Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2021 Volume IV: The Earth’s Greenhouse and Global Warming

Making mathematical sense of Global Warming 2

Curriculum Unit 21.04.03
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Introduction and Rationale

Weather and climate form a complex system affected by ever-changing conditions of the atmosphere, oceans, glaciers and land. The climate of a specific place is determined by the average weather conditions over a long period of time. In other words, climate is about weather statistics and therefore climate change is a statistical phenomenon, the effects of which are seen in the world around us. Thus climate science requires large-scale application of mathematics.

Mathematics is needed for describing and projecting changing climate and communicating those findings. In order to describe the changing climate, we need to know first of all what is “normal”. For this, we have to calculate environmental measurements concerning temperature, rainfall, snow cover, sea level, amount of carbon dioxide in the atmosphere etc. By calculating averages, analyzing variance and making diagrams, we can find out whether the climate has changed and how. (15)

This unit is designed to give students an introduction to this pressing societal problems and to teach students how to analyze some of the compiled data on global warming through rates, ratios and proportions; students will also learn to make projections and predictions using slope, and linear and exponential functions.

To teach this unit, the teacher has to have at least a general knowledge of global warming, the greenhouse effect, and the carbon cycle. I thought that it was important to explain the basics of these topics. This unit is designed as a math unit, to help students gain a deeper understanding of linear functions, slope, exponential functions, as well as rates, ratios and proportions. Global warming, the carbon cycle, and the greenhouse effect, will be the real life application to which we will apply our mathematics.

Curriculum Content

Global Warming

The Oxford Dictionary defines Global Warming as “the increase in temperature of the earth’s atmosphere that is caused by the increase of particular gases, especially carbon dioxide”

This process of the earth’s temperature rising over the course of time is referred to as global warming. The earth’s climate has been getting steadily warmer over the last 50 years. The world’s climate does change naturally, but human activity is contributing to this warming.

Global warming is generally attributed to the Greenhouse Effect. Gases that trap heat in the atmosphere are called greenhouse gases. The Greenhouse Effect is created by the increase in the levels of greenhouse gases in the atmosphere. While we hear mostly about carbon dioxide there are other greenhouse gases that also play a major contributing factor to the warming of the Earth’s temperature. These other gases include, but are not limited to, methane, water vapor, and methane. (14) (15)

This ongoing change in climate has unpredictable effects, which include extreme weather conditions. This is a major concern. Scientists predict that if global warming continues we can expect more powerful and extreme weather; more powerful storms, heavier rains and flooding, as well as hotter summers and droughts. These climate related weather events have more than tripled since 1980. (14) (15)

Carbon and Carbon Dioxide

Carbon is the backbone of life on Earth. We are made of carbon, we eat carbon, and our civilizations—our economies, our homes, our means of transport—are built on carbon. Carbon is both the foundation of all life on Earth, and the source of the majority of energy consumed by human civilization. We need carbon, but that need is also entwined with one of the most serious problems facing us today; global climate change.

Earth’s carbon is stored in rocks, oceans, atmosphere, plants, soil, and fossil fuels. When fossil fuels are burned and carbon dioxide is produced it is released into the atmosphere. Changes that put carbon gases into the atmosphere result in warmer temperatures on Earth.

Without human interference, the carbon in fossil fuels would leak slowly into the atmosphere through volcanic activity over millions of years in the slow carbon cycle. By burning coal, oil, and natural gas, we accelerate the process, releasing vast amounts of carbon (carbon that took millions of years to accumulate) into the atmosphere every year. (5) (6) (7)

Carbon Dioxide

Carbon dioxide (CO_2) is the primary greenhouse gas emitted through human activities. In 2019, CO_2 accounted for about 80 percent of all U.S. greenhouse gas emissions from human activities. Human activities are altering the carbon cycle–both by adding more CO_2 to the atmosphere, and by influencing the ability of natural sinks, like forests and soils, to remove and store CO_2 from the atmosphere. While CO_2 emissions come from a variety of natural sources, human-related emissions are responsible for the increase that has occurred in the atmosphere since the industrial revolution. (2)

The main human activity that emits CO_2 is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation, although certain industrial processes and land-use changes also emit CO_2. The main sources of CO_2 emissions in the United States are described below. (2)

*Transportation***.** The combustion of fossil fuels such as gasoline and diesel to transport people and goods was the largest source of CO_2 emissions in 2019, accounting for about 35 percent of total U.S. CO_2 emissions and 28 percent of total U.S. greenhouse gas emissions. This category includes transportation sources such as highway and passenger vehicles, air travel, marine transportation, and rail. (2)

Electricity. Electricity is a significant source of energy in the United States and is used to power homes, business, and industry. In 2019, the combustion of fossil fuels to generate electricity was the second largest source of CO_2 emissions in the nation, accounting for about 31 percent of total U.S. CO_2 emissions and 24 percent of total U.S. greenhouse gas emissions. The types of fossil fuel used to generate electricity emit different amounts of CO_2. To produce a given amount of electricity, burning coal will produce more CO_2 than natural gas or oil. (2)

Industry. Many industrial processes emit CO_2 through fossil fuel consumption. Several processes also produce CO_2 emissions through chemical reactions that do not involve combustion, and examples include the production of mineral products such as cement, the production of metals such as iron and steel, and the production of chemicals. Fossil fuel combustion from various industrial processes accounted for about 16 percent of total U.S. CO_2 emissions and 13 percent of total U.S. greenhouse gas emissions in 2019. Many industrial processes also use electricity and therefore indirectly result in CO_2 emissions from electricity generation. (2)

Carbon dioxide is constantly being exchanged among the atmosphere, ocean, and land surface as it is both produced and absorbed by many microorganisms, plants, and animals. However, emissions and removal of CO_2 by these natural processes tend to balance, absent anthropogenic impacts. Since the Industrial Revolution began around 1750, human activities have contributed substantially to climate change by adding CO_2 and other heat-trapping gases to the atmosphere. (18)

Emissions and Trends

Carbon dioxide emissions in the United States increased by about 3 percent between 1990 and 2019. Since the combustion of fossil fuel is the largest source of greenhouse gas emissions in the

United States, changes in emissions from fossil fuel combustion have historically been the dominant factor affecting total U.S. emission trends. Changes in CO_2 emissions from fossil fuel combustion are influenced by many long-term and short-term factors, including population growth, economic growth, changing energy prices, new technologies, changing behavior, and seasonal temperatures. Between 1990 and 2019, the increase in CO_2 emissions corresponded with increased energy use by an expanding economy and population, including overall growth in emissions from increased demand for travel. (19) (20)

Carbon dioxide emissions do not contribute only to the greenhouse effect. Much of the carbon dioxide that is emitted dissolves into the oceans. This causes the oceans to have increased acidity. Much of the carbon dioxide that is released will dissolve in the oceans, but this can take several hundred years. The increase in the oceans acidity can have devastating effects on fragile sea life. Coral reefs are already experiencing coral “bleaching” and reefs are dwindling. This is known as Ocean Acidification. (19) (20)

The Carbon Cycle

The carbon cycle plays a key role in regulating Earth's global temperature and climate by controlling the amount of carbon dioxide in the atmosphere.

Too much carbon dioxide can be harmful, but it is an important greenhouse gas, because it helps Earth's atmosphere to retain heat generated from the Sun.

Carbon dioxide enters the Earth's atmosphere through a natural process in the carbon cycle. Before the industrial revolution, the balance of carbon dioxide in the atmosphere was kept steady. Humans burn fossil fuels, such as gas and coal, which emit carbon dioxide, CO_2, into the atmosphere. When we burn fossil fuels, the carbon separates from the hydrogen and binds with oxygen in the atmosphere to produce carbon dioxide—CO2. A little CO2 in the atmosphere is a very good thing—because of the way it traps heat leaving the Earth's surface, the small amounts of CO2 in our atmosphere are responsible for keeping Earth's surface from freezing solid. (15)

Today, the biggest changes in the carbon cycle are happening because of people. We upset the natural carbon cycle by burning fossil fuels and clearing land. When we clear forests, we remove a dense growth of plants that have stored carbon in wood, stems, and leaves—biomass. By removing a forest, we eliminate plants that would otherwise take carbon out of the atmosphere as they grow. When we replace the dense growth with crops or pasture they store less carbon. We also expose soil that vents carbon from decayed plant matter into the atmosphere. Humans are currently emitting just under a billion tons of carbon into the atmosphere per year through land use changes.

Since the beginning of the Industrial Revolution, when people first started burning fossil fuels, carbon dioxide concentrations in the atmosphere have risen from about 280 parts per million to 387 parts per million, a 39 percent increase. This means that for every million molecules in the atmosphere, 387 of them are now carbon dioxide—the highest concentration in two million years. (1)

Effects of Altering the Carbon Cycle

All of this extra carbon needs to go somewhere. So far, land plants and the ocean have taken up about 55 percent of the extra carbon people have put into the atmosphere while about 45 percent has stayed in the atmosphere. Eventually, the land and oceans will take up most of the extra carbon dioxide, but as much as 20 percent may remain in the atmosphere for many thousands of years.

Excess carbon in the atmosphere warms the planet and helps plants on land grow more. Excess carbon in the ocean makes the water more acidic, putting marine life in danger. (14)

Ocean Acidification

Dissolving carbon dioxide in the ocean creates carbonic acid, which increases the acidity of the water. Ocean acidification affects marine organisms in two ways. First, carbonic acid reacts with carbonate ions in the water to form bicarbonate. However, those same carbonate ions are what shell-building animals like coral need to create calcium carbonate shells. With less carbonate available, the animals need to expend more energy to build their shells. As a result, the shells end up being thinner and more fragile. Second, the more acidic water is, the better it dissolves calcium carbonate. In the long run, this reaction will allow the ocean to soak up excess carbon dioxide because more acidic water will dissolve more rock, release more carbonate ions, and increase the ocean’s capacity to absorb carbon dioxide. In the meantime, though, more acidic water will dissolve the carbonate shells of marine organisms, making them pitted and weak.

Warmer oceans, a product of the greenhouse effect, could also decrease the abundance of phytoplankton, which grow better in cool, nutrient-rich waters. This could limit the ocean’s ability to take carbon from the atmosphere through the fast carbon cycle.

On the other hand, carbon dioxide is essential for plant and phytoplankton growth. An increase in carbon dioxide could increase growth by fertilizing those few species of phytoplankton and ocean plants (like sea grasses) that take carbon dioxide directly from the water. However, most species are not helped by the increased availability of carbon dioxide. (5) (6)

Methane Gas

Methane is another gas that is contributing to The Greenhouse Effect. Methane concentrations have risen from 715 parts per billion in 1750 to 1,774 parts per billion in 2005, the highest concentration in at least 650,000 years. (25),(26)

Methane gas is produced when living things decompose; it's also in natural gas.

It persists for just a short time in the atmosphere - unlike carbon dioxide - but methane is a much more potent global warming gas than CO2. (25),(26)

Cows and bogs release methane into the atmosphere, but it's by far mostly human activity that's driving up levels of this destructive greenhouse gas. Every time a cow burps or passes gas, a little puff of methane wafts into the atmosphere. Each of those puffs coming out of a cow’s

plumbing, added together, can have a big effect on climate because methane is a potent greenhouse gas—about 28 times more powerful than carbon dioxide at warming the Earth, on a 100-year timescale, and more than 80 times more powerful over 20 years. The effects aren’t just hypothetical: Since the Industrial Revolution, methane concentrations in the atmosphere have more than doubled, and about 20 percent of the warming the planet has experienced can be attributed to the gas. (25)

There's not that much methane in the atmosphere—about 1,800 parts per billion, about as much as two cups of water inside a swimming pool. That’s about 200 times less concentrated in the atmosphere than carbon dioxide, the most abundant and dangerous of the greenhouse gases. But methane’s chemical shape is remarkably effective at trapping heat, which means that adding just a little more methane to the atmosphere can have big impacts on how much, and how quickly, the planet warms. (26)

Methane is a simple gas, a single carbon atom with four arms of hydrogen atoms. Its time in the atmosphere is relatively fleeting compared to other greenhouse gases like CO2—any given methane molecule, once it’s spewed into the atmosphere, lasts about a decade before it's cycled out. That’s a blip compared to the centuries that a CO2 molecule can last floating above the surface of the planet. But there are many sources of methane, so the atmospheric load is constantly being regenerated—or increased. (25) (26)

Methane’s sources

Methane in the atmosphere comes from sources scientists think of as human caused, while the rest comes from sources that existed before humans started influencing the carbon cycle in dramatic ways.

Most of methane's natural emissions come from a soggy source: wetlands, which includes bogs. Many microbes are like mammals in that they eat organic material and spit out carbon dioxide—but many that live in still, oxygen-deprived spots like waterlogged wetland soils produce methane instead, which then leaks into the atmosphere. Over all, about a third of all the methane floating in the modern atmosphere comes from wetlands.

There are a variety of other natural methane sources. It seeps out of the ground naturally near some oil and gas deposits and from the mouths of some volcanoes. It leaks out of thawing permafrost in the Arctic and builds up in the sediments under shallow, still seas; it wafts away from burning landscapes, entering the atmosphere as CO2; and it is produced by termites as they chow through piles of woody detritus. (26)

Human sources of methane

Today, human-influenced sources make up the bulk of the methane in the atmosphere. Cows and other grazing animals get a lot of attention for their methane-producing belches and releases. Such grazers host microbes in their stomachs, gut-filling hitchhikers that help them break down and absorb the nutrients from tough grasses. Those microbes produce methane as their waste, which wafts out of both ends of cows. The manure that cattle and other grazers produce is also a site for microbes to do their business, producing even more methane. There are 1.4 billion cattle in the world, and that number is growing as demand for beef and dairy increases; together with other grazing animals, they contribute about 40 percent of the annual methane budget.

Other agricultural endeavors pump methane into the atmosphere, too. Rice paddies are a lot like wetlands: When they're flooded, they're filled with calm waters low in oxygen, which are a natural home for methane-producing bacteria. And some scientists think they can see the moment when rice production took off in Asia, about 5,000 years ago, because methane concentrations—recorded in tiny bubbles of ancient air trapped in ice cores in Antarctica—rose rapidly.

Methane also leaks into the atmosphere at gas and oil drilling sites. There are strict rules in place in many states and countries about how much leakage is allowed, but those rules have proven difficult to enforce. Recent studies suggest that wells in the U.S. alone are producing about 60 percent more methane than previously estimated by the Environmental Protection Agency.

Worldwide, the energy sector contributes about a quarter of the annual methane budget.

Waste is another major source of methane gas. Microbes in landfills and sewage treatment centers chomp through the detritus humans leave behind and in the process pump out tons of methane each year—about 14 percent of the U.S.'s annual footprint. (24) (25)

Methane's impact on climate, past and future

Methane may also have been the cause of rapid warming events deep in Earth's history, millions of years ago. Under high pressure, like the pressures found deep at the bottom of the ocean, methane solidifies into a slush-like material called methane hydrate. Vast amounts of methane are "frozen" in place at the bottom of the sea in this chemical state, though the exact amounts and locations are still being studied. The hydrates are stable unless something comes along to disturb them, like a plume of warm water.

A massive warming event that occurred about 55 million years ago may have been kicked off by destabilized hydrates, some scientists think. Methane percolated up from the seafloor into the atmosphere, flooding it with the heat-trapping gas and forcing the planet to warm drastically and quickly.

In the modern atmosphere, methane concentrations have risen by more than 150 percent since 1750. It's not clear whether this rise will continue, or at what rate, but the IPCC warns that keeping methane emissions in check is necessary in order to keep the planet from warming further. (24) (25) (26)

Methane Emissions

In 2019, methane (CH4) accounted for about 10 percent of all U.S. greenhouse gas emissions from human activities. Human activities emitting methane include leaks from natural gas systems and the raising of livestock. Methane is also emitted by natural sources such as natural wetlands. In addition, natural processes in soil and chemical reactions in the atmosphere help remove CH4 from the atmosphere. Methane's lifetime in the atmosphere is much shorter than carbon dioxide (CO2), but CH4 is more efficient at trapping radiation than CO2. Pound for pound, the comparative impact of CH4 is 25 times greater than CO2 over a 100-year period. Globally, 50-65 percent of total CH4 emissions come from human activities.

Agriculture. Domestic livestock such as cattle, swine, sheep, and goats produce CH4 as part of their normal digestive process. Also, when animal manure is stored or managed in lagoons or holding tanks, CH4 is produced. Because humans raise these animals for food and other products, the emissions are considered human-related. When livestock and manure emissions are combined, the Agriculture sector is the largest source of CH4 emissions in the United States. For more information, see the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* Agriculture chapter. While not shown and less significant, emissions of CH4 also occur as a result of land use and land management activities in the Land Use, Land-Use Change, and Forestry sector (e.g. forest and grassland fires, decomposition of organic matter in coastal wetlands, etc.).

Energy and Industry. Natural gas and petroleum systems are the second largest source of CH4 emissions in the United States. Methane is the primary component of natural gas. Methane is emitted to the atmosphere during the production, processing, storage, transmission, and distribution of natural gas and the production, refinement, transportation, and storage of crude oil. Coal mining is also a source of CH4 emissions.

Waste from Homes and Businesses. Methane is generated in landfills as waste decomposes and in the treatment of wastewater. Landfills are the third-largest source of CH4 emissions in the United States. Methane is also generated from domestic and industrial wastewater treatment and from composting and anaerobic digestion.

Methane is also emitted from a number of natural sources. Natural wetlands are the largest source, emitting CH4 from bacteria that decompose organic materials in the absence of oxygen. Smaller sources include termites, oceans, sediments, volcanoes, and wildfires.

Greenhouse Gas Emissions and Trends

Methane emissions in the United States decreased by 15 percent between 1990 and 2019. During this time period, emissions increased from sources associated with agricultural activities, while emissions decreased from sources associated with landfills, coal mining, and from natural gas and petroleum systems.

Each gas's effect on climate change depends on three main factors; how much is in the atmosphere, how long does it stay in the atmosphere, how strongly does it impact the atmosphere.

How much is in the atmosphere? Concentration, or abundance, is the amount of a particular gas in the air. Larger emissions of greenhouse gases lead to higher concentrations in the atmosphere. Greenhouse gas concentrations are measured in parts per million, parts per billion, and even parts per trillion. One part per million is equivalent to one drop of water diluted into about 13 gallons of liquid (roughly the fuel tank of a compact car).

How long do they stay in the atmosphere? Each of these gases can remain in the atmosphere for different amounts of time, ranging from a few years to thousands of years. All of these gases remain in the atmosphere long enough to become well mixed, meaning that the amount that is measured in the atmosphere is roughly the same all over the world, regardless of the source of the emissions.

How strongly do they impact the atmosphere? Some gases are more effective than others at making the planet warmer and "thickening the Earth's blanket." Each greenhouse gas remains in the atmosphere for different lengths of time, and each absorbs energy with different strength. Gases that absorb more energy, per pound, contribute more to warming Earth. (22)

Conclusion

Most of us, however, will observe changes in the carbon cycle in a more personal way. For us, the carbon cycle is the food we eat, the electricity in our homes, the gas in our cars, and the weather over our heads. We are a part of the carbon cycle, and so our decisions about how we live ripple across the cycle. Likewise, changes in the carbon cycle will impact the way we live. As each of us come to understand our role in the carbon cycle, this knowledge empowers us to control our personal impact and to understand the changes we are seeing in the world around us.

Appendix on Implementing District Standards

Material in this unit will be used as real world problems for the teaching of several aspects of the Common Core State Standards and the Math Practices for middle school. The activities are aimed at helping students to develop an understanding of slope, linear equations, exponents, exponential curves, rates, unit rates, proportions, finding percents, and ordering decimals.

Common Core State Standards This first group of standards are seventh grade standards, They can be found at http://www.corestandards.org/Math/

Analyze proportional relationships and use them to solve real-world and mathematical problems.

CCSS.MATH.CONTENT.7.RP.A.1

Compute unit rates associated with ratios of fractions, including ratios of lengths, areas and other quantities measured in like or different units. *For example, if a person walks 1/2 mile in each 1/4 hour, compute the unit rate as the complex fraction* $^{1/2}/_{1/4}$ *miles per hour, equivalently 2 miles per hour*.

CCSS.MATH.CONTENT.7.RP.A.2

Recognize and represent proportional relationships between quantities.

CCSS.MATH.CONTENT.7.RP.A.2.A

Decide whether two quantities are in a proportional relationship, e.g., by testing for equivalent ratios in a table or graphing on a coordinate plane and observing whether the graph is a straight line through the origin.

CCSS.MATH.CONTENT.7.RP.A.2.B

Identify the constant of proportionality (unit rate) in tables, graphs, equations, diagrams, and verbal descriptions of proportional relationships.

CCSS.MATH.CONTENT.7.RP.A.2.C

Represent proportional relationships by equations. *For example, if total cost t is proportional to the number n of items purchased at a constant price p, the relationship between the total cost and the number of items can be expressed as $t = pn$*.

CCSS.MATH.CONTENT.7.RP.A.2.D

Explain what a point (x, y) on the graph of a proportional relationship means in terms of the situation, with special attention to the points (0, 0) and (1, r) where r is the unit rate.

CCSS.MATH.CONTENT.7.EE.B.4

Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

This next group of standards are eighth grade standards, and can also be found at the website referenced above.

Understand the connections between proportional relationships, lines, and linear equations.

CCSS.MATH.CONTENT.8.EE.B.5

Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways. For example, compare a distance-time graph to a distance-time equation to determine which of two moving objects has greater speed.

CCSS.MATH.CONTENT.8.EE.B.6

Use similar triangles to explain why the slope m is the same between any two distinct points on a non-vertical line in the coordinate plane; derive the equation y = mx for a line through the origin and the equation $y = mx + b$ for a line intercepting the vertical axis at b.

Analyze and solve linear equations and pairs of simultaneous linear equations.

CCSS.MATH.CONTENT.8.EE.C.7

Solve linear equations in one variable.

These standards are applicable to all grades, k-12

Standards for Math Practices

CCSS.MATH.PRACTICE.MP1 Make sense of problems and persevere in solving them.

CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively.

CCSS.MATH.PRACTICE.MP3 Construct viable arguments and critique the reasoning of others.

CCSS.MATH.PRACTICE.MP4 Model with mathematics.

Mathematical Learning Activities

The following section outlines some sample activities that can be used in the classroom in order to facilitate mathematical learning and the use of mathematical modelling to make predictions. This section provides a brief overview of some of the possible activities and some strategies for helping students progress through the content. I have provided a list of student resources for them to reference when researching and collecting data.

Lesson Activity 1: Using Ratios and Unit rates to compare CO2 emissions in different countries. (5-6 days)

This first activity is a set of lessons that should require a few classes for each part, dependent on your students. Proportional reasoning is a long unit packed with different pieces. Students will learn about rates, unit rates, proportions, and more while learning about Global Warming and CO2 emissions. They will collect their own date, and then learn how to apply the math.

Measuring rainfall, and collecting data from previous years. Temperatures over spans of years.

With our focus on SEL and Social Justice, we will discuss if there is a social issue here.

Students will gather data on the carbon dioxide (CO2) emissions from different countries around the world. We will have a discussion on equity, and is it “fair” that countries that don’t emit much still have the same amount in the atmosphere as the top emitting countries. Students will write a ratio of CO2 emissions to area for each country. Students will create a list ranking the countries by CO2 emissions. Students will then find the area of each country in square miles. Students will then write a ratio of CO2 emissions per square mile of each country. Students will then determine each countries unit rate, comparing CO2 emissions to one square mile. Students will then create a list ranking countries CO2 emissions based on the unit rates. (This will also be a review of ordering decimals for students.)

Students will also gather data on the CO2 emissions for each of the same countries on a per capita basis. Students will create a ratio based upon the CO2 emissions per the total population of each country. Students will create a list ranking the countries by CO2 emissions. Students will then determine the unit rate of CO2 emissions per capita. Students will then create a list ranking countries in order of their CO2 emissions per capita.

Students will use proportions to compare ratios that they have written to determine if any countries have the same rate of CO_2 emissions per the same factor.

Lesson Activity 2: Using percent to reduce a carbon footprint. (2 days)

Students will determine their personal carbon footprints. They will look at each item on their list, and brainstorm ways to reduce individual items. Students will then find the percentage of CO_2 they are saving from being emitted with the changes they make.

Lesson Activity 3: (Linear Equations)

At the conclusion of this lesson students will:

KNOW: The slope intercept form of the linear equation ($y = mx+b$);

UNDERSTAND: The limitations of using linear equations when modeling real world phenomena; and that continued CO_2 emissions at current rates leads to predictable outcomes for atmospheric carbon (AC) levels and average global temperatures (AGT).

BE ABLE TO DO: • Write linear equations from real-world situations and use them to predict future events.

Data Collection:

Students will research carbon dioxide emissions and will collect data on carbon dioxide emissions, and atmospheric concentrations for 2 different years. Students will then make predictions of carbon dioxide emissions in future years, using a linear model.

Understanding Linear Equations:

Students will be learning about slope, the y intercept, the relationship between the x and y axis, and an equation written in slope-intercept form. The equation $y = mx +b$ is one of the most important in all of algebra. The graph $y = mx + b$ is a straight line of ordered pair, i.e. solutions in a line.

Students need to learn: x is independent of y, and y is dependent on x; how to find the slope of a line from 2 points (2 ordered pairs); the y intercept is where we start, the y value without any x; the y intercept, b, is always a constant.

Lesson Activity 4: (Scatter Plots)

Students will gather data and plot the points on a graph. We will discuss what the data means. We will look if the data is linear, or not. Does it have a linear trend?, or is it curved? We will discuss scatter plots and how to write an equation of the trend of the data and how to make predictions.

Lesson Activity 5: (Exponential Equations)

At the conclusion of this lesson students will:

KNOW: The general form of the exponential equation ($y = bg^x$)

UNDERSTAND: The limitations of using exponential equations when modeling real world phenomena. That continued CO_2 emissions at current rates leads to predictable outcomes for atmospheric carbon levels and average global temperatures.

BE ABLE TO DO: • Write exponential equations from real-world situations and use them to predict future events

*Data Collection**:*** We know that to have Linear Growth we have to be adding the same amount every year. But the amount of carbon dioxide that is being added each year is going up from the previous year. This cannot be modelled as a linear function, but rather is a Linear function. We cannot use a linear equation to predict into the future, but instead we will use an exponential model to make predictions into the future.

The exponential equation looks like this: y = bg^x It works for situations where the rate of change of y is changing.

Lesson Activity 6: Nasa Math

Students will explore global warming and apply mathematics to solve different problems related to global warming using the Nasa Math website: https://spacemath.gsfc.nasa.gov/Warming.html

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Student Resources

Reducing carbon footprint. What can we do?

http://www.countdownyourcarbon.org/our-assumptions.html

CO2 emissions by country

https://www.ucsusa.org/resources/each-countrys-share-co2-emissions

CO2 emissions in the U.S> by state

https://en.wikipedia.org/wiki/List_of_U.S._states_and_territories_by_carbon_dioxide_emissions

Controlling Greenhouse gas emissions in transportation

https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#transportation

Overview of Greenhouse Gases

https://www.epa.gov/ghgemissions/overview-greenhouse-gases

Nasa Space Math

https://spaceplace.nasa.gov/

Connecticut Department of Environmental Protection: Global Warming Tools
https://portal.ct.gov/DEEP/Climate-Change/Climate-Change