Examining Climate Change and its Impacts in North Carolina Through Problem Based Learning

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Background:

"We shall require a substantially new manner of thinking if mankind is to survive."
~Albert Einstein

I teach at Northwest School of the Arts, a 6-12 arts magnet school in Charlotte, NC. We have a diverse population of creative students that love to challenge the status quo. We are located in urban Charlotte and our population of students comes from all over Mecklenburg County and represents all strata of socio-economic status. Our students want to be at school and must audition and major in an arts discipline, while maintaining good academic standing. Northwest fosters an incredible supportive school with a wide variety of races, economic backgrounds, sexual orientation, and all around unique students. I cannot emphasize enough how different our school is without you visiting.

Northwest School of the Arts has 983 students comprised of 266 males and 717 females. The average graduation rate is 80% and is a school of distinction. I teach Earth and Environmental Science, AP Environmental Science, and co-teach AP Biology. All classes are taught on a rotating A Day B Day schedule. My Earth and Environmental Science class has 145 students and my AP classes have 25 students. Class size varies from 20 to 42. Two sections of Earth and Environmental Science are honors and two sections are standard. Classes are seventy-five minutes each. I plan to teach this unit in my Earth and Environmental Science class.

Teaching science at Northwest School of the Arts can be challenging, as my students' primary focus is often the arts. I try to create a challenging, hands-on, and engaging science course to meet their educational needs and encourage their interest in science.

My curriculum is based on the North Carolina Common Core Essential standards. I pace my school year based on Charlotte-Mecklenburg science pacing guides. Lessons, activities, and labs are designed to promote scientific inquiry. A typical unit involves teacher input, guided learning, group activities, laboratories-both as demonstrations and inquiry, and examination and explanation of results. I often supplement my units with Discovery Streaming and a variety of organizational websites such as National

Geographic, NASA, EPA, NPR, NOAA, etc. I am utilizing a Promethean Board and students have access to computer labs, which we use frequently for further research.

The Unit:

To put it mildly, I have been overwhelmed by the topic of environmental education. If I am overwhelmed, won't my students be as well? How can I make such a bewildering, yet important topic accessible and relevant to them?

This unit will focus on global climate change because I believe it will be one of the most critical issues this generation of students will deal with in their future. I hope to examine climate change from both a scientific and social perspective. I anticipate students being able to answer the following questions at the end of the unit: What is climate change? What is anthropogenic climate change? What does the scientific data say about climate change? What are the consequences of climate change? Impacts of climate change in the Southeast region? Mitigation and Adaptation? What does that mean for NC? Charlotte?

The unit will be a concluding activity to our study of the atmosphere and weather. It will last approximately two weeks (which is about a month with an A/B day schedule) and will be divided into three areas: climate change, impacts of climate change, and mitigation and adaptation. Students will be divided into groups to answer a problem related to climate change in the North Carolina/Charlotte region. Each group will be required to keep a work portfolio that contains tasks they need to complete in order to fully answer their question. This lends well to differentiation within the classroom. By providing different problems/questions students can choose an area that most interests them and create a project that utilizes their talents. Each task will have a different way to present the students knowledge such as a book, poster/mural, plays, public service announcements, and models. My students are very artistically inclined and a project such as this allows the students to use that talent in the classroom. High-level students maybe able to generate their own questions or complete their investigation with very little guided questions. Three scenarios will be outlined in this unit and other potential questions are:

- What are some ways the city of Charlotte could decrease it's energy use? What are alternative energies already in use in NC? Charlotte?
- Examine Charlotte's air quality. Will we have more 'red' days with climate change? What does that mean?
- Does urban sprawl contribute to global climate change? Does Charlotte address this?
- What are some weather changes we could expect in Charlotte and NC? How do we prepare?

- How will agriculture change in North Carolina?
- How will climate change affect North Carolina fisheries?
- Will climate change impact our water supplies? Will we experience drought or flooding?

Activity 1: Climate Change Background

> "Science, mathematics, and technology have a profound impact on our individual lives and our culture. They play a role in almost all human endeavors, and they affect how we relate to one another and the world around us. . . . Science Literacy enables us to make sense of real-world phenomena, informs our personal and social decisions, and serves as a foundation for a lifetime of learning."[1]

I often worry that by asking the question-do you think global warming is an imminent human threat, I am opening up the subject of climate change, also known by most students as global warming, to debate among my students. While 66% of Americans believe that global warming is occurring, only 46% believe that global warming is occurring due to human activities.[2] As an educator I feel a responsibility to produce students that are environmentally conscious as they make decisions about their future through personal choice and voting. To accomplish this, I think it is important for students to be exposed to and become savvy consumers of scientific information. Students must have the ability to evaluate sources, answer to the validity of those sources, and to understand and interpret scientific data accurately. Through our exploration of climate change, students will understand that scientific ideas are based on data derived from experiments and observations.

For students to truly understand global climate change they must first understand how the Earth is heated. I have found that students can tell you that the Earth receives all of its energy from the sun, but few understand how that happens. Energy from the sun is radiated to the Earth in the form of electromagnetic radiation specifically short wavelengths of light, both visible and ultraviolet. Approximately 30% of that energy is immediately reflected back to space by Earth's upper atmosphere. The remaining energy is then absorbed mostly by the surface of the Earth and slightly by the atmosphere. About 50% of the radiant energy that is absorbed is converted to heat, thermal radiation, resulting in increased temperature. Some of the thermal energy absorbed by the Earth is reradiated as infrared radiation since the surface temperature of the Earth is much lower than the sun. The greenhouse gases, primarily water vapor and carbon dioxide, in the atmosphere, then absorb the infrared radiation emitted. This is known as the greenhouse effect. Students are also very aware of the greenhouse effect, but tend to think of it in a negative context. I try to emphasize that Earth would be inhabitable without the

greenhouse effect because the temperature would be below freezing. It is human activities such as the burning of fossil fuels and the clearing of forests that have intensified the natural greenhouse effect and are causing global warming.[3]

Students often confuse the terms global warming and climate change. Global warming is a rise in global average temperature near the surface of the Earth. Climate is a much more complex term with temperature change as one aspect. Climate describes the complex interactions of the atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere. Essentially all systems on Earth including air, water, land, and living organisms create climate systems. Simplistically one can refer to climate as the 'average weather' of an area. Weather is the atmospheric condition in a given time and place. It most often includes the temperature, precipitation, humidity, wind, pressure, and cloudiness. Climate is an average of weather conditions over a period of time, months to hundreds or thousands of years, or more scientifically "the statistical description in terms of the mean and variability of relevant quantities over a period of time".[4]

The most common climate classification system is the Köppen system that was developed by using native plants and vegetation as indicators of climate. It is divided into five types of vegetation: tropical rain forests, hot desert, temperate deciduous forests, boreal forest, and tundra. Other vegetation such a grasslands and heathland are considered subdivisions of the main classifications. Tropical rain forests contain dense vegetation with rainfall that is heavy and year round. As an example, in the United States portions of Florida are considered tropical rain forest climates. Hot desert climates are dry areas with low growing shrubs and short woody trees such as the western United States. Temperate deciduous forests have mild climates with deciduous trees, which cover much of the eastern United States. Boreal forests are climates between temperate and polar climes and are dominated by coniferous trees. Tundra climates have small shrubs, sedges, and grasses whose growth is impacted by a short growing season and cold temperature.[5]

Changes in climate can be attributed to natural and anthropogenic (man-made) causes. Natural causes of climate change are atmosphere-ocean interactions, land surface-atmosphere interactions, volcanoes, and the sun. Water covers three quarters of the Earth's surface with most of that water contained in oceans. Ocean's high heat capacity moderates the more extreme daily and seasonal temperature variations that occur within the atmosphere over land around coasts and inland areas. Tropical cyclones develop over oceans and ocean currents carry heat that travels from the equator to the poles. This heat carried by ocean currents is responsible for Western Europe's climate conditions. Land surfaces, such as surface albedo, vegetation, and soil moisture interactions with the atmosphere can impact a region's climate. Climate induced changes in vegetation can greatly impact a region's water evaporation rate and runoff therefore affecting the region's climate. Volcanic eruptions can cause climate change by emitting dust and

particles of sulfur dioxide into the atmosphere. The particles can remain suspended in the atmosphere for several years and spread around the globe. These particles have the potential to reduce the amount of radiation reaching the Earth, thus causing a cooling in the lower atmosphere. Variations in the sun's output such as sunspot cycles and changes in the solar magnetic field can cause also cause climate changes. [6]

Climate change is defined as any significant change in the measure of climate over an extended amount of time. This includes significant changes in temperature, precipitation, wind patterns and/or other effects occurring over several decades or longer.[7] Global temperatures have been changing and the average global temperature had risen by 1.4^{o} F over the last 100 years. Global temperatures are expected to rise by another 2- 11^{o} F over the next 100 years.[8] In the United States, the average annual temperature has increased close to 1^{o} F. This increase in global temperatures is attributed to increased concentration of greenhouse gases in the atmosphere. Greenhouse gases are any gases that absorb infrared radiation within the atmosphere. When the concentration of greenhouse gases within the atmosphere is increased the greenhouse effect is intensified and the Earth's climate changes; it becomes warmer. Thus, global warming caused by increased greenhouse gases has caused global climate change.[9]

Although there may be some confusion by the American public about the causes of global warming, the scientific community agrees that increases in global average temperatures and climate change is unequivocally and largely anthropogenic or human induced. Ralph Cicerone, President of the National Academy of Sciences stated, "I think we understand the mechanisms of CO_2 and climate better than we do of what causes lung cancer...In fact, it is fair to say that global warming may be the most carefully and fully studied scientific topic in human history."[10]

Students must understand this concept to be scientifically literate. Humans, through their production of electricity, goods, and transportation, have caused global warming by increasing the concentration of greenhouse gases and aerosols. Thus causing climate change.[11] Carbon dioxide, water vapor, methane, nitrous oxide, ozone, halogen containing gases, and sulfur hexafluoride are all greenhouse gases present in the atmosphere.[12] Emissions producing greenhouse gases in the United States have increased by 14 percent from 1990 to 2008. Anthropogenic global emissions of greenhouse gases have increased by 26% from 1990 to 2005. Of those emissions, Carbon dioxide emissions have increased globally by 31% over the same time period and comprise nearly 75% of total emissions.[13] Emissions have contributed to increases in carbon dioxide, methane, nitrous oxide, and halogen containing gases (such as chlorofluorocarbons-CFCs) all greenhouse gases. Transportation and energy use emission far exceed known climate changes in various natural processes, such as solar changes and volcanic eruptions.[14]

- Carbon dioxide results from the burning of fossil fuels-primarily transportation, heating/cooling, and energy. A carbon dioxide feedback loop, plants absorbing carbon dioxide for use in photosynthesis, has been altered by deforestation. The present carbon dioxide concentration of 385 parts per million (ppm) is 30% higher than its highest level in over 800,000 years. If this trend continues, emissions from this century alone will cause carbon dioxide concentrations 2 to 3 times the current 385-ppm.
- Methane increases are related to agriculture, natural gas distribution, and landfills as well as occurring naturally in wetlands.
- While nitrous oxide is released naturally from processes in the soil and oceans, its levels have increased due to fertilizer use and the burning of fossil fuels.
- Halogen containing gases such as chlorofluorocarbons increased in the atmosphere due to refrigeration agents and industrial uses. These gases were found to cause ozone depletion and have decreased in the atmosphere in recent years due to international regulations.
- Human activities have also increased the concentrations of ozone, water vapor, and aerosols. Ozone has increased due to presence of carbon monoxide, nitrogen oxide, and hydrocarbons-all produced from human activities reacting chemically to produce ozone.
- Water vapor is an important greenhouse gas that has increased primarily from climate change. A warmer atmosphere can physically hold more water.
- Aerosols are small particles of varying size and chemical composition released from the burning of fossil fuels and biomass. Aerosol dust has increased in the atmosphere due to surface mining, agriculture, and industrial processes.[15]

The energy balance between the Earth-atmosphere system is measured in terms of radiative forcing. This system is altered when additional greenhouse gases and aerosols are added to the atmosphere absorbing outgoing infrared energy. Incoming solar radiation and outgoing infrared radiation are why the term radiative is used, and the term forcing is used to signify that the Earth's balance is being pushed from its normal state. Positive radiative forcing leads to a warming of the system as opposed to negative radiative forcing causing cooling. Increases in tropospheric ozone also add to forcing, whereas decreases in stratospheric ozone produce cooling within the stratosphere. Ozone within the troposphere traps radiated heat from the Earth, heat that would be absorbed by the stratosphere. Tropospheric warming and stratospheric cooling are related and greenhouse gases, specifically carbon dioxide, may be responsible. Aerosols can have a positive or negative radiative forcing based on the type, but overall contribute to negative forcing due to the affect in cloud properties. Changes in albedo, or the reflective property of a surface, can cause a forcing effect. Increased cloud cover can contribute a negative forcing by reflecting incoming solar radiation. Less solar radiation is available to heat the Earth and atmosphere.[16] Although anthropogenic changes have caused negative radiative forces, the positive forcing from long lived greenhouses account for a net positive radiative forcing causes global temperature increases. Greenhouse gases have caused a

positive forcing of 26% from 1990 to 2008. 80% of the increase in radiative forcing is due to carbon dioxide concentrations.[17]

Task 1: Climate Change

Scenario: You are a member of Charlotte's city council. As a member of city government you are responsible for city planning (how the land is used, roads, and public transportation). A proposal has been placed before you to approve increasing funding for public transportation. It would improve sidewalks and bike lanes, city buses, and the light rail. Taking the environment and economics into consideration, would you approve this funding? Create a proposal explaining your reasoning.

Guiding Questions: Students should begin addressing their assigned problem by listing what they know and what they need to find out through research. Some potential questions to guide them along are as follows.

- Why would Charlotte need improved public transportation?
- What anthropogenic causes have lead to global climate change?
- What is urban sprawl and does it contribute to global climate change? Why or why not?
- What is SMART growth?
- How could Charlotte address these issues?
- How would improved sidewalks and bike lanes reduce greenhouse gases?
- Economic impacts?

Guiding Information: North Carolina was the 6th fastest growing state in the 2000's according to the 2010 Census Data. This tremendous growth moved North Carolinas from the 11th to the 10th most populated state by 2010. Most of the population growth occurred in the Charlotte and Raleigh metropolitan area with Mecklenburg County having the highest population. [18] Between 2009-2010 65,000 people moved to Mecklenburg County and most settled in the University area, northern, and southwestern parts of the county. Increases in population have lead to increases in development. In 1976, the footprint per resident was 0.11 acres and 12.5% of county land was developed. Contrast that with 0.23 acres per person and 64.3% of county land developed in 2010. Projected growth could see 96.6% of the land in Mecklenburg County developed by 2030.[19]

Smart growth is a variety of conservation and development strategies to promote sustainability. Smart growth helps protect the natural environment and makes communities more attractive, economically stronger, and socially diverse. Smart growth

communities design neighborhoods that have shops, offices, schools, and parks that give residents the option of walking, biking, taking public transportation, or driving. The goal of smart growth is to create vibrant communities to live, work, and play that are also economically competitive. Mixed land use, compact building design, walkable neighborhoods, variety of housing choices, preservation of open space and natural beauty, variety of transportation choices, and community involvement in decision making are all principles of smart growth.[20]

Of North Carolina's emissions, 29% come from transportation and the burning of fossil fuels. Land use planning can reduce greenhouse gas emissions by using existing transportation structures and reducing vehicle travel. The Charlotte-Mecklenburg Planning Commission started initiatives to promote development that utilizes existing infrastructure and transportation resources. This results in reduced use of fuel for transportation, fewer miles traveled, and overall emissions and air quality. The City Council has adopted transit-oriented development zoning and subdivision that require sidewalks on both sides of the street to facilitate walking and transit use. In 2007, the City Council adopted general environmental development policies to minimize the negative impacts of land development and linking development decisions to the availability of supporting infrastructure. Planning on integrating land use with transportation and other public services creates opportunities for alternative means of transportation and overall long-term sustainability.[21]

Activity 2: Impacts of Climate Change in the United States

The impact of climate change is difficult to clearly outline as changes vary from region to region. What is known is that climate change is occurring in the United States and is projected to increase. Within the United States observed weather related climate changes include temperature rise, sea level rise, increase in heavy downpours, receding glaciers, thawing permafrost, longer growing season, longer ice-free season on oceans, lakes, and rivers, earlier snowmelts, and change in river flows.[22]

Weather related change:

- As previously stated the temperature of the United States is increasing. The average yearly temperature has increased by 1-2 ^{o}F in the United States with another degree of anticipated increase depending on the emissions scenario.
- Overall precipitation has increased in the United States over the last 50 years. A change in the frequency, duration, and intensity of rain precipitation, down pours, is primarily responsible for this change. The quantity of precipitation falling in the extreme 1% of rain events has grown by 20% with much of that seen in the Northeast and Midwest regions. An increase in heavy rainfall is projected to

increase with the incidence of the heavy rainfall events increasing and the incidence of lightest rainfall events decreasing.

- In addition to a change in the type of precipitation the US experiences, the patterns of precipitation have changed. Climate models predict that northern areas will experience an increase in precipitation, thus getting wetter, while southern regions will experience a decrease in precipitation, thus drier. Models are not as confident with what will happen in transitional areas between the increased and decreased precipitation regions.[23]

In addition to weather change, the United States is experiencing or is projected to experience a variety of climate change impacts on water, energy, transportation, agriculture, ecosystems, human health, and society. Thawing permafrost and declining sea ice in Alaska have contributed to coastal erosion, damaged roads and buildings, and threatened some community's future viability. Forest ecosystems are projected to experience a shift in species with the Northeast, famed for the spectacular fall colors, potentially losing beech, birch and maple forest to oak and hickory. Forests are projected to increase in the east, but decrease in the west. Vulnerability to insect infestation is also a concern. Coldwater fish species such as salmon and trout will experience stress as temperatures increase and stream flow decreases. This will have an effect on the ecosystem and tourism in the region. Shifts in the population of the US to the Southeast, Southwest, and coastal communities as well as an increase in the aging population leaves many vulnerable to extreme heat events, sea level rise, storm surges, and in some areas water scarcity. Coral reefs are threatened due to higher water temperature and ocean acidification. Changes in this rich marine ecosystem will have an impact on coastal tourism and fisheries health. Increases in heavy downpours potentially threaten transportation, infrastructure, agriculture, water quality, and human health. Coastal communities are increasingly threatened by sea levels rising and storm surges leading to the destruction of barrier islands and marshes as well as infrastructure destruction. Changes in weather patterns affect agriculture with increasing temperatures, pests, floods, weeds, and water scarcity. All of those factors will impact both livestock and crops. Heat waves are projected to increase in both frequency and intensity affecting quality of life with cities experiencing the most threat. Water scarcity in the Southwest will cause communities to make difficult decisions on water usage such as for agriculture and energy use. Changing temperatures will also create higher demands for energy with significant increase in energy use. As a result of increased energy demand and water scarcity, energy companies will experience competition for water needed for cooling in energy creation.[24]

Task 2: Impacts of Climate Change

Scenario: You are a local news producer in Charlotte and after watching the aftermath of Hurricane Sandy in the Mid Atlantic and New England states and the following discussions of climate change, you decide to create a segment for Charlotte. You decide

to investigate weather changes due to climate change we could experience in Charlotte and the Southeast region. Create a segment/ public service announcement exploring potential weather changes in our region due to climate change. Be sure to include ways that we can prepare for such events.

Guiding Questions:

- What is the climate and typical weather for the Southeast US?
- What is some weather related changes the Southeast/Charlotte will experience due to climate change?
- Why? Evidence?
- What are some affects of heavy downpours?
- Are we at an increased risk for tornadoes?
- Is there an increased risk for damage to homes, roads, utilities (electricity)?
- Charlotte is located in the Piedmont not the coast; will hurricane's still affect us?
- What about the mountain region? Increase potential for landslides?

Guiding Information: The Southeast region is comprised of Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Tennessee, Kentucky, Arkansas, Mississippi, Louisiana, and eastern Texas. Over 70 million people live in the Southeast region with many cities, Charlotte included, of over 250,000. The region contains 29,000 miles of coastline.[25] North Carolina is one of the few states that can be divided into three topographic regions, the Mountains, Piedmont, and Coastal plain. Within each region North Carolina can be divided into eight climate divisions: southern mountains, northern mountains, northern piedmont, central piedmont, southern piedmont, northern coastal plain, central coastal plain, and northern coastal plain. The city of Charlotte is located in the Southern Piedmont region. Because of North Carolina's diverse landscape climate changes poses different challenges within each region.[26]

The southeast has a humid subtropical climate with warm, wet, and humid summers with mild winters compared to the rest of the continental United States. There has been an increase of 2^{o} F since 1970 with the most change observed in the winter. Freezing days have decreased by four to seven days per year for most of the Southeast region. Most of the region has experienced an increase in precipitation by about 30 % since 1901 with the exception of South Florida, and heavy downpour events have increased in frequency. Even with an increase in precipitation, severe drought in the summer has increased by 12-14% since 1970. Climate models project a continued increase of temperature with an increase in extreme heat events. Lower emission scenarios predict an increase of 4.5^{o}F and a high emission scenario increase of $9\ ^{o}$F by 2080. Climate models are uncertain about precipitation changes, but seem to indicate that rain will occur more frequently in heavy downpours and dry intervals between rain. This pattern of

precipitation increases the risk of flooding and drought. Occurrences of strong hurricanes are predicted as well as sea level rise.[27]

In North Carolina average precipitation varies by region with the mountain region experiencing both the highest, 90 inches, and lowest, 37 inches, of average annual rainfall. Charlotte averages around 40 inches of precipitation a year. State temperature averages vary 20 ^{o}F in the state depending on the terrain. The Piedmont region averages a maximum temperature of 90 ^{o}F in July and 51 ^{o}F in January. As mentioned previously, temperatures and extreme heat events are predicted to increase. North Carolina experiences a variety of extreme weather events such as tropical storms, hurricanes, tornadoes, heavy rain, ice storms, droughts, and flooding. Due to this, North Carolina ranks among the top five states in weather disaster related losses in billions of dollars. There have been 30 separate weather disaster events since 1980. Tornado events are most common in the Piedmont and Coastal plain presenting a risk to the Charlotte Metro area. North Carolina is also among the top ten populated states with two thirds of its population located in the piedmont. Climate change will affect the states population's health with extreme heat events (both cold and hot), severe storms, flooding, and an increase in climate sensitive disease such as West Nile Virus. A projected decrease in air quality will also impact sensitive groups for example the elderly, children, and the poor. Potential climate change will challenge public health infrastructure, causing strain on environmental resources, and have a bearing on the state economy.[28]

North Carolina is among the top producers and consumers of energy with a projected increase in demand from extreme heat and cold events. Climate change has the potential to impact how North Carolina produces energy. The mountain region produces a tremendous amount of hydroelectric power and changes in precipitation could affect this. The Piedmont region's increase in population has caused an increase in energy usage and stress on water resources. The coastal region has the potential for creating wind energy, but is also threatened with sea level rise.[29]

Transportation in the state will also be affected by climate change. Mountain regions experience landslides that negatively affect local and major infrastructure. In 2004 when hurricane's Francis and Ivan moved through the area 130 landslides were triggered. Landslides can be triggered by repeated freeze and thaws as well as heavy precipitation all of which are predicted to increase. Rail buckling may occur in the Piedmont due to extreme heat. The Coastal region has two large ports, Port Wilmington and Port Morehead City, that may be impacted by climate change as sea levels rise. Sea level rise, flooding, and erosion will also affect the coastal area's transportation.[30]

The state's agriculture will be affected both positively and negatively depending on region. Higher temperatures will most likely prolong the growing season and

productivity, but weeds and pests also benefit from high temperatures. High temperatures also cause stress on crops and increased demand for water. Livestock productivity will decrease due to extreme temperature and weather and disease.[31]

Climate change will stress natural resources and ecosystems throughout the state. Forests and wetlands protect water quality and natural areas provide biodiversity, clean air, clean water, energy, recreational areas, and aesthetic value to residents of the state. Natural areas have a lesser ability to quickly adapt to climate change. The Mountain region supports great biodiversity with over 1 million acres of protected federal land including the Great Smoky Mountains. The Piedmont has the highest population in the state and this increase in population has caused development and stress on water and natural resources. Loss of wetlands threatens biodiversity and rare species in the coastal region. North Carolina's coast is particular vulnerable to climate chance with 2,300 miles of coastline. The coast is significantly vulnerable to sea level rise with a 1 meter predicted sea level rise. This will cause loss of wetlands and coastal erosion both of which increase the risk of further loss. An increased risk of higher strength storms and hurricanes will cause bad storm surges that threaten the population and infrastructure. Storm surges will increase flooding, both temporary and permanent.[32]

Activity 3: Mitigation and Adaptation

Climate change is happening. Both mitigation and adaptation strategies must be adopted in order to face the challenges climate change presents. Mitigation is essentially limiting the harmful and irreversible effects on our climate system by reducing greenhouse gases in the atmosphere and/or increasing carbon sequestration. Carbon sequestration is a natural or deliberate process that removes carbon dioxide from the atmosphere and storing it in the ocean, the land, or geological formations. Reducing greenhouse gas emissions is the single biggest mitigation strategy while carbon sequestration techniques are still being studied for feasibility and cost. Under current mitigation and sustainable development strategies greenhouse gas emissions will continue to rise over the next several decades. In order to stabilize the concentrations of greenhouse gases in the atmosphere, greenhouse gases need to peak and then decline. The lower the stabilization levels the quicker the peak which means that mitigation efforts made in the next several decades have a significant impact on achieving lower stabilization levels.[33]

Current or near future mitigation strategies are being utilized orare available in the energy supply, transportation, development, industrial, agricultural, forestry, and waste management sectors. Examples within energy supply are improved energy efficiency and distribution. This includes using gas instead of coal, nuclear energy, and renewable energy sources such as solar and tidal energy, application of carbon capture and storage, the removal of carbon dioxide from natural gas, and its future application to other

hydrocarbons. The transportation sector has developed more fuel-efficient vehicles and hybrids. Better public transportation has been created as well as the development of better biofuels and batteries. Buildings are using more efficient lighting and appliances, better insulation, and \solar technologies. Industry has also improved its energy efficiency and use of electric equipment. Carbon capture and storage in the production of ammonia, cement, and iron production could be used. Agriculture uses improved land management as a mitigation strategy to improve carbon storage. Better manure management through the capture of methane as well as improvements in fertilizer application reduces emissions. Energy crops used to create biofuel are being grown to reduce the use of fossil fuels. Reforestation and forest management increases biomass productivity and potential for carbon sequestration. Forests are also used as biofuels. Waste management techniques such as methane recovery, incineration with energy recovery, recycling, and composting have a mitigation factor.[34]

Mitigation at a personal level includes lifestyle changes and consumption change that leads to reduction in greenhouse gases. One can decrease household energy use through energy efficient light bulbs, appliances, heating and cooling smartly, and having your home properly insulated. Choosing renewable energy sources, reusing and recycling, and 'green' landscaping such as composting, for example, are all personal mitigation strategies that reduce greenhouse gases. Transportation choices like fuel-efficient vehicles or hybrids, car-pooling, utilizing public transportation, and walking and biking are also personal mitigation choices.[35]

Mitigation alone will not properly prepare for climate change, adaptation is also necessary. Adaptation strategies can be used for protection against climate change and to take advantage of climate change. Just like mitigation, adaptation strategies can be applied at a personal, local, national, and global level. An example of personal adaptation could be preparing an emergency kit for the home with water and food supplies. Anticipating changes in an ecosystem can allow us to manage them better and make informed decisions. This could potentially mean moving, changing agricultural crops, and creating different shelter. It is vital that the food supply be maintained so planting drought and heat tolerant crops and protecting livestock with better shelter that provides better airflow are important ways agriculture can make adaptations. Coastal communities will need to evaluate adaptations that protect against sea level rise and storm surges. Sea walls, evacuation plans, and shore protection are all strategies that can and are being implemented. In order for ecosystems to adapt to the changing climate, migration corridors must be protected to allow species to move and change with the environment. Management techniques should be utilized to promote robust ecosystems. Severe weather presents a variety of threats to infrastructure, communities, and individuals. As Hurricane Sandy has shown, as well as severe weather events in the past, energy infrastructures needs to be protected from weather related stress. Early warning systems and evacuation plans should be in place for communities. Urban planning is an adaptation as well as a mitigation strategy that can be employed. Open spaces, planting

trees, and restoration of streams and river banks can help preserve water quality as well as biodiversity and ecosystems.[36]

North Carolina's Department of Environment and Natural Resources (DENR) created a 2009-2012 Strategic Plan and Climate Change Initiative to address climate change with both mitigation and adaptation strategies to decrease the vulnerability and increase resiliency within North Carolina. Mitigation strategies identified by the DENR are the reduction of greenhouse gases and becoming an environmental leader in energy conservation and carbon management. This will be addressed in four ways: greenhouse emissions regulation and tracking, greenhouse gas emission reduction, 'green' energy development, and carbon sequestration. DENR's adaptation goals are to develop strategies to address sea level rise, climate sensitive ecosystems, water management, public health impacts, emergency management preparedness, and land use planning and development.[37]

Task 3: Mitigation and Adaptation

Scenario: The city of Charlotte has hired you as a consultant to improve energy efficiency in city schools. Your task is to design an energy efficient/environmentally friendly city building. Create a three-dimensional model of your school. Be sure to highlight or point out features of your model that are mitigation and/or adaptation strategies.

Guiding Questions:

- What are some ways the city of Charlotte and Charlotte residents could decrease it's energy use?
- What are alternative energies already in use here in NC? Charlotte?
- What are some mitigation strategies that could be use in the planning of a building?
- What are some adaptation strategies that will be needed in urban environments?

Background for Task 3:

North Carolina's greenhouse gas emissions are primarily generated through electricity production at 42% and transportation at 29%. The rest of the emissions produced in the state are from industrial fuel use at 13%, residential and commercial fuel use at 6%, agriculture at 6%, and waste at 4%. Energy production accounts for a significant amount of emissions produced in United States and North Carolina. Coal, a particularly dirty

fossil fuel, produces 60% of the electricity generated within the state. Coal has to be transported to North Carolina via trains or trucks mainly from West Virginia and Kentucky. In contrast, North Carolina is a consumer of nuclear energy, considered a cleaner energy, at a higher level than the rest of the country at 32%. The rest of the electricity production is from hydroelectric, natural gas, and petroleum sources. North Carolina ranks fifth in its production of nuclear energy according to the Energy Information Administration. Duke Energy has plans for two new nuclear plants to be operational by 2030. This should help reduce greenhouse emissions as nuclear energy has low carbon emissions. In 2007 North Carolina passed the Renewable Energy Portfolio Standard, which requires electricity producers to use 12.5% of renewable energy by 2021.[38]

Charlotte's emissions from energy use in homes and businesses, vehicles travelling within the city, and landfill emissions from 2006 totaled approximately 10.4 metric tons of carbon dioxide. About half of the emissions, 45%, produced were from energy production and an additional 35% were from vehicle fuels. Charlotte's residents' emissions in 2006 were 16.5 metric tons of carbon dioxide per capita.
Only 5.3 % of North Carolina's electricity was generated from renewable energy most of which was from hydroelectric power plants and biomass. Wind energy has the greatest potential for renewable energy production in North Carolina with potential locations along the mountain region and coastal areas. Although wind energy has the potential for tremendous energy production, the industry faces regulatory barriers for implementation as well as poor public support. Many communities fear wind turbines will negatively affect the regions natural beauty. Biomass in North Carolina, woody biomass and agricultural waste, is also a source for renewable energy. Many counties within the state with the lowest per capita income tend to have agricultural economies and would benefit from biomass energy development. North Carolina ranks fourth in total forest acreage, and second in hog and pig production providing excellent sources for biomass fuel production. Solar energy is also a viable alternative energy that could be used in North Carolina, but cost, productivity, and aesthetics of solar panels all pose problems. Financial incentives and tax credits could increase solar power production.[39]

Additional Classroom Activities:

Each group will be assigned to keep a work portfolio that demonstrates their learning. In addition to their task, students will be assigned additional activities to be completed. The additional activities will help them complete their task as well as provide them with a solid knowledge base of climate change.

Examples:
- ✓ Greenhouse effect lab

    - Students will create a model of the atmosphere and the greenhouse effect in a two little bottle. Students can analyze the effect of increasing carbon dioxide (antacid tablet) in the 'atmosphere'.
- ✓ Albedo lab
    - Students can observe albedo by measuring the temperature changes over various surfaces.
- ✓ Graphing carbon dioxide over time to examine evidence of anthropogenic climate change.
    - By using various sources students will create a graph of carbon dioxide levels over time. Students compare levels of carbon dioxide in pre-industrialized time to post industrial times.
- ✓ Create a fact sheet on a greenhouse gas. Each group will post their information within the classroom so that each greenhouse gas would be covered. I think I could create a bulletin board of these fact sheets so all of the classes could use them in answering the task/question.
- ✓ Examine the climate of the southeastern United States and Charlotte specifically.
    - In order to fully understand climate impacts the students need to understand their current climate.
    - Students will create climatograms of the Charlotte area representing monthly highs and precipitation averages over time. Ideally we could create a class data set with each group producing a climatogram from different decades.
- ✓ Calculation of their carbon footprint with an exploration of ways they can reduce their footprint.
- ✓ Research some climate change mitigation and adaptations and create an advertisement. Examples include reduction of emissions, use of alternative energies, clean coal technologies, carbon sequestration, sea level rise adaptation, water conservation/management, agricultural management, emergency management (weather), public health/insect control, and land use.

Resources

For Teachers:

Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009, Accessed September 2012. http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts

A good summary of climate change occurring within the United States. Information on how climate change will affect the nation is divided into sectors: water, energy, transportation, agriculture, ecosystems, health, and society.

IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.ipcc.ch/

The Intergovernmental Panel on Climate Change is the comprehensive website to visit for information on climate change. There are several documents available for download as well as frequently asked question sections that are easy to read. Each document has a tremendous amount of evidence and data on climate change.

Leiserowitz, A., Maibach, E., Roser-Renouf, C., & Hmielowski, J. D. (2012) "Climate change in the American Mind: Americans' global warming beliefs and attitudes in March 2012". Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change Communication. Accessed May 2012. http://environment.yale.edu/climate/files/Climate-Beliefs-March-2012.pdf

This is an interesting report on beliefs around climate change in the United States. It is mainly a data report with lots of statistics.

National Assessment Synthesis Team, "Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change," US Global Change Research Program, Washington DC, 2000.

This is a comprehensive document outlining impacts of climate change in each region of the United States.

Steingraber, Sandra. "Raising Elijah: Protecting Children in an Age of Environmental Crisis," A Merloyd Lawrence Book. Da Capo Press, a member of the Perseus Book Group 2011.

This is an engaging and easy to read book about climate change. Steingraber writes from her perspective as a scientist and mother. It provides solid science information and ideas that you can apply to daily living.

U.S. Climate Change Science Program, "Climate Literacy: The Essential Principles of Climate Sciences," U.S. Global Change Research Program / U.S. Climate Change Science Program, Second Version March 2009. Accessed June 5, 2012. http://www.climatescience.gov/Library/Literacy/

This booklet provides easy to read information on climate change meant for all age groups. It is organized into essential principles of climate science. This would be appropriate for students to read and would make an excellent 'jigsaw' activity to introduce climate change.

U. S. Environmental Protection Agency, "Climate Change Indicators in the United States," 2010 Accessed October 2012. http://epa.gov/climatechange/science/indicators/

Produced by the EPA, it provided information about indicators of climate change in the United States. It starts with greenhouse gases and US related weather and climate, and then describe indicators within the ocean, snow and ice, and society and ecosystems.

Helpful Websites:

National Aeronautics and Space Administration: Climate
http://climate.nasa.gov/

NASA's website contains a tremendous amount of information such as evidence, indicators, causes, effects, etc. There are links to NASA's climate page for educators and students.

National Oceanic and Atmospheric Administration: Climate
http://www.education.noaa.gov/Climate/

NOAA's climate page contains lots of scientific information as well as links to additional educator resources.

National Oceanic and Atmospheric Administration Jet Stream Topic Matrix
http://www.srh.noaa.gov/jetstream/matrix.htm

This website is a topic matrix of atmosphere and weather subjects. They are designed for students as an online weather school. Each topic is are very informational and contain lessons and quizzes.

North Carolina Climate Change
http://www.climatechange.nc.gov/

This is a great website for information specific to North Carolina. The link, Climate Adaptation Workshop, is particular helpful.

Power to Charlotte
http://www.power2charlotte.com/

This is the City of Charlotte's energy initiative. This website has a lot of great information related to Charlotte's energy use and sustainability. The resources page has links to many of Charlotte's governmental and local non-profit environmental and conservation agencies.

United States Energy Information Administration, North Carolina Information
http://www.eia.gov/beta/state/?sid=NC

This website provides statistics about energy, types and use, in North Carolina.

United States Environmental Protection Agency: Climate Change
http://www.epa.gov/climatechange/

The EPA website is a really good place to start researching climate change. It has a great deal of information and links. It also has a link to a companion student site.

United States Global Change Research Program
http://www.globalchange.gov/

The US Global Change Research Program is a program that integrates and coordinated federally funded research on climate change. Information can be found on regions or sectors within the United States. There are also links to climate change documents.

University of North Carolina Charlotte Renaissance Computing Institute
http://renci.uncc.edu/
This is a very good site for maps and land use has changed over time in North Carolina and Charlotte.

Student Reading List:

This reading list are some helpful website to get students started in the right direction in their research. Many of the websites give easy to read information on climate change as well as suggestions of changes they can make in their lives that reduce their carbon footprint.

Climate Kids from NASA
http://climatekids.nasa.gov/

Energy Kids: The US Energy Information
http://www.eia.gov/kids/

Environmental Protection Agency: Climate Change
http://www.epa.gov/climatechange/

Environmental Protection Agency's Student's Guide to Global Climate Change
http://www.epa.gov/climatechange/kids/index.html

Environmental Protection Agency's Personal Greenhouse Gas Calculator
http://www.epa.gov/climatechange/ghgemissions/ind-calculator.html

Power to Charlotte
http://www.power2charlotte.com/

US Energy Information Administration: North Carolina's Energy Profile
http://www.eia.gov/beta/state/?sid=NC

Environmental Protection Agency: Climate Change
http://www.epa.gov/climatechange/

Cool the Earth
http://www.cooltheearth.org/

Notes

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