

PROCEDURE:

PART I: ENGAGEMENT-

1. Initiate a discussion on human population with such questions as:

- How long have humans been on the earth?
- How do you think the early rate of human population growth compares with the population growth rate today?
- Why did this rate change?

2. Tell students that this investigation represents a model of population growth rates.

PART II: EXPLORATION: Have student groups complete the following activities.

1. Place the glass beakers on their desks.

2. Begin by placing two objects (e.g., corn or plastic beads) in it. **[The beaker represents the limits of an ecosystem or ultimately the earth.]**

3. Place 10 cups in a row on their desk.

   - In the first cup, place two objects.
   - In the second cup, place twice as many objects as the first cup (four).
   - Have students record the number of objects on the outside of the cup.

4. Continue this procedure by placing twice as many objects as in the former cup, or doubling the number, in cups 3 through 10.
   - Be sure students record the numbers on the cups.

5. Take the beaker and determine its height.

   - Have students indicate the approximate percentage of volume that is *without* objects.
   - Record this on the table as 0 time.

6. At timed intervals of 30 seconds, add the contents of cups 1 through 10.

   - Students should record the total population and approximate percentage of volume in the beaker that is without objects.

7. Students should complete the procedure and graph their results as total population versus results.

Note: Students may question the need for the 30-second intervals. The length of the time interval is arbitrary. Any time interval will do. Preparation of the graph can be assigned as hork.

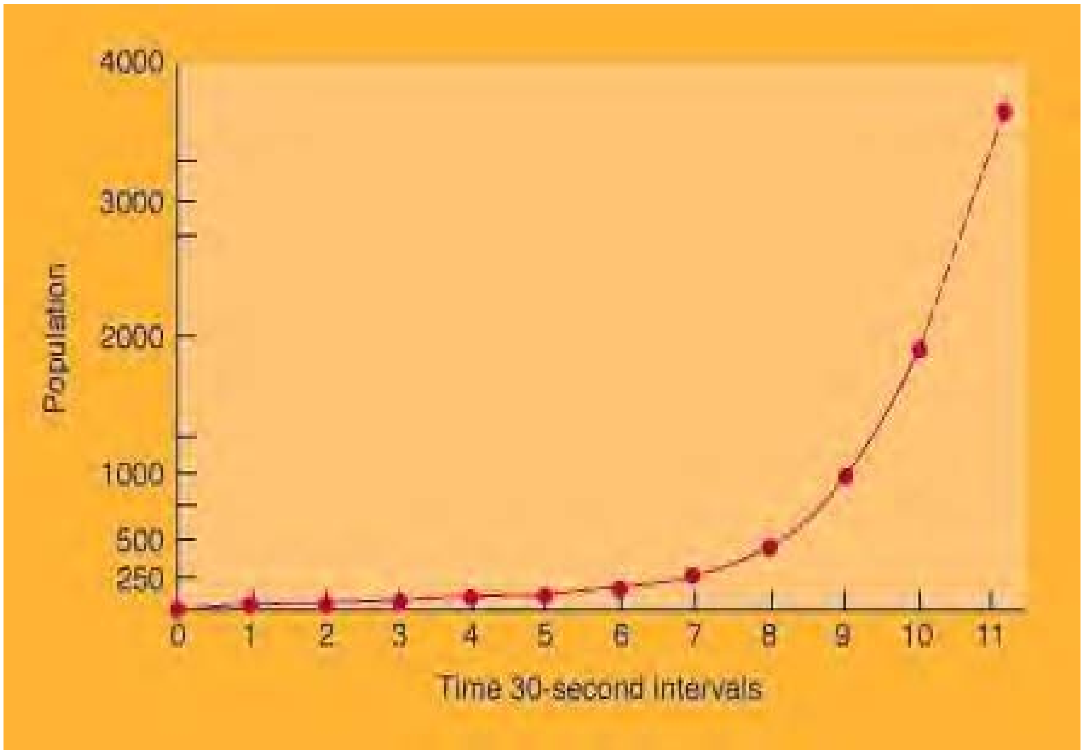


Figure 1--Sample population growth graph

TABLE 1 POPULATION GROWTH		
Time Internal	Population	Percentage of empty volume (400-ml beaker
0	2	99%
1	4	99%
2	8	99%
3	16	98%
4	32	97%
5	64	95%
6	128	93%
7	256	88%
8	512	80%
9	1024	70%
10	2048	50%
11	4096	0%

RANGE OF RESULTS

The mathematics involved in answering the questions may challenge some students. Assist students when necessary to enable them to accomplish the objectives of the investigation. Table 1 shows the population and the percent of the beaker's volume without objects. A typical student graph is shown in Figure 1.

PART III: EXPLANATION —

- Ask the students to explain the relationship between population growth and biological evolution in populations of microorganisms, plants, and animals.
- Through questions and discussion, help them develop the connections stated in the learning outcome for the activity. Evolution results from an interaction of factors related to the potential for species to increase in numbers, the genetic variability in a population, the supply of essential resources, and environmental pressures for selection of those offspring that are able to survive and reproduce.

PART IV: ELABORATION —

1. Begin by having students explain the results of their activity.

2. During the discussion of the graph, have the students consider some of the following:

- Are there any limitations to the number of people the earth will support?
- Which factor might limit population growth first?
- How does this factor relate to human evolution?
- Are there areas in the world where these limits have been reached already?
- Have we gone beyond the earth's ideal population yet?
- What problems will we face if we overpopulate the earth?
- How might human influence on, for example, habitats affect biological evolution?
- What factors enabled the rapid growth of the last decades and century?

Note: Students' answers to these questions will vary, depending on their background and information. The outcome, however, should be an intense discussion of some vital problems and should provide opportunities to introduce some fundamental concepts.

PART V:EVALUATION —

1. Human population on the earth is thought to have had a slow start, with doubling periods as long as 1 million years. The current world population is thought to be doubling every 37 years. How would this growth rate compare with the rates found in your investigation?

Answer: Both the population in the investigation and on the earth increase in a geometric progression. This means the graphs have the same shape. You can substitute 37 years for every 30-second interval and the numbers will represent actual world population growth. The slope of the graph would remain the same.

2. What happens to populations when they reach the limits to growth?

Answer: The populations stop growing because death rates (or emigration) exceed birth rates (or immigration).

Notes:

1. *Investigating the Earth.*
2. Thomas Malthus. 1993. *Essay on the Principle of Population.* Geoffrey Gilbert, ed. Oxford: Oxford University Press.

Teaching Activity: Industrial CO_2 Emissions

Introduction: The dominant anthropogenic source of greenhouse gases are the industrial processes that generate CO_2 - burning of fossil fuel and the production of cement. These activities also represent the greatest opportunity for reductions of greenhouse gases to the atmosphere. Major industrial and large developing countries such as China and India rank high on the international list of the countries with the largest emissions of CO_2. On a per capita basis, however, China and India rank very low. At present, the world's total emissions are over 6.5 million metric tons of carbon per year. The world's population is fast approaching 6 billion. Therefore, each person on the planet adds the equivalent of more than 1 metric ton of carbon to the atmosphere each year. The amount emitted varies, however, from region to region and from country to country. A concerted effort is being made on a global level to control and limit the effects of emissions as part of an international program to develop a clear and detailed picture of greenhouse gases and their sources.

Objectives:

- To calculate the per capita heating value contributed by several different countries;
- To illustrate that data in several different formats;

Important Terms: Per capita, greenhouse gases, X-axis, Y-axis, coordinates, global warming potential;

Materials: **Student Activity Sheet**, paper/pencil, colored pencil, ruler, calculator, graph paper;

Procedure:

1. Read and discuss the **Introduction** and the **Data Table**.
   - Be sure that students know the difference between total emissions and per capita.
   - Explain what "projected" population means.

2. Have students calculate the per capita contributions for each country using the following formula and then moving the decimal point in the final answer 3 places to the left:

Total carbon emissions	-	Total population	=	Per capita emissions
55,194	÷	28.58	=	1.931

- Students should record their answers on the **Data Table** in the correct spaces.

4. Students should then go on to create a bar graph of the top 15 countries with the highest total CO_2 emissions by industry sources for 1991.
   - Y- axis should be labeled: **Metric tons of carbon dioxide per capita**
   - X-axis should be labeled: **Country**
   - Y-axis notations should proceed from: **0 at the bottom to 30 at the top;**
   - A different color should be used for each country;

5. Students should write a title for their graph.

6. Students should then answer all questions in the **Analysis and Comprehension** section.

Data Table: CO_2 Emissions From Industrial Processes, 1995

Country	RANK	Total CO_2 (Millions of Tons)	Pop. (Project) 1995	Per Capita	COUNTRY	RANK	Total CO_2 (Millions of Tons)	Pop. (Project) 1995	Per Capita
Romania		138,027	23.51		United States		4,931,630	263.14	
Austria		68,331	7.86		Japan		1,091,147	125.88	
Portugal		41,792	9.88		Indonesia		170,468	201.48	
Netherlands		138,990	15.50		Sweden		53,498	8.77	
Venezuela		121,604	21.48		Nigeria		91,930	126.93	
Germany		969,630	81.26		Iraq		520,281	21.22	
Italy		402,516	57.91		Canada		410,628	28.54	
Hungary		63,574	10.47		Yugoslavia		87,225	24.11	
U.A.R.		59.459	1.79		Norway		58,672	4.36	
Iran		222,361	66.72		Switzerland		41,843	6.96	
Argentina		115,848	34.26		Poland		308,164	38.74	
China		2,543,380	1,238.32		South Africa		278,695	42.74	
Thailand		100,896	58.27		Brazil		215,601	161.38	
USSR		3,581,179	288.56		Korea, D.P.R.		243,235	23.92	
Spain		219,877	39.28		Egypt		81,667	58.52	
Czechoslovakia		191,356	15.88		Colombia		57,503	35.10	
Libya		43,008	5.41		Saudi Arabia		241,919	17.61	
India		703,550	931.04		Philippines		44,587	69.26	
France		374,113	57.77		Greece		72,866	10.25	
Belgium		102,079	10.03		Bulgaria		56,675	8.89	
Australia		261,818	18.34		Finland		52,047	5.05	
United Kingdom		577,157	58.09		Pakistan		68,487	134.97	
Mexico		339,873	93.67		Denmark		63,054	5.19	
Rep. of Korea		264,647	45.18		Algeria		55,194	28.58	
Turkey		142,555	62.03		Malaysia		61,196	20.13	

Student Activity Sheet: Industrial CO_2 Emissions

Introduction. The dominant anthropogenic source of greenhouse gases are the industrial processes that generate CO_2 - burning of fossil fuel and the production of cement. These activities also represent the greatest opportunity for reductions of greenhouse gases to the atmosphere. Major industrial and large developing countries such as China and India rank high on the international list of the countries with the largest emissions of CO_2. On a per capita basis, however, China and India rank very low. At present, the world's total emissions are over 6.5 million metric tons of carbon per year. The world's population is fast approaching 6 billion. Therefore, each person on the planet adds the equivalent of more than 1 metric ton of carbon to the atmosphere each year. The amount emitted varies, however, from region to region and from country to country. A concerted effort is being made on a global level to control and limit the effects of emissions as part of an international program to develop a clear and detailed picture of greenhouse gases and their sources.

Objectives:

- To calculate the per capita heating value contributed by several different countries;
- To illustrate that data in several different formats;

Procedure:

1. Read and discuss the **Introduction** and **Data Table** with your teacher.

2. Calculate the per capita contributions for each country using the formula below
   - Move the decimal point in your answer 3 places to the left.

Total carbon emissions	÷	**Total population**	=	**Per capita emissions**
55,194	÷	**28.58**	=	**1.931**

   - Record your answers in the **Data Table**.

3. Rank each country according to its per capita contribution.

4. Create a bar graph of the top 15 countries with the highest CO_2 emissions by industry sources for 1991.
   - Label the Y-axis: **Metric tons of carbon dioxide per capita.**
   - Label the X - axis: **Country.**
   - Make the Y-axis notations: **0 - 30 from bottom to top.**
   - Use a different color for each country.
   - Give the graph a title.

5. Answer the questions in the **Analysis and Comprehension** section.

Student Activity Sheet #1

Analysis and Comprehension:

1. What do scientists consider the dominant source of greenhouse gases from human activity? ____________________

2. What potential do these two activities hold for the future? ____________________

____

3. Why would you expect to find countries like China and India high on the list for total CO_2 emissions? ____________________

____

____

4. Why would they rank very low in per capita contributions? ____________________

____

5. What are the total emissions of CO2 for 1991? ____________________

6. What is the average per capita contribution?____________________

7. What are countries doing in an effort to control greenhouse gas emissions, especially CO_2? ____________________

____

8. What country has the highest per capita contribution? ____________________

9> What does that tell you about the living standards in that country? __________

____

____

10. List the 15 countries with greatest per capita contributions, from highest to lowest.

__________	__________	__________
__________	__________	__________
__________	__________	__________
__________	__________	__________
__________	__________	__________

11. Why do you think that Iraq's contribution in 1991 was so high? ______________

____

____

12. Which 3 of the top 15 countries would probably be the least comfortable to live in ? Why? ______________________________________

____

13. What can you say about the contribution made by the U.S. as compared to the contribution made by China and India, even though all are large countries?

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____

14. What sources of CO_2 have not been included in this data? ______________

____

15. How would the answer in #14 affect the ranks of countries like Colombia, Brazil and Indonesia? Why? ______________________________

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