My Carbon Footprint High School Curriculum

New York Hall of Science

About the New York Hall of Science

The mission of the New York Hall of Science (NYSCI) is to bring the excitement and understanding of science and technology to children, families, teachers and others by galvanizing their curiosity and offering them creative, participatory ways to learn. As New York City's only hands-on science and technology center, NYSCI serves close to a half-million annual visitors, offering an unparalleled range of 450 interactive exhibits, discovery labs, a science and technology library, and the largest outdoor science playground in the nation. NYSCI's educational programs are designed to engage diverse audiences in the exploration of STEM (science, technology, engineering and math) by offering immersive experiences that promote hands-on investigation and discovery. Some of NYSCI's longest-running and most successful programs provide STEM professional development, classroom support, and resources to K-12 teachers.

About Deutsche Bank Asset & Wealth Management

With more than €820* billion of invested assets, Deutsche Bank Asset & Wealth Management (AWM) is one of the world's leading investment organizations.

The Asset & Wealth Management Corporate Division is made up of two Business Divisions, Asset Management and Private Wealth Management. While Private Wealth Management serves the banking needs of wealthy individuals and families across the globe, Asset Management provides investment solutions to individual and institutional investors worldwide.

**As of March 31, 2012. Figures include Asset Management and Private Wealth Management.*

NYSCI's *My Carbon Footprint* is presented by Deutsche Bank Asset & Wealth Management.

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Introduction

With support from Deutsche Bank Asset & Wealth Management (AWM), the New York Hall of Science created *My Carbon Footprint*, an educational initiative designed to build awareness about climate change science among New York City's schoolteachers and students. The curriculum for *My Carbon Footprint* is geared towards high schools and was inspired by The Carbon Counter. Developed by Deutsche Bank, The Carbon Counter is the world's first real-time carbon counter that displays a current count of greenhouse gases in the atmosphere. *My Carbon Footprint* incorporates hands-on learning opportunities and digital tools such as The Carbon Counter to engage students and teachers.

Each student-centered lesson in *My Carbon Footprint* maps to science standards and focuses on one or two key scientific concepts related to global climate change. Taken as a whole, *My Carbon Footprint* gives students the foundation they need to understand climate change and its related issues. The curriculum contains three modules — Cycles, My Carbon Footprint, and Taking Action. The modules can be taught in whichever order is most effective for your classroom.

We hope you'll find this curriculum valuable.
Thank you for helping to teach the next generation about climate change.

Curriculum Modules

The scientific community agrees that climate change is happening, and it is happening here and now. The New York Hall of Science (NYSCI) created the *My Carbon Footprint* curriculum to educate youth about the science of climate change as well as empower students to examine the environmental impact of their actions.

The *My Carbon Footprint* curriculum contains three modules: Cycles, My Carbon Footprint, and Taking Action. The modules and lessons can be implemented in any order. The flexibility of *My Carbon Footprint* ensures that this standards-based curriculum fits seamlessly into your classroom.

In the first module, Cycles, students learn how small changes can impact Earth's cycles in big ways.

Key ideas include:

- The carbon cycle is essential for life on Earth. Increases in carbon emissions combined with the removal of carbon sinks can significantly impact the balance of the cycle.
- Increased levels of carbon dioxide are changing the pH of the ocean, which can negatively impact aquatic life.
- Global climate change will affect different parts of the world differently. It may alter patterns of precipitation resulting in increased potential for both flooding and drought depending upon the location.

In the second module, My Carbon Footprint, students discover how humans can affect their environment.

Key ideas include:

- Every action an individual takes has the potential to impact the environment in the form of greenhouse gas emissions. These impacts added together comprise a person's carbon footprint.
- Scientific modeling helps scientists understand climate change and its potential impacts. Models can be refined in light of new information.
- Breaking large numbers into smaller units that can be easily visualized helps make scientific information more accessible to the general public.

Finally, the third module, Taking Action, presents strategies to fight and prepare for climate change.

Key ideas include:

- A carbon trading system is an example of an economic approach to fighting climate change.
- Finding alternatives to traditional power sources such as coal, oil and natural gas is a key priority in lessening the effects of climate change. No single energy source will be the solution to our energy needs, but sources such as hydroelectric power hold great promise.

Module 1: Cycles

Carbon Cycle Jenga

Discussions of climate change can be confusing for students because this topic includes many interrelated factors. Exploring climate change in terms of Earth's cycles can provide students with a foundation for future exploration. This lesson will help students understand the delicate balance between carbon emissions and carbon sinks as part of the carbon cycle, as well as review common carbon sinks and sources of carbon.

Time to Complete 1 Class Period

Standards Addressed

Common Core English Language Arts
SL.9-10.4, SL.11-12.4

New York State Core Curriculum
Earth Science 1.2e, 2.2d
Living Environment 5.1d, 6.1b, 7.1 c, 7.2 c

New York City Scope and Sequence
Earth Science Unit 7
Living Environment Unit 3, Unit 4, Unit 9

Key Terms

Carbon Sink
Things that can absorb carbon dioxide. Sometimes they are natural like trees or algae, and other times they are man-made, like systems that allow humans to pump extra carbon into rocks at the bottom of the ocean.

Carbon Dioxide Emission
Carbon dioxide released into the atmosphere.

Materials

5 Jenga sets (or any block set)
4 sets of Carbon Cycle Jenga Cards shuffled and placed in a pile face down (available at the end of this lesson)

Preparation

You, or student volunteers, need to color the ends of the Jenga blocks to represent different parts of the carbon cycle.

For each set you will need:

Trees and plants: green (7 blocks)
Ocean: blue (10 blocks)
Transportation: black (8 blocks)
Energy: purple (6 blocks)
Factories: red (5 blocks)
Shipping: orange (5 blocks)
Soil: brown (5 blocks)
Atmosphere: yellow (5 blocks)
Animals: pink (3 blocks)

The students will be split into four groups, with each group getting one set of blocks. The blocks from the extra set may be required to supplement depending upon the cards students draw.

This lesson is meant to be a reinforcement of the concepts of carbon sinks and sources of carbon rather than a linear review of the carbon cycle. Instead, the lesson focuses on the idea of balance as well as the importance of carbon sinks. Students will begin to observe that even small changes can have big effects.

Procedure

1. Begin by asking students to list some common sources of carbon dioxide. Then ask students to name some common carbon sinks. You may have to spend time defining the term "carbon sink."
2. Break students into four groups and review the different colored blocks. Be sure to mention which factor corresponds to each color.
3. Have students set-up their Jenga tower as follows: Begin by mixing the trees and plants. The bottom layer should include one green block with a blue block on either side for a total of three blocks. The second layer should contain two green and one blue block, and the blocks should be placed perpendicular to the first layer. Continue this procedure using the blue, green, pink, yellow and brown blocks.
4. Students should not include red, black, purple or orange blocks. These should be left out of the tower.
5. Students are now ready to play. To determine which blocks get removed or added, students will draw a card and follow the instructions. As with a regular game of Jenga, they can only use one hand to remove a block. Ask students to be aware of any changes they may notice as they remove different types of blocks.
6. Unlike a regular game of Jenga, students should set aside any blocks they've removed rather than adding them back to the top of the tower.
7. If students go through the entire stack of cards, they can shuffle and reuse.
8. Some groups may finish before others, and you can have them play again. Ask them to take note of any changes they make when setting up their tower.
9. After you feel that each group has had enough time to go through the procedure, you can wrap-up the lesson. Ask students what caused their tower to fall. Depending upon the order they drew the cards, they may notice that a removal or degradation of carbon sinks caused the tower to fall, or they may notice that the addition of carbon from sources like cars or factories was the cause.
10. Emphasize that climate change is a complex idea that takes all of the factors they just saw into account. Earth's cycles are in a delicate balance. Although we need carbon dioxide to survive, too much carbon dioxide is causing the climate to change.

Extension

You can have students create their own cards or their own categories of blocks. You can also instruct students to change the cards or blocks to better emphasize specific ratios in the carbon cycle. For example, the ocean is Earth's largest carbon sink, so students would create more ocean blocks and less vegetation blocks.

Credit

This lesson was inspired, in part, by the Aquatic Ecosystem Game created by the Maria Mitchell Association.

Carbon Cycle Jenga Key

Green	Trees and Plants	7 blocks
Blue	Ocean	10 blocks
Black	Transportation	8 blocks
Purple	Energy	6 blocks
Red	Factories	5 blocks
Orange	Shipping	5 blocks
Brown	Soil and Rocks	5 blocks
Yellow	Atmosphere	5 blocks
Pink	Animals	3 blocks

The ocean pH has begun to change.

Remove two blue ocean blocks.

People refuse to carpool.

Add one black transportation block to the top of the pile.

A company has cut down acres of forest to make way for a new hotel.

Remove two green plant blocks.

Meat consumption is up resulting in excess methane.

Remove one pink animal block.

A new factory is built.

Add one red factory block.

Photosynthesis from a tree you planted results in some carbon dioxide being removed from the atmosphere.

Don't remove a block!

The decomposition of organic matter releases carbon into the atmosphere.

Remove one pink animal block.

New agricultural practices help the soil store more carbon.

Don't remove a block!

Rocks store carbon. Don't remove a block!	There is excess carbon in the atmosphere. Remove one yellow atmosphere card.
You buy a laptop that was flown in from another country. Add one orange shipping block.	Car companies create less fuel-efficient cars. Add one black transportation block.
The ocean is a major carbon sink. Don't remove a block!	You buy fruit that was shipped in from South America. Add one orange shipping block.
The ocean pH has begun to change. Remove two blue ocean blocks.	A company has cut down acres of forest to make way for a new hotel. Remove two green plant blocks.
City cars are idling in traffic resulting in increased carbon emissions. Add one black transportation block.	There is an increase in families flying to vacation destinations. Add one black transportation block.

Warming waters has reduced the ocean's ability to act as a carbon sink. Remove two blue ocean blocks.	The ocean pH has begun to change. Remove one blue ocean block.
People refuse to carpool. Add one black transportation block.	Car companies create more gas guzzling cars. Add one black transportation block.
City cars are idling in traffic resulting in increased carbon emissions. Add one black transportation block.	There is an increase in families flying to vacation destinations. Add one black transportation block.
Hotter summers result in more people using air conditioners. Add one purple energy block.	People leave their electronics charging overnight. Add one purple energy block.
A company has cut down acres of forest to make way for a new hotel. Remove two green plant blocks.	Mining practices release carbon that was stored in rocks. Remove one brown rock block.

Carbon Cookies

In the context of climate change, carbon dioxide and other greenhouses gases are discussed in a negative way. This negative focus can cause confusion among students regarding the greenhouse effect and the vital role greenhouse gases play in supporting life on Earth. This lesson is an engaging reminder that life as we know it requires balance within Earth's cycles; both too much and too little of certain gases can have negative effects on Earth's systems.

Since educators may not have access to ovens, modifications to this lesson are included after the procedure.

Time to Complete 1–2 Class Periods

Standards Addressed

Common Core English Language Arts
SL. 9-10. 4
RST. 9-10. 3

New York State Core Curriculum
Earth Science 1.2e
Living Environment 7.1 c, 7.2 c

New York City Scope and Sequence
Earth Science Unit 7
Living Environment Unit 9

Materials

You will need a cookie recipe. You may select any recipe you like, but keep allergies in mind when selecting your recipe.

Ingredients listed on the recipe

4 sets of measuring cups and spoons
4 mixing bowls
8 mixing spoons
4 baking sheets
Cooking spray
Oven

Preparation

Students will be split into four groups and each group will receive the same recipe with one key difference: each group will use a different amount of flour. Before class, you should prepare copies of the recipe that reflect these varying amounts. One recipe should have the correct amount of flour, and the others should have either too much or too little.

Procedure

1. Begin by telling students that today they will make carbon cookies and instruct them to wash their hands.
2. Split them into four groups.
3. Pass out recipes to each group, and tell them that they must follow the procedure (recipe) exactly. Students will not know that each group has a slightly different set of instructions.
4. Once students have prepared their mixture and placed the cookies on the sheet, student volunteers can take the sheets to the oven to bake.
5. While the class is waiting for the cookies to bake, review the topic of greenhouses gases. Ask students to name some greenhouse gases. Ask them to describe the greenhouse effect and why it is neces sary for life on Earth. During the discussion be sure to highlight that while too many greenhouse gases contribute to global climate change, we need some greenhouse gases to support life as we know it.
6. Once the cookies are done, have students examine the different baking sheets. They will notice that the cookies with too little flour have run together and those with too much flour are hard and dry.
7. If you wish, you can have students sample the cookies with the correct amount of ingredients.
8. Ask students what they think caused the difference in the cookies.
9. Reveal to them that they were working from different recipes that were identical except for the amount of flour.
10. Ask students to consider the cookies in light of the conversation about greenhouses gases you had while the cookies were baking. Ask students why these are "carbon cookies".
11. Tell students that this lesson can be used as a way to think about levels of carbon dioxide in the atmosphere. We need some carbon dioxide just like the cookies need some flour, but too much carbon isn't ideal either, just like the cookies that were hard and dry.
12. Wrap up by again emphasizing that when talking about climate change, the idea of balance is key. Carbon dioxide and other greenhouses gases are important, but we need these gases at specific levels.

Modifications

To modify, have student groups create the batter, but instead of baking it during the class period, store and refrigerate the batter, and then bake later in the day or at home. Bring in the cookies the next day for comparison.

If you are unable to access an oven to bake the cookies, you can make this a homework assignment to be completed either in groups or individually. Again, students should receive a mix of recipes. Instruct students to follow the recipe and then take pictures to document the outcome of the recipe. Compare photos in class.

Acids and Bases: Ocean Acidification

This lesson allows students to explore the concepts of acids and bases using the context of ocean acidification. Students will first complete an experiment that illustrates that the absorption of atmospheric carbon dioxide by the ocean causes the ocean to become more acidic. Then, the class will explore the effects that a change in pH might have on ocean life.

This lesson should follow an introduction to acids and bases and is meant to provide a real-world application to these concepts and an opportunity to work with pH indicators.

Time to Complete 1–2 Class Periods

Standards Addressed

Common Core English Language Arts
SL.9-10.4, Sl.11-12.4
RST.9-10.4, RST.11-12.4

New York State Core Curriculum
Chemistry 3.1ss, 3.1tt

New York City Scope and Sequence
Chemistry Unit 8

Key Terms

pH Indicator
A chemical compound that visually shows the pH of a solution.

Carbon Sink
Something that can absorb carbon. Sometimes it is natural like trees or algae, and other times it is man-made, like systems that allow humans to pump extra carbon into rocks in the bottom of the ocean.

Ocean Acidification
The decrease of the ocean's pH due to increased absorption of carbon dioxide.

Dissociation
The separation of a compound into simpler parts.

Materials

Bromothymol blue pH indicator solution *(available for purchase from any science supply company)*
1 small cup of water for each student
1 straw for each student
Pipettes
Paper towels
Goggles for each student
Shells or coral
Vinegar
Chalk of different colors, broken in half
2–3 Small plastic cups per student
pH paper *(available for purchase from any science supply company, pool supply store, or most pet stores)*
Gloves (optional)

Preparation

Place a small seashell into a container with vinegar a day before the class and let it sit overnight.

Directly before the lesson, place 4–5 drops of the indicator solution in a small cup of water. The water should be noticeably blue/green in color. Prepare one cup of water and indicator solution for each student.

Procedure: Introductory Activity

1. Direct students to put on goggles.
2. Ask students to take note of the color of the liquid in their cup.
3. Tell them that they will use the straws to blow into the blue liquid for 30 seconds. Some of the water might overflow onto the table, but they should try to be neat.
4. Instruct students to blow into the straw. Time them for 30 seconds. After 30 seconds, direct students to put their straws down. Students can now remove their goggles.
5. Again, ask students to notice the color of the liquid in their cup. They will notice that the liquid has turned yellow.
6. Ask students to hypothesize why the liquid changed color and what liquid they think was in the cup to begin with. Allow a few students to share their ideas.
7. You can prompt them by asking what they were exhaling into the cup. After a short discussion, explain that the cup contained water with a few drops of a pH indicator solution. If necessary, review the concept of pH and pH indicators. Now that they have this information, do they have a different idea of why their liquid turned color?
8. Explain that students exhaled carbon dioxide into the cup, which made the water slightly more acidic causing the indicator solution to change color. If you wish, you can discuss the following equation with students:

   $CO_2 + H_2O \leftrightarrow H_2CO_3$ (carbonic acid)

   The carbon dioxide and water combine to create carbonic acid.

Procedure: Ocean Acidification

1. Carbon dioxide plays a part in natural processes such as breathing, and carbon dioxide is an important part of our atmosphere. However, humans are adding carbon dioxide to our atmosphere at a faster rate than ever before through our use of fossil fuels. The ocean acts as a carbon sink. This means that the ocean absorbs carbon from the atmosphere.
2. Show students the following map to help them visualize how ocean pH has changed over the past three hundred years:

   www.epa.gov/climatechange/images/indicator_downloads/acidity-download2.png

   Encourage students to notice the areas with the largest change in pH (orange) and areas of smallest change in pH (blue).
3. Tell students that as more carbon dioxide has been produced, the ocean has absorbed more carbon dioxide than it has in the past, and the ocean pH has begun to change, becoming more acidic. This is similar to when the students exhaled carbon dioxide into the water and the pH indicator solution showed that the liquid became slightly more acidic. Although the change in numbers may seem small, they actually represent a significant change in ocean pH over time. This is a good opportunity to remind students that a change in one whole number on the pH scale (i.e. going from a pH of 8 to a pH of 7) represents a tenfold increase in hydronium ion concentration.
4. Ask students how a change in pH might affect ocean life. Prompt them to think about things they might have seen on TV or in magazines.

5. Show the class the shells and corals. These are made of calcium carbonate, the same thing we find in chalk and our bones. We are going to focus on what happens to shells as water becomes more acidic (pH decreases).

6. Instead of using actual shells, which we want to protect, ask students what can be used as a substitute. After a few responses, tell students they'll be experimenting with chalk instead of actual shells.

7. The next part of the procedure can be as open-ended or structured as you wish. You can have the whole class follow the same procedure, or you can give students time to explore what they are interested in.

   Optional: Give students a small cup filled half way with salt water. You can make salt water by adding about 3 1/2 teaspoons of salt for every 1000 mL of water and stirring well. This is not the same as ocean water but will work as a substitute. Using the pH strips, have students test the pH of the salt water. Select a few students to share their results. Then instruct students to add 1/4 cup of vinegar to the salt water. The cup should now be 3/4 full. Have students test the mixture with a new pH strip. Then ask the students how the pH changed when the vinegar was added.

8. Instruct students to fill a cup with vinegar, an acid, and test the pH of the liquid.

9. Then, allow students to select a piece of chalk. Ask students to make a prediction about what will happen to the chalk. Will different colors of chalk produce different results? Does the size of the chalk matter?

10. Instruct students to place the chalk in the vinegar and observe what happens. (Not only will students observe bubbles, they should also hear fizzing. If the classroom is loud, you may need to prompt students to listen for this reaction). If you wish, you can also provide students with gloves so they can notice any changes in the chalk's texture or structural integrity.

11. Students can use a new strip to test the pH of the vinegar to see if there has been a change.

12. After students have had time to observe what happens to the chalk as well as to test the pH, you can give them time to test other pieces of chalk, use a mixture of salt water and vinegar, or add more chalk to the same cup to observe and measure. Or you can ask students to begin cleaning up. If you wish, you can put the cups with chalk over to the side and leave them overnight so that students can see if there are long-term changes when chalk is placed in vinegar.

13. Ask students to recap what they observed when the chalk was placed in an acid. They should have seen that the chalk starts to dissolve in the vinegar. You can now show students the shell you placed in the vinegar overnight. They should see that it is greatly dissolved. Using the data they collected, ask students to make some conclusions about how a change in pH might affect ocean life.

14. You can revisit the equation from Part 1, and discuss how the formation of carbonic acid results in damage to sea life. The carbonic acid dissociates in ocean water, separating into hydrogen ions and bicarbonate.

    $H_2CO_3 \leftrightarrow H^+ + HCO_{3^-}$

    Some of the ions remain in the water altering the pH, while others combine with carbonate ions already in the water to create bicarbonate.

$H^+ + CO_3^{2-} \leftrightarrow HCO_{3^-}$-

When carbonate ions combine with the hydrogen ions, organisms that need the carbonate ions to form their shells suffer.

To clarify further, the increase in carbon dioxide absorption by the ocean has two effects. One is the change in pH, and the other is a decrease in available carbonate ions.

15. Be sure that students understand that the changes in the ocean's pH are much less drastic than the ones they measured today. Ocean life, however, is very sensitive to small changes in pH, so the amount of carbon dioxide that the ocean is absorbing can significantly affect the health of plants and animals.

16. Wrap-up the conversation by pointing out that learning about acids and bases as well as ways to monitor changes in pH are both vital to understanding the health of oceans or even just our pools or fish tanks at home.

Additional Resources

National Geographic
http://ocean.nationalgeographic.com/ocean/critical-issues-ocean-acidification/?source=A-to-Z

http://ngm.nationalgeographic.com/2007/11/marine-miniatures/acid-threat-text

NOAA
www.pmel.noaa.gov/co2/story/Ocean+Acidification

Stanford University
http://virtualurchin.stanford.edu/AcidOcean/AcidOcean.htm

Changing Water Cycle, Changing Weather

Floods and droughts have both been in the news lately, and climate change has the potential to create even more extreme precipitation levels. This lesson asks students to consider how climate change can result in both more and less precipitation. Students will observe the effect of temperature on evaporation and make connections to the water cycle in the context of global climate change.

Students should have a firm understanding of the differences between climate and weather before completing this lesson. Students should also be familiar with the water cycle.

Time to Complete 1 Class Period

Standards Addressed

Earth Science 1.2g, 2.2d

Materials

Per group
2 clear plastic containers about the size of a shoebox
2 small thermometers
Tape
1 desk/heat lamp
2 100 mL beakers
Water
Saran wrap
Soil
1 stopwatch

Per Student
1 Water Cycle Lab Sheet

For Pressure Demonstration
Diffusion Cloud in a Can, a stick of incense, or something else that could produce a small but visible amount of smoke. *(Diffusion Cloud in a Can is available for purchase from theatrical supply stores.)*
Aluminum tray of warm pebbles
Aluminum tray of ice

For Coriolis Effect Demonstration
Markers (1 per group)
Paper (1 sheet per group)
Old record (1 per group)

Preparation

If students will not have access to a sink, you can pre-measure out two 100 mL containers of water per group.

Prepare the materials for the demonstration while students are finishing Part 1.

Procedure: Part One

1. Ask students to think about the amount of rain their neighborhood has received over the past year. In the Northeast, students might mention occurrences of heavy precipitation events resulting in flooding. Tell students that in addition to heavy rains they observed, the Northeast also experienced very dry conditions during parts of 2012. You can illustrate this by using the U.S. Drought Monitor to access drought information and precipitation information from the National Weather Service: http://droughtmonitor.unl.edu/DM_northeast.htm http://water.weather.gov/precip/.
2. While we cannot say that a specific storm is caused by climate change, we can say that climate change has the potential to make both heavy precipitation and drought more severe. Point out that drought doesn't necessarily mean dust-bowl type conditions, but instead refers to extended periods of abnormally dry weather. What is abnormally dry in some areas could be normal in others, so drought is actually a complex and relative term. Ask students how it is possible that climate change might contribute to both flooding and drought.
3. If needed, take a moment to review the water cycle. Tell students that today they will examine the effect of temperature on evaporation.
4. Split students into groups and instruct students to follow the procedure on the lab sheet to complete the experiment.
5. After 15 minutes have passed, ask groups to share what they observed. Students will have noticed that the container with the lamp had a higher temperature, drier soil, and more condensation on the saran wrap.
6. Be sure that students understand that temperature is just one factor that affects the cycle of water. Higher temperatures lead to increased evaporation, which results in more water vapor in the atmosphere, but also drier land. Other factors can include things such as land use, vegetation and pressure.

Part Two

7. Ask students, "If the water vapor is rising into the atmosphere, won't it just return to Earth's surface as precipitation, wet the soil, and the cycle continues?"
8. After eliciting responses from two or three students, introduce the following ideas:
   - Weather variables are interrelated. Just as temperature affects evaporation, it also affects air pressure.
   - Warm air is less dense than cooler air, so it rises as it heats up. When it rises it isn't exerting as much pressure on the ground so this type of area with warm, rising air is called a low pressure system.
   - Low pressure areas are associated with rainy weather because as the heated air rises, it brings the evaporated water with it. This moisture condenses into clouds.
   - Conversely, cold, dense air exerts more pressure on the ground, so these areas are called high pressure systems.
   - Air flows from high to low pressure areas thus creating wind.

- The Coriolis effect and friction also contribute to the movement of air. The Coriolis effect is the apparent deflection of moving objects caused by the rotation of the Earth. Objects appear to move to the right in the northern hemisphere and to the left in the southern. This effect causes air to move in a curve as opposed to a straight line. Friction from Earth's surface can also change wind direction and speed.
- As these forces create and cause wind to move, the wind in turn moves the clouds. Eventually some of the water vapor that has condensed into clouds returns to Earth's surface as precipitation thereby redistributing the water elsewhere.
- In sum, while water does return to Earth's surface as precipitation, the clouds with water vapor don't stay in one area due to the wind, so the precipitation does not necessarily return to the exact area of Earth's surface that has been dried out. Other factors, such as runoff and groundwater storage can also affect how water is cycling.

9. To illustrate the idea that air moves from high to low pressure, perform the following demonstration:

- In an area of the room with no draft, spray some of the Diffusion Cloud in a Can.
- Ask students what they observe. The cloud should stay in about the same spot.
- Now place a tray with heated pebbles and the tray of ice next to each other.
- Spray some Diffusion Cloud in a Can above the two trays where they meet.
- Ask students what they observe. The cloud will move from high pressure (ice) to low pressure (pebbles).

To demonstrate the Coriolis effect:

- Split students into small groups.
- Instruct students to place a sheet of paper on an old record, fold over the edges, and tape the paper securely.
- One student should begin to rotate the record clockwise. They may need to balance it on a finger.
- As the record rotates, another student should attempt to draw a straight line on the paper from the outer edge of the record to the center. They should make sure the marker is gently touching the paper. If they press too hard, the record won't be able to rotate.
- After students have tried drawing the line, stop the record and ask the groups to observe what the drawing looks like.
- They will notice that the line is curved despite the fact that the student's movement was straight.
- Repeat the experiment rotating the record counterclockwise. The line will curve in the opposite direction giving students some information about how the apparent deflection differs between the northern and southern hemispheres.

10. Sum up by reiterating that higher temperatures increase evaporation so more water vapor is in the atmosphere but land dries out. Additionally, wind, which is affected by pressure gradients, the Coriolis effect, and friction causes clouds to move resulting in a redistribution of water. Therefore, temperature increases associated with climate change can impact the availability of water in different areas differently and there may be more extremes in precipitation. As with other cycles on Earth, changing one factor such as temperature can change the way the cycle functions.

Extension

In Part 1, have students introduce other factors that may affect the water cycle. For example some students could observe how increased evaporation affects rocky soil, some students could experiment with a container that includes a plant, etc.

As a class, you can track changes in pressure over time using a barometer.

Either as homework or an in-class research assignment, instruct students to find a data set related to the concepts they explored in this lesson. They should use the data set to look at information for their area over the past six months. Sample sets are included below as prompts.

www.ncdc.noaa.gov/sotc/drought/
http://water.weather.gov/precip/
http://data.giss.nasa.gov/gistemp/

Ask students what information they are able to gather from the data sets. What type of information are they not able to get from their data set? This exercise is meant to introduce students to different ways of presenting weather information, but be sure that students understand that six months of data is not enough to draw conclusions about climate change.

Modifications

You can choose to use a larger or smaller plastic container depending upon what is available to you. Be sure to adjust the soil and water levels accordingly.

nysci Water Cycle Lab Sheet

Materials Per Group

2 clear plastic containers
2 thermometers
Tape
1 desk/heat lamp
2 100 mL beakers of water
Saran wrap
Soil
1 stopwatch

Procedure

1. Gather materials.
2. Spread an even layer of soil about 2.5 cm high into one of the plastic containers.
3. Repeat for the second container.
4. Tape a thermometer to the inside of each container above the soil. Be sure that you can still read the thermometer.
5. Cut a sheet of saran wrap large enough to cover one container.
6. Repeat for the second container.
7. Fill two beakers with 100 mL of water in each beaker.
8. Quickly pour 100 mL water evenly over the layer of soil in each of the two plastic containers.
9. Seal both containers with Saran wrap.
10. Place a lamp so that is shining directly onto only one of the containers. The other container should be out of the light.
11. Start the timer.
12. After five minutes, record a first set of observations.
13. After 10 minutes, record a second set of observations.
14. After 15 minutes record a third set of observations.

nysci Observation Sheet

After five minutes, record your observations for the following factors: Temperature _____°C

Soil

Water

Other

After 10 minutes, record your observations for the following factors: Temperature _____°C

Soil

Water

Other

After 15 minutes, record your observations for the following factors: Temperature _____°C

Soil

Water

Other

Module 2: My Carbon Footprint

Carbon Footprint Comparison

A person's carbon footprint is a measurement of the greenhouse gases released into the atmosphere as a result of that person's individual actions. Energy use, food choices, and clothing purchases all contribute to this total. Carbon footprint calculators help individuals become more aware of their impact on the environment and may even give suggestions on steps to minimize their carbon footprint.

Carbon footprint calculators serve as an opportunity for people to learn how their choices impact the environment. They can also be used to help people make comparisons between themselves and others.

In this lesson, students will calculate their carbon footprint using calculators geared towards young adults, and will compare their findings with another class of students to determine what factors might cause differences between the two groups.

Time to Complete 2 Class Periods

Standards Addressed

Common Core English Language Arts
SL.9-10.1, SL.9-10.4, SL.11-12.1, SL.11-12.4
RST.9-10.4, RST.11-12.4

New York State Core Curriculum
Living Environment 7.1 c, 7.2 c, 7.31, 7.3b

New York City Scope and Sequence
Living Environment Unit 9

Key Terms

Carbon Footprint
The total amount of greenhouse gases released due to an individual's actions.

Carbon Footprint Calculator
A tool used to determine the amount of greenhouse gases an individual's actions releases into the atmosphere.

Materials

Computers with Internet
Paper and pencil

Preparation

You must identify another class that will be willing to compare carbon footprints with your students. This means that they will spend time following the same procedure you do to calculate their carbon footprints. They will also need to find time to discuss their results with your students.

Although you could use another class in your school, this lesson works best when the students are given the opportunity to learn about other teenagers they don't know. Using web conferencing or video calling programs like Skype, it is very easy to connect classrooms in different parts of the country or even the world. You do not need special equipment, and students find the use of technology highly engaging.

Two websites that can be useful in finding another classroom are:
www.cilc.org/c/community/collaboration_center.aspx/
http://education.skype.com/

You could also arrange to do the collaboration via e-mail, although a real-time connection has a greater impact.

Visit each of the websites included in the procedure to pick out questions that will spark discussion and to prepare for questions students may ask. For example, a person's carbon footprint is usually reported as metric tons of carbon dioxide, and students may have trouble understanding their results because they are unfamiliar with this unit of measurement.

Some of the sites require students to create a free account. Other carbon footprint calculators can be substituted as desired. You will note that although these calculators are geared towards young adults, young people may not know the answers to all the questions. You may wish to review the "My Carbon Footprint" middle school curriculum for a version of this lesson that asks students to create their own calculator. This can be found at mycarbonfootprint.nysci.org/curriculum.

Procedure

1. Ask students what the term "carbon footprint" means. Why do we care about our carbon footprints? If necessary, review the concept of greenhouse gases, and how increased carbon emissions from fossil fuel use is contributing to global climate change.
2. Introduce the Deutsche Bank Carbon Counter by visiting www.dbcca.com/dbcca/EN/. Tell students that this number represents the amount of greenhouse gases in the atmosphere, and it can be thought of as an indicator of the global carbon footprint. Today students will be investigating how their actions contribute to this large number.
3. Tell students they will use online carbon footprint calculators designed for young adults. Ask them why a tool like a carbon footprint calculator might be important. (Sample answers: to educate, to raise awareness, etc.) Instruct students to take notes while they visit each site. Which questions do they like? What questions are difficult for young people to answer? Would their friends want to use these sites? They should also record their results for each site.
4. Have students calculate their carbon footprint individually using the following carbon footprint calculators. Make sure they record their responses so that they can refer to them later. Some of the calculators measure the amount of carbon students save by taking positive actions, while other calculators indicate how much carbon students emit, so you should instruct the class to pay careful attention to the results they are recording for each site they visit.
5. www.epa.gov/climatechange/kids/calc/
   www.cooltheworld.com/kidscarboncalculator.php
   http://meetthegreens.pbskids.org/features/carbon-calculator.html

6. Have the class share out their data and work together to identify the class high, low and average for both carbon saved and carbon emitted.

7. Ask students to think back to the questions asked by the carbon footprint calculator to see if they can figure out why the class got the responses they did. (Did the class low have the lowest footprint because they don't watch TV? Was the high so high because they drove everywhere?)

8. Now tell students they'll be comparing their carbon footprint to that of another class. Be sure to give the students information about the other class. (i.e. what school they are from, if they are are from a rural or urban area, etc.).

9. Have the students predict which class will have the higher average carbon footprint and discuss why they made this prediction.

10 Before the comparison, have students generate a list of questions they have for the other group that might explain the other group's carbon footprint. They can use the calculators as inspiration. For example, they might ask, "What do you do for fun?" to see how much TV the other students watch, or "What is public transportation like where you live?" to get a sense of their vehicle use.

11. It is now time for the comparison. As noted in the preparation section, you can determine if you will do the comparison in person or using some sort of technology. You and the other educator can open the discussion by asking each group to reveal their high, low and average carbon footprints.

12. Then have the groups take turns asking each other questions to determine why each group had the footprints they had. Once the two groups have had time to discuss and learn about one another, ask them to summarize the conclusions they made about the results and to describe any positive actions they might have learned from the other class.

13. Wrap-up by emphasizing that the carbon footprint calculators the class used really only captured a small number of the choices that we make that impact the environment. It didn't even include food, clothing or cell phones! Tell students that the calculator can make them more aware of where they might be able to make better choices, but they should be mindful of everything they do. They don't have to change everything about their life, but they should be able to identify where they can make changes.

Scientific Modeling

Scientific models can come in different forms, and they allow scientists and other professionals to explore phenomenon that may be impossible to recreate in a lab. Climate models are key to understanding how the climate works, how it might change over time, and what that change could mean. Since climate change is so complex and can be influenced by many factors, climate models themselves are very complex. By exploring what models are and how they work, students will have a better understanding of the nature of science and how we learn about climate change. This will address misconceptions and help students evaluate misinformation presented in the media and elsewhere.

In this lesson, students will create their own basic models to predict how two factors will affect the rate at which an ice cube melts. They will use their experience building this basic model to think about how models can be used to predict climate change.

Time to Complete 2 Class Periods

Standards Addressed

Common Core English Language Arts
RST.9-10.3, RST.11-12.3
RST.9-10.4, RST.11-12.4

New York State Core Curriculum
Earth Science 2.1e, 2.1g, Standard 6

New York City Scope and Sequence
Earth Science Unit 7

Key Terms

Climate Modeling
The use of equations and other quantitative information to create representations of how Earth's atmosphere, land and water interact. These models help explain past, current and future climate conditions.

Materials

Stopwatches (1 per group)
Ice cubes (3 per group)
10 mL test tubes (1 per group)
Funnels (1 per group) *The funnel should be small enough to fit comfortably in a 10 mL test tube.*
Test tube rack (1 per group)
Beaker (1 per group)
Salt (1 tablespoon per group)
Data Collection Sheet (1 per student)

Preparation

Be sure to fill ice cube trays and freeze the day before. The ice cubes should be the same size, so take care when filling the trays.

To save time, measure out 1 tablespoon of salt for each group prior to the start of class.

Make copies of the data collection sheet.

Procedure: Introduction

1. Begin by asking students what the term "scientific model" means. After eliciting responses from the class, tell students that models can come in different forms. Some of them are physical, such as a model of a bridge, while other models come in the form of equations and graphs. Models are used all the time for different purposes. For example, weather-forecasters use models to help us decide if we need to bring an umbrella in the morning and advertisers use modeling to help decide where to place ads.
2. Ask students why models are important. Sometimes there is too much data to actually measure so we use different samples to build a model that can tell us about the whole. Other times, it is impossible to test the real-thing, as in the case of a bridge, so we use a model to test what will happen before building the actual bridge. In the case of climate change, we can't travel to the future to see how the climate will differ, but we can use the data from the past and present to build predictive models.
3. Show students the Deutsche Bank Carbon Counter: www.dbcca.com/dbcca/EN/
   The Carbon Counter shows a real-time count of the long-lived greenhouse gases in Earth's atmosphere. Can you measure all of the greenhouses gases being emitted at all times? (No)
   Ask students where they think the number for the Carbon Counter comes from.
4. Explain that the number comes from a model. Data from models helps researchers communicate accurate scientific data to the public. To create the Carbon Counter, scientists at the Massachusetts Institute of Technology (MIT) used observations from all over the globe. They put information from the observations into different equations that helped them to understand and even predict levels of greenhouse gases in the atmosphere.

   John Rilley, co-director of the MIT Joint Program on the Science and Policy of Global Change, and senior lecturer, Sloan School of Management, explains the process of calculating the number in the following way:

   We used measurements from an extensive global network and bring those together. The challenge of making this a real time measurement was to have an index that pulls together the many different GHGs (greenhouse gases) into a single measurement that makes sense.

   These measurements lag real time a little bit because of the time it takes to measure the concentrations. So we needed to forecast forward a little bit in order to get the real time measure.

   Tell students that today they will be creating their own models. They will use their models to predict information about the rate at which ice cubes melt.

Experimentation

5. Split students into smaller groups. Each group will gather their own data, and then the class will compile the data. Tell students that it is important to take multiple measurements to ensure accuracy.
6. Each group will receive one 10 mL test tube, one small funnel, a stopwatch, and one test tube rack. Instruct students to place the tube in the rack and then place one funnel inside the tube. Tell them that they will place an ice cube in the funnel, and use the stopwatch and data collection sheet to observe how much water melts into the test tube at certain points in time. Be sure that students understand that if the water level in the tube reaches the funnel, they may have to briefly lift the funnel out of the tube to get an accurate reading. Also, if the water level gets too high, students can dump the water into the beaker and then continue taking measurements by adding the new amount in the test tube to the amount of water in the beaker.

7. Since this experiment is time sensitive, each group should assign at least one member to each of the following roles prior to distribution of the ice cubes

   Recorder: This student will record their group's information and share it on the board for the whole class to see.

   Timekeeper: This student will monitor the time and instruct group members when to take a measurement.

   Measurement: This student will measure and report the water level in the test tube.

   Students can take turns with these different tasks and work together as long as each of the tasks is accomplished.

8. The groups will use the data collection sheets to keep track of data. After all of the groups have completed their set-up and been given instructions, you can distribute one ice cube to each group, and instruct them to complete Part 1 of the sheet.

9. Once students have completed Part 1, they can dispose of the liquid in the tube as well as whatever may be left of the ice cube.

10. After Part 1 has been completed, groups should share their data on the board for the whole class to see.

11. Instruct students to use the whole class data set to create a scatter plot showing the relationship between time and the amount of water that has melted into the test tube. This can be done either individually or in the smaller groups.

12. Once the graphs have been completed, ask students to describe the relationship and rate of change.

13. Now students should complete Part 2 of the worksheet. This part asks students to make a prediction of how much water will melt given different periods of time.

14. Instruct students to test their predictions using Part 3 of the worksheet. To test their predictions, students should repeat the set-up from step 6. This time, they do not have to take measurements until 18 minutes have elapsed.

15. While students are waiting for the 18-minute mark, initiate a class discussion about how models, such as the graphs they've created, might relate to climate change. Tell students that models help scientists make predictions about climate change. They use the data available to them to create equations and graphs, and continue collecting data to check their models and refine them. Of course, many factors contribute to climate change, so climate models are much more complex than the ones students built today. Ask students what type of factors might go into climate models. Answers may include amount of greenhouses gases, amount of cloud cover, or amount of trees and other vegetation. How might the number of factors affect the models?

16. Now return to the experiment. After students have taken their measurements for Part 3, ask if their predictions were correct. Were they close? Tell students that sometimes they may hear the word "uncertainty" when people are talking about climate change. In science, "uncertainty" doesn't mean not knowing. Instead, it means that observations or data may fall within a range. When students made predictions about melting, the amount of water they predicted may not have matched exactly with the observed result, but their observations should have fallen within the range they expected. Tell students to refine their model using the new data. They can do this by incorporating the new data into the graphs they created.

17. Now students will observe what happens when another factor is added to the ice melt model. Like time, salt can affect melting by lowering the freezing point of water. Students should now complete Part 4 of the worksheet, which asks groups to record melt given a certain temperature plus the addition of salt.
18. Again, students will place the funnel in a test tube to record melting. Students should quickly roll the ice cube in the salt so it is well coated, and then place the ice cube in the funnel. This will prevent excess salt from clogging the funnel.
19. Again, a representative from each group should share their group's results on the board, and then groups should create graphs representing the data.
20. Ask students how their model has changed given the introduction of a second factor. They may notice that the salt hastens the rate of melting even more than observed in Part 1 and that their graph has changed to reflect this new information.
21. *Optional* You can have students make and test predictions for Part 4 of the worksheet.

22 As you wrap-up this lesson, emphasize that it is important for the public to understand how scientists make climate predictions so they themselves can discern between reliable and non-reliable sources of climate change information.

Modification

The purpose of this lesson is to explore scientific modeling and think about how modeling is used in the context of climate change. This lesson uses ice melt to explore scientific modeling, but you can substitute a different experiment using a similar process if you wish.

Rather than starting with a new ice cube in Step 14, you can have students graph as the experiment is going on. This will allow students to analyze their graphs and make predictions quickly and then test their prediction using the same ice cube from Step 8. They will only have four minutes to make their prediction, so be sure to warn them that they should be analyzing their data from the start of the experiment and they should be prepared to test their predictions quickly. The conversation relating the experiment to climate models should then follow this test. Again, the major purpose of this lesson is the process, so if you do choose this modification, be sure that students have time to reflect on the process of collecting data, graphing and predicting, and then refining based on new data.

nysci Scientific Modeling Data Collection Sheet

Part 1

Record the amount of water that has melted into the test tube at the following times:

2 min.	4 min.	6 min.	8 min.	10 min.	12 min.	14 min.
mL	mL	mL	mL	mL	mL	mL

Part 2

Make a prediction of how much water will have melted at the following times:

18 min.	20 min.	22 min.
mL	mL	mL

Why did you make those predictions?____

____

Part 3

Test your predictions and record your results.

18 min.	20 min.	22 min.
mL	mL	mL

Part 4

Record the level of water in the test tube given the following times plus the addition of salt.

2 min.	4 min.	6 min.	8 min.	10 min.	12 min.	14 min.
mL	mL	mL	mL	mL	mL	mL

Exploring One Metric Ton: Visualizing Large Numbers

When the public encounters information about the amount of greenhouse gases emitted into the atmosphere, the number and units are often unfamiliar or difficult to conceptualize. In this lesson, students will use the Deutsche Bank Carbon Counter to help unpack large numbers relevant to climate change, including the concept of a metric ton.

Time Required: 2 class periods

Key Terms

Metric Ton
A unit of mass.

Mass
The amount of matter in an object.

Weight
The force of gravity on an object.

Climate Change Mitigation
Actions that reduce the amount of greenhouse gases entering the atmosphere in order to reduce the effects of climate change.

Climate Change Adaptation
Actions or strategies that help humans cope with changes that will be caused by or have been caused by climate change.

Standards Addressed

Common Core English Language Arts
SL.9-10.4, SL.9-10.5, SL.11-12.4, SL.11-12.5
RST.9-10.1, RST.9-10.3, RST.9-10.7, RST.11-12.1, RST.11-12.3, RST.11-12.7

Common Core Mathematics
Modeling Standards
A-REI.1

New York State Core Curriculum
Living Environment 7.1c, 7.2c, 7.3a, 7.3b

New York City Scope and Sequence
Living Environment Unit 9

Materials

Computer with Internet access
Calculator
Scales (1 per group of students)
Balloons (2 per group of students)

Preparation

The balloons should all weigh the same amount. Since balloons can be so light, be sure to test out step 6 prior to class to ensure that the weight of the balloon actually registers on the scale. If the scale is not sensitive enough, you can create a makeshift balance using a ruler, pencil or other easily accessible material.

Procedure

1. Direct students to the following website: www.dbcca.com/dbcca/EN/.
They will see the Deutsche Bank Carbon Counter. Ask students to articulate the number they see on the screen. Ask students what this number represents. This counter shows an up-to-date amount of metric tons of greenhouse gases in the atmosphere. There are many types of greenhouse gases but greenhouse gas concentrations are frequently expressed as an equivalent amount of carbon dioxide so students will be working with metric tons of carbon as a starting point. You should also highlight how quickly the number changes. Greenhouse gases are being emitted at an increasing rate and these gases are building up in the atmosphere.
2. Tell students that today they will identify different ways of helping people better understand a number this large.
3. First, students must consider the unit. Tell students that a metric ton is a unit of mass equivalent to about 2,204.62 pounds.
4. It can be difficult for students to understand that gas can be expressed in terms of metric tons. Take a moment to review the idea that gases are made up of atoms, atoms have mass, and the force of gravity gives mass weight.
5. To further demonstrate the concept that gases have weight, instruct students to perform the following procedure:

- In groups, instruct students to weigh an empty balloon with no air in it, and record the weight.
- Students should then inflate the balloon and weigh it again. Depending upon the type of scale available, students may have to put their hands near the balloon to take a measurement, but they should not touch or push down on the balloon.
- Students will notice that the inflated balloon weighs more than the balloon with no air.
- In order to drive this demonstration home, have students repeat this experiment with another balloon. They should again see an increase when the balloon is inflated.
- Point out that the air is made up of different gases, and that these different gases can have different weights.

6. Tell students that now that they've explored the unit, they will do research to find some actions or items that release the equivalent of one metric ton of carbon dioxide. The concept or item they choose should be something other students might be familiar with. It would be useful to do an example as a large group.

- For example, two incandescent bulbs produce roughly one metric ton of carbon dioxide per year.[1]
- Students do not have to choose one large action or item, but could instead perform calculations to show how many smaller items add up to a metric ton. For example, the production of a four-ounce steak results in 70.4 ounces of carbon dioxide being created, which is equal to 4.4 pounds. Multiply 4.4 pounds[2] by 501 to reach 2,204.4 pounds. A metric ton is equivalent to 2,204.62 pounds. This means about 501 steaks produce one metric ton of carbon.

7. Some resources to help students get started are:
http://visualization.geblogs.com/visualization/co2/
www.epa.gov/cleanenergy/energy-resources/calculator.html

   Instruct students to be careful when they are researching. Not only should they be using valid sources, but they should make sure that they take note of the units being used. They may have to perform calculations to express the actions in terms of metric tons.

1. http://visualization.geblogs.com/visualization/co2/#/bulbs_100w
2. http://visualization.geblogs.com/visualization/co2/#/food_beefsteak

8. Once students have completed their calculations, they should present their research. You may wish to have students create visuals to accompany their presentation.
9. Tell students that the websites and resources they used to identify how much carbon dioxide is produced by various actions are useful in helping the public understand what actions they can take to reduce the release of greenhouse gases into the atmosphere. Climate mitigation is a term that refers to these types of actions that seek to lesson climate change's impact by reducing the amount of greenhouse gases released into the atmosphere.
10. Now that students have explored the concept of one metric ton, return to the Carbon Counter. Again, ask students what number they see. They have been working with one metric ton, but the Carbon Counter shows that over 3 trillion metric tons are present in the atmosphere.
11. Ask students how the research they did might have differed if they were trying to identify actions equivalent to an amount this large. They may respond that they would have to work with much larger actions or items or that it would be difficult to get close to this number.
12. Since the amount of greenhouse gases in the atmosphere is already so large, climate mitigation is no longer the only course of action. Scientists have already begun to see the effects of climate change, and so scientists, policy makers, and even the public have begun to take actions that will help people cope with a changing climate. This is called climate adaptation.
13. Wrap up the lesson by telling students that tools such as the Carbon Counter help draw attention to the issue of climate change. Although the amount of greenhouse gases in the atmosphere may be hard to visualize, by exploring other ways of relating to units like one metric ton, we can begin to internalize what is actually happening to our atmosphere.

Modifications

The research portion of the lesson can be completed as homework and more time can be spent on the presentation.

Module 3: Taking Action

Carbon Trading

Introduction

Industries create large amounts of greenhouse gases that cause global climate change. Carbon trading is one proposed mechanism for forcing businesses to reduce their greenhouse gas emissions. Carbon trading works as part of a cap-and-trade system in which the government decides to limit, or cap, the amount of carbon industries may produce. At the start of this type of system, companies either receive an allotted number of carbon credits, or an auction takes place and companies bid on these credits. Each credit represents a certain amount of carbon that the company may emit or release into the atmosphere. If they go over their allotted number of credits, they either need to buy credits from other companies, or pay a fine.

This game introduces students to the idea of a carbon trading system, and requires students to use their critical thinking skills. The game highlights many of the problems and complexities associated with this type of scheme. For instance, companies may wish to invest money in research and development to design new, greener technologies in order to reduce their emissions in the hope that they make a profit by selling their extra credits, but this profit is not guaranteed. Similarly, if the fines for going over emissions allowances are not high enough, companies may not invest in research and development and instead decide to just pay the fine. Additionally, if the government sees that companies routinely come in under their allotment, the government may decide to lower the cap. By not limiting their pollution levels, companies may ensure that the government does not lower the cap.

Finally, monitoring how much pollution each individual company may release is difficult, and companies can get away with reducing more than their share without having to pay for it.

Key Terms

Carbon Credit:
A permit to release a certain amount of carbon dioxide into the atmosphere.

Cap and Trade:
A system in which an upper limit is put on the amount of pollution that may be emitted by members of the system. Each member is allotted a certain number of credits, and members may buy credits from one another in order to comply with the limit.

Carbon Trading:
A cap-and-trade system dealing specifically with carbon dioxide.

Time to Complete: 1 class period

Standards Addressed

Common Core Mathematics
S-CP.5, S-CP.7

New York State Core Curriculum
Living Environment 7.2c, 7.3a, 7.3b

New York City Scope and Sequence
Living Environment Unit 9

Materials

Die
Play money
Carbon Trading Game cards
(included at the end of this lesson)
Poker chips, Jenga blocks, etc. to act as carbon credits
Clock or timer to keep track of trading time

Preparation

This game presents a simplified version of complex carbon trading systems, and the rules of the game can be changed to reinforce different content. After students have become more familiar with the carbon trading system, they can generate their own game cards. Some of the game cards do not have a direct link to the carbon trading system, but can inspire class discussion about sources of greenhouse gases and offsetting carbon emissions. Be sure to read through all of the cards to facilitate this discussion.

Procedure

1. Introduce the idea of a cap-and-trade and a carbon trading system. Tell students that the cap is on an entire industry rather than on a specific company. (For example, as a whole group, auto manufacturers can only release 80 metric tons of carbon per year. That means one company might release 10 metric tons, while another might release 20 metric tons, and everything is acceptable as long as the group total stays under 80 metric tons.)
2. As a class, decide on an industry (i.e. auto manufacturers, coal plants, something fictional, etc.).
3. Split the class into groups. Each group will be a business. They can pick a business name if they'd like.
4. At the start of the game, each business will start with $1,000.
5. At the start of the game, each business will start with 20 one-metric-ton-carbon-emission credits, represented by poker chips, jenga pieces, etc. This means that the business can emit 20 metric tons of carbon without getting fined. The class will play four rounds. If they go over 20 metric tons at the end of the four rounds they will be fined $300. Each round represents one year.
6. To see how much carbon a business emits, they will roll a die. The teacher will act as a banker/ the government. For example, if a group rolls a four, the teacher will collect four chips.
7. After rounds one, two and three, companies will have four minutes to trade with each other. For example, if in the first round a group rolls a low number, they may choose to sell some of their credits to another business who may be in danger of going over. Or they can choose keep their credits. The group selling the credits can charge as much as they'd like. (To facilitate trading rounds, it may be best to have one representative from each group be the spokesperson and announce the deal their company is willing to make. Additionally, the teacher may wish to prompt companies to make counter offers.)
8. If a group rolls a one or a six they will pull a card. These cards can either be good or bad for the business and may involve choices.
9. It may help to designate one student as the recorder. This student can use the whiteboard to keep track of the amount of credits and money each company has after each round. This will help students visualize the teams that might be selling credits and those that might be buying credits.
10. The group with the most credits AND the most money wins. If there is a group that has the most money and another with the most credits, a class discussion/vote will decide upon the winner. Is it better to have credits or money? Alternatively, keep track of how much companies are selling carbon for, and use that as the value of a credit to calculate the winner.
11. After the four rounds, discuss the fine. Was $300 enough to make the business worried about going over? What cards did companies get, and what did those cards tell us about how successful a system like this could be in encouraging companies to reduce the amount of pollution they create.
12. Now, play four rounds with a fine of $700. How does this compare to the game when there was a $300 fine?
13. Sometimes the government sees that an industry regularly comes in under their allotment so they

choose to lower the cap. You can choose to play another four rounds where companies are only allowed 15 credits. Alternatively, play with two dice, so that companies emit more pollution, making it more difficult to come in under the cap.

14. Wrap up the lesson by asking students to describe how this system was successful or not successful in encouraging companies to reduce carbon emissions. They may mention factors such as uncertainty and rapid changes in the price of carbon. Remind students that this is just one economic strategy for reducing the output of carbon, but other strategies exist. For example, researchers at MIT's *Joint Program on the Science and Policy of Global Change* recently released a study indicating that a carbon tax could improve the economy while reducing levels of pollution. Dr. John Reilly, a co-author of the study, explains the difference between a cap-and-trade system and a carbon tax:

    "A cap-and-trade system creates allowances that firms who emit pollution must turn in equal to the amount of their emissions. These allowances can be bought and sold and a "price" for carbon is established. The price will depend on the amount of allowances created relative to expected demand. Because expected demand can vary, this price will vary just as the price for crude oil varies. In a carbon tax system the government directly sets the tax rate, and so it only changes as prescribed by the government agency responsible for setting it. Both a carbon tax and a cap-and-trade system can create revenue for the government through either tax collections or the auction of allowances. The government can fund existing programs, cut other taxes, or just send a check to every household. With a cap-and-trade system, the government can also just give the allowances away; but since the goal is to establish a market for them, it's essentially equivalent to giving the revenue away."

15. Finish by telling students that the critical thinking skills they used today are the same ones policy makers must use when developing strategies for combating and preparing for climate change.

Carbon Trading Game Cards

You have the option of investing in research and development. You can choose to pay $100 to the banker right now. If you pay $100, in future turns, if you roll a 5 or 6 you will still only pay 3 credits. Or you can choose not to invest.

The public likes that you are trying to be a cleaner company, and they start buying more of your products. Get 1 credit back.

You start an education campaign to help the community become aware of climate change. Get 2 credits back.

You plant trees to offset your emissions. Get 1 credit back.

Your CEO decides to stop taking long flights to business meetings.
Get 1 credit back.

There is an accident at your business and you release extra pollution. Pay 3 credits.

You have the option of investing in research and development. You can choose to pay $200 to the banker right now. If you pay $200, in future turns, if you roll a 4, 5 or 6 you will still only pay 3 credits. Or you can choose not to invest.

A rival company is willing to give you a deal. Pay $200 to get 2 credits back.

You cut down trees to build a new factory. Lose 2 credits.

You have not been properly reporting your carbon emissions data. Pay a $200 fine and lose 2 credits.

Hydroelectric Power

Introduction

Finding alternatives to traditional power sources such as coal, oil and natural gas is a key priority in lessening the effects of climate change. No single energy source will be the solution to our energy needs, and although energy sources such as solar and wind power have been growing in visibility, there are other alternatives that are increasing in popularity and feasibility.

In this lesson, students will explore hydroelectric energy by designing hydropower turbines. They will have the opportunity to select the size, number and position of turbine blades to examine different factors that must be considered when harnessing this type of energy. They will then use physics concepts such as potential and kinetic energy to describe and improve their designs.

Time to Complete: 2–3 class periods

Key Terms

Renewable Energy
Energy that comes from an unlimited source.

Alternative Energy
Energy that can replace or complement the use of fossil fuels.

Hydroelectric Power
Electrical energy produced by the flowing of water.

Potential Energy
The energy of an object due to its position.

Kinetic Energy
The energy of an object due to is motion.

Standards Addressed

Common Core English Language Arts
W.9-10.2, W.11-12.2, W.9-10.4, W.11-12.4
Sl.9-10.1, SL.11-12.1, SL.9-10.4, SL.11-12.4

New York State Core Curriculum
Earth Science 1.1i, 1.2g
Living Environment 7.2c, 7.3a
Chemistry 4.1a
Physics 4.1b, 4.1c, 4.1d, 4.1h

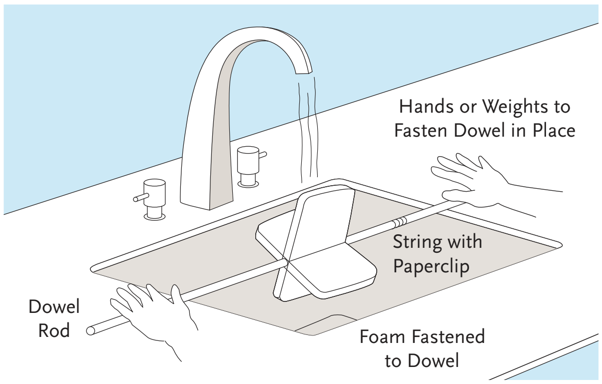
New York City Scope and Sequence
Earth Science Unit 4
Living Environment Unit 9
Chemistry Unit 1, Unit 3
Physics Unit 3

Materials

Goggles
Source of water (faucet, pitchers or water, etc.)
Wooden dowels
Foam core, plastic cups, other materials to create turbine blades
Scissors or X-Acto knives
String
Paperclip
Paper and pencil
Stopwatches (optional)
Hot glue gun

Preparation

You should create an example of a turbine as a demonstration and be sure to test it. The dowel must be able to turn freely under the water, so depending upon the size of the sink, you may wish to cut the dowels or purchase dowels that rest on the edge of the sink. You should also either loosely hold the dowel or put small weights on either side of the dowel to prevent it from spinning off the sink.



Example of turbine set-up

If you do not have a sink, you can have students pour water from pitchers over a container or basin. Again, the dowel must be able to move freely without spinning off the basin.

Procedure

Safety precautions should be exercised when cutting the turbine blades.

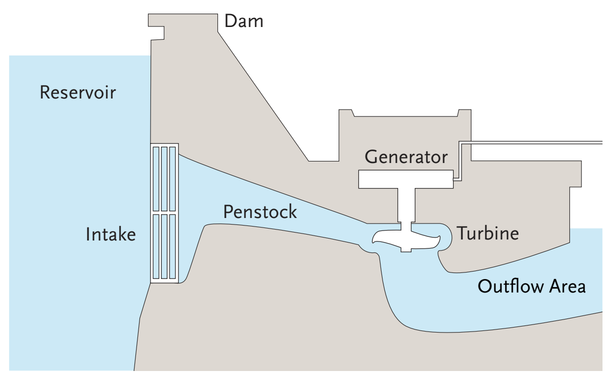
1. Begin by asking students to name different types of renewable energy sources. Common responses may include solar, wind, hydropower, biomass (biofuels) and geothermal energy.

   You should remind students that not all alternative energy sources are renewable. If needed, take a few moments to review the difference.

2. Tell students that today they will focus on hydroelectric power. If needed, work as a group to define the term. Once the group has a working definition, ask students to take a few minutes to individually draw what they think a hydroelectric power plant might look like. After students have been given the opportunity to brainstorm, ask a few students to share their drawings.

3. Using the students' work as a starting point, review the following points as a class:

   - There are various ways to use power from water, but to produce electricity that we can use, we need more than just water, we need a turbine.
   - Water flows from high to low, and by taking advantage of this fact, we can use water to spin a turbine and create electricity. The turbine rotates a shaft in a generator and produces electricity.
   - The higher up a water source is, the more potential energy it has and the more kinetic energy it will have as it flows downhill. But how did the water get this potential energy in the first place? The sun. The sun caused the water to evaporate and eventually turn the water to rain that deposits it at higher locations. This water eventually flows back down completing the water cycle. Even when we're not directly harnessing energy from the sun, the sun indirectly provides many types of renewable energy.
   - Hydroelectric power plants often involve dams and reservoirs. Water from a river or lake is held back by a dam and stored in the reservoir until it eventually flows to an intake area. It then flows through a gated channel called a penstock. Finally, the water reaches the turbine and then continues to flow to an outtake area.



4. Tell students that today they will work in groups to design turbines. Show the students the example you created and explain to the class that their challenge is to see whose system can move a paperclip from the bottom of the sink up to the dowel in the least amount of time.
5. After splitting students into groups, explain that each group must complete a labeled drawing of their design before they can start to build. Inform students that they can select the materials, shape, size, number and placement of the blades on the turbine. They will then hot glue their blades onto the dowel. Every group must attach a paperclip to the end of a string, and then tie the other end of the string to the dowel so that the paperclip is able to sit in the sink or basin. Once they have built their turbines, they will explain their reasoning and rationale for their design process, present their turbine to the group, and then test them.
6. Allow students time to discuss and draw.
7. Once you have approved of a group's drawing, they may begin building their turbine.
8. After all groups have completed building and the hot glue has dried, it is time to test. The groups will test one at a time so the other groups are able to observe the outcome of each test. Prior to testing, the groups should explain why they designed their turbine the way they did.
9. To test, a group member should place the turbine so that the paperclip hangs in the sink or basin. A group member can then begin pouring water over the turbine blades. (Make sure that you instruct all groups to pour at roughly the same speed or turn the faucet roughly the same amount to make a rough comparison of the turbines.) If you wish, other group members can use stopwatches to determine how quickly it takes for the paperclip to reach the dowel. The turbines may move quickly, so groups can test more than once.
10. After all groups have finished testing, tell students that they will now make recommendations about how they can improve their design. Students (either in groups or individually) should create a drawing of the entire system (water, sink, turbine, etc.) and either annotate their drawing or write a short description of what improvement should be made. Students should be sure to use the following terms

    friction
    efficiency
    potential energy
    kinetic energy
    work

    As an example, a paragraph might include some of the following:

    Due to friction between the counter surface and the dowel rod, the turbine's efficiency was reduced because the blades could not turn as fast as possible. Because of this, the distance the blades moved was lessened—even as the force of the water remained constant—greatly reducing the amount of work being performed by the turbine. To increase the potential energy of the system, we might try using soap to lubricate the ends of the rods, in turn, reducing friction at the point of contact with the counter surface, allowing the blades to spin more freely (and quicker). This should increase the kinetic energy of the system as a whole.
11. As a final discussion point, ask students if they think hydroelectric energy is a viable source of alternative energy. Why or why not? Are there certain conditions or certain uses for which hydroelectric power is best suited? How might a hydroelectric power plant affect the environment? You may prompt students by asking them about the abundance of water on Earth, or mentioning that hydropower is the most widely used renewable energy source in the world, but it is not without its trade-offs. For instance, many hydroelectric plants require a dam,

and the creation of dams can affect the migration, mating and food sources of animals living in the water. Emphasize again that no single source of energy will replace fossil fuels, so it is important that we consider when and where different sources will work best.

Extensions

You can direct students to create turbines that can be hooked up to a voltmeter or digital multi-meter and then measure the voltage produced.

Have students modify their designs based on their ideas from step 11 and then retest their turbines.

Using rubber tubing of different lengths and thicknesses, instruct students to experiment with the height of the water source and/or the water pressure. Height and pressure are two main factors to consider in hydroelectric power plant design.

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