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AP Environmental Science

See **overall course outline, with climate-change-relevant units marked**. (Word version in attachments below)

In this document are details for the Climate Change Module

1. **Overview of Climate Change Module**
2. **Climate Change Introduction**
3. **Climate Change Inquiry**
    1. **Study of Auto Exhaust**
    2. **Carbon Sink Challenge**

Student work on the Challenge can be found under my name at **http://www.resa.net/curriculum/curriculum/science/professionaldevelopment/climatechange/modules-and-units/**

The activities referred to in this module are included at **http://resa.net/curriculum/curriculum/science/professionaldevelopment/climatechange/carboncycle**

Page created 4/12/2011

Climate Change Module Overview

I. Introduction: This Unit part of a larger Climate Change Unit is designed for our AP Environmental Science class for High School Juniors and seniors.

Global Climate change describes trends and variations in Earth's climate and will be the emphasis in a 2-4 week module. Since Climate Change is also incorporated in other units, we will try to isolate and lift these elements from previous units and incorporate them into an isolated Climate Change Unit for this project.

Big Ideas that have already been incorporated into other units, that can be included in a stand alone module are;
1) Carbon Cycle: Unit- Ecosystem Ecology,
2) Landscape Ecology and Remote Sensing: Unit –Ecosystem Ecology,
3) Evaluate the primary causes of biodiversity loss and understand the scope of biodiversity: Unit- Biodiversity and Conservation Biology

Driving Question: How can we, your family and society, lessen our impact on Global Climate Change and what data supports these solutions?

II. Key knowledge and skills (Big Ideas)

A. Describe Earth's climate system and explain the many factors that influence global climate.
B. Characterize human influences on the atmosphere and global climate.
C. Summarize modern methods of climate research.
D. Outline current and future trends and impacts of global climate change.
E. Suggest ways we may respond to climate change.
F. Relate NASA remote sensing data to items A-E above.
G. Understand the ecological ramifications of climate change and the consequences that may take place concerning a loss of biodiversity.

III. Alignment

A. AP Environmental Science Alignment: These themes must be included in the AP Environmental Science course and will be part of the Climate Change Unit.

1. Science is a process.
• Science is a method of learning more about the world.
• Science constantly changes the way we understand the world.
2. Energy conversions underlie all ecological processes.
• Energy cannot be created; it must come from somewhere.
• As energy flows through systems, at each step more of it becomes unusable.
3. The Earth itself is one interconnected system.
• Natural systems change over time and space.
• Biogeochemical systems vary in ability to recover from disturbances.
4. Humans alter natural systems.
• Humans have had an impact on the environment for millions of years.
• Technology and population growth have enabled humans to increase both the rate and scale of

their impact on the environment.

5. Environmental problems have a cultural and social context.

• Understanding the role of cultural, social, and economic factors is vital to the development of solutions.

6. Human survival depends on developing practices that will achieve sustainable systems.

• A suitable combination of conservation and development is required.

• Management of common resources is essential.

More specific AP Topics included VII. Global Change -1. Global Warming, which has to incorporate (Greenhouse gases and the greenhouse effect; impacts and consequences of global warming; reducing climate change; relevant laws and treaties)

2. Loss of Biodiversity: which incorporates (Habitat loss; overuse; pollution; introduced species; endangered and extinct species, maintenance through conservation, relevant laws and treaties).

B. Climate Literacy Principles

1. Human Activities are impacting the Climate System
2. Climate Change will have consequences for the Earth System and Human Lives

Climate Change: Introductory Unit

Calendar for Climate Change Introductory Unit: (Each class is of 2 hour length). See below each day's lesson plan.
All activities and assessment are linked and found in the Appendix

Day 1
1. Pre-Test Yale on Climate Change

2. **(Engage)** Burning Hydrocarbons: A Preliminary Climate Change Investigation
Students research the chemistry of burning hydrocarbons.
Lab write up due on day 3.

3. **(Explore)** Inconvenient Truth: DVD

Day 2
1. Inconvenient Truth and DVD Extras (completed) and Inconvenient Truth assessment, due on day 5

2. Lecture and Discussion from the Book, Environment, the Science Behind the Stories, Withgott & Breenan, 2008.
http://wps.aw.com/wps/media/access/Pearson_Default/4893/5010916/login.html

This lecture & discussion which for me took place over parts of 5 classes. The timing, length and inclusion of each of these topics can be left to the discretion of the teacher and should cover : (**Overview for Students)**
- The Earth's climate system
- Human influences on the atmosphere and climate
- Methods of climate research
- Impacts of global climate change
- Ways we can respond to climate change

(Explain) Topics covered today from the Book, Environment, the Science Behind the Stories, Withgott & Breenan, 2008

1. Central case study: Rising Seas May Flood the Maldives
2. Our Dynamic Climate
    a. What is climate change?
    b. The sun and atmosphere keep Earth warm
    c. Greenhouse gases warm the lower atmosphere

d. Carbon Dioxide is the greenhouse gas of primary concern

Day 3

(Explain) Topics covered today from the Book, Environment, the Science Behind the Stories, Withgott & Breenan,

1. The Carbon Cycle and Climate Change
   a. Photosynthesis and respiration
   b. Sediment storage of carbon
   c. The oceans

2. **(Enhance)** Lab on animal respiration: Effect of Temperature on Cold-Blooded Organisms. Crickets are used to study the effect of temperature on the metabolism of cold-blooded organisms. You will determine how temperature affects the respiration rate of crickets by monitoring carbon dioxide production with a CO_2 Gas Sensor.
(lab report due on Day 6)

3. Collect Burning Hydrocarbons: A Preliminary Climate Change Investigation lab report

Day 4

(Explain) Topics covered today from the Book, Environment, the Science Behind the Stories, Withgott & Breenan, 2008

1. Our Dynamic Climate
   a. Other Greenhouse gases add to warming
   b. Aerosols may exert a cooling effect
   c. Radiative forcing expresses change in energy over time
   d. Other non atmospheric factors that influence climate
2. Studying Climate Change
   a. Proxy Indicators; The Science behind the story, Reading the History in the World's Longest Ice Core.

1. **(Enhance/Enrich)** Lab on Plant Respiration and Photosynthesis
Using the CO_2 Gas Sensor, you will monitor the carbon dioxide consumed or produced by plants. (on website) (lab report due on Day 8)

Day 5

1. **(Evaluate)** Collect Inconvenient Truth assessment

2. **(Explore)** Climate News from the Climate Project
Reason, allowing students to understand current research.

3. **(Explore)** Studying Snow and Ice Changes. Students examine how snow and ice cover have changed on the Earth from 1994 to 2004, and to practice using some of the data analysis tools available at My NASA Data. **Learning Outcomes:**

- Understand how calculations can be performed on data expressed as maps, such as averaging or subtracting.
- Observe changes in snow and ice over a 10-year period and draw conclusions about trends indicated by the observations.

Due on day 8

Day 6

1. **(Evaluate)** Collect Effect of Temperature on Cold-Blooded Organisms lab report

(Explain) Topics covered today from the Book, Environment, the Science Behind the Stories, Withgott & Breenan, 2008

1. Studying Climate Change
    a. Direct atmospheric sampling tells us about the present
    b. Models help us understand climate
2. Current and Future Trends
    a. IPCC summarizes evidence of climate change and predicts future impacts
    b. Temperature increases will continue
    c. Changes in precipitation vary by region
    d. Melting ice and snow have far-reaching effects
    e. Rising sea levels impact
    f. The Science behind the story, Timing Greenland's Glaciers as they race to the sea

2. **(Explore)** Weighing the issues: Student Discussions: Two topics
    a. Climate Change and Human Rights
    b. Environmental Refugees: Relocation of an entire culture do to sea level rise

3. **(Explore)** Arctic Report card: Update for 2010: Each group of two students will be assigned one topic to report on for tomorrow. Three minute presentation.

Day 7

1. **(Evaluate)** Arctic Report card: Update for 2010 presentation

(Explain) Topics covered today from the Book, Environment, the Science Behind the Stories, Withgott & Breenan, 2008

1. Current and Future Trends
    a. Climate change affects organisms and ecosystems
    b. Climate Change exerts societal impacts
    c. Are we responsible?

2. **(Enhance)** Lab on pH changes of water
A pH sensor will be calibrated and used to measure the pH of solutions. We will determine the effect on pH of adding carbon dioxide to distilled water and to surface water. Lab report due on day 9

3. **(Explore)** Student debate. Taken from Viewpoints, a workbook that accompanies the text cited above. The debate is on the topic: Responding to Climate Change, must regulations be part of governmental climate change policies. The two sides of this topic are; 1) Carbon taxes, Not Regulations, Are the Best Climate Policy, 2) Using Carrots and Sticks to Reduce the Risks of Climate Change.

Day 8

1. **(Evaluate)** Collect, Studying Snow and Ice Changes from " My NASA Data" paper

(Explain) Topics covered today from the Book, Environment, the Science Behind the Stories, Withgott & Breenan, 2008

1. Shall we pursue mitigation or adaptation
2. Electricity generation is the largest source of U.S. greenhouse gases
3. Transportation is the second largest souse of U.S. greenhouse gases
4. Multiple strategies to tackle Climate Change
5. Reducing your carbon footprint

2. **(Explore)** March of the Polar Bears: Global Change, Sea Ice, and Wildlife Migration. Students will use NASA satellite data to study changes in temperature and snow-ice coverage in the South Beaufort Sea, Alaska, correlate with USGS ground tracking of polar bears, and relate this to global change, sea ice changes, and polar bear migration.

Learning Outcomes:

- Students will analyze maps and time series data to understand changes.
- Students will construct data-based explanations and conclusions.
- Students will better understand global change through a local case study.
- Students will consider the impact of environmental changes on wildlife.

- Students will consider the impact of human activities on life and the Earth.

Due on day 10

Day 9 and 10 starting the Inquiry unit.

Day 9
(Evaluate) Collect lab pH changes of water.

(Enhance/Enrich) Lab on Vehicle Exhaust. (which will take place over the next 3 days). Compare Air Pollution scores, Fuel Economy and Greenhouse scores among various vehicles. Use a CO_2 Gas Sensor to measure the amount of carbon dioxide found in the exhaust. Measure the length of time it takes to inflate a large garbage bag (40-45 gallon bag) and the size of a balloon after it is attached to the vehicle's exhaust for five seconds. (see separate file on this activity).

Day 10

(Evaluate) Collect March of the Polar Bears: Global Change, Sea Ice, and Wildlife Migration report

Appendix

1. An Inconvenient Truth Assessment
http://www.resa.net/downloads/science__pd/an_inconvenient_assessment_20120601_154035_6.doc

2. Pre-Post Yale test on Climate Change
https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxpY2NhcnNwcm9qZWN0fGd4OjY2ZDVmZDlkZGIzNGU5MzY&pli=1

3. Burning Hydrocarbons: A Preliminary Climate Change Investigation
http://resa.net/curriculum/curriculum/science/professionaldevelopment/climatechange/carboncycle/

4. Environment, the Science Behind the Stories, Withgott & Breenan, 2008.
http://wps.aw.com/wps/media/access/Pearson_Default/4893/5010916/login.html

5. Lab on animal respiration: Effect of Temperature
on Cold-Blooded Organisms.
http://resa.net/curriculum/curriculum/science/professionaldevelopment/climatechange/carboncycle/

6. Lab on Plant Respiration and Photosynthesis
http://resa.net/curriculum/curriculum/science/professionaldevelopment/climatechange/carboncycle/

7. Climate News from the Climate Project
http://www.theclimateprojectus.org/climatenews.php

8. Studying Snow and Ice Changes
http://mynasadata.larc.nasa.gov/preview_lesson.php?&passid=69

9. Arctic Report card: Update for 2010 http://www.arctic.noaa.gov/reportcard/

10. Lab on pH changes of water

http://resa.net/curriculum/curriculum/science/professionaldevelopment/climatechange/carboncycle/

11. March of the Polar Bears: Global Change, Sea Ice, and Wildlife Migration.
http://mynasadata.larc.nasa.gov/preview_lesson.php?&passid=69

Climate Change: Inquiry Unit

I. Introduction: This Unit part of a larger Climate Change Unit is designed for our AP Environmental Science class for High School Juniors and seniors.

Global Climate change describes trends and variations in Earth's climate and will be the emphasis in a 2-4 week module. Since Climate Change is also incorporated in other units, we will try to isolate and lift these elements from previous units and incorporate them into an isolated Climate Change Unit for this project.

Big Ideas that have already been incorporated into other units, that can be included in a stand alone module are;
1) Carbon Cycle: Unit- Ecosystem Ecology,
2) Landscape Ecology and Remote Sensing: Unit –Ecosystem Ecology,
3) Evaluate the primary causes of biodiversity loss and understand the scope of biodiversity: Unit- Biodiversity and Conservation Biology

Driving Question: How can we, your family and society, lessen our impact on Global Climate Change and what data supports these solutions?

II. Key knowledge and skills (Big Ideas)

A. Characterize human influences on the atmosphere and global climate.
B. Suggest ways we may respond to climate change.
C. Design a long-term project based on the Carbon Cycle and human impact on this by burning fossil fuels. There challenge will be to design carbon sinks.

III. Alignment

A. AP Environmental Science Alignment: These themes must be included in the AP Environmental Science course and will be part of the Climate Change Unit.

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• Science constantly changes the way we understand the world..
2. The Earth itself is one interconnected system.
• Natural systems change over time and space.
• Biogeochemical systems vary in ability to recover from disturbances.
4. Humans alter natural systems.
• Humans have had an impact on the environment for millions of years.
• Technology and population growth have enabled humans to increase both the rate and scale of their impact on the environment.
5. Environmental problems have a cultural and social context.
• Understanding the role of cultural, social, and economic factors is vital to the development of solutions.
6. Human survival depends on developing practices that will achieve sustainable systems.
• A suitable combination of conservation and development is required.
• Management of common resources is essential.

B. Michigan High School Science expectations

1. The **1.1** Scientific Inquiry and **1.2** Scientific Reflection and Social Implications will be a major part of this unit.
2. **E2.3A** Explain how carbon exists in different forms such as limestone (rock), carbon dioxide (gas), carbonic acid (water), and animals (life) within Earth systems and how those forms can be beneficial or harmful to humans.
3. **E2.3d** Explain how carbon moves through the Earth system (including the geosphere) and how it may benefit (e.g., improve soils for agriculture) or harm (e.g., act as a pollutant) society.
4. **E2.4B** Explain how the impact of human activities on the environment (e.g., deforestation, air pollution, coral reef destruction) can be understood through the analysis of interactions between the four Earth systems.
5. **E4.2B** Explain how interactions between the oceans and the atmosphere influence global and regional climate. Include the major concepts of heat transfer by ocean currents, thermohaline circulation, boundary currents, evaporation, precipitation, climatic zones, and the ocean as a major CO_2 reservoir.
6. **E5.4** Climate Change
7. **B3.1** Photosynthesis and Respiration
8. **B3.3b** Describe environmental processes (e.g., the carbon and nitrogen cycles) and their role in processing matter crucial for sustaining life.
9. **B3.4C** Examine the negative impact of human activities.
10. **B3.4d** Describe the greenhouse effect and list possible causes.
11. **B3.4e** List the possible causes and consequences of global warming.

C. Climate Literacy Principles

6. Human Activities are impacting the Climate System

7. Climate Change will have consequences for the earth System and Human Lives

Calendar for Climate Change Introductory Unit: **(Each class is of 2 hour length). See below each day's lesson plan.**

Day 1-3:
(Exhance/Enrich) Lab on Vehicle Exhaust. Compare Air Pollution scores, Fuel Economy and Greenhouse scores among various vehicles. Use a CO_2 Gas Sensor to measure the amount of carbon dioxide found in the exhaust. Measure the length of time it takes to inflate a large garbage bag (40-45 gallon bag) and the size of a balloon after it is attached to the vehicle's exhaust for five seconds.

A Study of Vehicle Exhaust

-Tom Green, wtgreen68@mac.com

Introduction

"Over the past 200 years, deforestation and the burning of fossil fuels such as coal and oil have caused the concentration of heat-trapping "greenhouse gases" to increase significantly in our atmosphere. These gases prevent heat from escaping to space, somewhat like the glass panels of a greenhouse. The levels of these gases are increasing at a faster rate than at any time in hundreds of thousands of years. If human activities continue to release greenhouse gases at or above the current rate, we will continue to increase average temperatures around the globe. Increases in global temperatures will most likely change our planet's climate in ways that will have significant long-term effects on people and the environment. Transportation sources emit greenhouse gases that contribute to climate change. In 2008, transportation sources contributed approximately 27 percent of total U.S. greenhouse gas emissions. Transportation is also the fastest-growing source of U.S. greenhouse gas emissions, accounting for 47 percent of the net increase in total U.S. emissions since 1990, and is the largest end-use source of $C0_2$, which is the most prevalent greenhouse gas." (EPA 2010, 2)

Calculating the CO_2 emissions from a gallon of fuel, the carbon emissions are multiplied by the ratio of the molecular weight of CO_2 (m.w. 44) to the molecular weight of carbon (m.w.12): 44/12. For all oil and oil products, the oxidation factor used is 0.99 (99 percent of the carbon in the fuel is eventually oxidized, while 1 percent remains un-oxidized.) Gasoline carbon content per gallon: 2,421 grams, gasoline is approximately 87% carbon (US Department of Energy, 6).
Diesel carbon content per gallon: 2,778 grams (EPA 2010, 3).

CO_2 emissions from a gallon of gasoline = 2,421 grams x 0.99 x (44/12) = 8,788 grams = **8.8 kg/gallon = 19.4 pounds/gallon**

CO2 emissions from a gallon of diesel = 2,778 grams x 0.99 x (44/12) = 10,084 grams = **10.1 kg/gallon = 22.2 pounds/gallon**

Preliminary Investigation

1. All students list their vehicle (or parents), year, make, model, transmission, 2WD or 4WD and type of fuel on the board and the approximate number of miles the vehicle is driven in the last year.

2. Working with a partner, each team chooses their vehicle (two total).

3. Three criteria initially will be researched on each vehicle (or for vehicles before 2000 only fuel economy can be found). (EPA 2010, 4 & 5). The students can use a search engine and put in Green Vehicle EPA to find this information. Please record on the table supplied, the information from number 1 above and the three criteria you will be researching, only fuel economy for vehicles prior to 2000.

   a. **Air pollution Score:** This score reflects vehicle tailpipe emissions that contribute to local and regional air pollution, creating problems such as smog, haze, and health issues. Vehicles that score a 10 are the cleanest, meaning they emit none of these types of pollutants. Emission standards are for the major pollutants in vehicle exhaust: 1) NMOG, NMHC, or THC—types of

carbon-containing compounds, including hydrocarbons, 2) NOx—Oxides of Nitrogen, which combine with hydrocarbons to create smog, 3) PM—Particulate Matter, tiny particles of solid matter that lodge in the lungs and deposit on buildings, 4) CO—Carbon Monoxide, a colorless, odorless, poisonous gas, 5) HCHO—Formaldehyde, a lung irritant and carcinogen.

b. Fuel Economy: The fuel economy values provide EPA miles per gallon (mpg), city and highway estimates for each car and light truck.
Combined fuel economy = 1 / [(0.55/City fuel economy) + (0.45/Highway fuel economy)]

For example, if City = 20 mpg and Highway = 30 mpg, then
Combined example = 1 / [(0.55 /20) + (0.45/30)] = 23.5 mpg
Please use this way of calculating and list combined fuel economy along with highway and city.

c. Greenhouse Score: This score reflects emissions of carbon dioxide (CO_2) and other greenhouse gases. The score reflects a vehicle's tailpipe greenhouse gas emissions. A vehicle's CO2 emissions are based on the carbon content of the fuel used and the fuel economy of your engine. In addition to CO_2, the GHG score includes the tailpipe greenhouse gas emissions of methane (CH_4) and nitrous oxide (N_2O), are largely dependent on a vehicle's emission control technology and the miles traveled.

d. For each vehicle, calculate how much CO_2 would be produced if the vehicles traveled 12,000 miles last year (use either metric or English units). Use the combined miles per gallon in the calculation. Now calculate this using the actual miles driven.

4. Example using a 2006 4WD Toyota Matrix, gas.
   a. Air Pollution Score: 2
   b. Fuel Economy: 22 City/ 29 Highway/ 25 Combined
   c. Greenhouse Score: 7
   d. 12000/25 x 19.4 lbs/gallon = 9312 lbs
      12000/25 x 8.8 kg/gallon = 4224 kg

      Actual driving
      6000 miles
      6000/25 x 19.4 = 4656 lbs
      6000/25 x 8.8 = 2112 kg

5. Share these results with the rest of the class

Data Table

Vehicle Description

Air Pollution Score	Fuel Economy	Greenhouse Score	CO_2 produced per 12,000 miles	CO_2 actually produced in a year (number of miles)

Vehicle Description

Air Pollution Score	Fuel Economy	Greenhouse Score	CO_2 produced per 12,000 miles	CO_2 actually produced in a year (number of miles)

Investigation

Objectives

In this investigation, you will

1. Compare Air Pollution scores, Fuel Economy and Greenhouse scores among various vehicles.
2. Use a CO_2 Gas Sensor to measure the amount of carbon dioxide found in the exhaust of 2 vehicles.
3. Measure the length of time it takes to inflate a large garbage bag (40-45 gallon bag) and the size of a balloon after it is attached to the vehicle's exhaust for five seconds.
4. Compare vehicle CO_2 results and inflation rates and compare these results with your preliminary investigation on the classes' vehicles.
5. Discuss how we can reduce our carbon footprint concerning how and what we drive.

Materials

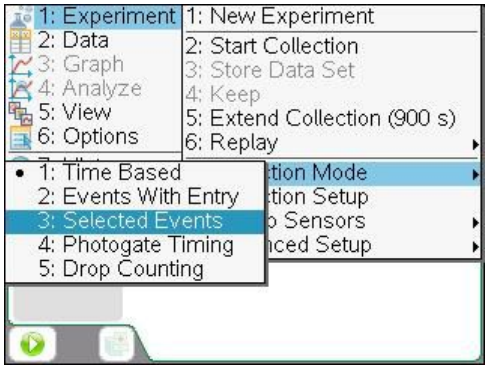
TI-Nspire handheld
Dataquest App
Lab Cradle
Vernier CO_2 Gas Sensor
Manila Folder
10-20 Gallon Trash Bag
Duct tape
Ruler
Vehicle
Stopwatch
Helium Quality 12 inch balloon

Procedures

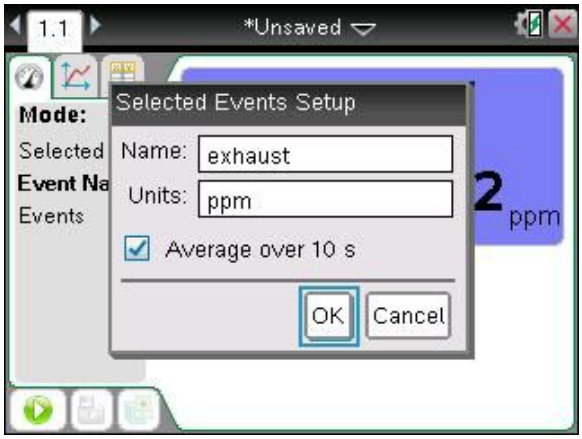
1. Turn on the calculator. Connect the CO_2 Gas Sensor to CH 1 of the lab cradle. Select the high setting (on the sensor 0-100,000 ppm) the and the temperature sensor.

2. If Dataquest doesn't open automatically, click on the Dataquest icon, to open the app

3. Go to Menu>Experiment> Collection Mode > Selected Events.



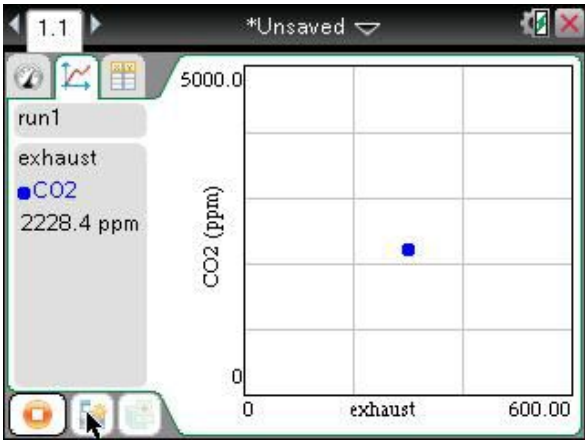
4. For the name use exhaust and units are ppm.

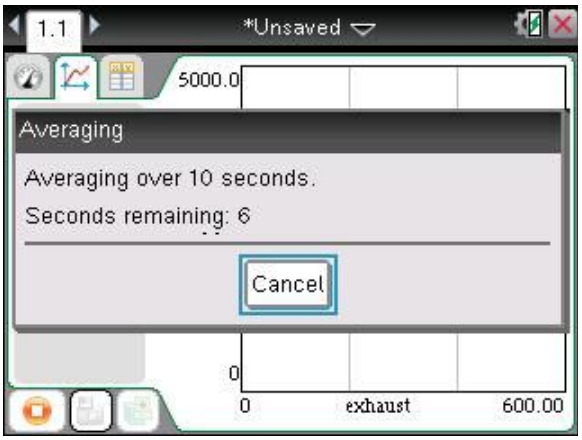


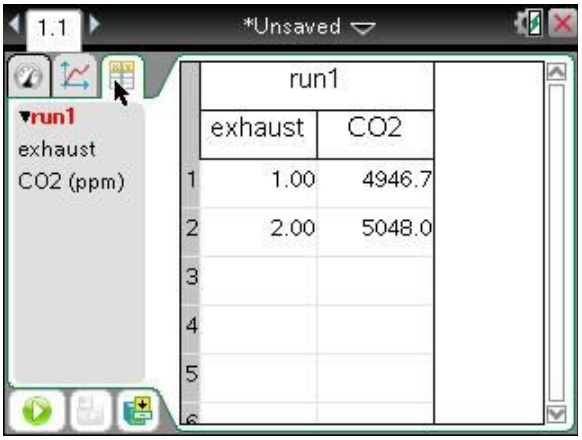
5. Let the sensor reading stabilize, if the reading is outside the range of 200-600 pm, reset the sensor by using a pencil to press in the cal hole on the side of the sensor. When the light flashes you will notice it is reset.

6. Go outside to the vehicle you will be testing. Turn on the vehicle and let it run for 1 minute. Once the vehicle has been running (make sure it is in park (automatic) or neutral (stick shifts) and put the emergency brake on, hold the CO2 Respirator Chamber to the tailpipe and collect exhaust for 5 seconds, when complete immediately put a cap on the Chamber. Take the Chamber inside if that is where your sensor and interface is.

7. Uncap the Chamber and immediately put the probe in the chamber. Click the start button, wait till the CO2 readings stabilize and then click the keep button which will start data collection for 10 seconds. This is automatically put in your table in Dataquest. Press keep once more and if both readings are close record this.







8. Take a manila folder outside to your vehicle's exhaust pipe and wrap it around the tailpipe, tape the folder to create a cylinder a little larger than the tailpipe. Duct tape both end securely. Attaching a 40-45 gallon trash bag to the folder. Tape it to the folder. Take this to your vehicle's exhaust pipe, make sure the car has been running for at least one minute, attach the folder and bag to the tailpipe, have your partner with a stopwatch record the time it takes to inflate the bag.

9. Inflating a balloon.

a. Create a cone with a manila folder. Go out to the vehicle you are testing and put the large end of the cone over the exhaust pipe so it fits snugly and duct tape it closed. Now attach a Helium Quality 12 inch balloon to the small end of the folder and attach with duct tape. Make sure there will be no leaks.

b. Turn the vehicle on and let run for 1 minute. Attach the funnel to the exhaust tailpipe, make sure it fits tight and the second it starts too inflate have someone time it for 5 seconds. Remove and twist the balloon stem to seal.

c. Measure the circumference of the balloon at its largest spot. Record all data in the table below.

8. Get a copy of all your classmates' results (see example data sheet) in order to answer the questions below.

Data

Vehicle Make and Model	CO2 Exhaust ppm	Inflation time (secs)	Inflation Circumference (cm)

Questions

From yours and your classmates research:

1. Compare Foreign vehicles to US produced vehicles in all 3 EPA categories, combined mpg, air pollution score and greenhouse score. Is there a difference, please discuss the results. Hint: You could use a 2-sample T test. If there is a difference why do you think this is?

2. Compare vehicles built before 2004 to vehicles built from 2004 and later in all 3 EPA categories, combined mpg, air pollution score and greenhouse score. Is there a difference, please discuss the results. Hint: You could use a 2-sample T test. If there is a difference why do you think this is?

3. Compare combined mpg to Air pollution score for all vehicles (2000 and later). Compare combined mpg to greenhouse score. Hint: Try a scatter plot and then a linear regression, look at the correlation coefficient. Is there a correlation? Why or why not?

4. What are your conclusions concerning the amount of CO2 generated by an individual's vehicle. List 4 ways an individual could lessen this amount and give a reason for each of your answers.

5. Is there a relationship between CO2 emissions that you measured and any of the data previously gathered?

6. Is there a relationship between inflation time and balloon circumference size that you measured and any of the data previously gathered?

7. Calculate for your vehicle and your partners how much NOx , CO, NHOG and PM generated per year by these vehicles (only if 2000 or later).

8. Using just your vehicle, summarize any other findings (data) relevant to exhaust emissions.

9. On measuring exhaust from your vehicle (bag inflation time, balloon circumference and respiration chamber CO2 amount), what could be sources of error?

Suggested Report

Introduction: What is the main theme of this investigation?
Data: List all data used in this investigation.
Questions: Answer the above Questions
Conclusion: What have you learned from the investigation?

References (all from EPA)

1. http://www.epa.gov/oms/consumer/05-autos.pdf
2. http://www.epa.gov/oms/climate/basicinfo.htm
3. http://www.epa.gov/oms/climate/420f05001.htm#1
4. http://www.epa.gov/greenvehicles/Aboutratings.do
5.

http://www.epa.gov/greenvehicles/Index.do;jsessionid=b9e0e65638e211eb3e30192284292c32dc95047138d0da21b7ec1f36414271e2
6. http://www.fueleconomy.gov/Feg/co2.shtml

Teacher Section

The CO2 sensor will not function if Relative Humidity is over 95%. The results may not necessarily be accurate because of this, but the reason to do this is for students to realize the vast amount of this Greenhouse gas that is generated by our vehicles. The inflation times and balloon inflation size if done to the same level of inflation or time may be a better measure to compare different vehicles. But they also have problems also, for example tailpipe sealing is a variable as is the timing.

It may be of interest to put a Relative Humidity sensor by the tailpipe to give the students an idea of the amount of water vapor created when hydrocarbons are burnt.

Day 4- 34

This investigation will last for a minimum of 1 month and though other modules will be done during this time, the beginning of every class period will start with students either collecting data or starting a new experiment.

1. **(Exhance/Enrich)** Students will start a project, which will last one month. Carbon Sink Challenge (investigating CO_2 sinks). The overall challenge is for students to find materials (both commonly occurring and found in nature or readily available to humans) that would act as a carbon sink (carbon absorber).

They will work in teams of two or three. **(Evaluate)** They will keep a journal that will be checked once a week, each trial will be prior approved, a paper will be do following our normal format (attached) and a 5 minute presentation will be do one week after the project is completed. Every two days a new treatment will be implemented.

The first day is the control, gathering baseline CO2 data

Carbon Sink Challenge
With TI-Nspire

A carbon sink is a natural or artificial reservoir that accumulates and stores some carbon-containing chemical compound for an indefinite period. The process by which carbon sinks remove carbon dioxide from the atmosphere is known as carbon sequestration (Wikipedia, 11 January 2011). The overall challenge is for students to find materials (both commonly occurring and found in nature or readily available to humans) that would act as a carbon sink (carbon absorber).

Investigation

Objectives

In this investigation, you will:

1. Research the carbon cycle with an emphasis on carbon sequestration.
2. Generate new questions that can be investigated in the laboratory or field.
3. Conduct scientific investigations using appropriate tools and techniques.
4. Describe a reason for a given conclusion using evidence from an investigation.
5. Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.
6. Develop an understanding of a scientific concept by accessing information from multiple sources. Evaluate the scientific accuracy and significance of the information.

Materials

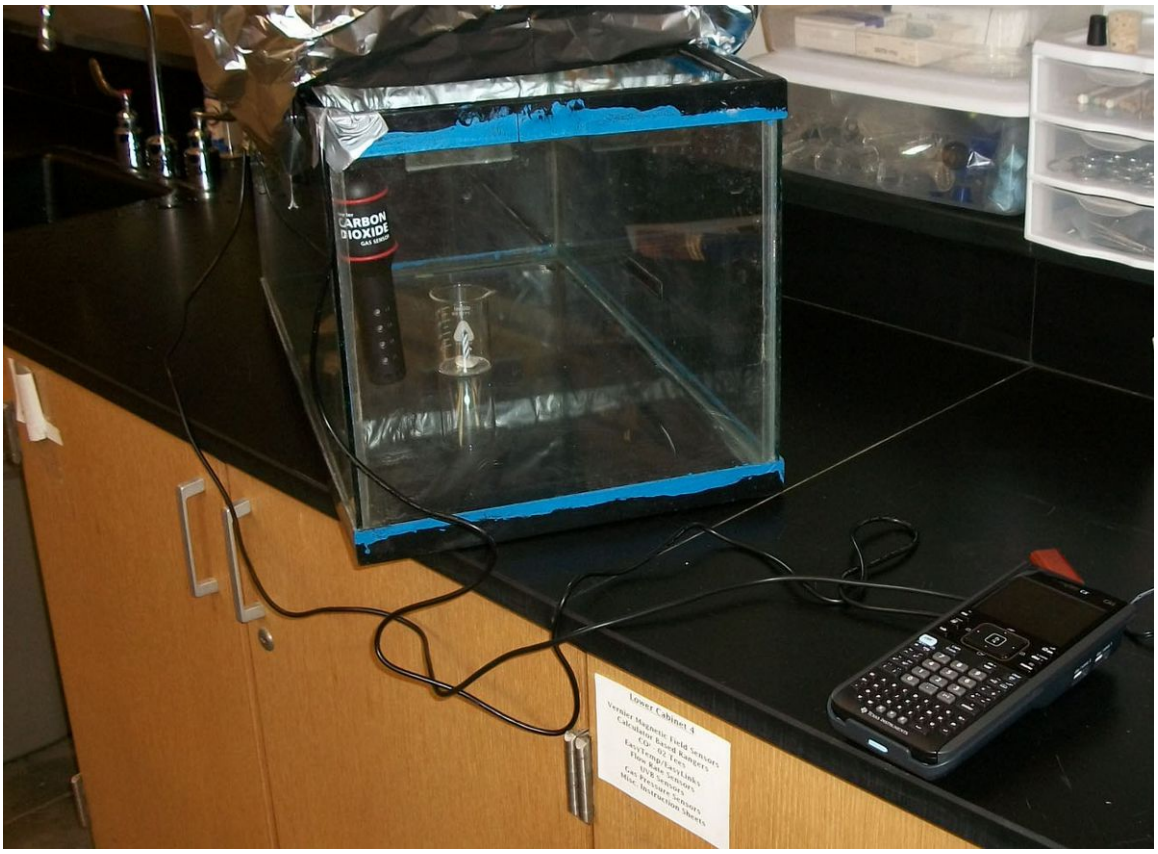
TI-Nspire handheld
Dataquest application
Lab cradle
Vernier CO_2 Gas & Relative Humidity Sensor
Birthday candle
Beaker
Aquarium
Duck tape
Aluminum Foil
Silica Gel
Assortment of Materials that could be used by student for carbon sequestering

Procedures

The CO_2 Gas Sensor can give inaccurate readings when Relative Humidity is above 95%, all experiments should include Relative Humidity readings and with those activities, also use a desiccant (Silica Gel will not react with CO_2). Direct intense light used for an extended period will also cause inaccurate readings.

First the students will set up data collection for the control over a period of 47 hours.

1. Aquarium used should be at least 20 inches wide, 12.5 inches high, 10 inches wide. Volume is 2500 in^2.



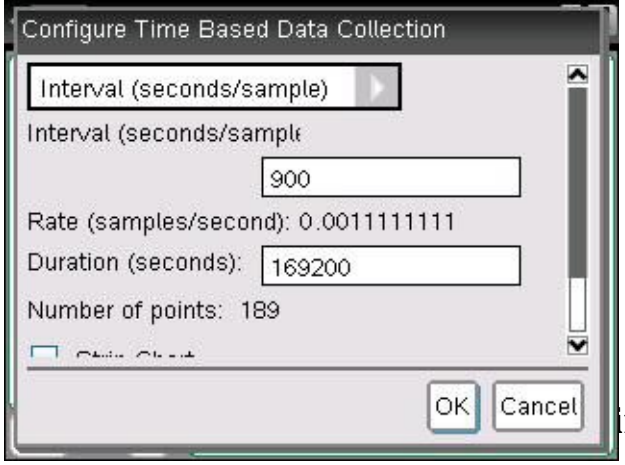
2. If your CO_2 Gas Sensor has a switch, set it to the high (0–100,000 ppm) setting. Connect the CO_2 Gas Sensor to the ch1 of the lab cradle interface and the relative humidity sensor to channel 2.

3. Duct tape the CO2 sensor to the side of the aquarium with the switch to the high position (0-100,000 ppm). Also duct tape a Relative Humidity sensor to the other corner of the aquarium (not shown).

4. Put 1/2 of a birthday candle on a 100 ml beaker on a slide using silly putty or other material to hold it.

5. If Dataquest doesn't open automatically, click on the Dataquest icon, to open the app. Wait five minutes for the sensors to equilibrate.

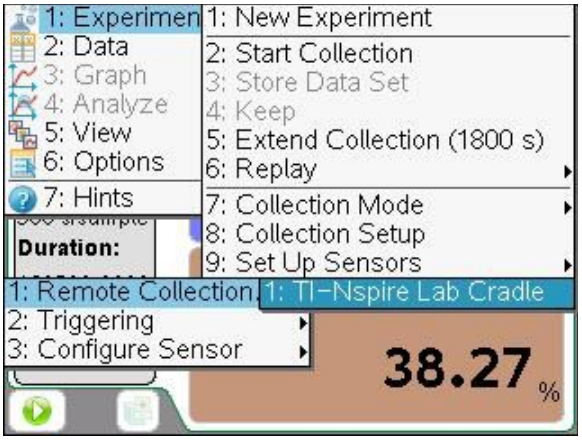
6. Go to menu and in the Experiment submenu, choose Collection Setup. Select Interval (seconds per sample). Enter 900 as the interval, the Duration is 169200 seconds (47 hours). Number of points will be 189. Click OK.

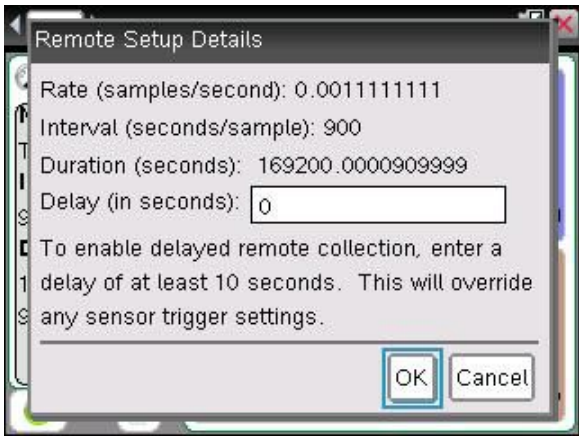


n.

Do steps 7- 11 if you would like to disconnect the calculator. If not go to step 12.

7. Now go to Experiment/Remote Collection/TI-Nspire Lab Cradle

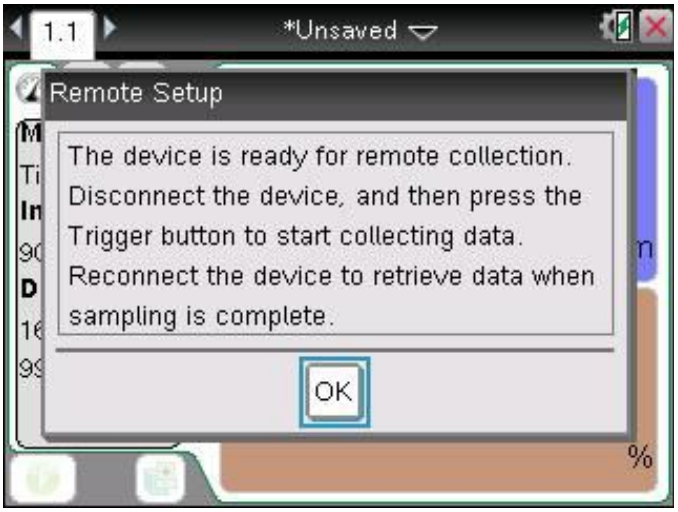




Just click OK

8. Disconnect the TI-Nspire

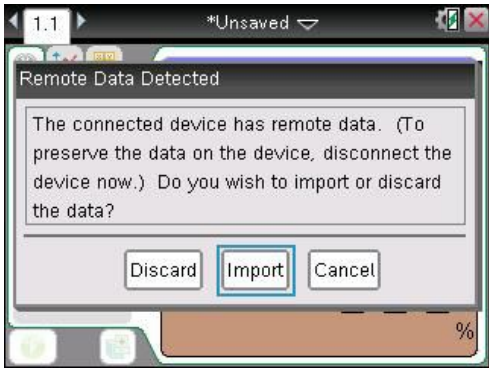
9.



Click OK

10. Press the trigger on the Lab Cradle. Data will be collected for 47 hours. Wait 15 mins before lighting the candle. Once lit immediately and quickly cover the aquarium with aluminum foil, taping down all sides with duct tape to seal.

11. At the end of 47 hours, reconnect the TI-Nspire. You will get the following screen. Click import and then go to the graph View.



12. With the graph view, click in the graph. Go to the peak at the beginning of the sampling period and record the CO_2 level, then go to the last data point and record the CO_2 level. Subtract the two and this is the amount lost over the sampling period. This is your control. Be sure to record this in your journal. All else will be compared to this.

13. Have students research the materials they will use to lower the CO_2 in the enclosed aquarium more than the control. Teacher should approve all materials prior to use and the student's justification. If the material is a growing plants (oats) or fresh leaves (spinach) or water, make sure the amount is limited because of water vapor generated via the plant, use plenty of **desiccant**.

14. Allow the students to test 3-5 different materials over a 2-4 week time frame. If growing plants in aquarium, time would be longer.

Suggested Report

Introduction: What is the main theme of this investigation? Describe natural and artificial sinks.
Hypothesis and Reasons
Procedure
Data: List all data used in this investigation.
Analysis
Conclusion

Reference

http://en.wikipedia.org/wiki/Carbon_sink

Teacher Section

An excellent non-biological carbon sink is Calcium Hydroxide powder that is cheap and works very quickly.

Carbon Sink Challenge extends over month.

After the challenge the students will take the
(Evaluate) Post – Test Yale