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Energy and a Changing Climate for English Language Learners

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Rational

Energy and a Changing Climate for English Language Learners, is written for the English language learners taking phychem at Wilbur Cross High School in New Haven, CT. The students bring a wide variety of skill sets to the school as well as growth areas to the class. Many of the students are from Spanish speaking countries in Central and South America. There are also a few students from African and Middle Eastern countries. This past year the main languages of the students included Spanish, Pashto, Persian, Dari, Urdu, Swahili and French. In my science classes students are working on both their language and science skills.

At Wilbur Cross on the International Academy of Digital Arts and Sciences the ninth and tenth grade students stay together as a cohort and take phychem and biology together. The classes run on a block schedule with A and B days four periods per day 80 min per period.

Starting off the year with this unit will cover how energy and the atmosphere keep the earth a livable temperature for life. The unit is written to cover the following Next Generation Science Standards (NGSS) HS PE ESS2-4 (use a model to describe how variations in the flow of energy into and out of Earth’s systems result in changes in climate.), HS PE ESS2-2 (analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.) and ESS3-5 (analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.).

The purpose of this unit is to provide students with an understanding of the earth’s energy budget and how energy enters and leaves the earths’ atmosphere in a supportive environment to English language learners. My unit *Energy and Earth’s Climate for English Language Learners* will focus on the science around how energy affects earth’s climate.

It is important for students to learn about climate change not just because it is in the curriculum but because it will greatly affect their generation and the generations of students to come. All students including the ELLs should have the opportunity to learn about relevant environmental issues of their time in a way that they can understand.

Background

Before teaching a unit on how energy influences climate it is important to review some basics of energy. Energy is defined as the capacity to do work. [1] There are six forms of energy: chemical, electrical, radiant, mechanical, thermal and nuclear.[2] Chemical energy is the energy stored in the bonds between atoms. Electrical energy is energy generated from the movement of electrons. Radiant energy is the energy that is associated with electromagnetic waves. Mechanical energy is the energy attributed to an object because of its movement or position. When the nuclei of atoms are split or fused the type of energy produced is nuclear energy. Thermal energy is the energy of moving or vibrating molecules also known as heat energy.[3] The types of energy focused on in this unit will be thermal and radiant energy. The flow of incoming energy from the sun (radiant energy) and outgoing energy from the earth (thermal energy) is what drives the earth's climate.

In order to more fully comprehend how the earth's climate may be influenced we need to explore the first law of thermodynamics. The first law of thermodynamics or the law of conservation of energy states that energy can neither be created nor destroyed only transferred from one system to another. Types of heat transfer include radiation, conduction or convection. Heat always moves from the warmer area to the cooler one. Radiation is a type of energy transfer where two objects exchanging energy do not have to be in direct contact, for example the sun heats the earth through radiation.[4] Conduction is where the heat exchange is done through direct contact for example a pan on an electric burner is heated through conduction.[5] Convection has to do with fluids both liquid and gaseous. Here the warmer fluid will rise and expand while the cooler fluid will sink.[6] Convection explains how a baseboard heater near the floor of a room can heat the whole space.

It is the movement of incoming energy from the sun and outgoing energy from the earth that drives the climate. If the net energy in and out are equal then the climate stays the same. If there is more energy out than in the earth's climate it will get colder and if the opposite is true then the climate gets warmer.[7] This concept is comparable to maintaining weight. If you wish to gain weight you need to eat more calories than you are using. If you want to lose weight you need to use more calories than you are eating and to maintain a steady weight, calories in need to equal calories out. However, if the earth did not trap some energy it would be too cold for life. It is the atmosphere that traps heat close to earth creating the comfortable living conditions for those in the biosphere.

For this unit the earth will be thought of as a system. A system may be opened or closed. In terms of matter, earth is a closed system; our planet does not exchange matter with space (meteorites are the exception).[8] In terms of energy however earth is an open system. Energy from the sun enters earth's atmosphere and warms the surface of the earth and this energy is then re-radiated by the earth back into space. Earth systems science is the study of the different earth spheres and their interactions with the other spheres. Four major earth spheres include the atmosphere, biosphere, geosphere and the hydrosphere.

Atmosphere: is the layer of gases that extends several hundred kilometers away from Earth's surface and it is divided into several layers.

Biosphere: includes all life on earth.

Geosphere: includes all of the rocks, minerals and soils on earth.

Hydrosphere: includes all the water on earth.

Cryosphere: includes all of the frozen water on earth.[9]

Nearly all of the energy available at Earth's surface is from the sun. The energy travels through space and arrives in the form of electromagnetic waves. Electromagnetic waves are waves that travel at about the speed of light (300,000 km/s), have both electrical and magnetic properties and can pass through solids, liquids, gasses and even empty space. The different characteristics of a wave include amplitude, crest, trough, wavelength and frequency. Amplitude is the height of a wave from rest position. A crest is the high point of a wave while a trough is the lowest point on a wave. Wavelength is the distance between two crests or two troughs. Frequency is how many complete waves pass a given point in a second. The shorter the wavelength the higher the frequency. In order to get our bearings on what has a longer wavelength infrared radiation or ultraviolet radiation we will need to look at the electromagnetic spectrum.[10]

The electromagnetic spectrum begins with radio waves which have the longest wavelengths. Items such as radios use radio waves. Microwaves are shorter than radio waves and are used in microwave ovens and radar. Next is the infrared region of the electromagnetic spectrum which transmits heat.[11] With shorter wavelengths from approximately 700 nm to 400 nm is visible light, this range of wavelengths is what humans can see. Ultraviolet radiation has a higher frequency than visible light. Also known as UV rays this type of electromagnetic radiation can be used to sterilize and cause sun burns. X-rays have an even higher frequency than UV rays and have many medical purposes such as allowing people to see inside the body. Finally, the highest frequency and shortest wavelength EM waves are gamma rays. Electromagnetic rays are important for climate studies because sunlight is made up of a range of EM waves and sunlight provides the energy that warms the earth. Sunlight is made up of a range of wavelengths including some infrared all visible light and a portion of the UV region of the electromagnetic spectrum.[12]

The greenhouse effect is where incoming energy from the sun enters earth's atmosphere as shortwave radiation and the earth's surface reradiates this energy as longwave radiation (i.e., heat) which can then be lost to space or trapped by greenhouse gasses. Several things can happen to incoming shortwave energy from the sun 1) it can be reflected back to space while in the atmosphere 2) It can be reflected by earth's surfaces with a high albedo 3) it can be absorbed by the earth's surface.[13] Clouds have a high albedo which means that they reflect lots of shortwave energy. Albedo is a measure of something's reflectivity. Snow and ice have a high albedo while the open ocean is a darker color and has a very low albedo. Light colors have a higher albedo while darker colors have a lower albedo.[14] This is why you are hotter in a black t-shirt on a sunny day than in a white one.

The energy absorbed by earth's surfaces is then reradiated as longwave radiation in the infrared region of the electromagnetic spectrum that can be lost to space or trapped by greenhouse gases such as carbon dioxide CO_2, nitrous oxide N_2O, methane CH_4 and water vapor H_2O. This is a normal process that keeps the earth a livable temperature.[15] Humans however are altering this process by adding immense amounts of CO_2 from burning fossil fuels into the atmosphere every year changing the amount of energy leaving the earth and the troposphere.[16]

Carbon dioxide is a molecule made up of a carbon atom with an oxygen atom bonded to each side in a linear shape. When infrared radiation reradiated from the earth comes into contact with a CO_2 molecule it causes the bonds between the atoms to move. These bond motions include both bending and stretching. When the molecule returns to its normal shape the energy is then released back into the atmosphere in random directions. This process only happens with electromagnetic energy in the infrared region. Visible light and UV rays do not cause this to happen. (video)

Greenhouse gases heat the Earth by absorbing reradiated heat from the Earth's surface and limiting the energy that escapes back to space. Different greenhouse gasses can affect the Earth's average temperature differently. Two ways that greenhouse gases are different from each other include their ability to absorb energy known as radiative efficiency and how long they stay in the atmosphere or lifetime.[17]

The Global Warming Potential (GWP) according to the EPA "is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO2)."[18] (EPA website) This means that a larger GWP for a gas the more or less that it warms the atmosphere compared to CO2 during that time period. Usually for GWPs the amount of time is 30 or 100 years.[19] GWPs are important for policy makers; they provide a unit of measure, which allows the policy makers to determine which gases have the most impact and compare ways to most effectively reduce climate change through targeted emissions reduction.[20]

Greenhouse gases

Carbon dioxide or CO_2 is a molecule made up of one carbon atom and two oxygen atoms. Carbon dioxide is released naturally through processes such as respiration and volcanic eruptions.[21] Respiration, the metabolic process of breaking down sugar for energy releases CO_2. Anthropogenic sources of atmospheric CO_2 include deforestation, land use changes, and burning fossil fuels. Fossil fuels include coal, crude oil and natural gas which are burned for energy. The process of burning organic matter such as fossil fuels or wood is known as combustion which releases CO_2. Energy rich fossil fuels were formed over a very long time from organic matter that eventually was stored underground. Because of their slow rate of formation fossil fuels are a nonrenewable resource. As a result humans are burning a nonrenewable resource and putting many billions of tons of carbon into the atmosphere from the combustion reaction of these fossil fuels. Humans are taking carbon that was stored in the geosphere and are adding it to the atmosphere. This is a problem because CO_2 is a greenhouse gas with a very long lifetime in the atmosphere, ~1000 years.[22]

Methane or CH_4 is another greenhouse gas that is made up of one carbon atom and four hydrogen atoms bonded together. It is 30x stronger than CO_2 at absorption of long wave radiation over a 100-year time scale. Methane is present at much smaller quantities than CO_2 in the atmosphere and has a much shorter atmospheric life, approximately 8-12 years. Methane is produced by anaerobic decomposition. This means it is found both in natural ecosystems such as wetlands and anthropogenic sources such as landfills, flooded rice fields, and the guts of cattle.[23] A future source of methane scientists are concerned about is methane from permafrost thaw.[24] As permafrost thaws they become waterlogged and go through anaerobic decomposition of the organic matter that has been stored for thousands of years.

N_2O or nitrous oxide is another greenhouse gas found in the atmosphere. It is a gas produced by soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning.[25] Another source of nitrous oxide is internal combustion engines. N_2O also has a long lifetime in the atmosphere and is also a very powerful greenhouse gas.

Water vapor is the most abundant greenhouse gas and acts as a feedback to the climate. Water vapor increases as the Earth's atmosphere warms, so does the possibility of clouds and precipitation create possibilities for both positive and negative feedback loops.[26]

Ozone (O_3) is also a greenhouse gas but a potential source of misconception for students. Ozone in the stratosphere protects the Earth from harmful UV rays. However in the 1970's a hole in the ozone layer was observed and attributed to the use of chlorofluorocarbons or CFCs. With the Montreal protocol in 1987 the world came together around this issue to ban the future use and phase out the current use of CFCs. The misconception among students is that the hole in the ozone layer is what is causing climate change.

Feedback Cycles

With a changing climate it is important to make predictions for what the future climate will look like. In order to do this several important feedback loops, need to be taken into consideration. A feedback loop is where the product of a change is used as the input and results in an enhanced effect or a mitigating effect.[27] For example our body needs to regulate our internal temperature. When we get too hot we sweat. Sweating results in evaporative cooling lowering our body temperature. This feedback is an example of negative feedback. Here the reaction to the change brings our body back to a normal temperature maintaining homeostasis. A climate example of negative feedback is where warming atmospheric temperatures will result in more water vapor in the air. This water vapor could increase cloud cover. Clouds have a high albedo and could result in a cooling of the climate. A positive feedback loop is where a change to a system results in an amplification of the initial change. For example, in a warmer world snow and ice are melting. Snow and ice have a very high albedo and help keep the planet cool by reflecting lots of light. When snow and ice melt they are replaced by darker surfaces such as ground or open water both have a much lower albedo and would result in increased warming of the atmosphere amplifying the initial warming. When making predictions of future climates feedbacks need to be considered.

By adding many tons of carbon, in the form of CO_2, to the atmosphere and other greenhouse gasses humans are increasing the global average temperature as a result.[28] We are able to determine how carbon added to the atmosphere will continue to increase the global average temperature. One way we know this is by looking at paleo-climate data such as ice core samples. Other sources of past environmental conditions include very old tree rings and corals. Thousands of years old the layers of ice on some ice sheets contain air bubbles which are able to tell us about past atmospheric conditions. With this and other data it is possible to look back into the earth's climate history and see the gasses in the atmosphere that most affect the earth's climate.

How do we know CO_2 is increasing in the atmosphere? Data has been collected regularly and frequently measuring the concentration of CO_2 at the Mauna Loa observatory since 1958.[29] Charles David Keeling from the Scripps Institution of Oceanography made several discoveries with his data collection. One was that the earth "breathes" with a yearly max and min CO_2 concentration. The max is in the fall when the plants become dormant in higher latitudes, and the min is when the plants grow in the spring with the increase of photosynthesis.[30]

A rising global average temperature is a problem for many reasons. Effects of this temperature and CO_2 increase include; sea level rise, weather pattern changes, increase in frequency and severity of storms, ocean acidification and a frost-free growing season.[31] Sea level is rising not just from the melting of glaciers and sea ice. As water heats up and the molecules move faster and farther apart: the water expands.[32] Drastic changes in weather patterns leads to change in precipitation and can lead to both floods and droughts.[33] With a warmer global average temperature come warmer ocean waters. Ocean warming leads to more water vapor in the atmosphere. Warmer ocean also creates stronger convection currents which consequently speeds up storms and increase severity.[34] Increasing temperatures mean a frost free growing season. This lack of a freeze can increase ranges for disease vectors such as mosquitoes and ticks.[35] One effect of increasing CO_2 levels in the atmosphere is ocean acidification caused by change in ocean pH. CO_2 can dissolve in the ocean and make carbonic acid. This acidification of the ocean has many reaching effects including negatively impacting calcifying organisms such as corals and mollusks.[36]

A rising global average temperature is a problem not just for the natural world but for humans too. Changes in weather patterns are resulting in many destructive forces such as wildfires, flooding and frequent severe hurricanes.[37] These climate change fueled forces damage infrastructure and cost lives. Everyone is affected but there are more vulnerable groups.

Since climate change has been recognized by global policy makers there have been two major UN Climate agreements: the Kyoto Protocol and the Paris agreement.[38] The Kyoto Protocol was created in 1997 and was a legally binding agreement to decrease greenhouse gas emissions with the goal of decreasing them by 5% from 1990 levels. This agreement only required developed nations to participate.[39] Paris Agreement was signed in November 2016 this agreement's goal was to limit global average temperature increase to 1.5 degrees Celsius above pre-industrial levels and requested that all nations participate.[40] These are two historic pieces of global legislation to combat climate change.

There is hope! Humans need to focus both on adaptation and mitigation strategies. Adaptation refers to adapting to the current and future impacts of climate change.[41] For example adaptation strategies for dealing with sea level rise could be building a sea wall. A mitigation strategy is different in that its goal is to address and limit the cause of climate change and example of this is carbon sequestration or finding a way to store large amounts of carbon, maybe by putting it underground or into the deep ocean.[42] Other mitigation strategies include alternative energy sources, and tax on industry for adding CO_2 to the atmosphere.

Teaching Strategies

This section will provide a look at strategies for teaching English Language Learners or ELLs about energy as it relates to climate and how this balance is changing. There are 10 generally useful strategies for teaching ELLs outlined in the "El strategies Desk Cards" put out by the RESC Alliance.[43]

General EL Strategies

- Provide explicit vocabulary instruction for potentially new vocabulary prior to and during lesson
  - examples include: word walls, personal bilingual dictionaries, word cards with pictures, games, etc.
- Use visuals as much as possible
  - Pictures gestures, pointing, graphic organizers
- Provide background knowledge and connect to students' prior knowledge
  - Examples include: KWL charts, anticipation guides, bilingual dictionaries, journal writing in native language, creating bilingual books, etc.
- Expect reading skills to come slowly.
  - If the student has learned to read in his/her native language, this will probably help him/her to

    - transfer reading skills to English. However, the student may be pronouncing words, but not really comprehending
- Adjust Activities and assessments according to the EL language level.
- Use scaffolding techniques and adapted content for comprehensible input
    - Examples: jigsaws, think alouds, graphic organizers, answer frames, sentence starters, taped text, adapted text, etc.
- Provide supplementary materials
    - Examples include: graphs, models, realia (actual objects), visuals
- Learn about student's culture and native language to better understand learning needs
    - What are the similarities of the phonetic systems?
- Use gentle correction to encourage use of correct patterns while at the same time encouraging risk taking with the language
    - Example: Student says "I eated breakfast." Teacher responds "I ate breakfast, too. I ate toast. What did you eat?"
- Frequent opportunities for oral interaction
    - Examples: Think-Pair-Share, Partner talk, Cooperative Learning, etc[44]

Classroom Activities

Classroom Activity One : Types of Heat Transfer

Objective: Students will be able to label different types of heat transfer including radiation, conduction and convection.

General Vocabulary: movement, heat, warm, cold, sun, Earth, water, air, up, down, direct contact, exchange, direction, red, blue, transfer.

Scientific Vocabulary: radiation, conduction, insulator, conductor, convection

Materials Required: Hot plate, beaker, water, plastic spoon, metal spoon, 2 small Erlenmeyer flasks, red food dye, blue food dye, an empty fish tank

A good way to begin this lesson is with a phenomenon that students can observe. One example is to have students touch a metal spoon. And ask does it feel warm or cold? After holding the spoon for 20 seconds, how does it feel now? Which way did the heat move, from your hand to the spoon or from the spoon to your hand? The next phenomena could be a beaker of boiling water. Which way is the heat moving from the hot plate to the beaker or from the beaker to the hot plate? Which way does heat move from something hotter to something colder or the other way?

The next part of the lesson would be direct instruction that reviews the objective as well as review the general and scientific vocabulary with as many clarifying images as possible. Students could take notes or make flashcards that they accumulate throughout the year or use vocabulary worksheets.

After some form of notes students will be broken into 3 or 6 groups depending on how many stations you are able to set up. There are three different stations one for radiation, conduction and convection separately.

Stations will be numbered 1, 2, and 3. At each station students will have to identify the type of heat transfer exhibited by the activity.

Station number one will be radiation. One idea for this station could be an image that students need to label and has a picture of a person warming their hands near a fire. Students could also be asked to label the fire and hands to practice their English vocabulary. A second picture could be of the sun sending radiation visualized as waves with a short wavelength and again students could be asked to label the sun and the earth as well as the type of heat transfer depicted.

Station number 2 will be conduction. Here students will have a hot plate with a beaker of water on it. The water should be hot but still comfortable to touch. Students will have a metal and plastic spoon which they will stick into the water at the same time for 10 seconds. After removing the spoons students will observe which spoon feels warmer. Here students could be asked the type of heat transfer that heated the beaker, the water and the spoons? Also, which spoon was a better conductor of the heat and which was a better insulator.

Station 3 will be convection. At this station students could take a small Erlenmeyer flask filled with hot water dyed red with food coloring and very cold blue water from an ice bath and place them in a room temperature tank or a tall clear container. The cold blue water may need to be tipped over for the cold dense blue water to come out of the flask. Red hot water will rise out of the flask when placed on the bottom of the tank. Both flasks should be placed in the tank at roughly the same time. Once in the room temperature water the hot red water will rise and the cold blue water will stay on the bottom of the tank. This will last until the red water cools then sinks and the blue water warms then rises. One question could have students draw and label the colors of the water they saw and where they went in the tank.

A good closing or exit ticket for this lesson could be to provide different examples of radiation, conduction and convection and see if students can identify each. This would require a visual aid such as a video or picture for students to understand what is happening and correctly identify each type of heat transfer.

Classroom Activity Two: Is Carbon Dioxide Able to Trap Heat?

Objective: Students will be able to make observations and record temperature differences between a mixture of gases and pure carbon dioxide.

General Vocabulary: soda bottle, baking soda, water, vinegar, tube, air.

Scientific Vocabulary: Carbon dioxide, reaction, heat, temperature, mixture

Materials Required: 3 clear soda bottles, 2 caps to the soda bottles with holes drilled in them, plastic tubing, water, two thermometers, modeling clay, baking soda, vinegar, scale or balance, permanent marker for labeling bottles, container for water bath, heat lamps.

This lab ambient air (a mixture of gases) is compared to a bottle with pure CO_2. Both bottles are placed equal distance from their own heat lamps and the rate at which the gases heat up and cool down are measured. For this experiment follow or modify the following procedure adapted from an activity book published by the National Atmospheric and Atmospheric Administration.[45]

1. Label your clear 2L soda bottles Air (clear bottle no holes), CO_2 (clear soda bottle with no holes) and Reaction Chamber (soda bottle with the hole in the side for plastic tubing).
2. Put the thermometers and plastic tubing into 3 different caps and make a tight seal using the modeling

clay. The thermometer should extend about 1.5 below the cap and the tubing should extend 1 inch below its cap. Now you have 2 caps with thermometers and one with plastic tubing.

3. Take the free end of the plastic tubing and make sure it extends into the clear soda bottle with the hole in the side. Then make a tight seal with the modeling clay.
4. Place a cap with a thermometer on the soda bottle labeled air. Next put the other cap with the thermometer on the soda bottle labeled CO2.
5. Put the cap on enough to keep it attached to the bottle but loose enough so that air can escape if you squeeze the bottle.
6. Measure 60 ml of vinegar with your graduated cylinder.
7. Mass two tablespoons of baking soda. (do not forget to use the mass of your weighing dish to figure this out)

   Mass of baking soda = mass of baking soda AND dish - mass of dish

8. Fill your water bath halfway with water.
9. Fill the soda bottle labeled CO2 all the way to the top with room temperature water.
10. Place the CO2 bottle upside down in the water bath and insert the tube from the reaction chamber.
11. Use a funnel to place your massed baking soda into the CO2 bottle.
12. The next steps need to be done quickly. Read the instructions first. Pour 60 ml of the vinegar into the reaction chamber and QUICKLY fasten the sealed cap to the bottle. (easiest way to do this is to have on person pour the vinegar while the other person holds the bottle in one hand and the cap in the other)
13. Swirl the CO2 bottle once the reaction has slowed. And Add more vinegar once it has stopped. Do not forget to measure and record how much vinegar you used.
14. React Baking soda and vinegar until the CO2 bottle is completely filled with carbon dioxide gas.
15. Once the CO2 is filled with CO2 remove it from the water and quickly cap it with the cap with the thermometer.
16. Cap the air bottle with the cap with a thermometer.
17. Take the starting temperature of the bottles Air and CO2 (this is time 0)
18. Place the sealed bottles labeled Air and CO2 under a heat lamp so that they receive the same amount of light.
19. Record the temperature inside each bottle every min for 15 min.
20. Graph your results.

Classroom Activity Three - Sample Ice Cores

Objective: Students will be able to conclude for themselves which factor most affects climate by collecting data and analyzing graphs.

General Vocabulary: matches, years, past, influence, ice, air, bubbles

Scientific Vocabulary: ice core, methane, volcanic ash, dust, carbon dioxide, graph, climate, temperature

Materials Required: 6 petri dishes, 4 different types of beads to represent different atmospheric components, glue, labels

This activity is where students look at replica ice core samples to determine which factor most influences the climate over the last 150,000 years. The options are methane, volcanic ash, dust or carbon dioxide. Looking at petri dishes with glue and different marbles which represent air bubbles or particles of dust or ash students record, graph and interpret their results to see which factor over time best matches the graph of temperature over the last 150,000 years. This activity is from an eesmarts climate change advanced workshop.[46]

Ice Core Key

Each

Blue bead is equal to 50 ppm of CO_2

Clear bead is equal to 50 ppb of Methane

Wooden bead is equal to 50 particles of Dust

Wooden Bead with marker is equal to 50 particles of volcanic ash

150,000 years ago =	200 ppm of CO_2	= 4 blue beads
	350 ppb of CH_4	= 7 clear beads
	200 particles of dust	= 4 wooden beads
135,000 years ago =	300 ppm of CO_2	= 6 blue beads
	500 ppb of CH_4	= 10 clear beads
	170 particles of dust	= 3 wooden beads
100,000 years ago =	230 ppm of CO_2	= 5 blue beads
	450 ppb of CH_4	= 9 clear beads
	150 particles of dust	= 2 wooden beads
	40 ppm volcanic ash	= 1 dotted bead
50,000 years ago =	200 ppm of CO_2	= 4 blue beads
	400 ppb of CH_4	= 8 clear beads
	450 particles of dust	= 9 wooden beads
	240 ppm volcanic ash	= 5 dotted beads
20,000 years ago =	190 ppm of CO_2	= 4 blue beads
	350 ppb of CH_4	= 7 clear beads
	180 particles of dust	= 4 wooden beads
	80 ppm volcanic ash	= 2 dotted beads
10,000 years ago =	260 ppm of CO_2	= 5 blue beads
	400 ppb of CH_4	= 8 clear beads
	40 particles of dust	= 1 wooden bead

Classroom Activity four - Sources of Carbon Dioxide

Objective: Students will be able to observe and conclude which contributes more carbon dioxide to the atmosphere, human breath or car exhaust through a laboratory experiment.

General Vocabulary: breath, car exhaust, balloon, air, straw, cup, twist tie, blue, green, yellow, most, least

Scientific Vocabulary: bromothymol blue, indicator, carbon dioxide,

Materials Required: 4 different colored balloons, twist ties, straws, 4 clear cups, bromothymol blue indicator, car exhaust (not from a hybrid car), bike pump, human breath, baking soda, vinegar, Erlenmeyer flask, water

Which contributes more CO_2 to the atmosphere? Human breath or car exhaust? Students will answer this question in this lab by bubbling pure carbon dioxide, human breath, car exhaust and ambient air through bromothymol blue and observing how yellow each solution turns. Students will capture each gas in a balloon then make sure all the balloons are the same size. Gases will be captured in a balloon sealed with a twist tie. The more carbon dioxide present the more yellow the solution will turn. CO2 when mixed with water makes carbonic acid. Bromothymol blue turns yellow in the presence of an acid.[47]

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Student Reading List

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1. Global Weirdness by Climate Central

   A digestible book on climate change for young readers. This book explains climate change and its impacts including severe storms, deadly heat waves, relentless drought, rising seas and the weather of the future.

2. https://climate.nasa.gov/

   This website has great articles and images that help explain what is happening to our warming planet.

3. https://keelingcurve.ucsd.edu/

   This website has lots of information on carbon dioxide in the atmosphere including real time data on the concentration of carbon dioxide at their research station in Hawaii.

4. Kiss the Ground - Documentary

   This documentary can be found on Netflix and proposes a solution to climate change and more robust agricultural practices.

Annotated Bibliography

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1. Britannica, The Editors of Encyclopedia. "Electromagnetic spectrum". *Encyclopedia Britannica*, 11 Mar. 2019, https://www.britannica.com/science/electromagnetic-spectrum. Accessed 6 July 2021.

   This web page provides basic background information on electromagnetic radiation in the different ranges of the electromagnetic spectrum. It also has information on ways each different section is used for example microwaves are used in cooking and radar.

2. Dobson, K., John S. Holman, and Michael Roberts. *Physical Science*. New York, New York: Holt, Rinehart and Winston, 2008.

   This text book contains lots of information on basic scientific principles of physics and chemistry. The most useful sections for this curriculum unit are those on heat transfer and wave properties.

3. "Earth as System" Window to the Universe. Last modified August 16, 2013 by Roberta Johnson. https://windows2universe.org/earth/ess1.html

   The article "Earth as a System" on the window to the universe webpage has good information on the definition of the four earth spheres. This webpage is where I found my information on the Earth's spheres for this unit.

4. eesmarts. "Climate Change Advanced Workshop." Energize CT 2018

   This booklet has an activity called Slice of Ice from which the ice core lab in this unit is modified from. The booklet also contains many other climate change oriented classroom activities.

5. "Energy: The Driver of Climate" Climate Science Investigations, Last modified 1/14/16 http://www.ces.fau.edu/nasa/module-2/ accessed (6/6/21)

   This booklet contains most everything you need to understand climate change as it relates to energy, including energy transfer to electromagnetic waves to greenhouse gases. This source provided information for much of this curriculum unit.

6. EPA. "Understanding Global Warming Potentials" LAST UPDATED ON SEPTEMBER 9, 2020. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

   This webpage by the EPA provides a good definition of a GWP or global warming potential and provides some examples and answers common questions about them.

7. "HS-ESS2-4 Earth's Systems" Next Generations Science Standards, Accessed on 7/1/2021, https://www.nextgenscience.org/pe/hs-ess2-4-earths-systems

   This page on the NGSS website provides a detailed breakdown of the specific standard HS ESS 2-4. This is useful when teaching this particular standard.

8. IPCC, 2014: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

   The synthesis report from the 2014 IPCC report contains lots of information on the state of and recommendations for dealing with climate change.

9. Martha Benduski, "Paris Agreement vs Kyoto Protocol [Comparison Chart]" Care about climate., December 9th, 2020, https://www.careaboutclimate.org/blog/paris-agreement-vs-kyoto-protocol-comparison-chart

   This source nicely compares the Paris Agreement to the Kyoto Protocol citing key similarities and differences between them displayed in a comprehensive chart.

10. “More on Energy”. Clay Center. 2016 https://www.theclaycenter.org/wp-content/uploads/2016/10/Energy-Curriculum-Forms.pdf

    Information on this webpage explains the six different forms of energy and provides some detail on each one.

11. NASA's Jet Propulsion Laboratory | California Institute of Technology. “The Effects of Climate Change” Accessed June 8, 2021. Site last updated: July 1, 2021. https://climate.nasa.gov/effects/

    This source has information on 7 global effects of climate change as well as regional effects within the United States.

12. NOAA. “Discover Your Changing World with NOAA an Activity Book”. 2013. Accessed June 8, 2021. https://oceanservice.noaa.gov/education/discoverclimate/

    This activity book contains several classroom activities with background information on climate change and the scientific principles of each activity.

13. NOAA. “PROBLEM SOLVING ACTIVITY: CLIMATE CHANGE AND FEEDBACK LOOPS” Accessed June 8, 2021 https://gml.noaa.gov/education/info_activities/pdfs/PSA_analyzing_a_feedback_mechanism.pdf

    This pdf document has a feedback loop activity with lots of background information on feedback loops and climate change.

14. “The Keeling Curve” Scripps Institution of Oceanography at UC San Diego. Accessed June 8, 2021. https://keelingcurve.ucsd.edu/

    This website has lots of information on carbon dioxide in the atmosphere including real time data on the concentration of carbon dioxide at their research station in Hawaii.

15. The RESC Alliance. “EL Strategies Desk Card” revised 2015 https://www.crec.org/docs/4339/RESC_Alliance_Desk_Cards_Revised_2.pdf

    This document has many strategies for working with different levels of English Language Learners. It also has 10 general strategies for working with students learning the English language.

16. Tucker, L. and Sherwood, L. Understanding Climate Change, Grades 7–12. NSTA Press Book. Pub Date:4/1/2019

    This book has many different classroom activities for educators teaching about climate change.

17. W W W Chemistry, “Greenhouse Gases - How CO2 Traps Heat”Accessed June 8, 2021, Last updated Sep 29, 2020. https://www.youtube.com/watch?v=IpMsQ3SlLe0

    This video provides an explanation for exactly how CO_2 is able to trap heat at the molecular level.

Appendix

The unit is written to cover the following Next Generation Science Standards (NGSS)

HS PE ESS2-4 (Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.),

HS PE ESS2-2 (Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.)

ESS3-5 (Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.).]

[1] Dobson, K., John S. Holman, and Michael Roberts. *Physical Science*. New York, New York: Holt, Rinehart and Winston, 2008.

[2] More On Energy. https://www.theclaycenter.org/wp-content/uploads/2016/10/Energy-Curriculum-Forms.pdf.

[3] Ibid.

[4] Dobson, K., John S. Holman, and Michael Roberts. *Physical Science*. New York, New York: Holt, Rinehart and Winston, 2008.

[5] Ibid.

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[7] "Energy: The Driver of Climate" Climate Science Investigations, Last modified 1/14/16 http://www.ces.fau.edu/nasa/module-2/ accessed (6/6/21).

[8] "Energy: The Driver of Climate" Climate Science Investigations, Last modified 1/14/16 http://www.ces.fau.edu/nasa/module-2/ accessed (6/6/21).

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[12] "Energy: The Driver of Climate" Climate Science Investigations, Last modified 1/14/16 *http://www.ces.fau.edu/nasa/module-2/ accessed (6/6/21)*

[13] Ibid.

[14] Ibid.

[15] Ibid.

[16] Ibid.

[17] EPA. “Understanding Global Warming Potentials” LAST UPDATED ON SEPTEMBER 9, 2020. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.

[18] Ibid.

[19] Ibid.

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[23] “Energy: The Driver of Climate” Climate Science Investigations, Last modified 1/14/16 *http://www.ces.fau.edu/nasa/module-2/ accessed (6/6/21).*

[24] Ibid.

[25] Ibid.

[26] Ibid.

[27] NOAA. “PROBLEM SOLVING ACTIVITY: CLIMATE CHANGE AND FEEDBACK LOOPS” Accessed June 8, 2021 https://gml.noaa.gov/education/info_activities/pdfs/PSA_analyzing_a_feedback_mechanism.pdf

[28] “Energy: The Driver of Climate” Climate Science Investigations, Last modified 1/14/16 http://www.ces.fau.edu/nasa/module-2/ accessed (6/6/21).

[29] “The Keeling Curve” Scripps Institution of Oceanography at UC San Diego. Accessed June 8, 2021. https://keelingcurve.ucsd.edu/.

[30] Ibid.

[31] NASA's Jet Propulsion Laboratory | California Institute of Technology. “The Effects of Climate Change” Accessed June 8, 2021. Site last updated: July 1, 2021. https://climate.nasa.gov/effects/.

[32] Ibid.

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