**Global Warming as an Overarching Idea for Junior and High School Science Instruction**

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**Overview**

Much is in the news these days about global warming and its impact on humanity. Conversely, the debate about humanity's impact on global warming, also called anthropogenesis, is also an issue. The climate has many interrelationships, each of which is studied by some form of science. In order to determine the impacts of each, a model must be created. A science model of global climate must be able to be wrong- must be testable- a scientist must be able to make predictions which can ultimately be verified. This means that a scientist must decide which data should be chosen, which variables will be relevant to the problem, and how those specific variables affect the outcome. Using the science of global warming as an overarching question, students should be able to use each of the high school sciences to determine if anthropogenesis of greenhouse gases is responsible for climate change. They should be able to rationalize the net effect on global systems of human interactions. Yet before a student can comprehend the impact a human has on global warming, he must first understand the impacts humans have on the environment itself.

The student must understand the makeup of the earth's environment, from the layers of the atmosphere to the concept of weather relating to currents found in the ocean. This also involves understanding the carbon and water cycles, and a basic understanding of spectrophotometry, as well as a thorough understanding of the concentration of different gases in our atmosphere, and which of these are considered to be greenhouse gases. The student must also be able to distinguish between our responsibility to the planet as per pollution, and our responsibility toward reducing the impetus of global warming. At that point a student can relate the environmental impacts of humans to the global warming issue. Students who understand the footprint they create can then relate that information to the footprint made by their country, and then can relate that further as a statistical representation of how much impact each country actually creates. However, if the planet becomes completely unlivable, which country causes the most problem just doesn't matter, and all students must take responsibility to reduce any part of the impetus possible. With the innovation of hybrid automobile engines, alternative fuels, and "green buildings," numerous other issues arise, and with proper background, the student can see how each new innovation has repercussions throughout the world, and may actually be creating further negative issues globally.

This curriculum introduces the different sciences used in the measurement and determination of impact of anthropogenic events. It includes ways that biology, chemistry, earth/space science, environmental science, and physics courses can be used to help high school students determine the impacts of humans on the environment. In addition, it suggests cross-disciplinary ideas with history and English classes to allow students to see that science is not a class unto itself, but is all around the students, every day of their lives, no matter what they are doing.

## Rationale

The typical standardized test for science mandated to be taken (and passed) in high school includes many aspects of science. There are numerous questions on astronomy, biology, chemistry, cosmology, environmental science, general science, physics, scientific theory and law, as well as reading and interpretation of several types of graphs. Unfortunately, schools have limited their science programs by mandating 5 classroom programs, thus eliminating lab times, have reduced spending for science, which eliminates the materials needed for students to explore the scientific information they are given, and has cut the curriculum to the point that many of the classes which would introduce the ideas on these standardized tests are no longer available for the students to take. This means that the students are either destined to fail the science standardized tests, or that the basic science teachers, (i.e., biology, chemistry, and physics, the only three classes left to take in the typical high school environment,) must pick up the missing pieces and somehow incorporate them into their curricula.

In order to incorporate these now missing topics, a more overarching curriculum must be taught by the teacher. Within these overarching topics, several types of sciences can be introduced and worked through the three years of high school science by the various science teachers to whom the student is assigned. This requires teachers to develop, or find, curricula that can be used by each teacher to increase the knowledge gained from one year to the next, while using the same overarching principles.

In addition, students need to be aware of how the topics learned in a science class do not relate solely to the science class. Students need to be aware of how they can use the information in their "real lives" and can extrapolate from what they are learning in class in order to keep abreast of the current issues and events occurring globally around them. In this way, the students are constantly thinking about, and relating to, the science around them in their everyday lives, and can be proficient in political, environmental, and local conversations regarding scientific issues. In addition, with the ability to think outside the classroom about the science they have learned, they should be able to successfully project from the knowledge in the classroom onto a standardized test.

Many current issues can be used as an overarching theme, but I believe one of the most constructive is that of global warming. The students have all heard the term, and have some idea of what it means to their lives, but when polled, have no idea about how scientists arrive at the idea of global warming, nor what it really means might happen around them and globally. The issue of global warming is based on all three remaining sciences in the standard public high school, covers all of the topics on the standardized science tests, allows for cross-curriculum teaching as well as extended learning for the three years of formal science, and connects the student to real, current, valuable issues, allowing them to use the information easily outside of the classroom[i].

When asked to give their overall impressions of global warming before any formal teaching is done, the students offer many ideas. Many connect the event to the melting of the ice caps, although when asked where those ice caps are and how we know they are melting, one often receives blank stares. Some relate it to the temperature of their local area, but when confronted with the average temperatures of their areas over the past 10 or 20 years, cannot explain why the concept of "warming" doesn't hold consistent. Some of the students connect the issue to the devastating weather phenomena that have occurred recently, but cannot explain why or how the weather relates to global warming. Some will connect the term with the hole in the ozone layer, and will explain that the earth will become uninhabitable if the hole continues to expand, but cannot explain what ozone is, nor how the hole is expanding. I have yet to have one student be able to explain how we even know the ozone layer actually exists, or how we know the hole exists, or where it is located! Many students have seen the movie "The Day After Tomorrow" but cannot explain how New York becomes a frozen wasteland if we are talking about global *warming*. Still others relate global warming to automobile emissions, but cannot explain how it is related, nor what can be done to change it. In other words, the actual comprehension of the global warming issue is non-existent.

Before any comprehensive study of global warming, basic scientific skills and knowledge need to be taught. As an overarching theme, global warming permits the introduction, and then over subsequent years, more in-depth study, of many parts of science. Of particular interest, the students will be able to work with the concept of hypotheses, experimentation, and data analysis. Global warming deals with air quality, but also deals with weather and climate, which in turn, relate to the earth's layers of the atmosphere, their chemical makeup and temperature inversions, the positions of the continents, ocean currents and wind patterns. These earth science topics used to be covered in an earth/space science course no longer offered by many public high schools. Students will be able to identify the types of sciences used in each area of the issue of global warming, and relate each type to their health, their local impact, their more far-reaching impacts, and the laws and responsibilities of different countries toward the environmental health of our planet.

With any study of global warming, students will learn that science requires careful thought, didactic planning, continual repetition of experimentation, clear communication of results, and out-of-the-box thinking. All of these relate to the scientific method, which can be taught first as an introductory lesson, and then can be inferred from the information given the students as they learn about global warming. As they learn about each detail relating to, and causing, global warming, the teacher can continually redirect the students' thinking to recreate what may have been the scientists' hypothesis, and to imagine the experiment that may have been done. Further, for each step of the learning process, the students can be encouraged to develop ways to disseminate the information to the public, which increases their use of intercommunication skills and data gathering and data organization.

The topic of global warming is an excellent lead into data collection and organization. The time period for which reasonably reliable near-surface temperature records exist from actual observations from thermometers with quasi-global coverage is generally considered to start in about 1850. Earlier records exist, but coverage and instrument standardization are less, therefore, these earlier records are viewed with considerable skepticism[ii]. The temperature data for the record come from measurements from land stations and ships. A study of the technological advances, and discussion of the reliability of the older readings, is a natural segue from the topic of global warming. While temperature changes vary both in size and direction from one location to another, the numbers from different locations are combined to produce an estimate of global average change. This allows for mathematical practice of computations, and allows for further debate as to the reliability of the evidence and a discussion of historical instrumentation used.

Few students are aware that the air they breathe consists of more than just oxygen. When confronted with the idea that their breathing air contains more nitrogen, a substance which causes death when breathed in by itself, than oxygen, most students are stunned. Many have heard of the "bends" caused by nitrogen in the bloodstream of divers, and are aware that there is a "decompression machine" that is used to help some divers survive the episode, but are not aware of the nitrogen in the air they breathe! It is important for the students at this point to understand the makeup of the air they breathe, and how these elements combine to form molecules, which is a comprehensive introduction to chemistry and the periodic table of elements. It is then an easy step to demonstrate how the presence of other molecules can disrupt the fragile chemical balance of the air they breathe. This, in turn, can lead to a lesson on air pollution and vehicle emissions.

Using atmospheric gases as a base, the periodic table of elements can be introduced to the students. They can be led to understand the atomic makeup of the molecules found in the atmosphere, and the basic structure of these molecules. In addition, the students can be given an introductory course into electron orbitals and Lewis dot structures, to help them understand how one atom can replace another to create a new molecule. Upper level chemistry can also take advantage of further investigation, as the students learn about transient dipole moments and the "floppy" vibration motions whose quantum states can be excited by collisions at energies encountered in the atmosphere by $CO_2$ and $O_3$. They can compare linear molecules' modes with those of asymmetric molecules, and can begin to have a deeper understanding of how radiation is absorbed by the molecules in the atmosphere. In this way, they can begin to quantify the effects of different emissions on the atmosphere.

When studying the "other greenhouse gases," other than carbon dioxide, students are introduced to methane ("marsh gas.") This is released by natural process (e.g. from decay occurring in swamps and naturally from plants,) to human activities, which may now account for over one-half the total of methane found in the atmosphere. This occurs from growing rice in paddies, burning forests, and raising cattle. In addition, it is a result of the decomposition that occurs in landfills. This leads to a cross-curricular discussion, as students can be encouraged to try to find alternative grains to feed the underdeveloped countries, and will realize the corner into which humans have boxed themselves. This subject also leads to possible discussions about how much the earth can support humans, and what types of laws or recommendations should and can be made.

Besides $CO_2$ and methane, nitrogen is of concern to our future on Earth. Earth's atmosphere is about 78% nitrogen, making it the largest pool of nitrogen on the planet. Nitrogen is essential for many biological processes and is crucial for any life here on Earth. It is in all amino acids, is incorporated into proteins, and is present in the bases that make up nucleic acids, such as DNA and RNA. In plants, much of the nitrogen is used in chlorophyll molecules which are essential for photosynthesis and further growth. Fixation is necessary to convert gaseous nitrogen into forms usable by living organisms. Some fixation occurs in lightning strikes, but most is done by free-living or symbiotic bacteria. However, due to their very high solubility, nitrates can enter groundwater, which creates a concern for drinking water because it can interfere with blood-oxygen levels in infants, and cause eutrophication in water bodies, which causes a loss of oxygen availability to the organisms living in the water, and causes their deaths. Nitrogen is a common ingredient in fertilizers, which brings us back to the sustainable farming techniques the students must learn. Combustion of fossil fuels pollution emitted by vehicles and industrial plants, and extensive cultivation of legumes has more than doubled the nitrogen found in the atmosphere. This can then bring the students back to the idea of the unique molecular signature on the spectrum that each molecule has, and again how it impacts the global climate.

Many students are aware that automobile manufacturers are attempting to use fuels other than fossil fuels, but don't know why, and don't know what the alternatives are that are being offered, nor how those alternatives may affect the air they breathe as well. As a side note, many of my ninth graders cannot tell you what a "fossil fuel" is, nor how it was formed! A further lesson should include how humans have used fossil fuels since the industrial revolution, and what is emitted by the burning of these fuels. Most students have heard of a "catalytic converter" but do not know its relationship to air pollution and greenhouse gases[iii]. A brief historical tour of the first environmental summits will turn up surprising information to the typical high school student. At this point, the students have a basic understanding of how humans are affecting the balance of chemicals in the lower atmosphere.

A lesson should be included which helps the student to distinguish between the variety of ways energy is transferred between the earth's surface and the atmosphere. Radiation, convection, and conduction all play a role in the weather and climate of the earth. The wave motion of radiation is an excellent introduction to physics, and relates primarily to global warming as the absorption of the radiated photons from the sun gets converted to heat. Chemistry is revisited as well, because of the absorption of different wavelengths by different molecules. The rays with the shortest wavelengths are absorbed by oxygen and nitrogen molecules, they are transformed into ions, and form the ionosphere, whereas the ultraviolet rays of slightly longer wavelength are absorbed by ozone in the stratosphere, and infra-red rays, at the other end of the spectrum, are absorbed by carbon dioxide and water vapor in the troposphere. This is an excellent opportunity to hone the students' graphing skills, as they attempt to disseminate this information in a logical way.

It is important for students to understand a feedback system and the law of conservation of energy as it relates to global warming. Despite variations with time, place, and season, the earth's surface temperature maintains a fairly constant average value of about 15°C (59°F). To maintain this constant average temperature, the earth's heat flow must be balanced- the net flow of heat to the earth must be zero. The earth maintains its constant average temperature of 15° C by getting rid of heat just as quickly as that heat arrives. In that way, the earth's store of thermal energy never changes. The laws of conservation are the basis for all physics, and can be used as a further introduction to the physics course[iv].

The effect of the trapping of air by the layer of the atmosphere[v], caused by temperature inversions, cloud covers, and reactivity to infrared radiation by the so-called greenhouse gases has been understood by scientists for about a century, and technological advancements during this period have helped increase the breadth and depth of data relating to the phenomenon known as the "greenhouse effect." Currently, scientists are studying the role of changes in composition of "greenhouse gases" from natural and anthropogenic sources for the effect on climate change. A number of studies have also investigated the potential for long-term rising levels of atmospheric carbon dioxide to cause slight increases in the acidity of ocean waters and the possible effects of this on marine ecosystems and, concurrently, on humans[vi,vii]. Quantum mechanics provides the basis for computing the interactions between molecules and radiation. Most of this interaction occurs when the frequency of the radiation closely matches that of the spectral lines of the molecule, determined by the quantization of the modes of vibration and rotation of the molecule. For this reason, the curriculum of global warming allows even the more advanced physics class to continue their investigation of the issue.

The study of global warming offers an excellent opportunity to incorporate marine biology into the curriculum[viii]. Oceans play a large role in weather patterns on Earth. They are the largest reservoir of moisture and absorb heat more effectively than land and ice surfaces, and store heat more efficiently than land. Vertical motions in the ocean are critical to the exchange of heat and gases, such as $CO_2$ between the surface layer and the deep ocean[ix]. Because the oceans and atmosphere store and exchange energy in the form of heat, moisture, and momentum, solar heating of the earth and its atmosphere can be demonstrated to drive the large-scale atmospheric circulation patterns, and seasons. It influences the daily cycle of surface temperature over land and the ocean is a direct carbon dumping ground. Salinity and algal growth are used to determine changes in the global climate, and influence the currents, which in turn influence weather patterns. In addition, this would be an opportune time to discuss water pollution and the marine debris accumulation and its effects on the marine habitats.

Using the overarching theme of global warming leads naturally into a basic environmental course. Students need to be aware of what activities they do, and do not do, that increase global pollution, and thus affect the delicate balance that keeps the globe's climate in check. Students should learn the difference between point and nonpoint source pollution, the use of fossil fuels, and the environmental summits which have been held to discuss these issues. The students should be introduced to the difference between anthropogenic and natural sources of pollution. After doing so, they can begin to determine their own impact through the use of electronics, food packaging, waste management, and the over use of products in the United States. They should be able to determine their carbon footprint, and should, as well, be able to compare their impact to that of a student in other countries. In this way, the students can begin to see how science is integrated into all aspects of life, and can understand how the little difference made by one individual can accumulate to make a large impact on the entire globe. Through this part of the investigation, a cross-curriculum approach can be done, again, with a world history teacher, so that students can compare the use of technology and creation of pollution between the technological and third-world countries[x,xi].

Students have been introduced to the idea of plate tectonics in middle school, but by high school have forgotten the topic, and need further knowledge to relate the topic to global warming. Many people debate that $CO_2$ is found in the atmosphere because of volcanoes, but the students do not know how volcanoes are formed, or how they affect their immediate surroundings, much less their more far-reaching affects. In order to be able to disseminate the proper arguments, students should be taught a basic understanding of plate tectonics, how volcanoes and earthquakes (and tsunamis) form, and some of the far-reaching implications of these events. This can be used easily in a cross-curriculum activity with a history class, as there have been numerous large-scale natural disasters to study over the past few years[xii]. A further introduction to chemistry should include a spectrometry lesson, so that students can understand how scientists actually know what molecules are present in the atmosphere, and how they can monitor the changes in concentration of these molecules. At this point, as an introduction to physics, a basic lesson in the spectrum of light should be added, so that students understand that there are more and less harmful light energies emitted by the sun, and can relate which type of light energy reacts with which chemicals in the atmosphere, so that they can begin to form a working knowledge of what might be causing a warming effect in the atmosphere and here on Earth.

Revisiting earth-space science, students should be made aware that the earth's axis is tilted, and the orbit is not a perfect orbit. These two facts are responsible for the seasonal changes on Earth. This is important because the solar heating of the polar latitudes varies greatly throughout the year, which drives a strong "heat engine," or circulation, of the atmosphere, which in turn drives large mid-latitude storm systems as heat moves from the surplus in the equator to the deficit in the polar regions[xiii]. The position of the earth relative to the sun also affects the amount of radiation received. While one hemisphere points toward the sun, the other points away. This allows for the frozen climate at the poles[xiv], which becomes a discussion in global warming, as the melting of the polar ice caps[xv] is one reason that dire predictions for the future are made[xvi].

Revisiting physics, the Coriolis Effect, which is a product of the earth's rotation, should be studied. This effect complicates the global wind patterns, which in turn affect the weather patterns. The Coriolis Effect is an accelerating frame of reference and because of it, the earth's winds appear to curve away from straight-line paths. Because of this, large weather systems, like hurricanes, rotate. It creates westward-running trade winds near the equator, and eastward-running jet streams in the northern and southern hemispheres. These wind patterns move moisture and air from one place to another, creating weather patterns and global wind patterns[xvii]. Because weather affects every student's lifestyle, an in-depth study of the Coriolis Effect, temperature, cloud patterns, dew point, and regional winds should be studied. In this way, the students are able to understand the weather as related by the local news, and will have the ability to understand what effects global warming might have on their local and the global weather patterns.

Global warming is also a fantastic introduction to sustainable food sources. Yale University is striving to be the most "green" university in the United States, and has begun serving seasonal vegetables and fruits grown in their own sustainable gardens in their cafeterias. Students hear about "green" buildings and "sustainable futures" but have no idea what these catch phrases mean, nor how they relate to themselves. Because public school students today rarely have the opportunity to maintain farmland and food stuffs, they take for granted what they eat and are ignorant of the possible negative effects of improperly run farmland. This overarching topic allows students to grow foods, create a greenhouse, create roof gardens, and practice integrated pest management. This will also alert them to some of the controversial topics seen in the news about deforestation in order to make room for more food growth, pesticide accumulation in the biosphere, and give them a simple understanding of the "greenhouse effect" even though that term is a misnomer[xviii,xix].

Global warming also leads to a cross-curricular approach because the history of the use of CFCs can lead the students further to understanding how technology by humans has negative impacts on the environment, and may be contributing to an overall warming of the global climate. Studying the industrial revolution leads a student easily toward understanding why it is now fairly certain that the overproduction of certain “greenhouse gases”, notably carbon dioxide, is caused by human technological advances. In addition, a study of environmental laws, and how they are determined, increases a student’s awareness of how these chemicals were originally allowed into the atmosphere, and what is currently being done to correct the situation.

The concept of global warming also allows for debate as to the use of monies by governmental agencies. From time to time, governments have decreased the funding to these agencies. Much of the instrumentation used includes satellite technology developed by NASA[xx] and its counterparts in other countries. In addition, space born instruments, such as the Multi-Angle Imaging SpectroRadiometer (MISR) and the Moderate-Resolution Imaging SpectroRadiometer (MODIS) are providing global maps of surface vegetation so that scientists can model the exchange of trace gases, water, and energy between vegetation and the atmosphere. Students should be aware of the issues involved in determining what monies go to which agencies, and should be able to argue their perspective as to whether or not NASA should continue to receive funding toward the study of global warming.

This topic also allows for students to debate the importance of the issue itself, as to whether a person should be concerned about global warming itself, or more specifically, should concentrate on sustainable resources and pollution. With the instrumentation used today, scientists have determined that there was a warming in the early Jurassic period (about 180 million years ago,) with average temperatures rising by 5° C (9° F.) Levels then dropped back to normal over roughly the next 150, 000 years. Global temperatures on both land and sea have increased by 0.75 °C (1.35° F) relative to the period 1860 to 1900, and since 1979, land temperatures have increased about twice as fast as ocean temperatures (0.25 °C per decade against 0.13° C per decade.) The global average air temperature near the Earth’s surface rose 0.74 +- 0.18° C during the hundred years ending in 2005. Climate model projections summarized by the IPCC indicates that average global surface temperature will likely rise a further 1.1 to 6.4° C (2.0 to 11.5° F) during the twenty-first century. Students can use this to determine what effects this will have on sea level, the intensity of extreme weather events, the amount of and pattern of precipitation, the changes in agricultural yields, trade routes, species extinctions, and increases in the ranges of disease vectors. Global warming allows the students to examine the data and determine the broad changes that may be caused by this event.

**Objectives**

It is my intention that this curriculum will be able to be used at all levels of high school science, with a cross-curricular ability to help students mesh the information between classes together and realize that science impacts all parts of their lives and is happening *to* them, every minute of every day, no matter what they are doing or thinking about. I hope that the students, through this curriculum, will develop stronger skills in creating and interpreting data, including graphs, determining potential risks and the means by which to model them, and have a strong grasp of environmental topics in order to successfully interpret the standardized tests given, even though the classes on which these questions are based are no longer offered in the public schools. It is my hope that the students will see that they cannot prove the theory of global warming is right, but that there are numerous facts, which come from a variety of sources, so this begins to demonstrate that *something* is going on. The many lines of evidence seem to coalesce[xxi].

According to the IPCC (2205,) there is a balance of evidence which suggests a discernible human influence on global climate. This curriculum is designed to allow students to be able to judge which parts of the global warming issue are valid, and which are hype. If you make it easy for lay people to understand, but then add sensationalism for better impact on human interest, you may not be giving valid data. It is important for students to be able to eliminate the artifice in the information they are receiving via the media. They need to understand that the law of unintended consequences applies to all human activities, and be able to see more than two steps ahead. They should, by completing this unit, be able to hold a clear and rational discussion of how much harm humans can really do, and how they know this. They should be able to know how to measure $CO_2$ amounts and apply it to temperature changes actually recorded[xxii]. They should be able to distinguish between the cyclical changes in global temperature and the changes specifically measured since the industrial revolution. They should be able to read graphs and identify when the trends on different graphs seem to support each other, while looking intently for error bars and misinformation. They should be able to relate how a 1° warming at the equator works out to be a 12° warming at the poles.

**Strategies**

A quick review of the scientific method must be done before in-depth study of global warming commences. The students must understand that there is a problem to be solved, and a specific series of steps which are used, and then communicated, in order to determine validity of the arguments presented. The students will also be given a review in graph interpretation and mathematical deduction, particularly in using percents. During the introductory period, students will be asked to graph the air we breathe in two forms; histogram and circle graph.

The next step will be to introduce the periodic table of elements, and explain the basic atom and its components, having the students determine the number of protons and electrons, neutrons, and isotopes of the elements, then the students will practice drawing the orbitals in order to determine how atoms bond to form molecules. At this point, the specific molecules relating to global warming will be introduced, and the students will use materials to build models of each of the "greenhouse gases" and demonstrate how ozone bonds.

Students will use the internet to define the industrial revolution and describe specific advancements they use that are a direct result of this period. They will then research the first two environmental summits and create a visual outlining the topics discussed at both forums. They will have an open discussion during class about fossil fuels and how they are used by humans today, as well as their makeup and the emissions created by their use. A brief sketch of a catalytic converter by each student will help the students to connect the summit findings to their everyday lives.

The use of prisms, the creation of a color wheel, and a simple chromatography lab will allow the students to understand the light spectrum, and a brief lecture will connect this knowledge with the absorption by the molecules in the atmosphere and the resultant affects on the temperature. A lecture on the separate layers of the atmosphere will help the students to understand the temperature inversions and the importance of balance within each layer to global temperature.

Once global temperature is introduced, students will be prompted to create a power point presentation of the oceans, the interaction the oceans have on climate and temperature, the currents, and the pollution problems, and possible outcomes due to anthropogenesis. When finished outlining ocean pollution, air pollution is the next step. Students will create a comical poster to complete and illustrate the sentence "you know there's air pollution when…."

A quick illustration of the climates of different Earth's regions will help students understand the difference between weather and climate. A calendar of weather events for the area will keep the students aware of the subject after school hours as well. A lecture on the position of the earth's axis and its rotation and orbit will help students to define the many interacting forces which control both weather and climate. Finally, students will again visit the internet to use the Google Earth site in order to download current pictures of the ice caps and compare them to pictures taken previously.

If the principal permits, a study of the green index for the school is usually a big success with high school students. A visit to CCI in the southside helps students to appreciate just how easy it is to make a positive impact, and how special it is that Pittsburgh has a green convention center. They enthusiastically will plant roof gardens to help to reduce electricity used by the building, and enjoy planting and maintaining a garden throughout the school year. They particularly enjoy finding their own grown foods on the cafeteria menus!

Pittsburgh is home to Rachel Carson, one of the first leading environmentalists. A study of her life, and the changes which have taken effect because of her research, helps to drive home to the students that environmental sustainability is a local issue. A tour of Kennywood during environmental days allows the students to realize how planting and maintaining a green environment is an ongoing process, and significantly impacts society in a variety of ways. A study of the environmental laws that have been developed over the last 65 years also allows the students to realize how desperately humans are trying to reduce their negative impacts to the earth, and how difficult it is to define what should be a law, and what should be a recommendation. Lastly, a debate about whether government should be allowed to police an individual's use of materials and their wastes helps the students to realize how difficult initiating changes can be.

**Classroom Activities**

Week 1: periodic table of elements, orbitals, and Lewis dot structures.
Culminating activity: hand on lab to "build" molecules

Week 2: prisms, color wheel, chromatography lab
Culminating activity: internet search to determine which atmospheric molecules respond to which wavelengths.

Week 1: periodic table of elements, orbitals, and Lewis dot structures.
Culminating activity: hand on lab to "build" molecules

| | Objectives and procedures | Materials |
|---|---|---|
| Day 1 | Introduction to organization on periodic table of elements. Students will color metals, nonmetals, and noble gases different color schemes. Students will create flash cards for elements found in atmosphere but are not told that that is what they are. | Black and white Periodic table of elements for each student, colored pencils<br>Note cards |
| Day 2 | Introduction to organization by atomic makeup. Students will complete a worksheet filling in # of protons, electrons, average atomic mass, and # neutrons. | Worksheet per student, periodic table of elements from previous day. |
| Day3 | Introduction to orbitals and outer shell electrons. Students will learn the 2-8-8-8, etc. rule and draw orbitals for the first 20 elements. | Blank orbital worksheet per student. Periodic table of elements from day 1. |
| Day4 | Introduction to Lewis Dot Structure and bonding of "free" electrons on outer orbit. Students will use the 2-8-8-8 rule to mathematically compute how many valence electrons will be found for elements 6-24. Students will draw basic bonds between several Lewis Dot structures to understand how atoms interact. | Blank Lewis dot structure worksheet per student. Periodic table of elements from day 1. |
| Day 5 | Modeling bonding. Students will use the materials given to build Lewis dot structures of several elements and then bond them together appropriately. Molecules may be eaten at end of class if students were careful to keep materials and hands clean. | Various candies for each atom used, toothpicks to connect valence electrons to nuclei, colored toothpicks to connect valence electrons together to demonstrate bonding. |

Week 2: prisms, color wheel, chromatography lab
Culminating activity: internet search to determine which atmospheric molecules respond to which wavelengths.

| | Objectives and Procedures | Materials |
|---|---|---|
| Day 1 | Introduction to light spectrum. Students will use this class period as inquiry based lesson to demonstrate how the light we use, both naturally and man-made, is made up of several colors. Students are to record all observations in journal. | Prism per student, SUNNY DAY and FLASHLIGHT with working batteries for every two to four students required. Journals. |
| Day 2 | Introduction to white as a color. Students will be instructed in the use of a compass to create a specifically sized circle out of white poster board. Students are then to divide the circle, using a protractor, into 6 equal sections. (this is easily divided into 360 .) Students are to color each section, using indelible markers or crayons (markers work better) in the proper order clockwise: red, orange, yellow, green, blue, violet. Wheels must be left overnight to dry. | White poster board. Protractor and compass for each student. Indelible markers and/or crayons for each group of students. Scissors. Directions for lab on handout. |
| Day 3 | Continuation of color wheel lab. Students are to match, section for section, and color for color, back and front of circle. Students are to poke two holes in the center of the circle through which they will feed a string so that it makes a loop, with the color disc suspended in the middle of the loop. Students are to help one another to wind up the disc, then alternately pull and release on the loop of string to get, and keep, the disc spinning. Students are to observe the color created by the rapid mixing of all the colors on the wheel. | Colored disc from previous day. Markers and/or crayons from previous day. String and scissors. Lab handout from previous day. |
| Day 4 | Introduction to chromatography. Students will follow direction in kit to determine the pigment colors found in a plant leaf. | Chromatography kit from Ward's[xxiii]. Sample leaves from neighborhood plants. |
| Day 5 | Introduction to atoms having specific wavelength reactions. Students will use the internet to search for which wavelengths and corresponding colors each of the following atmospheric molecules reacts: $O_2$, C, $N_2$, S, $CO_2$, Methane, $H_2O$. Students will record all information found. | Use of internet. Journal. |

**Appendix-Content Standards**

The Pittsburgh Public Schools offers specific standards which relate to this overarching topic, as can be specifically referenced in the appendix. The goal of the science standards for Pittsburgh is to create "science literate citizens through an inquiry-based approach that builds understanding of fundamental scientific processes and principles of biology, chemistry, physics, earth science, and ecology[xxiv]."

For state standards[xxv], this curriculum includes the following topics: unifying themes, including applying patterns in science and technology, applying elements of scientific inquiry to solve problems, analyze energy sources and transfers of heat, interpret meteorological data, apply biotechnical technologies as they relate to growing, propagating, and maintaining, apply appropriate instruments and apparatus to examine a variety of objects and processes, evaluate impacts and consequences of scientific and technological solutions, analyze how man-made systems have impacted the management and distribution of natural resources, explain how multiple variables determine the effects of pollution on environmental health, natural processes and human practices, analyze the efforts of increased efficiency in agriculture through technology, analyze health benefits and risks associated with integrated pest management, explain how cycles effect the balance of an ecosystem, analyze how human activities can cause change in an ecosystem, explain why environmental laws and regulations are developed and enacted.

In addition, numerous standards for the 11$^{th}$ grade PSSA testing are met through the use of this curriculum. For the Pittsburgh Board of Education, for the PSSA, this curriculum touches upon and can expand upon the following topics included on the test: reasoning and analysis; processes, procedures, and tools of scientific investigation; using models; comparing and analyzing patterns; natural processes which impact the environment; human practices and how they affect resources; energy and the environment; renewable and nonrenewable energy sources; processes that change Earth's surface; and weather and climate[xxvi].

**Bibliography/Resources:**

1) Annotated reading list for students
2) list of materials for classroom use
3) for teachers: reference list for background information, found as bibliography/works cited.

Reading List for Students:


Cherry, Lynne, Braasch, Gary. *How We Know What We Know About Our Changing Climate: Scientists and Kids Explore Global Warming (About Our Changing Climate)* Dawn Publications, USA. 2008. This book focuses on students as a vital part of the research teams assisting scientists in documenting the changes in our environment. The book is a pleasure to read with all its beautiful pictures and clearly explained concepts. A teacher's guide is available for order.

Emanuel, Kerry, Layzer, Judith a., and Moomaw, William R. *What We Know about Climate Change.* Massachusetts Institute of Technology. MIT Press, USA.2007. A sound authoritative analysis of what we really do and don't know. Includes the philosophic underpinnings of different views, the history of global warming, the science, and the politics.

Open University (2004-01-30). "The Open University Provides Answers on Global Warming". http://www.open.ac.uk/. An excellent website for any search on global warming information.

Ruddiman, William F. *(March 2005). "*How Did Humans First Alter Global Climate?*".* Scientific American **292** (3): 46–53. An excellent background for students to recognize the impact humans can have on the environment.

R. W. Wood: Note on the Theory of the Greenhouse http://www.wmconnolley.org.uk/sci/wood_rw.1909.html. an excellent introduction to the so-called greenhouse effect.

Science at NASA. http://nasascience.nasa.gov/ NASA Oceanography: The Water Cycle. Explains the importance of the ocean in the water cycle, and the oceans' affect on weather and climate.

Tenneson, Michael. *The complete idiot's guide to Global Warming*. Alpha Books- Penguin Group Inc., USA.2008. Provides clear explanations of current evidence and future predictions, and offers ways to be part of the solution.

Thompson, Graham R. and Jonathan Turk, 1992: *Earth Science and the Environment*. Saunders College Publishing. 622 pp. An excellent reference book for global warming information.

Understanding and Responding to Climate Change – Highlights of National Academies Reports. United States National Academies (2005). http://dels.nas.edu/dels/rpt_briefs/climate-change-final.pdf

Vitousek, PM; Aber, J; Howarth, RW; Likens, GE; Matson, PA; Schindler, DW; Schlesinger, WH; Tilman, GD (1997). "Human Alteration of the Global Nitrogen Cycle: Causes and Consequences". *Issues in Ecology* **1**: 1-17. Another example of how humans can impact the environment.

Wall Street Journal article, May 23, 2006 an article describing an alternative view of global warming by anthropogenic means. The author is an American lawyer and politician, not a scientist, but is a regular columnist for the Wall Street Journal and gives a biased account of anthropogenic impacts. Great for starting a debate in class.

List of Materials for Classroom Use.

Ward's Scientific Catalogue:
http://www.wardsci.com/Default.asp?bhcd2=1211134304

CD or Video: An Inconvenient Truth: can be ordered at www.paramount.com/homeentertainment

Periodic table of elements, Colored pencils, Notecards, Proton, electron, neutron worksheet, Orbital worksheet, Lewis dot structure worksheet, Various candies, Colored and wooden toothpicks, Prism, Flashlight with batteries, Journals, Internet use, Poster board, Protractor, Compass, Indelible markers: red, orange, yellow, green, blue, violet, Scissors, String, Ward's chromatography lab, Leaves, Video: An Inconvenient Truth, Television with video player

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Reference Information/Bibliography/Works Cited

Malnor, Carol L. *How We Know What We Know About Our Changing Climate: Lessons, Resources, and Guidelines for Teaching About Global Warming.* Dawn Publications, USA. 2007. Multiple lesson plans with clear graphics, detailed explanations, and written to be of high interest to students.

[i] IPCC assessment reports, see http://www.ipcc.ch/ . http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter7.pdf IPCC Fourth Assessment Report, Working Group I Report "The Physical Science Basis", Section 7.3.3.1.5 (p. 527)

[ii] Antarctic temperature data – Monthly mean surface temperature data and derived statistics for some Antarctic stations. British Antarctic Survey. http://www.antarctica.ac.uk /

[iii] http://reports.eea.eu.int/EMEPCORINAIR4/en European Environment Agency's 2005 Emission Inventory Guidebook

[iv] Fleagle, RG and Businger, JA: An introduction to atmospheric physics, 2nd edition, 1980

[v] Lutgens, Frederick K. and Edward J. Tarbuck (1995) *The Atmosphere*, Prentice Hall, 6th ed., pp14-17, ISBN 0-13-350612-6. An excellent reference about all layers of the atmosphere and their interactions.

[vi] Estimated deaths & DALYs attributable to selected environmental risk factors, by WHO Member State, 2002, AND

[vi] Air Pollution, Heart Disease and Stroke from the website of the American Heart Organization January 5, 2008. Both of these articles allow for students to become aware of some of the proven health risks directly contributable to pollution.

[vii] National Research Council: Committee on Air Quality Management in the United States, Board on Environmental Studies and Toxicology, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies (2004). Air Quality Management in the United States. National Academies Press.

[viii] Science at NASA. http://nasascience.nasa.gov/ NASA Oceanography: The Water Cycle.

[ix] http://www.noaa.gov/

[x] http://www.bhopal.org/whathappened.html. This is information about the worst recorded environmental disaster on record.

[xi] Simi Chakrabarti. "20th anniversary of world's worst industrial disaster", Australian Broadcasting Corporation.

[xii] Hotz, Robert Lee. "Huge Dust Plumes From China Cause Changes in Climate" Science Journal. July 20, 2007. this is an excellent example of how other countries affect global climate change as well.

[xiii] Svensmark, Henrik *(July 2000). "*Cosmic Rays and Earth's Climate*"* . Space Science Reviews ***93*** *(1-2): 175-185.*

[xiv] Amos, Jonathan. "Deep Ice Tells Long Climate Story.". BBC NEWS | Science/Nature | Deep ice tells long climate story 9/2006.

[xv] U.S. Geologic Survey. GLACIER RETREAT IN GLACIER NATIONAL PARK, MONTANA.

[xvi] Graph by Robert Simmon, based on data from Lorius, C., J. Jouzel, C. Ritz, L. Merlivat, N.I. Barkov, Y.S. Korotkevitch, and V.M. Kotlyakov. 1995. A 150,000-year climatic record from Antarctic ice. *Nature* 316:591-596.

[xvii] Marsh, Nigel; Henrik, Svensmark (November 2000*). "*Cosmic Rays, Clouds, and Climate*"*. Space Science Reviews **94**: 215–230. http://www.springerlink.com/content/u348727n87q617l3/

[xviii] Piexoto, JP and Oort, AH: Physics of Climate, American Institute of Physics, 1992 (quote: ...the name water vapor-greenhouse effect is actually a misnomer since heating in the usual greenhouse is due to the reduction of convection)

[xix] Ann Henderson-Sellers and McGuffie, K: A climate modelling primer (quote: *Greenhouse effect: the effect of the atmosphere in re-readiating longwave radiation back to the surface of the Earth. It has nothing to do with glasshouses, which trap warm air at the surface*).

[xx] Hansen, James E.; *et al*. Goddard Institute for Space Studies, GISS Surface Temperature Analysis. NASA Goddard Institute for Space Studies.

[xxi] Wall Street Journal article, May 23, 2006 an article describing an alternative view of global warming by anthropogenic means. The author is an American lawyer and politician, not a scientist, but is a regular columnist for the Wall Street Journal

[xxii] http://www.esf.org/index.php?id=855/ a web site on coring the ice in Antarctica
[xxiii] http://www.wardsci.com/Default.asp?bhcd2=1211134304
[xxiv] http://www.pps.k12.pa.us/pps/lib/pps/_shared/1340_DistrictGuide_v08.pdf, pages 21-22
[xxv] http://www.pps.k12.pa.us/143110127103415203/lib/143110127103415203/Bio_SAI.pdf, Specifically, 3.1, 3.2, 3.4, 3.5, 3.6, 3.7, 4.2, 4.3, 4.4, 4.5, 4.6, 4.8, and 4.9
[xxvi] standards S11.A.1, S11.A.2, S11.A.3, S11.B.3, S11.C.1, S11.C.2, S11.D.1, and S11.D.2