Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
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Budgeting for a Better Tomorrow

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Introduction

I teach fifth grade at Nathan Hale School in New Haven, Connecticut. My fifth-grade classroom is composed of a diverse, multicultural community of learners that encompass a wide spectrum of achievements, interests, learning and social needs. Children learn and progress best when they are allowed to best apply the skills, they learn in a manner that befits their abilities and talents. This happens when they participate in interdisciplinary curriculum that not only involves choice but encompasses various learning and assessment strategies that celebrate how they learn. As mentors and role models for children it is extremely important that we integrate and connect their learning to the world around them. This then invites students to be more engaged and take ownership of their learning as it opens up the notion that their understanding and actions affect not only how they live in the present, but also their future.

This unit will teach students about “Carbon and Ecosystems.” They will begin by analyzing the four spheres: biosphere, hydrosphere, atmosphere, geosphere and how they are interconnected. They will understand that one system cannot exist without the other in order to maintain proper functioning within our planet. The students will learn about the various types of ecosystems that exist and how living organisms depend on other living and non-living organisms for survival. This being said, students will examine how the spheres interact and how changes in one, affects another. Students will understand that ecosystems are fueled by the energy from the sun and cycles from which they are powered.

It will focus on what the carbon cycle is and its’ influence in our lives. Carbon is essential for all life on Earth and is also in our atmosphere. It regulates the Earth’s temperature and provides an essential source of the energy to fuel our economy. The carbon cycle describes how carbon moves throughout the Earth’s spheres. By gaining a deeper understanding of how carbon moves, we can better regulate our daily decisions to help sustain our future.

Human activities are altering the carbon cycle. We will learn that while aquatic and forest ecosystems serve primarily as a ‘sink,’ human impact such as deforestation or land use can alter the amount of carbon in the atmosphere faster than it can be absorbed. Students will learn about ecosystems and the interactions and energy flow within it. They will learn about the cycle of matter and energy transfer in an ecosystem, its functioning over time and reaction to change. They will be introduced to the disruptions that a physical or biological component will cause to its populations. They will dissect human activity and understand how our actions today affect the carbon budget of tomorrow. They will understand that burning fossil fuels and land use greatly affects the amount of carbon in the atmosphere. As the unit progresses, students will conduct investigations and research how to reduce human impact, consequently leading them to develop possible solutions.

Objectives

Students will be introduced to what an ecosystem is, its place within Earth's four spheres, how they interact and our place within it. Students will understand how energy drives the ecosystem and the cycles that sustain it. Along the way, students will discover the food chain, prey-predator relationships and the driving force to keep the cycle going. They will understand, through a climate change lens, what happens when one piece of the ecosystem is removed and or added. Students will also understand the role of carbon within an ecosystem and what we can do to facilitate a balance.

This unit will be taught over an eight-week period. Weeks one and two will focus on what are the four spheres of the Earth and the ecosystems within it. Students will be able to discuss the factors within an ecosystem, abiotic and biotic. They will understand and be able to define organism, community, population and habitat. Students will demonstrate how the environment affects organisms in an ecosystem and vice versa.

During week three, students will be introduced to the energy flow within an ecosystem. They will learn about the role of the sun, the water cycle, nitrogen cycle and the carbon cycle. Students will participate in hands-on investigations to better comprehend the interactions as well as understand the processes of primary production and decomposition. Weeks four through five will allow students to dissect a food web and take a closer look at food chains. This will lead to a deeper understanding of the interdependent relationships that exist within each, as well as prepare students to understand how the pieces of the puzzle fit.

In week six, students will apply their background knowledge to understand the interactions, energy and dynamics within an ecosystem. Week six will allow students to grasp how an ecosystems' carbon budget can impact atmospheric carbon dioxide. Students will investigate how carbon is both stored and released. They will understand greenhouse gasses and their effects. They will discuss how carbon fluxes can impact an ecosystem, with a better comprehension of its disruptions of a carbon budget. They will now investigate more fully how carbon plays an essential role in life and how we need it to fuel our daily lives in our community, our homes and in our transportation. During these weeks, students will come to understand that not only is carbon a foundation for life but that it is also a major source of energy. Students will investigate the movement of carbon between land, atmosphere and oceans and how human contribution can play a part in this. It is here that students will also begin to question the role of carbon as a necessary evil in that it contributes to global climate change. In weeks seven and eight students will learn about global warming and its impact on climate change. Because of this, students will then begin to think about changes they can make to budget for a better tomorrow.

Content Background

The 4 Spheres

The four interdependent spheres make up all of the living and non-living components of our Earth. The Earth can be broken into four subsystems, known as spheres, namely the geosphere, also called the lithosphere or 'all the land on Earth,' the hydrosphere or 'all the water on Earth,' the biosphere or 'all the living things on Earth,' and the atmosphere or 'all the gasses that surround the Earth.'

Geosphere

"Geo" means Earth. The geosphere, also referred to as the lithosphere contains all the rocks and minerals from the ground to the Earth's core. It is the solid outer part of the Earth that includes the core, the mantle and the crust. It is the Earth's outermost layer below the atmosphere. Its surface is uneven, ranging from high mountain ranges to flat plains and deep valleys. The outer layer consists of soil rich in nutrients, oxygen and silicon layered with a semi solid mantle rich in oxygen, silicon, iron and magnesium and which below lies a liquid core made of nickel and iron coupled with a solid core at the center of the Earth. [1]

Hydrosphere

"Hydro" means water. This sphere ranges from 10- 20 kilometers in thickness and contains all of the solid, liquid and gaseous water on Earth such as oceans, rivers, lakes, groundwater and water frozen in glaciers. It extends about 12 kilometers into the atmosphere from the surface of the Earth and then down into the lithosphere. Only a portion of this water is fresh that flows from precipitation in the atmosphere to the surface of the Earth as groundwater, rivers and streams. Most the fresh water is stored frozen. Ninety-seven percent of the Earth's water is found in the oceans. Water is essential for life and makes up for about 90 % of living things.[2]

Atmosphere

"Atmos" means air. This sphere contains all the gasses surrounding the Earth. It extends from less than one meter below the Earth's surface to more than ten thousand kilometers above the surface. The gases in the atmosphere help support life on Earth. The upper portion protects the living things on the biosphere from ultraviolet radiation from the sun and absorbs and emits heat. This is where weather occurs.

Biosphere

"Bio" means life. The biosphere contains all of the living things on Earth including people, animals, plants, insects and micro-organisms. In this sphere living things interact with all the other spheres. They need water from the hydrosphere, chemicals from the atmosphere and nutrients gained from the biosphere. It is here that the living things create ecological communities otherwise known as biomes, dependent upon their physical surroundings. They have common characteristics based on the environment they exist in. The seven major biomes include deserts, grasslands, tundra, taiga, tropical rainforest, savanna and temperate forest.

How the Four Spheres Interact

The four spheres drive the processes on Earth and support life. Although each are previously described in terms of its features and all have their own identities, they all interact. The spheres are connected such that a change in one, often results in a change in another. This is because the various materials on Earth often change form or cycle amongst the spheres. They can get recycled into other phases. For example, when a plant dies, it settles into the ground and then becomes broken down by microorganisms which later becomes soil to feed new plants. The water cycle also goes through different phases as well as locations such that it evaporates from the oceans, rains down into lakes or onto the ground. Even rock is recycled under the Earth's surface which then resurfaces as a volcanic eruption resulting in chemical weathering.

Just like these examples, almost every process or event on Earth involves more than sphere. Ocean currents in the hydrosphere affects air temperature in the atmosphere by moving heat from the equator to the poles. Another example is when erosion happens on land by wind or water from the atmosphere or hydrosphere or both, which then shapes the land geosphere. Such events that either occur naturally like a hurricane, or are caused by humans, such as pollution effects two or more spheres. These events can either cause changes or be the effect of a change in the spheres. This cause-and-effect relationship is referred to as an interaction. Interactions can cause changes both locally and worldwide. Understanding these interactions helps people understand and prepare for its effects. Understanding the interactions within and between the spheres will later help students understand the how the cycles and relationships within an ecosystem interrelate.[3]

Ecosystems

Now that we have an understanding of the four spheres, let's look at life within the spheres and how its supported. "An ecosystem is the interacting system made up of all the living and nonliving objects in a specified volume of space." [4] They form a delicate balance to help sustain each other and interact with the non-living elements, such as climate, soil and water. An ecosystem can range from a small pond to a vast ocean. A change, addition or alteration of an ecosystem can disrupt the balance, much like the effects that ripple through the interdependent spheres.

This balance often can fluctuate between the interactions among the populations or community within a habitat. A population is a group of individuals of the same species. A community is all the organisms or populations in a habitat. A habitat is where something lives and a community is what lives there. A community consists of all the organisms that live in a particular area rather than a single species, including microbes, fungi, animals and plants.

Every ecosystem is composed of both abiotic and biotic components that interact in order to keep the balance. Abiotic refers to all of the non-living chemical and physical features such as air, temperature, weather, climate, water, soil and minerals. They vary from region to region and are important to supporting life. Within an ecosystem there are limiting factors that can determine or restrict population growth and diversity of biotic factors in an ecosystem. Biotic refers to all the living organisms in the environment that compete for resources. They have a direct or indirect influence on other organisms in. the environment such as plants, animals and their waste material. An ecosystem is self-sufficient and cyclical in which nutrients are transported around and within the ecosystem. One example is organic carbon. Organic carbon transfers energy from organism to organism through digestion and then is added back to the atmosphere as carbon dioxide. Later, the carbon dioxide is taken from the atmosphere by photosynthesis and converted back to organic carbon and the cycle continues. Various nutrient cycles apply to every ecosystem. First, we will take a look at two types of ecosystems, followed by the cycles that exist in each.

Types of Ecosystems

Ecosystems are often categorized as either terrestrial or aquatic. They are categorized in accordance to their characteristics. Terrestrial ecosystems are land based and include forests and grasslands. Forests usually get more rain than grasslands and are home to a variety of animals depending on the type, deciduous or rainforest. Black bear, deer, red fox and rabbit are found in a deciduous forest while panther, monkeys, snakes and spiders are found in the rainforest. Temperatures vary in accordance with location. Grasslands consist mostly of fertile soil and tall grasses. Grasslands are home to prairie dogs, bison and grasshoppers.

Aquatic ecosystems are water based and can consist of fresh water lakes and ponds, rivers or saltwater oceans, estuaries or marshes. Lakes and ponds are bodies of freshwater surrounded by land and are usually shallower with an even water temperature throughout. Plants and algae often occupy much of the edges. It is home to fish, amphibians, ducks, turtles and beavers. Oceans on the other hand are large bodies of saltwater that are divided by continents. The conditions, sunlight, temperature, depth and salinity of the ocean will determine what types of ecosystems thrive there. Many organisms live in the shallower areas because the sunlight can warm the water, making food abundant. Organisms that live here include jellyfish and seaweed, fish and crabs. Other organisms live in the open ocean, the surface or deep within, such as coal, plankton, fish, octopus, whales and sharks. [5]

Energy and Nutrients in an Ecosystem

Neither terrestrial nor aquatic ecosystems could not exist without the energy to support it. Energy is often defined as the ability to do work. There are various forms of energy such as thermal, radiant, chemical, nuclear, electrical, motion, sound, elastic and gravitational. These forms are categorized by energy potential which is stored energy, energy of position and kinetic energy or energy in motion in waves, electrons, atoms, molecules, substances and objects. Energy can neither be created nor destroyed, it must be transferred or changed from one form into another. The primary source of energy in the majority of these ecosystems is energy from the Sun. Light energy that powers most ecosystems enters through plants because of their ability to capture visible light and transform it to a usable chemical form (sugar) via photosynthesis. Although this is the most widely used energy source in an ecosystem, other examples include fossil fuels, geothermal energy, wind and water. Energy flows consistently in and out of an ecosystem like a cycle. Energy in an ecosystem flows from the Sun to plants and algae and ultimately to animals, bacteria and other organisms that consume them. This energy is transferred via a food web.

Food Chain and Food Webs

Just as the four spheres are interconnected and a change in one sphere can create a change in another, food webs have a similar reaction through energy transformation and transfers. Food chains represent the transfer of energy and nutrients through a succession of organisms in a repeated process of eating and being eaten. As the energy is transferred each organism plays a role. Plants, algae and bacteria are known as producers because they can produce their own food, while the consumers or other organisms that eat or decompose living things are consumers. The amount of energy that is transferred from producer to consumer and consumer to consumer varies in accordance with their food chain. Food chains follow one path of energy and materials transferred while a food web follows many interconnected links of food chains in a complex system.

In a food chain producers and consumers in an ecosystem are arranged into a “feeding group,” known as a trophic level. Energy flows through each level, but not all of the energy generated or consumed in one level is available to the next. In each transfer, energy is lost to processes like respiration. Only about 10% of the available energy is on average transferred to the next trophic level. A large amount of energy is lost into the atmosphere as carbon dioxide. When energy is transferred from one trophic level to another, it is organic carbon moving up the food chain. When organic carbon is decomposed to carbon dioxide to get energy to maintain the function of an organism, the carbon goes into the atmosphere as carbon dioxide and is lost. Because of this there are often three-five trophic levels in an ecosystem since there is not enough energy to support more than that. With less energy at the higher trophic levels, there are generally fewer organisms. The organisms tend to be larger in size, but fewer in number.

All food chains and webs have at least two or three trophic levels. Each of the trophic levels differs in its nutritional relationship with the primary energy source, the Sun. Solar radiation from the Sun if first used by the primary producers or autotrophs such as plants and algae who manufacture their own food source through photosynthesis in the first level. Levels two through five are made up of consumers or heterotrophs who do not produce their own food but instead consume plants directly, other organisms, or dead organic matter in order to acquire nutrition. They also use this energy for themselves to maintain functions, such as respiration. The second level, known as the primary consumers, consists mostly of herbivores (plant eating), gaining their energy from primary producers either directly or through their detritus. Levels three through five consist of carnivores (meat eating) and omnivores (plant and meat eating). Carnivores and omnivores that eat herbivores, called secondary consumers make up the higher trophic levels. The secondary consumers are then consumed in level four and identified as tertiary consumers. Levels four and higher often consist of animals known as apex predators, who have no natural predators.

The decomposers, such as fungi, bacteria, earthworms and flies do not have an independent trophic level, but recycle waste from all the other levels consume the dead plant and animal material, convert it into energy and nutrients to help plants grow. [6]

Cycles in an Ecosystem

Interactions within the ecosystem amongst the trophic levels keep the ecosystem in balance. Just as this balance is necessary to support life, so must the cycles that sustain it remain in balance. The growth of the organisms within each ecosystem depends upon the elements and compounds that are most essential and have their own interlinking cycles. The three main cycles in an ecosystem are the water cycle, the carbon cycle and the nitrogen cycle. Together, these cycles are responsible for removing waste materials and then replenish the ecosystem with nutrients to sustain life.

The Water Cycle

There would be no life on Earth without water, as all living things need water to survive. The water cycle is the repeated movement of water between the atmosphere and the Earth’s surface. Earth’s water is recycled through the processes of evaporation, condensation, transpiration and precipitation. The water cycle describes how water evaporates from the Earth’s surface, rises into the atmosphere where it will cool and condense into rain or snow in clouds then later fall again as precipitation. It is a constant global process circulating water from clouds to land and the ocean, and then back to the clouds.

Precipitation is when water falls to the Earth from the atmosphere in the form of rain or snow. As water droplets in a cloud are enlarged, they become too heavy to remain in the air and gravity pulls the water to Earth. It is a vital component to how water moves because it connects the ocean, land and atmosphere. Most water in the air is from evaporation off the oceans. Evaporation is the changing of a liquid into a gas. As bodies of water like oceans and lakes absorb heat energy from the Sun, the liquid water is changed into a gas called water vapor. While some of the precipitated water is absorbed into soil and used by plants, the plants lose this water through their leaves in transpiration. This water is then released by the plant as water vapor through their stomates. Water used by animals during cellular respiration is also released into the air as water vapor when they breathe, sweat or excrete. Condensation is the changing of a gas into a liquid. As the air rises, it cools, the water vapor loses heat, condenses and changes back into a liquid. The water vapor that changed into droplets of water form clouds. This cycling is linked with the exchange of energy between the atmosphere, ocean and land that determines the Earth’s climate. Impacts of climate change occurs primarily through water cycle changes.[7]

The Nitrogen Cycle

Another primary nutrient critical for the survival of living organisms is nitrogen. It is one of the elements organisms need to make proteins. It is also one of the main elements needed by Rubisco, the enzyme that facilitates primary production. Although abundant in the atmosphere, about 78 percent, as dinitrogen gas, it is mostly inaccessible in this form to most organisms making it a scarce resource which then can limit primary productivity in an ecosystem. Nitrogen needs to be combined with other elements in order that organisms can use it. Nitrogen, therefore undergoes different transformations in an ecosystem changing forms as it is used. The process of combining nitrogen from the atmosphere with other elements is known as nitrogen fixation. This process makes dinitrogen gas accessible to organisms. Here the nitrogen is transformed into usable nitrogen by nitrogen-fixing bacteria that live in water, soil, or the roots of legume plants. This bacteria changes nitrogen into ammonia, while other bacteria will change ammonia into nitrates. Once the nitrogen has undergone these transformations it can be used by plants and animals. Plants get their nitrogen from the soil, while animals get it from eating the plants or other animals that have eaten the plants. Decomposers break down dead organisms and wastes into ammonia which can also be turned into nitrates in the soil by nitrifying bacteria. Still other bacteria, called denitrifies, will break down the nitrates and release nitrogen gas and returned into the air continuing the cycle of using and reusing nitrogen in an ecosystem.[8]

Carbon Cycle

Carbon is the foundation of life on Earth. It helps regulate the Earth’s temperature, is a key ingredient in the food we eat and is an energy source that fuels the economy. Carbon is the backbone of all organic compounds found in nature. It is also found in inorganic forms such as carbon dioxide. Carbon is found in a variety of forms and can enter the atmosphere in many ways. The most common way for carbon to be removed from the atmosphere is through plants by photosynthesis, where by the carbon dioxide is converted to sugar. Just as carbon exists in terrestrial ecosystems, it can also enter aquatic ecosystems by becoming soluble in water and forming compounds like carbonic acid or by being used by organisms to form shells of calcium carbonate. Additionally, it is found as ions known as bicarbonates from weathered rocks. Carbon generally gets back to the form of carbon dioxide from the process of respiration by living thing things, reentering the atmosphere or aquatic ecosystems. The process by which carbon moves into and out of different spheres is known as the carbon cycle.[9]

The carbon cycle follows a series of steps. First, carbon moves from the atmosphere to plants. In the atmosphere, carbon is attached to oxygen in a gas called carbon dioxide (CO2). Through the process of photosynthesis, carbon dioxide is pulled from the air to produce food made from carbon for plant growth. Then carbon moves from plants to animals and bacteria. Through food chains, the carbon that is in plants moves to the animals that eat them. Animals that eat other animals get the carbon from their food too. Next, carbon moves from plants and animals to soils. When plants and animals die, their bodies, wood and leaves decays bringing the carbon into the ground. Some is buried and will become fossil fuels in millions and millions of years. Carbon then moves from living things to the atmosphere. Each time you exhale, you are releasing carbon dioxide gas (CO2) into the atmosphere. Animals and plants need to get rid of carbon dioxide gas through a process called respiration. From here, carbon moves from fossil fuels to the atmosphere when fuels are burned. When humans burn fossil fuels to power factories, power plants, cars and trucks, most of the carbon quickly enters the atmosphere as carbon dioxide gas. Each year, nine billion tons of carbon is released by burning fossil fuels. Of this massive amount, nearly five billion tons stays in the atmosphere. Most of the remainder becomes dissolved in seawater or stored in terrestrial ecosystems in a carbon sink. Carbon then moves from the atmosphere to the oceans. The oceans, and other bodies of water, absorb some carbon from the atmosphere. The carbon is dissolved into the water.[11]

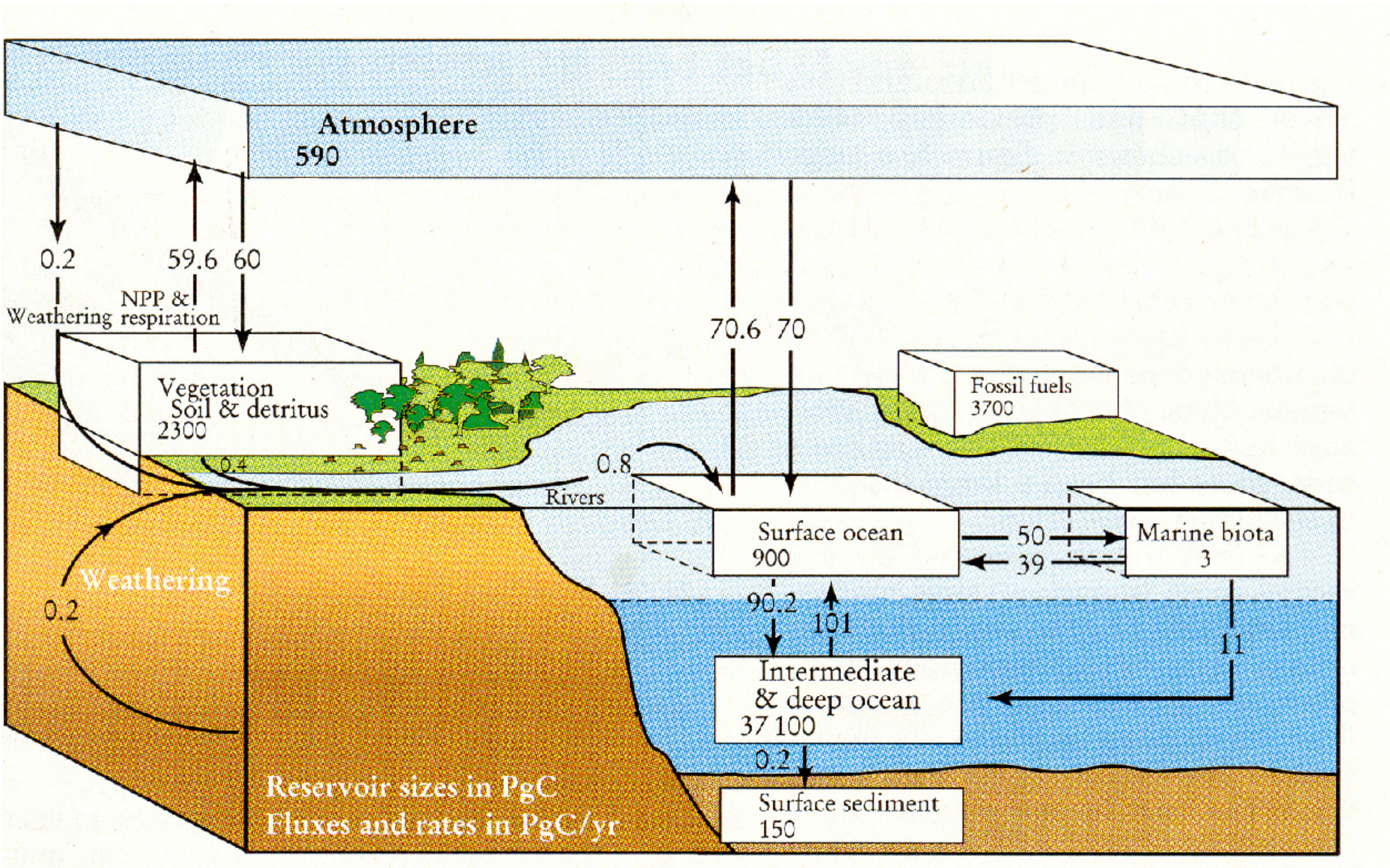

Figure 1: Pre-Anthropogenic Carbon Balance[10]

Sink Versus Source

Because Carbon is constantly moving between stores like the forests, soil, oceans, atmosphere and fossil fuels, the stores act as either a sink or a source. Processes that release carbon dioxide into the atmosphere are called “sources”, while processes that absorb it are called “sinks.” A sink absorbs more carbon than it gives, while a source gives off more than it absorbs. The balance between global sinks and sources effects the amount of carbon in the atmosphere at any given time. Natural sources of atmospheric carbon dioxide include volcanoes, fires, decomposition, respiration, digestion and in some cases oceans and bodies of fresh water. Photosynthesis, and reactions of atmospheric carbon dioxide with rock minerals are natural sinks. Over very long time scales the creation of coal and other fossil fuels were carbon sinks.

Sinks and sources work together to create a carbon budget. As we learned, our planet has a natural way of subtracting carbon from the atmosphere, but each year we are adding more than can be subtracted, causing the remaining to build up in the atmosphere, thus forming an atmospheric carbon excess. Because ecosystems vary by type as well as their place in the world the carbon budget varies in relationship to its' location on Earth.[12]

The Carbon Budget

The pre-anthropogenic carbon budget is a conceptualization of how the earth's carbon budget balanced before major human disturbance. Creating this natural carbon budget helps us to understand how the carbon budget changes due to carbon dioxide pollution. While forests and oceans act as natural carbon sinks, it is increasingly difficult to balance the amount based on the rate in which greenhouse gases are getting added to the atmosphere. We want to limit the rise of average global temperatures to less than 2 degrees Celsius, so that the amount of carbon dioxide building up in the atmosphere is limited and won't compromise our future climate from irreversible effects.

Carbon Pools

In an effort to prevent these effects we must understand that carbon is in a constant state of movement and is stored in a variety of pools. The four most relevant categories connected with the overall carbon cycle are found within the lithosphere, oceans, atmosphere, terrestrial ecosystems.

The largest amount of carbon on Earth is stored in sedimentary rocks that were produced either by the hardening of mud into shale over time or by calcium carbonate particles from shells and marine organism skeletons into limestone. The Earth's crust also stores a sizeable amount of carbon as hydrocarbons known as fossil fuels, formed millions of years ago from ancient living organisms.

Next, the Earth's oceans contain a large pool of carbon stored with their great depths in the form of dissolved inorganic carbon. A much smaller amount of carbon is located at the surface of the ocean. The carbon at the surface of the ocean exchanges with the atmosphere through carbon dioxide dissolving into the water and through the growth, death and decay of plankton.

Carbon is also stored in the atmosphere in the form of carbon dioxide along with smaller amounts of methane and various other compounds. The carbon found here is of vital importance due to its influence on global climate. Although the amount is relatively small, the size of the atmospheric carbon pool makes it very sensitive to disruptions and interactions caused by increases in the sources or sinks from other pools.

Carbon is also contained in terrestrial ecosystems in the forms of plants, animals, soils and microorganisms. These forms are all organic, entering in the form of dead plant matter broken down during decay that then releases the carbon back to the atmosphere. There are also very large stores of inorganic carbon in soils in the form of carbonate and silicate minerals. These minerals interact with the carbon dioxide to form bicarbonate which is a carbon sink on land.

Carbon Fluxes

This movement or transfer of carbon from one pool to another is called a flux. It moves through these pools through a variety of processes or fluxes including photosynthesis, plant respiration, litter fall, soil respiration, and ocean -atmosphere exchange. During photosynthesis, as plants combine the energy from the sun and carbon dioxide with water and soil, carbon is removed from the atmosphere and stored within the plants. Depending on the lifespan of the plant, carbon is stored for relatively long periods of time. Plants also release carbon dioxide back into the atmosphere through respiration. Plants are made of carbon, as they shed their leaves, roots and branches, this carbon is transferred into the soil in terrestrial ecosystems. This dead plant material is called litter. Plants aren't the only organisms that release carbon dioxide through respiration. Dead organic matter is decomposed releasing carbon dioxide into the atmosphere at a rate of sixty gigatons of carbon a year and because it takes years to decompose, it can also be stored in the soil.

Inorganic carbon, absorbed and released within the ocean surface and air, happens through diffusion. After it is dissolved, the carbon dioxide goes through chemical reactions joining water and carbon dioxide to form carbonic acid. Within the ocean there is also a lot of carbonates from the weathering of rocks on land that are delivered to the oceans by rivers. The formation of carbonate causes oceans to store a much larger amount of carbon as well as provides marine animals with this mineral to help form shells. Additionally, aquatic plants break down on a much quicker scale than on land. The total amount of uptake and loss of carbon from an ocean is dependent on the balance between inorganic and organic processes.

This is in addition to fluxes associated with human activities in fossil fuel combustion, and land cover change. The most important flux that stems from human activities is the combustion of fossil fuels, coal, oil and natural gas, because the main byproduct of fossil fuel is carbon dioxide. Land cover change in the form of deforestation is another human activity that causes a flux of carbon to the atmosphere. As population increases, native ecosystems are converted to farms and urban areas. Forests and other native ecosystems generally contain more carbon than that which replace them. This results in a net flux of about 1.5 gigatons of carbon per year.[13]

Climate Change and The Greenhouse Effect

It's imperative to understand the budget and the roles we play in it because carbon dioxide is a greenhouse gas contributing to global warming and climate change. Climate is how the atmosphere behaves over a long period of time. It is the long term global or regional average of temperature, humidity, and rainfall patterns. Some may confuse the term climate with weather. Weather, however describes the short-term changes in the atmosphere. Water cycling in and out of the atmosphere significantly impacts weather patterns on Earth. This exchange of energy between the atmosphere, ocean and land determines the climate on Earth. The impacts of climate change occur mainly through changes in the energy, water and carbon cycles. Climate change refers to the rise in average surface temperatures on Earth primarily due to human use of fossil fuels. This releases greenhouse gases into the air that trap heat in the atmosphere causing a range of effects on ecosystems like the rising sea levels, severe weather events, droughts and wildfires. [14]

The greenhouse effect is the process that occurs when gasses in the Earth's atmosphere trap the Suns' energy or heat, helping to keep it warmer than it would be without an atmosphere. Carbon is one of the greenhouse gasses that traps this heat. Other gases include methane, nitrous oxide and sulfur hexafluoride. Water vapor however is the most important because globally it is the most abundant. The concern however is generally placed upon carbon dioxide, the second most abundant followed by methane, nitrous oxide and sulfur hexafluoride because human impact play a large role in the growing concentrations of these gasses.

Green House Gasses

Carbon Dioxide – a colorless, odorless gas made up of two oxygen atoms and one oxygen atom. It is produced when an organic compound like wood or fossilized organic matter like coal, oil or natural gas is burned in the presence of oxygen. It’s removed from the atmosphere by carbon sinks.

Methane- a colorless, odorless, nontoxic gas that is made up of four hydrogen atoms and one carbon atom. Methane is the main constituent of natural gas and is combustible. It is released when organic matter decomposes in the absence of oxygen. Natural sources include wetlands, swamps, marshes, termites and oceans. Mining fossil fuels and the transportation of natural gas are human sources as well as the digestive processes of cattle and buried waste in landfills. It is broken down in the atmosphere when it reacts with hydroxyl radicals.

Nitrous oxide is a colorless, non-flammable gas with a sweet smell and is often known as ‘laughing gas’ and used as an anesthetic. It is produced naturally in the rainforests and oceans. Man-made sources include the use of fertilizers in agriculture, nylon, nitric acid production, car with catalytic converters and the burning of organic matter. It is broken down in the atmosphere by chemical reactions driven by the Sun.

Sulfur hexafluoride is a potent man made, greenhouse gas with a lifetime of more than a thousand years. Because of this, a small amount can have a significant impact on global climate change. It is primarily used in the electrical industry in high voltage circuit breakers, switchgear and in the magnesium metal casting industry.

Although the Earth’s atmosphere consists primarily of nitrogen and oxygen, and these greenhouse gases are trace in comparison, they influence the Earth’s climate. [15]

Climate Change and its Impact

The effects of global climate change are evident in our environment and climate influences ecosystems. This also means that as the climate changes, ecosystems are affected in a variety of ways. It affects ecosystems and their species directly as well as interacts with other human stressors like development that can lead to dramatic changes. Current food webs and ecosystems can be transformed by climate as it alters where a species may live, how they interact and the timeline of seasonal events. For example, for many species, the climate where they live influences stages in their life cycle in terms of migration, blooming and reproduction, but the timing of these events change as winters are shorter and milder. Earlier springs also change the nesting periods for various bird species which shifts migration timing. Since different species vary in their ability to adjust to such changes in the ecosystem, the ecosystem becomes vulnerable and asynchronies can develop like migration timing, breeding, pest avoidance and food availability all of which can alter growth and survival rates. For instance, warming can force species to move to higher elevations where they can better adapt and survive. Similarly, with the rise of sea level saltwater intrusion into a freshwater ecosystem may force some species to relocate or die. This then can cause a disruption in the existing food chains by removing predators or prey that currently exist there. Mountain and arctic ecosystems in particular are very sensitive to climate change. The rate of species extinctions especially in these sensitive regions could greatly increase with projected warming. Climate change also overwhelms the capacity of ecosystems to mitigate extreme events like wildfires, floods or droughts. Ecosystems can act as natural buffer to such events, but climate change can hamper its ability to deter the impacts making it more susceptible to damage. Some examples include reefs and barrier islands that protect the coastal ecosystems from storm surges, wetlands absorbing floodwaters and cyclical wildfires that help clear forest debris, preventing larger fires.

In addition to ecological shifts, agriculture and fisheries are affected because they are highly dependent on climate. Climate change can make it difficult to grow crops, raise animals and catch fish. As temperature and carbon dioxide levels rise, some crop yields rise, while with more severe warming floods and droughts will reduce the yields. The severity of droughts and floods challenge farmers and ranchers and also can threaten food safety. Livestock can be at risk due to heat stress and reduced quality of their own food supply. Warmer water temperatures can cause shifts in habitat ranges in fish and shellfish which can disrupt ecosystems. Fisheries are affected by the changes in water temperatures that make waters more open to invasive species and shift life cycle timing for some species of fish.

We are all vulnerable to the impact of climate change on our health. Warmer climate is said to increase the risks of illnesses from extreme heat and poor air quality and can expose more people to diseases by supporting the spread of pathogens and parasites. Changes in the air we breathe due to warmer temperatures worsens air quality that can lead to asthma attacks, and other respiratory and cardiovascular issues in addition to changes in allergens and allergic illnesses. Exposure to extreme heat can lead to heat stroke and dehydration as well.[16]

Human Impact

As we can see global climate change affects us as individuals as well as the ecosystems in which we are a part of, ranging from air quality and the food we eat to a broader scale of the existence of species in an ecosystem and natural disasters. Because of the impact, it is vital to examine human practices and our contribution to the changing so to better understand the budget and proactively plan to stay below projected means. Human activities are impacting the climate system. Scientific studies on climate indicates that most of the increase in global average temperatures are likely due to increases in greenhouse gas concentrations from the burning of fossil fuels. As a result, the amount of carbon dioxide in the atmosphere is rising. These gases are projected to remain in the atmosphere for hundreds of years before being removed through natural processes. Global climate patterns are being altered also by reducing forest cover, the rapid expansion of farming development and industrial activities. Although the ocean absorbs much of the carbon released during the burning of fossil fuels, the extra carbon is lowering the oceans pH in what is known as ocean acidification which interferes with marine organisms.[17]

What Can We Do?

Climate change is a challenging problem where our lives, species and ecosystems as well as the viability of the economy and future habitability is at stake. Although climate change cannot be stopped it can be slowed. In order to avoid the worst consequences, it is necessary to reach a net zero carbon emissions by 2050 at the latest. This means that the amount of carbon released into the atmosphere is equal to or less than what is taken out. In order to reach this goal, there needs to be a transformation in how electricity is produced and consumed, a better transportation system, an end to deforestation and a climate friendly agricultural system. In order to make such changes a reality, significant federal policies enabled. This is a global issue and therefore requires international agreement.

More than just reducing emissions is needed to address this global issue. Carbon dioxide needs to be actively removed from the atmosphere. This can be done by both afforestation or reforestation and enhanced land management practices. Enhancements in technology can also help where carbon dioxide in air can be captured or prevented from leaving smokestacks. These are expensive fixes and the scale and speed of taking action is important, dependent on strong state and federal policies and investment into research and development. Cutting carbon may be a long-term solution, but until then we need to adapt, which means discouraging development in high-risk areas, building resilient communities and planning ahead for water scarcity. From there we need to act. In addition to seeking out government leaders and supporting activists’ groups.[18]

In addition to becoming more politically active and letting your local, state and national leaders know that you support action that will decarbonize the country, there are steps that you can do to help reduce your carbon footprint. Simple changes to your daily lifestyle can go a long way if everyone pitches in over time. Some things you can do include altering your diet. Eating mostly fruits, veggies, grains and beans can make a difference, since meat and dairy are responsible for about 14.5 percent of manmade global greenhouse emissions due to feed production, processing and the methane released from livestock. Choosing organic and local foods that are in season also helps, because transporting food uses fossil fuels and fuel for cooling to keep food safe. Reducing food waste by freezing and reusing, as well as composting food waste contributes to the reduction of your carbon footprint. Other fixes include daily habits like clothing. Buying trendy clothing that comes and goes quick, adds to the landfills as well as requires fossil fuels for the transportation of the garments. You can choose recycled clothing from consignment shops instead. Washing your clothes is cold water instead of hot reduces the amount of carbon dioxide. Other related helps include buying less stuff, recycling more often and using reusable bags, avoiding excess packaging and looking for energy efficient products when buying electronics, appliances, lighting or office equipment. You can reduce your carbon footprint in your own home by switching from incandescent lightbulbs to LED. Although they cost more, they last longer and use only ¼ of the energy. Other simple changes including turning off lights and unplugging devices when not in use, turning down your thermostat and using less air conditioning. If you have a water heater, simply turning it down to 120 degrees Fahrenheit can save more than 500 pounds of carbon dioxide a year. Installing a slow flow showerhead and taking shorter showers also helps. Transportation is also a great contributor to carbon dioxide emissions because electricity comes from natural gas and renewable energy. Some changes you can make is to drive less: walk or use public transportation when necessary. Combine your errands into less trips, to reduce driving. If possible, choose a hybrid or electric vehicle. When flying choose nonstop flights when possible and economy class. These are simple steps that can be made to help reduce the carbon budget that if done collectively can make a big impact.[19]

Classroom Activities

Activity 1: Interaction of the Four Spheres

Objective:

1. Students will explore various materials to describe each of the four spheres and explain how two or more of the spheres interact in different ways through the Earth's systems and processes.
2. Students will create labeled sketches or models to explain the interaction of one or more of the Earth's spheres.
3. Students will think about humans in the biosphere and how our actions impact all of the Earth's spheres.
4. Students will brainstorm methods to reduce human impact on the Earth's spheres.

Materials:

- Rounded rocks
- Earth's Sphere labels printed and cut apart

- Scissors
- Sand
- Mud
- Silt
- Water
- Photos of streams, lakes, oceans
- Photos of snow, ice, glaciers
- Photos of clouds, fog
- Photos of plants, animals and humans
- Classroom plants and/or pets
- Science notebooks

Vocabulary:

- Atmosphere: The atmosphere might be the most difficult to conceptualize because the gases that comprise it are not visible. We can see clouds, which are made from water vapor (hydrosphere), and smoke in the air (ash is part of the geosphere). Earth's atmosphere is critical to the biosphere. Animals and plants utilize different gases in the atmosphere to support life processes. The air we need to breath is found relatively close to the Earth's surface. Our atmosphere is mainly made of nitrogen, oxygen, argon, carbon dioxide, and some other trace gases. The troposphere is closest to the Earth's surface, followed by the stratosphere, mesosphere, thermosphere and exosphere. Each layer has a different composition and temperature.
- Biosphere: The biosphere includes humans as well as all other life forms, both plant and animal. Microorganisms and elephants are both part of the biosphere. Plant roots can break rocks or anchor soil to a hillside. Earth's largest animals (whales) rely on the hydrosphere to support their bodies. Almost all life forms require water to live.
- Geosphere: Geo means Earth. The geosphere is made up of Earth's rocks, minerals, sediments, volcanoes, magma, mountains, and canyons. These materials and features were formed through the rock cycle, which involves all spheres. For example, fossils (biosphere), erosion by water (hydrosphere), and erosion by wind (atmosphere). Soil contains rock and mineral components which are part of the geosphere, but on a higher educational level, soil also contains organic matter (biosphere), air pockets (atmosphere), and water molecules (hydrosphere) too small to be seen.
- Hydrosphere: The hydrosphere contains all of Earth's water. The majority of liquid water is found in the ocean as saltwater. Liquid freshwater is found as lakes, rivers, streams, and ponds, but also as groundwater under the Earth's surface. Water vapor is found throughout the atmosphere and forms clouds. Water cycles around the planet but as it does so it flows over and through the geosphere, evaporates into the atmosphere, and is even incorporated into the biosphere (we drink water).

Introduction: All materials from the core of the Earth to its' atmosphere, fall into one of four categories: the geosphere, hydrosphere, biosphere, and atmosphere. The interaction between these four spheres make-up most of the processes on Earth. For example, the hydrosphere shapes the geosphere when waves crash into rocks creating sand and ocean currents, which affects the atmosphere and have a major impact on weather. The Earth is constantly changing. To better understand the processes that change it we can visualize Earth as four interacting systems—the geosphere, biosphere, hydrosphere, and atmosphere. Humans are part of the biosphere, but have the ability to impact all of Earth's spheres in both positive and negative ways. For example, recycling is positive, but piling trash in the geosphere is negative, each of which impacts the other three spheres. In this lesson we will explore interactions between the four spheres- land, life, water and air.

Procedure:

1. Pass around rounded rocks from a local stream, river or beach. Ask students to record questions that the materials inspire.
2. Facilitate a discussion about their observations and questions, leading them to think about how the rocks became rounded.
3. Students will filter through four centers set up around the room- each labeled geosphere, hydrosphere, biosphere and atmosphere. The centers should each be populated with the following items- Geosphere (rocks, sand, mud, silt, soil.) Hydrosphere (water, photos of streams oceans, lakes, snow, ice glaciers, clouds, fog.) Biosphere (actual or photos of plants, pets and interactions between plants, animals and humans.) Atmosphere (photos of atmospheric layers, clouds.) While filtering through each of the four centers, students have to develop a definition for each of the four spheres, explaining what they mean.
4. Bring class together after all have filtered through the stations to discuss their definitions and develop a class definition for each, explicitly discussing each as a system with components. Then ask students, “Do these spheres influence each other? How?”
5. Tell the students that they are going to watch a video. (video- https://www.generationgenius.com/videolessons/earths-spheres-video-for-kids/) While they are watching they should be listening for answers to the following questions that are posted: In the investigation with the aquariums, which of the Earth’s spheres are represented? What happened to the temperature of the atmosphere when hot water was added? Does water temperature have an effect on air temperature? Which two of Earth’s spheres are represented in the example of erosion? How did the example with dry ice show that land affects water and air? Which of Earth’s spheres are humans a part of, which do they impact? Give examples.
6. Facilitate a discussion using the discussion questions.
7. Following the discussion, turn the focus back to the activity centers. The students will identify different interactions between two of Earth’s spheres. Each student should choose an interaction between two spheres that they come up with to write about in their science notebook. Students create a labeled sketch explaining their interaction in addition to explaining it using written words. Students should list all the components of the system they are modeling.

Closure: Students are now ready to apply what they have known to real life scenarios. Provide students with one or more scenarios involving interaction between Earth’s spheres. Ask students to explain which spheres are interacting and how. Example scenarios include: • Formation of beach sand • A landscape with different kinds of plants on opposite sides of a mountain. • Glacial striations on rocks. • Glacial erratic boulders (huge rocks that were carried and deposited by glaciers). • Freeze-thaw weathering. • Avalanche paths on mountainsides. As students explain, illicit class discussion to enhance their explanations.[20]

Activity 2: Energy Flow and Cycles in an Ecosystem

Objective:

1. Students will be able to describe the importance of energy flow and nutrient cycles in sustaining Earth's ecosystems.
2. Students will diagram the flow of energy through simple food chains and food webs.

Materials:

- (per group 4-5 students in each)

- 1 piece of cardboard or construction paper
- 1 or 2 nature or wildlife magazines
- scissors
- glue
- balls of string

Vocabulary:

- Carbon Cycle: The continuous circulation of carbon atoms in the biosphere as a result of photosynthetic conversion of carbon dioxide into complex organic compounds by plants, which are consumed by other organisms: the carbon returns to the atmosphere in the form of carbon dioxide as a result of respiration, decay by fungi, bacteria, etc., and combustion of fossil fuels.
- Carnivore: An animal that eats only meat.
- Combustion: The process by which fuel burns. For this to occur, three elements are required: Fuel, heat and oxygen.
- Condensation: The process in which water vapor changes into liquid water.
- Consumer: An organism requiring complex organic compounds for food, which it obtains by preying on other organisms or by eating organic matter.
- Decomposition: The breakdown of a substance into different parts or simpler compounds. Decomposition can occur due to heat, chemical reaction, decay, etc.
- Ecosystem: A functional unit consisting of all the living organisms (plants, animals and microbes) in a given area, and all the nonliving physical and chemical factors of their environment, linked together through nutrient cycling and energy flow. An ecosystem can be of any size — a log, pond, field, forest or the Earth's biosphere — but it always functions as a whole unit.
- Energy: The capacity for vigorous activity; available power; the capacity to do work. For example, I eat chocolate to get quick energy.
- Environment: The surroundings in which an organism lives, including air, water, land, natural resources, flora, fauna, humans and their interrelationships. (Examples: Tundra, coniferous forest, deciduous forest, grassland prairie, mountains and rain forest.)
- Evaporation: The process whereby atoms or molecules in a liquid state (such as water) gain sufficient energy to enter the gaseous state (such as water vapor).
- Food Chain: A sequence of organisms, each of which uses the next, lower member of the sequence as a food source.
- Food Web: A complex network of many interconnected food chains and feeding interactions.
- Herbivore: An animal that eats only plants.
- Hydrologic Cycle: The continuous cycle of evaporation and condensation that controls the distribution of the Earth's water as it evaporates from bodies of water, condenses, precipitates, and returns to those bodies of water.
- Nitrogen Cycle: The continuous circulation of nitrogen in nature, consisting of a cycle of chemical reactions in which atmospheric nitrogen is compounded, dissolved in rain, and deposited in the soil, where it is assimilated and metabolized by bacteria and plants, eventually returning to the atmosphere by bacterial decomposition of organic matter.
- Omnivore: An animal that eats both plants and animals.
- Photosynthesis: The process in green plants by which carbohydrates are made from carbon dioxide and water using sunlight as the energy source.
- Precipitation: Water falling, in a liquid or solid state, from the atmosphere to Earth (e.g., rain, snow, hail).

- Producer: Any organism that is capable of producing its own food, usually through photosynthesis.
- Respiration: The process in which an organism uses oxygen for its life processes and gives off carbon dioxide and water.
- Transpiration: The process by which water absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface, principally from the leaves.

Introduction: In this lesson, students will learn about energy and nutrient flow in various biosphere climates and environments. They will learn about herbivores, carnivores, omnivores, food chains and food webs. Students will understand the interdependence between producers, consumers and decomposers. Students are also introduced to the roles of the hydrologic (water), carbon, and nitrogen cycles in sustaining the worlds' ecosystems such that living organisms survive.

Procedure:

1. What is an environment? Can you think of an example? What do you think supports these environments or keeps them running? What fuels the animals and plants that live within the environments and ecosystems we just discussed? It's energy! Today we are going to learn about how energy moves through an environment or ecosystem and how this knowledge helps us make better choices.
2. Discuss with students: Why did you eat your most recent meal? We know that we have to eat to provide ourselves with the raw materials that help us to move, grow and stay healthy. Our food gives us the energy we need to perform daily activities. Do you know of other sources of energy and for what they are used? For example, fossil fuels (oil and coal) and renewable energy (solar or wind) are used for transportation, heating, cooling and electricity. Did you know that energy actually flows around in a system? For example, the energy in fossil fuels is changed into the heat or power that we need to run appliances or heat our homes — that energy moves from one form to another. It is the same with the food we eat; our bodies take the energy from the food and turn it into energy to move and grow.
3. Have you heard of a food chain? A food chain traces the energy of nutrients through the organisms that eat them- show students' examples. This includes the production of the vegetables, fruit, cheese, eggs or meat that you had for breakfast or will have for lunch or dinner. Energy is in all this food! From where does the energy in food come? Well, all the energy in food starts with the sun! students draw their own example of a food chain.
4. Draw examples of simple food chains that show how energy moves from one place to another. The arrows in these food chains illustrate the direction of energy flow — starting with the sun providing nutrients to producers, which use photosynthesis to become food for consumers. What are producers and consumers? A producer is any organism that is capable of making its own food, usually through photosynthesis, such as a plant. A consumer is any organism that gets its food by eating producers or other organisms. A food web is what happens when one organism gets energy from more than one source, such as a human eating vegetables, ham and cheese.
5. Model Human Food Web activity with students. Divide the class into teams of eight students each. (Groups may be larger or smaller, if desired, but they must be at least five students each.) Have all the students stand in a circle. Distribute a ball of string or yarn to one member of each group. This person represents the sun and starts each food web. Have the first student hold tightly to the end of the string and toss the ball of string to another person in the group, across the circle. Have the second person name one thing in the ecosystem that uses energy from the sun. Next, have this person clasp the string with one hand and toss the ball of string on to another student in the circle with their other hand. Have the third student name something that eats or is eaten by the previous item named. Continue until all students in the circle are connected with the ball of string at least once. Have the student groups stop

and look at the web they have created. Are some webs more complex than others? Why? Point out to students how they have modeled a food chain or food web.

6. Now have students create their own. Divide the class into groups. Ask each group to think of a terrestrial food chain and an aquatic food chain, and create each of these with words on one side of a piece of paper, using arrows to show the energy flow. Discuss the food webs they created as a class in Part 1, and tell them that they are now going to construct a food web using pictures. Pass out an assortment of nature and wildlife magazines. Instruct the groups to make food webs on the other side of their paper by either drawing pictures of the living things in their food chains or finding them in the magazines and gluing them onto the paper. Suggest that they use arrows to show the direction of the flow of energy between the images.
7. Conclude with an informal discussion: How do we use the energy that is in the food we eat? We need energy to move, keep warm (we give off heat all the time, and this heat energy comes from the food we eat) grow, think, stay healthy and stay alive! Any energy that is left is stored in our bodies. Only a fraction of the energy that an herbivore, or plant eater, gets from the plant food that it eats becomes part of its body (its mass). The rest of the energy from the plant food is lost as waste (in droppings) or is used up (for movement, keeping warm or just surviving). The same goes for carnivores, or meat eaters, and omnivores, organisms that eat both meat and plants. When a carnivore or omnivore eats another animal, only a fraction of the energy from its animal food is incorporated into its body. Energy is lost at each link in the food chain because the living things pass on much less energy than they receive. This energy loss means that most food chains are only four or five links long. Discarded plant and animal (organic) materials eventually decompose, returning energy, in the form of nutrients, to the soil. The food chain alone is not responsible for the survival of plants and animals, humans. It is important to recognize that other nutrients, such as carbon, nitrogen, oxygen and water, also play a part in maintaining the ecosystems in which the living organisms of the world depend. How could we survive without water or air? Just as energy flows through organisms and the environment, these other nutrients also flow through the biosphere in cycles. For example, part of the water cycle includes water evaporating from rivers and oceans into the atmosphere where it builds up in clouds (condensation) and returns to the ground as rain or snow (precipitation).

Closure: Today, let's think about how we might get energy, and other nutrients, such as water, carbon, nitrogen, and oxygen for organisms to survive.[21]

Activity 3- What Contains Carbon?

Objective:

1. Students will learn that carbon is a common element on the Earth and is found in many forms in both living and non-living things.
2. Students will recognize that carbon moves between Earth’s four spheres.
3. Students will communicate ways that carbon impacts us and the Earth.

Materials:

- What Contains Carbon? Worksheet (list the items in a table with last three boxes in the 1st column blank (11x4) with a check box of yes/no, explain.)
- Seashells
- Piece of Wood
- Plastic

- Fabric
- Carbonated Beverage
- Cup of Water
- Post-its
- Chart Paper

Vocabulary:

- Calcium Carbonate: a white insoluble solid which occurs naturally as chalk, limestone and marble and is a main component of chicken eggshells, snail shells, shells of marine organisms and pearls.
- Carbon: a naturally abundant nonmetallic element that occurs in all organic compounds and can be found in all forms of life.
- Carbonate: to dissolve carbon dioxide in a liquid.
- Carbon Dioxide: a colorless, odorless gas that is present in the atmosphere, breathed out during respiration, produced by decaying plants, used by plants during photosynthesis, and formed when any fuel containing carbon is burned.
- Hydrocarbon: compound containing only hydrogen and carbon; often occurring in fossil fuels.

Introduction: (Pre-assess) Ask students what they know about Carbon. Students can complete a word map about what they know. Discuss with students that carbon is an integral part of life on Earth, give an example of carbon in the graphite in their pencils. Explain that carbon combines with many other elements to form other substances. Carbon does however elicit negative consequences which means it can both help and hurt the planet. Explain that the amount of carbon remains somewhat consistent but there are more or less in various parts across the planet and that it is important for there to be certain levels of carbon in the oceans and atmosphere for plants and ocean animals. Give students post it notes for them to jot down ideas that carbon can be a help or a hurt. Create a T chart where students will post there notes in the appropriate column. Begin a discussion about what other everyday objects contain carbon, and chart what the students' thoughts and explanations are without confirming or denying their thoughts.

Procedure:

- Show students the objects (seashells, wood, plastic, fabric, carbonated beverages, water.)
- Ask students to individually predict whether or not each of these objects contain carbon or not and record on the "What Contains Carbon?" worksheet. Students must include an explanation for their conclusion.
- Then put students in groups of 5 to discuss their choices and explain their reasoning. After discussing students can choose to alter their choices with explanations for reasoning.
- Once all worksheets are complete, bring class together as a whole and ask students to share out their answers and how they may be able to confirm their answers.
- Discuss each object and explain why they each contain carbon.
- As a class, classify the objects into living/ used to be living and non-living groups.
- Students complete the bottom three rows on the worksheet, by choosing three different items in the classroom that they use on a daily basis that contains carbon. Students can then confirm their choices through research to find out whether or not the objects they chose contain carbon or not.

Closure: Ask students to take second look at the original list of both, "What contains Carbon?" and the "Carbon helps and Hurts," from the beginning of the lesson. Students can revisit the original "What contains Carbon?" list and alter it by highlighting only the objects that contain carbon. Next, students can use remaining post-its to list new ways that carbon helps or hurts the planet. Students can then discuss how their understanding of the role of carbon in our world changed from the beginning of the lesson to the end. Students should also discuss what new understandings surprised them and what changes in their lifestyle can make a big difference.[22]

Activity 4: Carbon Cycle Role Play

Objective:

1. recognize that there is a finite amount of carbon on earth.
2. model how carbon moves around in the environment, from one place to another.
3. identify how humans influence the carbon cycle.

Materials:

- 14-28 of a small, lightweight objects to represent carbon (e.g., ping pong balls.)
- Carbon Cycle Role-Play Cards (7 total, one per group)
- Chalk, if needed for drawing regions

Introduction: Remind students of the “What contains Carbon?” activity. Have students share what their learning was. Discuss how does the finite amount of carbon on this planet move around in the environment, from one place to another? How do the geosphere, biosphere, hydrosphere, and atmosphere interact? In this active demonstration, students will model the carbon cycle, and consider way in which human actions play a role. Explain to your students that the carbon contained in any one thing doesn’t stay there forever. The carbon atoms move from one thing to another in what is called the carbon cycle. Parts of the carbon cycle happen very quickly, like when plants take in carbon dioxide from the atmosphere for photosynthesis. But, other parts of the carbon cycle happen very slowly. Tell students that in this activity, they will learn how carbon moves from one place to another, by performing a carbon cycle role-play

Procedure:

1. Divide students evenly into 7 groups and distribute the appropriate role-play card to each group. Each group will be a team of actors that will play a certain part of the carbon cycle (atmosphere, water, algae, marine snail, sediments & rocks, trees, or caterpillars). The table provided at the end of the lesson plan summarizes all the groups, their options for carbon flow, the explanation for each carbon flow, and their script lines.
2. Distribute 2-4 ping pong balls to each group and explain that these represent carbon atoms.
3. Have students in each group review their role play card to figure out their role in the carbon cycle and decide as a group using their “Options for carbon movement” how they are going to move their carbon. Explain that they can give their carbon to only one other group, or if they have plenty, they can give the carbon to more than one group. Explain that carbon exists in all of these things at the same time and only a portion of the carbon in each thing moves. Therefore, when each group moves their carbon, they can’t give away all their carbon: they must keep at least one carbon atom. As they move their carbon, they must say their script lines to explain the carbon movement that they have chosen. One at a time, ask each group to give their carbon to another group (or groups). Run the role-play a number of times, telling students to make different choices about carbon movement each time. If you have time, consider running the following variations: Have all the groups moving their carbon at the same time: Have one person from each group be the deliverer of carbon and the other group members remain to receive

carbon from other groups. Tell students that this is a more chaotic, but more realistic acting out of the carbon cycle, since in the real-world carbon moves between all these areas at the same time.

4. Trace the journeys of only few carbon atoms: Use only one carbon atom (ping pong ball) and start it with one group. Each group that gets the atom makes a decision about where it goes next. Assign one student to write the journey on the board or a piece of paper. Do this multiple times so that you can compare the journeys of several individual atoms through the different spheres and see how the carbon cycle does not move in one direction, but moves in lots of different directions at the same time.
5. Explain to students that they just acted out the carbon cycle without human involvement, but humans greatly influence the carbon cycle with some of their activities. Have students guess what movement corresponds to the following human activities: Humans extract and burn fossil fuels for energy (carbon moves from the sediments and rocks where fossil fuels are buried into the atmosphere). Humans cut and burn trees to use land for farming, ranching, or building (carbon moves from the land plants into the atmosphere.) Pull students aside and have them be the humans. Ask them to move the carbon in the appropriate manner for the human activities that you discussed. How did this affect the carbon cycle?
6. Explain that humans have not created more carbon on earth, but that we move carbon from one place to another more quickly than would naturally happen and that this has consequences for the climate of the planet. Some salient examples: Burning fossil fuels takes carbon from sediments and rocks where fossil fuels are buried and puts it into the atmosphere because when fossil fuels are burned, they release carbon-containing gases. Cutting and burning trees takes carbon from the land plants and puts it into the atmosphere because when trees are burned, the carbon that was stored in their structures is released as carbon-containing gases.
7. Ask students if they can think of other human activities that might affect the carbon cycle.

Closure: Work with your students to draw all of the carbon flows that they acted out, relying on the groups as “experts” for their representation. Encourage students to provide explanations for the processes underlying each of the arrows.[23]

Activity 5: Global Climate Change, Understanding the Greenhouse Effect

Objective:

1. Students will understand what global climate change is and how it affects our lives.
2. Students will learn about greenhouse gases and begin to consider what events are causing an increase in the amount of greenhouse gases in the atmosphere.

Materials: (For each pair or small group of students)

- three thermometers
- two clear glass jars that will fit over the thermometers
- sun lamp or sunny windowsill
- paper towels
- scientific notebooks or journals for recording data and observations
- graph paper
- one clock to be used by the entire class

Introduction: Students study past climate change, explore the effect of greenhouse gases on Earth's atmosphere today, and consider human impact on global warming. Changes to Earth's global climate have had and will have major consequences for life on Earth. Using evidence preserved in ice for tens of thousands of years, scientists are searching for an understanding of the history of Earth's climate changes in order to better predict what the future holds for life on the planet. In this lesson, students learn about ways in which we study past climate change, and reflect on the present condition of Earth's climate. They explore the effect of greenhouse gases on Earth's atmosphere, and begin to consider the human impact on global warming.

Procedure:

1. Write the word climate on the board and ask students to try to define it. Write down their suggestions on the board. Once the list is complete, help students synthesize their ideas into a class definition.
2. Ask students to think about the term global climate. Ask them how global climate might differ from regional or local climate. Discuss with students that the term global climate describes Earth's overall climate variability, such as average temperature, average precipitation, average intensity of winds, and other conditions of Earth's overall atmosphere and at its surface. Separate from any specific weather events or local climate conditions. Show Climate Change Video and discuss the following questions: What is the difference between weather and climate? How do scientists measure the average world temperature in past eons? Before 8000 B.C., dramatic changes in average temperature occurred over just a few years' time. What was happening to the global climate before 8000 B.C.? (https://cptv.pbslearningmedia.org/resource/ess05.sci.ess.watcyc.climatechange/climate-change/)
3. Analyze the Methane Concentration graph. When did the largest change in methane gas concentration occur? Look at the Methane graph with the temperature overlay showing. What is the general relationship between methane concentration and temperature? Analyze the Calcium (Dust) graph. When did the largest change in calcium dust concentration occur? Look at the Calcium graph with the temperature overlay showing. What is the general relationship between calcium dust concentration and temperature?
4. Analyze the Insolation graph. When did the largest change in insolation occur? Look at the Insolation graph with the temperature overlay showing. What is the general relationship between insolation and temperature? What else besides the chemicals in the atmosphere affects the temperature on Earth? How might any of these variables (temperature, methane concentration, calcium dust concentration, and insolation) be used to determine past or future climatic conditions?
5. Divide the class into small groups to begin exploring the effects of greenhouse gases on our atmosphere. Distribute the prepared materials to each group. Have each group place three thermometers within a few inches of each other on a sunny windowsill or under a sun lamp. Be sure that all three thermometers receive the same amount of light for the entire class period. Have students move on to the next activity, but ask them to periodically check the thermometers until they are at exactly the same temperature. Ask students to record this temperature and the time.
6. Now cover two thermometers with glass jars, leaving one thermometer uncovered. Students should place a wet paper towel inside one of the two jars. Use water at room temperature to wet the paper towel. (In this experiment, the water vapor will act like a greenhouse gas and increase the temperature in the jar with the wet paper towel even more than the temperature in the dry jar.) Continue with the next activity, but have students periodically check all three thermometers and record the temperature and time.
7. The presence of greenhouse gases, compounds in the atmosphere that trap heat, maintains Earth's temperature. Human activities, however, are increasing greenhouse gas concentrations and affecting global temperatures. Show students the video to introduce them to these concepts, and have them answer these questions: What is the greenhouse effect? What are four naturally occurring greenhouse gases? What would Earth be like without the greenhouse effect? What are some manmade sources of

greenhouse gases other than power plants and automobiles? What natural phenomena produce greenhouse gases? https://cptv.pbslearningmedia.org/resource/phy03.sci.phys.matter.greenhouse2/global-warming-the-physics-of-the-greenhouse-effect

8. If they have not already done so, have students take temperature readings of the thermometers inside the jars and compare them to the temperature of the thermometer outside the jars. Then show the video: https://cptv.pbslearningmedia.org/resource/phy03.sci.ess.watcyc.co2/global-warming-carbon-dioxide-and-the-greenhouse-effect/ and discuss the following: Why does the image of the scientist fade after carbon dioxide has been turned on? How does this explain the greenhouse effect? What would the scientist feel like if he were inside the tube? How does this explain the effect of carbon dioxide on the temperature of the atmosphere? How long does it take for carbon dioxide to spread throughout Earth's atmosphere? How long does it take to be absorbed into the oceans?
9. In small groups, have students take their final temperature measurements and analyze the data that they have collected. Students should graph the data to show how the temperature of the thermometers under the "dry" glass jar and the "moist" glass jar changed throughout the day, and how these temperatures compared with the temperature of the thermometer outside the jars. Finally, ask students to write a summary of their findings and how these results compare to the greenhouse effect of our atmosphere.

Closure: Have students discuss the following: What tools/methods are used to study climate change in the history of Earth? What is the general climatic trend on Earth as revealed by the evidence gathered through these methods? Distinguish between the greenhouse effect and global warming. In what ways are humans having an effect on the concentration of greenhouse gases?[24]

Appendix on Implementing District Standards

This unit is intended to follow the core disciplinary ideas, cross-cutting concepts and science and engineering practices as outlined through Next Generation Science Standards. The students will cycle through a series of lessons and investigations that will take them on a cross curricular journey to better enable them to understand the world around them and their place in it. Grade five students will demonstrate their understanding by developing models to describe the movement of matter within an ecosystem and understand the interdependent relationships that exist within it. In accordance with Next Generation Science Standards, they will learn:

LS2.A: Interdependent Relationships in Ecosystems. The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as “decomposers.” Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem.

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems. Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment.

ESS2.A: Earth Materials and Systems. Earth’s major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth’s surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather.

ESS2.C: The Roles of Water in Earth’s Surface Processes. Nearly all of Earth’s available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in stream.

ESS3.C: Human Impacts on Earth Systems. Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth’s resources and environments.

MS-ESS2. D.1 Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.

MS-ESS3. D.1 Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth’s mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

Resources for Students

Baby Professor. Fun Facts about Carbon: Chemistry for Kids The Element Series | Children's Chemistry Books.

Chambers, Catherine. Stickmen's Guide to Earth's Atmosphere in Layers (Stickmen's Guides to This Incredible Earth.)

Dickmann, Nancy. Leaving Our Mark: Reducing Our Carbon Footprint

Gove, Susan. Kids Get It: Shrinking Our Carbon Footprint

Larson, Paul. The Four Spheres of Earth (Science Readers: Content and Literacy

Earth Book: Hydrosphere, Geosphere, Atmosphere, and Their Interactions

McKinney, Barbara. A Drop Around the World: The Science of Water Cycles on Planet Earth for Kids (Earth Science, Science Books for Kids, Nature Books)

https://climatekids.nasa.gov/

Resources for Teachers

Le, Kelly T. Teaching Climate Change for Grades 6–12Empowering Science Teachers to Take on the Climate Crisis Through NGSS

Lovejoy, Thomas. Biodiversity and Climate Change: Transforming the Biosphere – January 8, 2019

Reichle, David. The Global Carbon Cycle and Climate Change Scaling Ecological Energetics from Organism to the Biosphere- 2020

Various Climate Change lesson plans and activities. https://www.jpl.nasa.gov/edu/teach/tag/search/Climate+Change

Learn Science. https://science.nasa.gov/learners/wavelength

Climate Change and Human Health Lesson Plans. https://www.globalchange.gov/browse/educators

Annotated Bibliography

Archer, David. Global Warming, Understanding the Forecast. New Jersey: John Wiley and Sons, 2012. This book is a comprehensive introduction to all aspects of global warming.

Bernhard, A. The Nitrogen Cycle: Processes, Players, and Human Impact. (Nature Education Knowledge, 2010) https://www.nature.com/scitable/knowledge/library/the-nitrogen-cycle-processes-players-and-human-15644632/ (accessed May 11, 2021). This online scientific journal provides resources for teachers and middle school-high-school students.

Bernstein, Schachter, Winkler and Wolfe. Life and Science- Concepts and Challenges. New Jersey: Pearson Learning Group, 2003. This middle school life-science textbook provides student concept knowledge, scientific skills and investigations.

Biology Dictionary. “Trophic Level.” Accessed May11, 2021, https://biologydictionary.net/trophic-level/. This is resource provides curricular resources for middle to high school science connected with NGSS standards.

ByJu’s Learning Program. “Ecosystems.” Accessed May 11, 2021, https://byjus.com/biology/ecosystem/#terrestrial-ecosystems. This website provides study materials for middle school science including videos and course offerings for teachers.

California Academy of Sciences. “Carbon Role Play,” accessed on June 6, 2021, https://www.calacademy.org/educators/lesson-plans/carbon-cycle-role-play. This website provides educator resources for the classroom and at home.

California Academy of Sciences. “What Contains Carbon?” accessed on June 6, 2021, https://www.calacademy.org/educators/lesson-plans/what-contains-carbon. This website provides educator resources for the classroom and at home.

Center for Educational Technologies. “Earth System Science.” Accessed May 11,2021, http://www.cotf.edu/ete/ESS/ESSmain.html. This site discusses the interactions of the four spheres.

Columbia Climate School. “The 35 Easiest Ways to Reduce Your Carbon Footprint.” Accessed on May 11, 2021 https://news.climate.columbia.edu/2018/12/27/35-ways-reduce-carbon-footprint/. The Climate School at Columbia provides background knowledge about the Earth Sciences.

Generation Genius. “The Four Spheres,” accessed on June 6, 2021, https://www.generationgenius.com/wp-content/uploads/2018/03/. The-Four-Spheres-Lesson-Plan-GG.pdf. This is a K-8 teaching resource, partnered with NSTA presenting science standards through lesson plans, quizzes, videos and reading.

National Aeronautics Space Administration. “Basics of the Carbon Cycle and Greenhouse Effect.” Accessed May 11, 2021. https://gml.noaa.gov/education/carbon_toolkit/basics.html. This educational online resource explains scientific concepts and provides interactive lesson plans for educators.

National Aeronautics Space Administration. “Carbon Cycle.” Accessed May 11, 2021. https://www.noaa.gov/education/resource-collections/climate/carbon-cycle#:~:text=Human%20activities%20have%20a%20tremendous. This educational online resource explains scientific concepts and provides interactive lesson plans for educators.

National Aeronautics Space Administration. “Earth System Models.” Accessed May 11, 2021. https://www.gfdl.noaa.gov/climate-and-ecosystems-comprehensive-earth-system-models/. This educational online resource explains scientific concepts and provides interactive lesson plans for educators.

National Aeronautics Space Administration. “Precipitation Education.” Accessed May 11, 2021, https://gpm.nasa.gov/education/water-cycle. This is an interactive website complete with lesson plans and webinars, deigned to match NGSS standards.

National Aeronautics Space Administration. “Teaching Essential Principle Six.” Accessed May 11, 2021. https://www.climate.gov/teaching/essential-principles-climate-literacy/teaching-essential-principle-6-human-activities-are This educational online resource explains scientific concepts and provides interactive lesson plans for educators.

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National Oceanic and Atmospheric Administration. “Teacher Background, Earth’s Spheres.” Accessed May11, 2021, https://www.esrl.noaa.gov/gmd/education/info_activities/pdfs/TBI_earth_spheres.pdf. This document provides teachers with background information about the four spheres and how they interact.

National Science Teachers Association. “Learn About Earth’s Spheres.” Accessed May 11, 2021, https://www.generationgenius.com/earths-spheres-for-kids. This is a resource for teachers with lesson plans, videos and background information that build from NGSS standards.

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Teach Engineering, “Energy Flow in an Ecosystem,” accessed on June 6, 2021, https://www.teachengineering.org/. This website offers K-12 STEM curriculum.

Union of Concerned Scientists. “Climate Solutions.” Accessed on May 11, 2021. https://www.ucsusa.org/climate/solutions. This website is governed by concerned scientists providing the latest information about climate change.

United States Environmental Protection Agency. “Climate Change Impacts.” Accessed May 11, 2021. https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-ecosystems_.html. This website provides detailed and current information about environmental issues as well lesson plan ideas for educators.

University of Michigan. “The Global Water and Nitrogen Cycles.” Accessed May 11, 2021. https://globalchange.umich.edu/globalchange1/current/lectures/kling/water_cycle/water_nitro.html This online article explains the roles of the water and nitrogen cycles.

Notes

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