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Global Warming: Is Our Local Environment Ready for the Change?

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Introduction

We face many challenges from the effects of global warming. Consensus of scientific opinion is that the Earth's climate is being affected by human activities. These activities are modifying the concentration of atmospheric constituents that upsets the balance of absorbance or scattering of radiant energy from the Sun, thus causing the Earth to heat up.

To facilitate students to reach a level of understanding of this complex environmental problem, one must teach the science behind the greenhouse effect. This unit will explore the atmosphere and all its components, properties, and processes. Students will also gain a better understanding of the chemistry involved with the major air pollutants and the atmosphere. This unit will give the students a better understanding of the atmosphere and how the human experience affects atmospheric processes.

By using the issue of global climate change, the students can see how the delicate balances of the Earth's biogeochemical cycles are important to all biota. Our society is burning the global supply of fossil fuels, which formed over a 300 million year period, in only a few hundred years, a blink of geologic time. The input of sulfur, nitrogen, and carbon rivals the overall flow of nature. This human-induced global warming is currently happening and has strong momentum to continue in the foreseeable future. Our global society and ecosystems are currently affected by this warming and the impacts are felt in almost all aspects of the environment.

Although there is less consensus of the scientific community as to the details of the outcomes of global warming, there is however, ample research and evaluation as to the extent of greenhouse warming and its potential impacts in peer-reviewed and published scientific literature. Students will be exposed to the potential impacts derived in this literature and engage in critical thinking exercises to tie these potential impacts to their local environment. Students will evaluate findings of relationships between current observed biological changes and human activities.

The intended audience for this curriculum unit is 9 th grade vocational students enrolled in my Environmental Landscape Technology Program. These students will spend the last nine weeks of the course engaged in this unit as a survey of the types of skills and topics that will be addressed in their career and technical education for the remaining three years of their high school experience. This unit would lend itself well to any

environmental science class. I have the luxury of time within my curriculum, since students are enrolled in my program for three plus years in a block-scheduling situation. This nine-week unit is a great survey of many aspects of the environment and analyzes the problems that may arise with further greenhouse warming. This sequence would be a true environmental science class and would really engage students whereas on a whole, environmental science has become an elective science that is of the "rocks for jocks" mentality and not rigorous or thought provoking. Environmental science is not a secondary and useless science: it is the real application of many aspects of science and is very multidisciplinary in nature. Many science and mathematics concepts seem to make no sense to students since they cannot see the relevance to their application. Through the context of environmental science, students can see relevance to biological and physiological processes, chemical reactions and mathematical calculations and interpretation. I hope that you will be able to implement some of the brain-based pedagogy of this unit into your environmental science class to improve the engagement of your students and to also put some real science into your classes. I think of my classroom as a catalyst for intrinsically motivating students on the environment. I strive to do this by developing relevant and engaging curriculum units which is ultimately how to increase the students' understanding of content and empower students with the ability to analyze information and develop their higher order thinking skills.

The unit and individual labs will be based upon the learning cycle model which is based on scientific inquiry. Students are encouraged to develop their own understanding of a scientific concept, explore and deepen their knowledge and understanding of the concept, and then apply the concept to a new situation. The method breaks down into three different phases in the learning process. The exploration phase is the first introduction to the topic and is done in small collaborative groups without any direct instruction from me; the role of the instructor is to facilitate the process by asking questions and observing. Students are given physical materials or some sort of information (graph, data, article) with which they are to solve a problem with the help of my questioning. The hope is that the students reach a state of disequilibrium in which they formulate questions and hypotheses from their observations. The second phase is concept development. Within this part student groups share their observations, pose questions, and share their hypotheses derived from the experience. My role is to then provide definitions and explanations to student's experiences in the exploration phase, tying a meaning to the prior experience they just had. This will introduce and develop the scientific concept that is the objective of the lesson. The final phase is the concept application phase; this is when you facilitate another small group experience that places the concept in another situation in which the students must use their experiences and the information gained during the concept development phase to solve another situation or problem. An example of a learning cycle lesson is included as part of the appendix.

Being a vocational instructor, I see first hand the importance of active discovery of skills and content information, compared to passive reception of information in a lecture context. This rings true and can be performed in a classroom setting. This is further enhanced with hands-on vocational skills that are part of this unit. The hands-on activities that are incorporated into this unit mimic the actual tasks that a research scientist or environmental field technician would do as part of their job. This puts the students in practical learning situations that are relevant to the learning and most times brings about an intrinsic motivation for learning the content. The data collected by my students will be uploaded to the NASA G.L.O.B.E. website (www.globe.gov) via the Internet, which also helps with the motivation, since they are engaging in an international data sharing project. Students can appreciate the data they will be analyzing much better if they have actually collected some data in the field themselves. Having students analyze data throughout the unit helps develop creative and critical thinking skills that are usually not developed in normal classroom instruction. There are only three examples of lessons used in this unit included in this document due to space restrictions. There are however, tens of lessons embedded throughout the narrative explanation of this global warming unit and the web links to use to access the activities via your computer are included in the teaching

resources section of the unit.

The first day of the unit, students are given a schedule of the weekly topics and are placed into research groups that will research and present to the class how global warming will affect their assigned aspect of the environment each Monday during the third through ninth weeks of the unit. The student groups will be given a binder that includes journal articles, Internet resources, and other information on the specific topic. Student groups will read through and decipher the information in the binder as well as "researching the research" on the web to develop a multimedia presentation to kick off each weekly section of this unit. The students will be given a rubric indicating the minimum requirements for the presentation but have quite a bit of creative license when developing their presentation. This project will be done out of class time and will be the responsibility of the research group. We are fortunate that the students are able to stay after school for extra help on Tuesdays and Thursdays throughout the year and are provided with transportation home. This also helps build a group dynamic and overall good work ethic since students are required to interact and take responsibility for learning outside the classroom.

Background on the Atmosphere - Week 1

In order for my students to grasp the far-reaching effects of pollutants, they must understand the atmosphere and its properties. Our state science curriculum includes a unit in eighth grade on meteorology that should cover these topics, but from talking with freshman students, these things are not well understood. Meteorology is a great topic to teach to students also, since it is really relevant to their lives, and it lends itself well to many engaging laboratory based experiences.

The Earth was formed some five billion years ago, and was probably so hot that it did not retain any of the primitive atmosphere it had to begin with as indicated by the current absence of noble gases. The first atmosphere most likely consisted of hydrogen, helium, methane, ammonia, nitrogen, neon and a small amount of argon. Scientists assume that volcanoes five billion years ago emitted the same gases as today consisting of nitrogen, water vapor, and carbon dioxide. The gases were expelled from the Earth's interior by a process known as outgassing. Since nitrogen is not very chemically active, the expelled nitrogen filled the atmosphere. The large amount of water vapor expelled resulted in the formation of clouds which in turn, produced rain. This rain accumulated on the Earth's surface in river, lake and ocean basins. Luckily for us these large water reservoirs acted as large sinks for the carbon dioxide. Also, on the continental portions of the early Earth the calcium silicates ($CaSiO_3$) contained combined with the carbon dioxide to form quartz (SiO_2) and calcium carbonates ($CaCO_3$) binding up even more of the carbon dioxide into solids on the surface and kept CO_2 from filling the atmosphere. Due to the distance from the Sun, the Earth was cool enough for this sequestering of carbon dioxide in these two processes to operate. To give you a perspective as to the significance of the distance lets look at our neighbor Venus. The primitive atmosphere of both planets was the same but; the temperature of Venus without an atmosphere was a warm 20 ◦ C, too hot for the efficient formation of carbonates so almost all of the carbon dioxide expelled from the interior of the planet accumulated in the atmosphere. Thus 90-95% of Venus's atmosphere today is made up of carbon dioxide, and with this type of atmosphere the surface of Venus is approximately 400 ◦ C, which melts lead, destroys all familiar life, and is essentially a dead planet compared to the Earth which has a surface temperature of approximately 10 ◦ C and flourishes with biodiversity.

While oxygen makes up 21% of the current atmosphere of the Earth there was only a trace in the atmosphere when life originated on Earth. Single celled bacteria were the first life forms and did not need oxygen to live. Oxygen first appeared on the planet when these bacteria developed the ability to split water molecules apart by harnessing the energy of sunlight, making them the first photosynthetic organisms. They produced enough oxygen that accumulated over geologic time. With these processes acting simultaneously they have produced the delicate balance of 78% nitrogen and 21% oxygen we observe today. There are other gases present in the atmosphere. The permanent gases, concentrations remain relatively constant, are oxygen and nitrogen, as well as neon and argon. These gases are not involved in the global warming process and thus we need not spend a lot of time on them with the students. The reason why these gases are not greenhouse gases (GHGs) is because their molecular structure is transparent both to incoming solar radiation as well as outgoing infrared radiation. The variable gases, however, will need to be discussed in detail with the students. These gases are the main greenhouse gases, and include water vapor (approximately 0-4%), carbon dioxide (approximately 0.035%), methane (approximately 0.0002%), and ozone (approximately 0.000004%). What makes these greenhouse gases is that their molecular structure is made up of three or more atoms, making them transparent to incoming solar radiation and opaque to outgoing infrared radiation so they trap in the transmitted infrared radiation in the atmosphere heating it up and upsetting the natural balance. A good activity is to have students construct three-dimensional models of these molecules in order to see their heat trapping ability. [1]

The lowest layer of the atmosphere where the right mixture of gases can support life is a very tiny layer of our atmosphere, approximately ten miles up from the Earth's surface, called the troposphere. Within this small layer almost all of our weather and climate is created. The moisture available to the planet is encompassed in this small layer, as well as the balance of all the gases that have been added to our atmosphere through the human experience. To give the students perspective you can quote Carl Sagan "If you had a globe covered with a coat of varnish, the thickness of that varnish would be the thickness of the atmosphere compared to the Earth itself." Once they visualize that, they should have the realization of how small and vulnerable our immediate atmosphere is. There are many other upper layers that make up the outer atmosphere but again they do not play a lead role in global warming. Hopefully they have had this information in prior grades; in Delaware it is part of the middle school science curriculum. One misconception you should address with your students when going over the structure of the atmosphere is the stratosphere and ozone. In the stratosphere, oxygen atoms (O) are formed through the photolysis of oxygen (O_2) by harmful ultraviolet (UV) light. The products of this lysis form ozone molecules (O_3). Ozone is in turn photolyzed to regenerate more oxygen atoms and oxygen by absorbing harmful UV light, thus protecting the biota on Earth. Many will tell you that global warming is caused by the ozone hole and that is simply not true. The two issues are apples and oranges; two totally different issues. You can however discuss the fact that the ozone hole is now closing up due to governmental legislation eliminating the uses of chlorofluorocarbons (cfcs), and with the newly developed chemicals we have reversed this environmental problem giving us hope that our efforts to combat global warming may make a difference if we act now. Have students read an article about the shrinking of the ozone hole due to these regulations that were imposed on the chemicals that caused the problem. [2]

The climate system is a very complex system driven by the energy of the Sun, involving the oceans, the atmosphere, various Earth surfaces, and plant and animal life. There are so many factors that affect climate and the weather that it is very hard to make long-term predictions. Substantial uncertainties are present in predictions over more that a three-day period. One thing you must discuss with your students is the difference between weather and climate. They are not one in the same! Simply, weather is what changes from hour to hour, day to day, and month to month. Climate describes how the weather tends to be in a certain place over

the long term; you may want to term it "average weather". It is really important to understand the difference between weather and climate to understand the issue of global warming. I use an example when talking with students to help them distinguish this difference. If on a day in July you are asked, what has the weather been like in Delaware? You may answer, "It was hot and muggy yesterday, but today it is clear and cool." On the other hand, if you were asked what the climate is like during the summer in Delaware you would be correct to answer, "in the summer it is hot and muggy." They must realize that even though a day happens to be clear and cool, that does not mean the climate has changed. When climate does change, it usually changes relatively slowly and this change is very slight, changing a fraction of a degree over period of tens of years.

Factors that determine the climate of an area are numerous. One of the major factors is the proximity to the ocean. Ocean currents can increase or reduce temperatures depending upon their origin. Coastal areas are cooler and wetter than inland areas. There are a number of reasons for this. One is that clouds form here more readily since the warm air from the land meets with the cool air from the ocean. This phenomenon will change depending upon the ocean temperature during the different seasons of the year, relative to the adjacent continental temperature. Generally, the more inland an area is, the less moisture and thus the hotter it is since the moisture from the oceans evaporates before it reaches the center of the continent. The direction of the prevailing winds also makes a difference in the climate since if they move from the ocean to the continent they may carry substantial amounts of moisture; on the other hand if they are moving from the center of the continent they may move drier air. Altitude plays a major role in the determination of the climate of an area. Mountains are a great example (not in Delaware since we are as flat as it gets…) since mountains receive more rainfall than the low lying areas because the temperature of the top of the mountains is lower and closer to the dew point than the temperature at sea level. The higher the place above sea level, the colder it will be since in the troposphere as altitude increases, air becomes thinner and is less able to absorb and retain heat. That is why you see snow on the tops of mountains all year round although global warming is altering that. Proximity to the equator is a large determinant of the climate since the equatorial countries receive more solar energy than anywhere else on Earth due to its position in relation to the Sun. The equatorial regions receive full Sun incidence, whereas in the higher latitudes the same amount of energy is spread out over a wider area due to the tilt of the Earth. Have students determine the factors that affect their local climate. They can look at maps to see the prevailing winds, determine their height above sea level, and their proximity to the ocean. Students need to access information online to determine the local climate of their area and relate how this climate is derived**.**

Air pressure creates the constant changing skies and sets winds in motion. Air pressure is the force air exerts on everything it touches. Air moves at variable speeds and the speed responds to pressure differences that depend on temperature. Warm the air up and the speed increases, cool it off and it slows down. The impacts of the billions of bouncing air molecules are what determine the pressure. Air pressure depends upon the sheer number of air molecules in a given space and how fast they are moving. Winds are the result of the action of various forces that are happening simultaneously. The main force that starts winds in motion is air pressure. Higher pressure pushes air toward lower pressure. The greater the difference in pressure, the faster the wind moves. There are other forces that help to determine how strong the wind will be and which way they will blow. Pressure gradient force is the key factor in the strength of winds. This force is affected by the size of the pressure difference between high and low as well as the distance between them. The closer together the high and low pressure areas are and the larger the difference in pressure, the stronger the winds. Friction is a big factor in velocity of the winds. Obviously, the nearer to the surface and the more buildings, trees, and objects it rubs up against the slower the winds. There is much less friction over water than land which is a key factor in hurricane formation. And lastly the wind will not move in a straight line due to the Coriolis Effect. This phenomenon is due to the spinning of the Earth, which is why winds curve when they blow.

Using the information from the Wikipedia article on atmospheric circulation, have students chart winds to determine their origins and the temperature effects they will have on the climate. [3]

Albedo is Latin for white and is an essential concept to address with the students. Albedo is the reflectivity of surfaces. Albedo is expressed by a number between zero and one. An albedo of one would indicate the highest reflectivity possible like a perfect mirror. On the other hand an albedo of zero would indicate a perfect absorber of radiation which scientists call a black body. But obviously the surfaces of Earth will fall in between this range. This is a key aspect to greenhouse warming. Common Earth surfaces such as glacial ice reflect most of the solar energy and have an albedo of approximately 0.8, whereas the oceans have a much lower albedo and absorb the energy of the Sun with an albedo of 0.2. The albedo of the Planet Earth is 0.4, which equates to 40% of all the incident solar radiation being reflected by the Earth and 60% being absorbed. There is much speculation as to the amount of change in albedo produced by the increasing melting ice around the globe. There are many labs that model this concept that you would be able to do with your students. A very simple one would be just using colored paper. [4]

Water vapor is a natural greenhouse gas, and accounts for the largest portion of the greenhouse effect. Increasing temperature will increase vaporization and the amount of water vapor in the troposphere which will magnify the effect of the greenhouse gases. On the other hand, the increase in water vapor may increase the formation of clouds, and more clouds, will increase the albedo thus reducing the amount of solar radiation that is absorbed. This could be such a factor as to reverse the warming and actually cause cooling. The lesson canned cloud in the unit addresses cloud formation in a learning cycle approach.

Background on Global Warming - Week 2

The greenhouse effect is a very important process that is essential in order for Earth to be inhabitable. Solar radiation enters the Earth's atmosphere and then is either reflected or absorbed by the Earth surface depending upon the albedo of the surface. The reflected part retains spectral properties similar to the incoming radiation, and thus can be reflected out of the atmosphere unimpeded, just as it entered. The absorbed portion of the radiation will become thermal radiation at the temperature of the Earth surface, not at the temperature of the incoming radiation. This is emitted from the surface as infrared radiation, or heat. Because the atmosphere is opaque to infrared radiation it will become trapped and raise the temperature of the Earth. This process keeps Earth at a mean temperature of 10 ◦ C, without this process the Earth's mean temperature would be minus 25 ◦ C and frozen. Our very existence is dependent upon the greenhouse effect.

You or your students may ask then what the problem is with the greenhouse effect. Under normal conditions the atmosphere naturally traps only a portion of the outgoing infrared radiation. With the increase of greenhouse gases in our atmosphere the proportion of the infrared radiation that is being trapped is increasing. Looking at this trend just with a basic understanding of laws of balance and conservation you should realize that inputs should equal outputs in order to keep equilibrium. If we are seeing less and less output of infrared radiation from our atmosphere, it will pile up and cause warming. Of the greenhouse gases CO_2 is the most notable since it constitutes about 80% of the greenhouse gas emissions. We emit CO_2 when we burn fossil fuels to power our communities, transport ourselves, produce the products we use in our lives, or when we burn our forests.

Looking at the greenhouse effect on Venus, with a surface temperature is 400 ◦ C, will give us a different view of how increasing the amount of carbon dioxide will affect the amount of warming. The atmosphere on Venus is made up of 90-95% carbon dioxide, which traps almost all of the infrared radiation emitted at the surface of the planet after absorption. The Earth's atmospheric concentration of CO_2 has made dramatic increases in recent years. Currently, according to NOAA and the Scripps Institution, the Earth's atmosphere has 384ppm (parts per million) of CO_2 a rise of almost 10ppm in four years from 375ppm in 2002, and a rise of almost 60ppm in the last fifty years from 315ppm in 1958 when the recording started at the Mauna Loa Observatory in Hawaii. You say well fifty years is only blink of time in the history of the planet, is this reason to care?

Scientist have also dug core drills of ice from glaciers around the world and analyzed small bubbles of gas trapped in the snow the year it fell. They can measure how much carbon dioxide was in the Earth's atmosphere at the time. They can also measure the exact temperature by calculating a ratio of isotopic abundance of oxygen-16 and oxygen-18 which can be equated into degrees Celsius. They can even count backward in time year by year by the clear line that separates the years in the ice cores. They have ice core data that depicts temperature and carbon dioxide levels back one thousand years and at no point was the concentration of CO_2 as high as it is today. Even the medieval warm period is dwarfed by today's measurements of CO_2 and temperature.

Scientists have been able to ascertain a record of CO_2 and temperature data from ice cores in Antarctica that dates back 650,000 years and again there is no evidence of a concentration of CO_2 as high as it is today. There is however a striking trend that when there is more CO_2 in the atmosphere, the temperature of the Earth increases because there is more infrared radiation trapped within our atmosphere. Current increase of carbon dioxide in the atmosphere contributes to an increase in solar energy input of 0.1W/m^2 per year on the Earth's surface. The steady solar energy input is about 340 W/m^2. Using these figures, in 100 years the energy input into the Earth's climate system would have increased by 3% at the present time. Scientists have seen a warming trend over the past 140 years by analyzing the annual land, air, and sea surface temperature records that have been recorded since 1860 and have found that the temperature rise has been accelerating recently. Twenty of the twenty one hottest years have happened in the past twenty five years. With the hottest year on record being 2005! Have students perform a math related lesson on graphing global temperature and CO_2 concentrations and comparing the two graphs.

To understand why there is such an increase in the amount of CO_2 in the atmosphere you must look at the primary sources of greenhouse gas emissions. In the US, the largest source is from our power plants; approximately 40% come from the burning of fossil fuels for this purpose, and coal accounts for 93% of these emissions. We should look to natural gas as an alternative to coal since natural gas produces half of the CO_2 emissions for the same amount of energy produced.

The second largest producer of CO_2 comes from our cars and light trucks, contributing 20% of the total emissions. The US has the lowest standards for gas mileages in the world, with Japan's average nearly double the average American vehicle. For example, using the EPA's 2000 fuel Economy Guide, a 2000 Dodge Durango (produced here in Delaware!) gets twelve miles per gallon in the city and will produce approximately 800 pounds of CO_2 in a distance of 500 city miles. A 2000 Honda Insight that gets 61 miles to the gallon will only produce approximately 161 ponds of CO_2 over the same 500 city miles. Imagine how much we could reduce the carbon emissions from our cars if the gas mileage standard was increased. We have the technology to do it; we just need more US consumers to buy vehicles based on fuel economy. Other forms of transportation also

play a significant role in carbon emissions. Another 13% of the US carbon emissions come from large, mostly commercial, trucks. The IPCC estimates that aviation also contributes 3.5% of the emissions and could increase to 15% by 2050. And that buildings and structures also give off CO_2 emissions and contribute to 12% of the US total. The building emissions come mostly from the generation and transmission of electricity accounting for about 70 %, the combustion of natural gas in furnaces and water heaters constitutes about 20 %, and the remaining 10 % comes from fuel oil energy related emissions.

There are numerous other signs of a global warm-up other than just atmospheric data. One very obvious one is the global distribution of ice. You can look anywhere on Earth where there is ice and it is changing. Close to home we can look at glacier national park that was home to around 150 glaciers when it was named in 1910. Today there is fewer that 30 and the projection is that most if not all of the glaciers will be gone within 30 years. The snows of Kilimanjaro have melted more than 80% in the last 100 years. The arctic sea ice has thinned significantly, so much that it has been reduced by 10% in the past 30 years. In permafrost regions in the northern hemisphere, Spring freshwater melt happens nine days earlier than it did 150 years ago and the fall freeze is now ten days later. This thawing of the permafrost has attributed to large areas of ground subsidence in Alaska.

Changes in the salinity and the pH, level of the oceans are another sign of global warming. Salinity of the oceans is changing with a significant increase in the salinity at the equator and a significant decrease at the poles. This is attributed to global warming due to the increase in evaporation tied to the increasing atmospheric temperatures. This evaporation increase at the equator concentrates the salt in the surface of the ocean at those latitudes. The resulting water vapor is then transported to the poles and at the higher latitudes it precipitates and ultimately returns the fresh water to the ocean. The worry is that North Atlantic waters will become too fresh and the ocean conveyor that is driven by the sinking of the saltier water in the northern latitudes could slow down. Analysis of the ice cores has told us that this has happened before in Earth's history. This has caused the North Atlantic to cool and brought drought to other portions of the Northern Hemisphere in the Earth's past.

The changes in pH of the ocean seem inevitable when you think about the fact that over half of the CO_2 emissions end up in the ocean, a daily dose of approximately 22 million tons! When seawater and CO_2 combine they form a weak carbonic acid. This is making the ocean more acidic and there is evidence that the lowering of the pH may be harmful to marine life. Many of the animals in the ocean build their shells out of calcium carbonate from seawater. As the pH drops, so will the ability of these organisms to grow. These organisms are the basis of many ocean food chains and support some of the largest organisms on the planet, namely whales.

Many skeptics of global warming will discuss how the Earth will take care of its children, through the guise of the GAIA Hypothesis. This is wishful thinking and the Earth actually is resilient and has been able to offset quite a bit of the anthropogenic effects of our society. It does this by way of natural portions of the planet that are called "sinks". These areas are places that sequester and therefore buffer the effects of the excess carbon input to the system, the identified sinks are the Earth's forests and the oceans, which are now starting to show signs they, are not as efficient at sequestering carbon as they once were. The Kyoto protocol uses this sink concept as a means to achieve emission reduction commitments. For every ton of carbon stored in a sink, the country is allowed to emit an additional ton from the burning of fossil fuel. This concept is flawed since the sequestering of carbon by trees is only temporary. Land use changes, forest fires, and even insect outbreaks can release this carbon into the air. Another interesting concept is that many of these forest plantings by countries to off set their carbon emissions are happening in farmland or boreal regions that would normally

covered by ice. By changing the land use of these areas to forests, the albedo is changed so that there is more absorbance of solar radiation. We may find that these newly planted areas are actually adding to the problem more than helping it!

There are serious uncertainties regarding the detailed reactions of the climate system to the increase in greenhouse gases. The problem is not to only identify the significant component of the problem but to understand the feedback between them. The uncertainties stem from a number of different phenomena that are not well understood. These include solar variability, physics of aerosols, and the physics of clouds.

Many of the predictions include temperature increases tied to dates and are not valid since we do not know the actual rate of the increase in the future. What we should be doing is looking how a doubling of carbon dioxide will affect the climate system. Some researchers predict the doubling of atmospheric CO_2 in a matter of tens of years. For students to understand what this may mean to their existence on this planet the students will engage in a series of activities in which they explore the possible environmental effects.

Exploring the Possible Local Environmental Effects

The remaining seven weeks of the unit will be structured to facilitate an overall learning cycle approach that builds upon itself from week to week. Having the students introduce the topic each week will help heighten the interest of the students in the subject matter and may facilitate better questioning by the students. Content related lectures, labs and hands-on activities tied to the student presented information each week will clear up misconceptions about the topic and facilitate a better understanding of the content.

The weekly unit schedule will have a Monday presentation by the student group. Every student must pose at least one written question on an index card to the research group to answer about a topic addressed in their presentation. Students will then break into their research groups and look at selections from *The Inconvenient Truth* by Al Gore that will relate to the aspect of the environment they will be exploring for the particular week. A matrix that includes all of the selections based on the weekly topics is in the appendix. Student research groups will engage in discussion of the graphics, pictures, and reading that is relevant to the topic. I will facilitate the discussion with probing questions and provide limited assistance. They must develop a group synopsis of the information presented to them and prepare a concisely written memo to me on their analysis of the information.

Tuesday will start out with the distribution of the memos to all of the research groups to determine the overall consensus of the groups and what information the students would like to explore about the topic. When I use this strategy in my classroom I place three columns on the board titled: known, questions, and next steps. The students will give me feedback as to what things are known from the memos and they are added to the known section. Next the students are asked if they have any questions about the topic and those are added to, you guessed it, the questions section. Lastly the students are asked about the next steps we should take in order to find the answers to the questions they have or to substantiate the known information and that is placed on the board. You may want to also put this on an overhead so you can refer to it as you work through the unit. This is an excellent prep for the exploration phases of this weeklong learning cycle approach, talk about engaged minds! The remaining half of the period will be devoted to a map or aerial photograph related activity that the students will interpret and discuss.

Wednesday brings us to the sampling aspect of the week. Students will engage in the scientific process by collecting environmental data related to the weekly topic. Depending upon the weekly topic this may spill over to Thursday's period. Thursday will be spent analyzing the data collected and starting the concept development stage during which I will be developing the scientific principles and the implications of the measurements that are collected to clarify the concepts and discuss the prior activities of the week. Students will then engage in accessing similar data from the Internet to see what types of data have been collected in the local area. Students will construct some sort of data table and determine trends in data and discuss the current state of that aspect of their local environment.

Friday is the application of this data and phenomenon on a broader sense to the global environment. This period will involve discussion and the application and impact this is having on a global scale and what the possible consequences global warming may have on this aspect of the global environment.

Due to the limited number of pages within this unit, I will not be able to include all of the lessons in sequence for the remainder of the weeks. In the following sections I have identified relevant field experiences, data manipulation, and map interpretation exercises that I would use to help the students reach a level of understanding of the scientific basis for the possible environmental effects due to global warming.

Affect of Global Warming on Soil - Week 3

To explore how the greenhouse effect may affect and relate to the topic of soils, I would engage my class in the following activities. I will have students use a soil survey, a book of aerial photos available at your local Natural Resources Conservation Service (NRCS) office or available on-line. [11,12] Students determine the survey page that corresponds to our school campus and ultimately the place they will sample using the weekly protocol. By looking at this there is an overlay that tells them the type of soils that should be present when they go out to sample, as well as a wealth of information about each soil and what types of properties it exhibits. Have students determine the soils on campus as well as the use limitations for the particular soils. I would then have my students collect soil at a site on our school campus using the sampling protocol and then conduct the soil characterization protocol. There are many methods to collect a soil profile; I would recommend using the soil auger method. These protocols, as well as, background information, student sheets, and data sheets is available at the GLOBE website. [13] Within this the students determine the characteristics of the soil they collected. They will determine the structure, color, consistence, texture, and the presence or absence of free carbonates in the soils. Once students have characterized the soil available on campus they should then engage in the use of the GLOBE project visualization page to make a map of global soil moisture from the data collected. [14] Students will compare the map they produce at the GLOBE website to the map on pages 114-115 from *The Inconvenient Truth* to determine any similarities and differences to these values and write a hypothesis about how they believe the global warming issue will affect soil moisture.

Affect of Global Warming on Plants and Trees - Week 4

To explore how the greenhouse effect may affect and relate to the topic of plants and trees, I would engage my class in the following activities. I will have students identify features on local aerial photographs; aerial photos are available at your local United States Geological Survey (USGS) office or available on-line. [15] Students will look at the aerial photo that corresponds to their home address through terra server and determine the land use of the areas surrounding their home. Using our local aerial photo, the students determine the amount of area that is covered by trees. The easiest way I have found to have the students calculate area on an aerial photo is to use clear plastic or overheads on which the students can trace the outline of the various areas while it is laid upon the aerial photo. Be sure that you explain this before the students start to mark on your aerial photos! Students will then calculate the area that corresponds with this to get a sense of the percentage of land that trees occupy. I will have my students look at the woodlot that is adjacent to the school in an aerial photo to get a sense of scale of the area in which we will be doing our weekly field work in. I will then have my students conduct a vegetation analysis in our woodlot, using the biometry (measuring of living things) sampling protocol. There are a couple methods to collect the biometry measurements, depending upon your sampling location. You can even do the protocol in a grass field if that is all that is available. [16] Students will determine tree height and circumference (great math ties here!), canopy cover, ground cover, and graminoid (grass) biomass. Students in my class will also take tree core samples using an increment bore and if time permits we will discuss the concept of dendrochronology and that scientists can determine higher atmospheric temperatures cause thicker rings in trees. Once students have completed the sampling protocols I will have the students engage in a lab activity to measure the amount of photosynthesis using graphing calculators with CO_2 probe technology. Students will set up the apparatus that will take CO_2 measurements over a twenty four hour period. Students will work through the calculations included in the case for planting a tree activity that will calculate the amount of CO_2 taken in by an individual tree and then expanded to the amount per acre, and ultimately to the amount of CO_2 that the forested areas can sequester**.** Lastly, students will retrieve the information from the calculators and graph the results. The calculators can then be hooked to the computers to import the graph to place into a report with some rationale to prove that the plant in the vessel went through both photosynthesis and cellular respiration during the sampling period. I will revisit the prior lesson on CO_2 sequestering by a tree and discuss how insignificant and temporary tree planting is in reducing the global warming problem.

Affect of Land Cover on Global Warming - Week 5

To explore how the greenhouse effect may affect and relate to the topic of land cover, I would engage my class in the following activities. Students will analyze Landsat satellite imagery available on-line. [17] Students will visually interpret a Landsat image of Dover, Delaware to identify different land cover classes and calculate the percentages of the land uses in the overall image using the protocol. [18] Students will then have a field experience to analyze our school site and determine the Modified UNESCO Classification Scheme (MUC) value of the campus by using the manual land cover protocol. [19] Students will also analyze aerial photographs of the surrounding area of our school to determine how the different MUC values appear in aerial photographs. Students will engage in an activity to use the GLOBE data to interpret land cover. Using the GLOBE

visualizations students must access data from two other schools with the same MUC class and determine the types of environmental conditions present to determine the factors that are important in determining land cover. [20]

Affect of Global Warming on Aquatics - Week 6

To explore how the greenhouse effect may affect and relate to the topic of aquatics, I would engage my class in the following activities. I have students identify features on local topographic maps; topographic maps are available at your local United States Geological Survey (USGS) office or available on-line. [21] Students will delineate the watershed of a local surface body of water by identifying the higher elevation contour lines that are the boundaries for the watershed of the surface water body. Students will calculate the area of the land that collects water for this surface water body and discuss the possible types of environmental hazards that are present within the watershed. Students will sample water from a local surface water source, in my case the constructed wetland on my campus that collects the rainwater from the athletic fields, and they will engage in running three water quality parameter tests using the GLOBE water temperature and pH protocols. [22,23] Students will engage in an activity to understand the significance of these measurements and the range of each that is acceptable for aquatic life. Students will access the NOAA nowCOAST website to determine the current sea surface temperatures of the local area. [24] Students will also access a website to watch an animation of the change in the ocean surface temperatures over time. [25] Students will also look at pages 78-79 of *The Inconvenient Truth* and develop a position statement on the state of the ocean temperature and what it may mean for the myriad of different aquatic life forms that may be affected by this change.

Sea Level Rise from Global Warming - Week 7

To explore how the greenhouse effect may affect and relate to the topic of sea level rise, I would engage my class in the following activities. Students will be introduced to the arctic region and the size of the ice mass of Greenland, using a map available on-line. [26] Guided by a simple student sheet, students will make their own estimation of the sea level rise if the Greenland ice sheet were to melt. In order to visualize the local effects of sea level rise, students will be given a topographic map of Wilmington, Delaware. Students will determine the areas that would be lost due to flooding using the contour lines to determine the extent of the high water line for various scenarios. The area of the inundated land will then be calculated. This lesson is included in the lesson section of the unit. Students will view an animation of how a one meter rise in sea level would change the local landscape of Wilmington, Delaware. [27] Students will also look at pages 198-209 of *The Inconvenient Truth* and develop an appreciation for the possible impacts of sea level rise on the world at large. Students will use the internet to access information in order to determine an estimate of the amount of people who might be displaced by the sea level rise in Florida, focusing only on the populations of the major cites of Fort Lauderdale, Miami, Naples, and West Palm Beach if the scenario on page 199 from *The Inconvenient Truth* were to become a reality.

Affects of Global Warming on Animals - Week 8

To explore how the greenhouse effect may affect and relate to the topic of animals, I would engage my class in the following activities. Students will access range maps for common birds in our area, the black-throated Green Warbler, Eastern Bluebird, and the Blue Jay. Students are to contrast and compare the migration paths of these three birds and discuss with their research group how they may be affected by global warming. [28] Students will engage in a field experience to check the bluebird trail on the Hodgson campus. Students will be given the nesting data for the previous year as well as any current year data gathered prior to this experience. Students will make the observations at each of the boxes to determine the type of nest present and the stage the young are in currently. Setting up a bluebird trail at your school is easy and a great hands-on project for your students. [29] Students will also use the internet to access the great backyard bird count data for Delaware. Results from the 1998 and the 2006 count will be analyzed for any major differences in number and species.

What We Can Do To Reduce Our Share of Global Warming - Week 9

Kick off the week by sending home the How Much CO_2 Does Your Family Produce worksheet to have students fill out with their family. Have students read through pages 305-321 of *The Inconvenient Truth* and then work with their research group to develop a multimedia presentation to inform the public on what they can do to reduce their share of the global warming problem. Students should be given basic guidelines they need to follow in order to develop the presentation in order for you to assess them effectively, remember you get only what you ask for with students, so think big! Require students to include images and text to introduce the viewer to the concept of global warming, the students must also include problems that the planet is facing due to global warming (assesses their understanding of the topics they have learned the prior weeks), students must also include a minimum of five things the average citizen can do to help out with the global warming issue. This is the culminating project of the unit and students should be given the entire class periods of this last week to prepare for the in class presentations on the last day of the unit. This would be a great day to have a supervisor or a community member to visit and see what great things the students are doing in your classroom. Have fun with this unit and encourage your students to walk the walk when it comes to global warming!

Example of Learning Cycle Lesson : Canned Cloud (cloud formation)

Exploration

Give to each of the student research groups a canning jar, ice, matches, and black construction paper. Ask the students to create a cloud in the jar under each of the following conditions:

Fill the jar with about 2cm of hot water. Invert the lid and place on top of the empty jar. Does a cloud form? (I

have students write observation in environmental journal)

Fill the jar with about 2cm of hot water. Invert the lid and place on top of the empty jar. Add ice cubes to the inverted lid. Does a cloud form? (I have students write observation in environmental journal)

Fill the jar with about 2cm of hot water. Invert the lid and place on top of the empty jar. Add ice cubes to the inverted lid. Light a match, drop into jar, and cover quickly with the ice filled lid. Does a cloud form? (I have students write observation in environmental journal)

Concept Development

I discuss the observations with the students and pose questions to lead them to identify the three essential components of a cloud as being water vapor (hot water), a lowered temperature or change in temperature (made possible by the ice), and a condensation nucleus or small particle upon which the condensation can occur (the smoke from the match). Identify the temperature at which a cloud forms as the dewpoint. Review the relationship between dewpoint, air temperature, and relative humidity. Help students understand that clouds may form when the relative humidity is 100%.

Concept Application

Give the students a two-liter bottle. Ask them to add 2cm of hot water to the bottle, spray with a small amount of air freshener, and quickly put on the cap. If they squeeze and release the bottle, they should see a cloud form. Ask them to write down their explanation of how the cloud was formed in light of their previous experience.

Students should note that two of the ingredients necessary for cloud development, water vapor, and condensation nuclei were obviously present. They probably will have a difficult time accounting for the temperature drop they observed in the previous experience. Explain that when they squeezed the bottle they were compressing and separating air molecules. When air molecules separate, they collide less often generating less heat. This cooling effect has the same effect on cloud formation, as did the ice cubes in the previous experience.

I show students a diagram of the pressure and temperature changes that occur in the troposphere with altitude. I ask students to explain the formation of clouds from rising air using both text and a diagram in their environmental journal.

Impact of Sea Level Rise on Wilmington, DE

This lesson was adapted from the Armada project, and can be easily adapted to a coastal town that is relevant to your students.

Each group of students will need:

USGS Quadrangle topographic maps, scale 1:24 000

Clear plastic to overlay on map

Set of dry erase markers

Guided Exploration

Examine a topographic map published by the US Geological Survey.

Use your knowledge of maps and the map legend to complete the following activities:

What do these colors on the map represent?

green - _____

blue - _____

red - _____

purple - _____

Trace a primary highway (major road) with the red marker. Trace light duty road (local road) with the black marker.

Trace a school with the green marker. Circle a neighborhood of homes with the black marker.

Trace a river with the blue marker. Circle a marsh with the green marker. Circle a rocky shoreline in black.

You will notice that the contour lines have an elevation interval. What is the elevation interval? _____ft. Scientists record data in metric measurements; what is the elevation in cm?

_____

Choose an area of your local map that covers a coastal area with relatively level ground. It will be more interesting to have an area with natural features (marsh, beach, rocky shoreline) as well as man-made features (houses, businesses, jetties, piers).

Looking at your map, first find the current shoreline, as determined by the mean high water mark. Trace the current coastline with the blue marker.

Now trace a new coastline if sea level was to rise 60cm. What is this in ft? _____ Trace this new shoreline in red.

Calculate the amount of area that will be inundated by this amount of sea level rise.

Look at the features of the map that are now inundated (covered) with seawater. Within your research group discuss the implications of the shoreline change and make notes in your Environmental Journal. For instance:

Is the entire coastline affected in the same manner?

What natural and man-made features will be affected?

How much land will be lost?

Will buildings, houses, marshes, etc. be inundated?

What animals/plants will be affected?

Will there be economic costs due to the coastal change?

Will the impact be short-term or permanent?

What if sea level was to rise 90cm? What is this in ft? _____ Trace this new shoreline in green. Discuss the same questions and make additional notes based on this new shoreline.

How Much C O_2 Does Your Family Produce?

Have students find out this data…

1) How many miles has your family driven in the past year and how many miles per gallon of gasoline do the cars get?

2) On the utility bill from your home, look at how many kilowatt-hours of electricity were used in the home in a year.

3) Look up how much natural gas was used in the home in the past year.

4) Estimate how many miles family members flew on trips taken in the past year.

Summing it up…

Miles driven

————————— = Gallons of gas used

Miles per gallon

1)(Gallons of gas used)(20) = Pounds of CO_2 produced

2)(# of kilowatt hours)(3) = Pounds of CO_2 produced

3)(# cubic feet of natural gas)(12) = Pounds of CO_2 produced

4)(# miles flown in airplane)(0.5) = Pounds of CO_2 produced per

Add the total number of pounds of CO_2 produced by the family directly (ADD 1-4).

Double that sum to account for the CO_2 produced indirectly through the purchase of goods and services. (Carbon dioxide is used in the production of many items you buy, in the heating and cooling of public buildings you use, etc.)

One forest tree absorbs 13 pounds of carbon dioxide each year; one acre of trees absorbs 2.6 Tons of carbon dioxide each year. How many trees would be needed to absorb all this CO_2 produced by your family?

Matrix of Inconvenient Truth Selections That Relate to Weekly Topics

(table 06.05.01.01 available in print form)