MR. GREEN
LESSON PLAN

FUTURESTATES

COMMUNITY CLASSROOM
ENGAGING STUDENTS AND EDUCATORS THROUGH FILM

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COMMUNITY CLASSROOM
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COMMUNITY CLASSROOM is an innovative education resource providing short documentary video content and accompanying curricular materials, lesson plans, and homework assignments to high school and community college instructors and youth-serving community-based organizations. Film modules are drawn from documentaries scheduled for broadcast on the Emmy Award-winning PBS series *Independent Lens*. Content is grouped into subject specific segments that correspond to lesson plans and educational activities. All COMMUNITY CLASSROOM lesson plans are designed with key education standards in mind, and are available free of charge online, along with the film modules.

COMMUNITY CLASSROOM is a program of the Independent Television Service, created with support from the Corporation for Public Broadcasting. Lesson plans were developed with guidance from the American Association of Community Colleges, KQED Education Network, National Association for Media Literacy Education, National Council for the Social Studies, National State Teachers of the Year, and PBS Teachers.

Global Warming
Lesson Plan Overview

Topics
Ecology; global warming; climate change; photosynthesis; human effects on climate change; science and technology in local, national, and global challenges; autotrophic/heterotrophic organisms; bioengineering; epidemiology; evolution.

Target Audience
Grade 9 Biology; Grades 10-12 Advanced, AP, or Dual-Credit Biology; Environmental Science. This lesson is designed to follow instruction in Ecology and ecological cycles and requires familiarity with the concepts of global warming and climate change. Knowledge of photosynthesis and genetic transfer are also recommended.

National Educational Standards
All components are aligned to the National Science Education Standards as presented by the National Academy of Science and available as a free download at http://www.nap.edu/catalog/4962

NS.9-12.3 LIFE SCIENCE
As a result of their activities in grades 9-12, all students should develop understanding of
- The cell
- Molecular basis of heredity
- Biological evolution
- Interdependence of organisms
- Matter, energy, and organization in living systems

NS.9-12.5 SCIENCE AND TECHNOLOGY
As a result of activities in grades 9-12, all students should develop
- Abilities of technological design
- Understandings about science and technology

NS.9-12.6 PERSONAL AND SOCIAL PERSPECTIVES
As a result of activities in grades 9-12, all students should develop understanding of
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

In addition to the National Standards for Science, the lesson plans provide an excellent framework for instruction in Media Literacy. This instruction further supports both NS.9-12.1 SCIENCE AS INQUIRY and NS.9-12.7 HISTORY AND NATURE OF SCIENCE by instructing students in methods that will make them more effective in media analysis. Information on Media Literacy can be found at www.NAMLE.net.

Time
Each lesson is designed for a 45-55 minute class period. The modules may be separated or combined to accommodate differences in instructional time. The entire unit may be completed in 3 days, but may also be extended to include additional activities or to provide additional time where needed (see Extension Activities).

Overview of *Mr. Green*

In this parable about climate change, a jaded government undersecretary becomes the unwitting test subject in an experimental program to curb global warming.

Summary of Lesson

In this lesson, students will analyze selected data that supports global warming, watch the film *Mr. Green*, analyze the validity of the solution presented in the film, and investigate the concept of carbon dioxide sequestration.

Background Brief

This is information for the teacher. It includes information that may help you help your students understand the underlying science in the film.

The Problem of Excess Carbon Dioxide

Since the beginning of the Industrial Revolution, the levels of atmospheric carbon dioxide have risen. The resulting increase in CO2 is contributing to a rise in the average temperature of the planet. This change in global temperature, often referred to as "global warming," is linked to many apparent widespread changes in our climate. Examples of these changes include greater storm intensity; increased drought, flooding, and wildfires; shifts in seasons; and more severe heat waves.

How Did This Happen?

The most commonly stated reason for global warming is the excessive burning of fossil fuels like coal, oil, and natural gas. The carbon within these fuels has been locked inside the original plant material for millions of years. Burning these products releases carbon from deep within the Earth into the atmosphere at an accelerated rate. While the ocean, soil, and plants have always acted as gigantic carbon "sinks," absorbing excess carbon dioxide from the air, the rate and amount of carbon dioxide released by the burning of fossil fuels is overwhelming the cycle, leading to a buildup of CO2 levels in the atmosphere.

What About the Trees?

The soils and land-based plants of the world are collectively the world's largest carbon sink. Through the process of photosynthesis, the trees and other plants are able to take in carbon dioxide gas and "tie it up" in the form of glucose as part of the biomass of the plant. Although plants do release some carbon dioxide as a waste gas during respiration, they sequester much more during the process of photosynthesis. However, deforestation has greatly reduced the number of forests on the planet. Also, rising temperatures and decreased rainfall have affected the efficiency of photosynthesis for many plants.

Euglena/Endosymbiont Theory

Is there such a thing as an organism that can be both photosynthetic (autotrophic) and heterotrophic? The protist known as Euglena is. In fact, the Endosymbiont Theory implies that in the past, many organisms were able to accomplish this feat. The chloroplast, which is the photosynthetic "machine," has its own genome. If you needed to isolate the gene for a chloroplast, you could find it in the plastid itself.

Genetic Engineering/Gene Transfer

Although certainly not likely to happen any time soon, the idea of genetically altering a human to express chloroplasts in the skin does deserve some consideration. If the chloroplast genome and its controls could be isolated, if there were vectors that could deliver it (such as pollen grains or viral particles), and if the host could avoid being harmed by the products of the chloroplast (glucose), then such a gene transfer might be possible. If the transfer worked, it could result in a planet of organisms with a combined carbon footprint of zero. Such a scenario might not reverse global warming, but it could potentially halt further warming.

Precautionary Principle

In 1998, the Precautionary Principle was presented as a proposed basis for future environmental and public health policy. In effect, it stated that when the health of humans or the environment was at stake, it was not always necessary to wait for scientific proof before taking protective actions. In other words, it followed the old adage "it is better to be safe than sorry." The Precautionary Principle is based on the ethical assumption that humans have the responsibility to protect, preserve, and restore the global ecosystem. It also puts the burden of proof that the action is harmless on those taking the action. Future development and cultivation of agricultural GMOs may be approved or prohibited based on this policy.

Commercial Production and Identification of GMOs

Web Resources:

For more information on genetic transfer, PCR, and bioengineering:

- http://www.hhmi.org (Click on "Biointeractive," then choose "Animation")
- http://wwwdnalc.org

For more information on Bt corn and Roundup Ready Soybeans:

- http://www.ars.usda.gov/is/br/btcorn
- http://www.ca.uky.edu/entomology/entfacts/ef130.asp

For more information on organic foods:

- http://www.organic.org
- http://www.organicfoodinfo.net

For more information on the Precautionary Principle:

- http://www.sehn.org
- http://www.precaution.org
- http://www.pprinciple.net/the_precautionary_principle.html

Additional information is available in most advanced biology textbooks.

Lesson 1

Objectives

Students will:

- Differentiate between the terms “global warming” and “climate change.”
- Discuss some of the issues associated with excess carbon dioxide in the atmosphere.
- Analyze data from three different sources to answer the following question: “Do we have any evidence to support or refute the proposition that the level of carbon dioxide in our atmosphere is increasing?”

Materials

- Worksheet 1 (see page 8).
- Worksheet 2 (see page 10).
- Graph paper.

Beginning (5-7 minutes)
Whole class discussion. The teacher should write the terms “Global Warming,” “Climate Change,” and “Something Else” on the board. The teacher will begin by asking students to place the term “Greenhouse Effect” under the correct heading(s). The teacher will continue this procedure with similar terms in an attempt to determine prior knowledge and to highlight misconceptions. Terms to include: ozone, CFCs, fossil fuels, humans, ocean, carbon dioxide, solar radiation, natural, unnatural, etc. When the list is finished, the teacher and students will discuss each choice and correct any misconceptions. Discussion ends with the question: “Do we have any evidence to support or refute the proposition that the level of carbon dioxide in our atmosphere is increasing?”

Middle (30 minutes)
The class will investigate ice core sample analysis data and data on atmospheric carbon dioxide levels (see Worksheet 1 and Worksheet 2 in supplemental materials). Organize students in groups of 4. Each group will organize and analyze data from both data sets. Two students will work on the ice core data, and the other two will analyze the atmospheric carbon dioxide data. Upon completion of their assignment, the teams will meet in their group to discuss their findings. When all groups are finished, the instructor will lead the class in a discussion and clarification of the findings. The work of both teams will be counted toward a single grade for the group.

End (10 minutes)
Return to the original question: “Do we have any evidence to support or refute the proposition that the level of carbon dioxide in our atmosphere is increasing?” Conclude with a brief discussion of class consensus. “What can we do about it?” Tomorrow we will look at one possible answer.

Assessment

- Responses during the introductory discussion and final discussion.
- Accurate completion and interpretation of group data activity.

Lesson 2

Objectives

The student will:

- View the *Mr. Green* film.
- Discuss the basic premise of film.
- Analyze the science behind the premise of the film.
- Evaluate the impact of photosynthetic humans on excess carbon dioxide levels.

Materials

- Computer/internet access for viewing film.

Beginning (10 minutes)
Remind students of data from the previous lesson. Ask: "Do we have any evidence to support or refute the proposition that the level of carbon dioxide in our atmosphere is increasing?" Discussion should lead to an affirmative answer. The instructor then asks, "What can we do about it?" The teacher and the students discuss some possible answers. The teacher asks students to consider the terms "carbon footprint" and "going green." The teacher may use examples from media to facilitate the discussion. The teacher then asks students, "Are we trying to reduce the amount of carbon dioxide we release into the atmosphere or are we trying to reduce the levels already present?" Students briefly discuss the statement, supporting their answer. The teacher then introduces the film by saying, "The film we are about to see presents an imaginative approach to reducing the carbon footprint of every human to zero."

*Middle (*30 minutes)
View *Mr. Green*.

Upon completion of the film, discuss the students' impressions of the film. It is likely that students will not find the solution presented in the film realistic or plausible. The teacher should use the following questions, which encourage students to think "outside the box."

- Do we know of any creature in nature that can be both autotrophic and heterotrophic? (Example: Euglenoids.)
- What does the Endosymbiont Theory imply?
- Do you have to have roots and leaves to be photosynthetic? What do you need?
- From a biotech standpoint, what would you have to isolate and transfer to create a photosynthetic human?
- In the film, is the transfer an infection or an actual gene transfer or both?
- Are there any repercussions to the development of photosynthetic humans, as presented in the film?
- Why was this film made?

End (5-7 minutes)
Wrap up the discussion and summarize major points. Students are the asked to respond to the writing prompt: "What if the transfer of chloroplasts to humans could be accomplished? Would it eliminate the human carbon footprint? If it did, would that be a good thing?"

Note: If the teacher wishes to complete the writing assignment in class, discussion time may be adjusted as needed.

Assessment

- Classroom discussion.
- Response paper.

Lesson 3

Objectives

The student will:

- Investigate methods of carbon dioxide sequestration.
- Evaluate the effects of sequestration on reducing carbon dioxide in the atmosphere.

Materials

- Worksheet 3: Carbon Sequestration (see page 12).
- Ticket Out Worksheet (see page 13).
- Access to computer for website information.

Beginning (5-7 minutes)
Review the major points of the film and the previous day's discussions. Ask students: "What can we do now? The film mentions carbon dioxide sequestration. What is it? Is it a viable answer to the problem of excess carbon dioxide in our atmosphere? Just because we can do it, should we? Today we will look at the feasibility of carbon dioxide sequestration."

Middle (30 minutes)
Students will investigate carbon dioxide sequestration. Go to: www.ccs-education.net and watch the CCS film. Using the Overview on the website and information from the film, students will complete the worksheet on carbon dioxide sequestration (Worksheet 3).

End (10-12 minutes)
Teacher will give a final verbal overview of topic. Students will complete a "Ticket Out" concerning what they have learned (see supplemental materials).

Assessment

- Accurate completion of the Carbon Dioxide Sequestration worksheet.
- Responses to Ticket Out questions.

Extension Activities and Modifications

Lesson 1

To save time, the teacher could use just the ice core data activity. It provides the information that links increased carbon dioxide levels to an increase in global temperatures. If the goal is to introduce students to the debate over global warming, excerpts from the film *An Inconvenient Truth* could be shown along with the IZZIT film *Unstoppable Solar Cycles*, which is available for free to teachers at www.izzit.org. The films present two opposing viewpoints and will encourage students to consider both sides of the argument.

Lesson 2

If time is an issue for the teacher, *Mr. Green* could be used as enrichment to support instruction in climate change. It can also be paired with the FUTURESTATES film *Seed* as enrichment to accompany a unit on biotechnology, and/or paired with the FUTURESTATES film *Rise* to further explore the possible repercussions of climate change.

Lesson 3

If time is short, this lesson can be foregone. In its place, the teacher may ask students to research other ways of reducing excess carbon dioxide in our atmosphere. The focus could be on renewable resources and energy efficiency. For more information:

- www.nrel.gov (Follow the links to student resources on renewable energy. This site has information on biomass, geothermal, hydrogen, solar, and wind energy sources.)
- www.ccs-education.net
- www.eere.energy.gov
- www.energy.gov/energytips.htm
- www.energy.gov/energyefficiency/index.html

Worksheet 1: Ice Core Data

Background Information

Although scientists have found substantial evidence that atmospheric carbon dioxide levels are rising, the increase does not necessarily imply an accompanying increase in global temperatures. Ice cores provide a unique look into the past composition of the atmosphere. They are a frozen record of the gases trapped in the ice at the time of its formation. As a result, levels of carbon dioxide (and other gases) can be determined from the cores. The most recent ice core data is typically from a decade or so in the past, as it takes time for the cores to form.

Purpose

In this lab, the students will analyze carbon dioxide data from the Law Dome ice cores and compare the CO2 levels to changes in the global temperatures within selected decades.

Procedure

Using the ice core data in Table 1, students will construct a dual-line graph showing the relationship between atmospheric carbon dioxide concentration as preserved in the ice cores and changes in global temperatures over a selected period of years. The X-axis should consist of the years, the first Y-axis should track the CO2 concentrations, and the second Y-axis should track the mean change in global temperature. Use a different color for each line. Be certain to appropriately label your graph.

The students will repeat this procedure using data from Table 2 and Table 3. Upon completion, there will be three separate graphs of the data. The students will then use the graphs to answer the analysis questions.

Table 1 – Ice Core Data Activity *

Year	Carbon Dioxide level (ppm)	Global Surface Air Temperature Change
1900	295.8	.02
1901	296.1	.02
1902	296.5	- .17
1903	296.8	- .27
1904	297.2	- .37
1905	297.6	- .17
1906	298.1	- .07
1907	298.5	- .36
1908	298.9	- .23
1909	299.3	- .26
1910	299.7	- .17

Table 2 – Ice Core Data Activity *

Year	Carbon Dioxide level (ppm)	Global Surface Air Temperature Change
1945	310.1	- .01
1946	310.1	.00
1947	310.2	.12
1948	310.3	- .03
1949	310.5	- .09
1950	310.7	- .17
1951	311.1	- .02
1952	311.5	.04
1953	311.9	.12
1954	312.4	- .08
1955	313.0	- .07

Table 3 – Ice Core Data Activity *

Year	Carbon Dioxide level (ppm)	Global Surface Air Temperature Change
1968	322.8	- .09
1969	323.8	.00
1970	324.8	.05
1971	325.8	- .10
1972	326.9	- .06
1973	328.0	.19
1974	329.2	- .07
1975	330.3	- .02
1976	331.5	- .23
1977	332.6	.15
1978	333.7	.06

*Ice Core Data – Historical CO2 record from the Law Dome DE08, DE08-2, and DSS ice cores, June 1998
Source: D.M. Ethridge, L.P. Steele, R.L. Langenfelds, and R.J. Francey
www.cdiac.ornl.gov/ftp/trends/co2

Global Surface Air Temperature Change – adapted from Hansen et al. (2001)
Tabular data available at: http://data.giss.nasa.gov/gistemp/graphs/Fig.A.txt
(6/29/2010)

Worksheet 2:
Atmospheric Carbon Dioxide Data

Background Information

Our atmosphere is only about 0.03% carbon dioxide, but that amount makes it possible for the planet to maintain a surface temperature necessary for life as we know it to survive. The atmospheric temperature directly influences oceanic temperatures and the interplay of the two creates our weather and climate. Even slight changes in the level of carbon dioxide may raise the average temperature of the planet. Atmospheric carbon dioxide concentrations have been measured for years. In any given calendar year, there are increases and decreases in the levels. The concern is not the natural fluctuations, but the apparent overall trend of increased minimum carbon dioxide levels. The longest continuous record of air samples comes from a facility on Mauna Loa, an inactive volcano and the highest point on the big island of Hawaii. The data for this activity is from the site in Hawaii.

Purpose

In this lab, students will analyze monthly atmospheric carbon dioxide data recorded at the Mauna Loa station and will compare the levels from samplings at 15 year intervals.

Procedure

Using the atmospheric carbon dioxide data in Table 1, the students will construct a dual-line graph showing the relationship between monthly atmospheric carbon dioxide concentration levels recorded on Mauna Loa in 1975, 1990, and 2005. The X-axis should list the calendar months, the first Y-axis should track the CO2 levels for 1990, and the second Y-axis should track the CO2 levels for 2005. Use a different color for each line. Be certain to appropriately label your graph.

The students will repeat the procedure using data from 1975 and 2005. Upon completion, there will be two separate graphs of the data. The students will then use the graphs to answer the analysis questions.

Is this prediction plausible?
This is the evaluator's opinion based on the evidence presented in defense of the prediction.

Table 1: Atmospheric Carbon Dioxide (ppm) for the years 1975, 1990, and 2005 *

Year	Carbon Dioxide level (ppm)	Global Surface Air Temperature Change
1900	295.8	.02
1901	296.1	.02
1902	296.5	- .17
1903	296.8	- .27
1904	297.2	- .37
1905	297.6	- .17
1906	298.1	- .07
1907	298.5	- .36
1908	298.9	- .23
1909	299.3	- .26
1910	299.7	- .17

Analysis Questions

1. Based on your knowledge of natural processes like photosynthesis, how could you explain the changes in carbon dioxide concentrations through the year?

2. When was the highest recorded level of carbon dioxide? (Which month and which year?) How could you explain the high level during this particular time?

3. Based on your graphs, what would you conclude about the overall trend in atmospheric carbon dioxide levels?

4. Is the information from the Mauna Loa site enough evidence to conclude that the amount of carbon dioxide in the atmosphere is increasing? Explain.

5. Is the information from the Mauna Loa site enough evidence to conclude that the amount of carbon dioxide in the atmosphere is responsible for global warming? Explain.

Worksheet 3: Carbon Dioxide Sequestration

Name:

Go to the following website: www.ccs-education.net

After watching the film (about 10 minutes) and reading about the process in the Overview section, use what you have learned to answer the following questions.

1. Name at least two ways we could reduce the emission of carbon dioxide.

2. a) How much has the global temperature already risen since the Industrial Revolution?

   b) Why didn't it rise much before then?

3. Although most of the "unnatural" CO2 appears to be associated with human energy sources, which source alone is responsible for 40% of the carbon dioxide emissions?

4. What is CCS? (Just provide the definition.)

5. Nature has already provided a natural form of sequestration in the metabolic activities of trees and in the solutional capabilities of the ocean. Both have successfully functioned as carbon dioxide "sinks" for the planet. Why aren't they sufficient now?

Ticket Out

Name:

In your own words, how would CCS technology create “clean” power plants?

Ticket Out

Name:

In your own words, how would CCS technology create “clean” power plants?

LESSON PLAN CREDITS

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About FUTURESTATES:
Imagining tomorrow's America today, FUTURESTATES is a series of independent mini-features — short narrative films created by experienced filmmakers and emerging talents transforming today's complex social issues into visions about what life in America will be like in decades to come. The first season of FUTURESTATES debuted in March 2010, and is available online at futurestates.tv.

About ITVS:
The Independent Television Service (ITVS) funds and presents award-winning documentaries and dramas on public television, innovative new media projects on the Web and the Emmy Award-winning weekly series *Independent Lens* on Tuesday nights at 10 PM on PBS. ITVS is a miracle of public policy created by media activists, citizens and politicians seeking to foster plurality and diversity in public television. ITVS was established by a historic mandate of Congress to champion independently produced programs that take creative risks, spark public dialogue and serve underserved audiences. Since its inception in 1991, ITVS programs have revitalized the relationship between the public and public television, bringing TV audiences face-to-face with the lives and concerns of their fellow Americans. More information about ITVS can be obtained by visiting itvs.org. ITVS is funded by the Corporation for Public Broadcasting, a private corporation funded by the American people.