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| **Target Grade***:*  High School | **Lesson Title:** **CO2: Find Out What It Means to You!**  **Developed by: Erin Woulfe**  **East Greenwich High School**  **East Greenwich, Rhode Island** |
| **Topic**: Chemistry |
| **State Standard – NGSS Performance Expectation(s)**  **HS-ESS2-6 - Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.**[Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.] | |
| **Lesson Performance Expectations** | |
| ***Lesson Length –*** *One 50 - 55-minute class period Lesson can be modified accordingly* | |
| ***Materials***   * [Carbon Cycle Model Blank](https://blossoms.mit.edu/sites/default/files/video/download/Carbon-Cycle-Model-Blank.pdf) * [Carbon Cycle Model with answers](https://blossoms.mit.edu/sites/default/files/video/download/Carbon-Cycle-Model-answer-key.pdf) (PDF) * [Carbon Cycle Process Signs](https://blossoms.mit.edu/sites/default/files/video/download/Carbon-Cycle-Process-Signs.pdf) (PDF) * [Carbon Cycle Product Signs](https://blossoms.mit.edu/sites/default/files/video/download/Carbon-Cycle-Product-Signs.pdf) (PDF) * [Data Blossoms Experiment - Activity4](https://blossoms.mit.edu/sites/default/files/video/download/Data-Blossoms-Experiment-Activity4.pdf) (PDF) * Graph Paper (or have the students use Excel or other graphing software) * Poster Paper (optional) | |
| **Lesson Objectives (main ideas):**   * How is carbon dioxide introduced and removed into and out of the Earth’s atmospheric system? * How can we know whether the **patterns** observed are just the natural cycles of matter on Earth or whether these **patterns** of carbon dioxide concentrations are abnormal in some sense? * What **effect** does increased carbon dioxide have on weather or climate? | |
| **Phenomenon**  **CO2 is a greenhouse gas that prevents energy from escaping the Earth’s atmosphere.** | |

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| [Gather Phase](#bookmark) | |
| **What Is the Teacher Doing?**  The concept for this lesson is an important one as all students live on a planet that is experiencing changes in temperature and weather patterns. Over time, these changes could impact overall changes in climate. Changes in climate would have an impact on recreation, agriculture and economic development. Climate change is a huge concept and, while it may seem to be beyond a student’s purview, increasing student awareness of and connections to climate change will provide greater recognition of ways to mitigate the problem. | **What are the Students (Ss) Doing?**  The students watch the first segment (**0:00 – 4:05**) of the BLOSSOMS video. From **0:55 – 4:05** of the first segment, students will watch a NASA video depicting a supercomputer model of CO2 and CO movement in the atmosphere during a one-year period. |
| **In the Classroom (Teacher):**  Teacher should pause the video at the **4:05** mark of the video. Teacher should encourage students to share their observations and questions with a partner. Teacher facilitates an all-class discussion where students share their observations and questions. Teacher should record the student questions on a white board or poster paper.  *Teachers should “look for” evidence of the following when students are using the practice of* ***Asking***  ***Questions****.*  ***Evidence Bullets (Look Fors):***   * pose questions that are testable * formulate testable hypotheses and pose questions in science that seek evidence relevant to the question * ask questions that require relevant empirical evidence   ask questions to determine relationships between independent and dependent variables.  From **4:07 – 5:47** of the BLOSSOMS videothe video teacher shares some of her questions such as:   * How is carbon dioxide introduced and removed into and out of the Earth’s atmospheric system? * How can we know whether the **patterns** observed are just the natural cycles of matter on Earth or whether these **patterns** of carbon dioxide concentrations are abnormal in some sense? * What **effect** does increased carbon dioxide have on weather or climate?   These questions should parallel some of the questions that the students have generated and shared during the whole class discussion.  The teacher should pause the BLOSSOMS video at the **5:45** mark and hand out materials. (NOTE: This can be done in a classroom setting however a large empty space like a hallway, gym, or classroom with desks pushed aside might be valuable for building the large cycle. The [Carbon Cycle Product Signs](https://blossoms.mit.edu/sites/default/files/video/download/Carbon-Cycle-Product-Signs.pdf)  could also be placed on top of desks if necessary. With the video paused at the **5:45** mark, the teacher will divide students into small groups of 2 -3 students. Each group/class will receive a set of [Carbon Cycle Product Signs](https://blossoms.mit.edu/sites/default/files/video/download/Carbon-Cycle-Product-Signs.pdf) and [Carbon Cycle Process Signs](https://blossoms.mit.edu/sites/default/files/video/download/Carbon-Cycle-Process-Signs.pdf) along with a [Carbon Cycle Model Blank](https://blossoms.mit.edu/sites/default/files/video/download/Carbon-Cycle-Model-Blank.pdf)  Have each group take **3 to 5 minutes** to assign their product to one of the processes. Teacher should walk around the room to formatively assess whether students are classifying the product with the correct processes. Once the products have been categorized with the processes, students will take **10 to 12 minutes** to link the process between the products to begin building their Carbon Cycle Model. While the students are working on their models the teacher should visit the groups to formatively assess their progress and use prompts to help the students keep on track for the lesson.  Once the groups have finished their initial Carbon Cycle Models the teacher should facilitate a whole-class sharing of each groups model and solicit feedback from the groups on each model. (NOTE: This could be done as a gallery walk where the models are posted around the room and the students can place sticky notes with questions directly on the models to help clarify and refine the models).  *Teachers should “look for” evidence of the following when students are using the practice of*  ***Developing and Using Models.***  ***Evidence Bullets (Look Fors):***   * use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems * reflect on the components of models of simple systems with uncertain and less   predictable factors. | **In the Classroom (Students):**  At the end of the first video segment, students are asked to discuss any observations and **questions** **(**see evidence bullets in the teacher column) with a partner relevant to the video. After discussing with their partner, the students should share their questions and observations with the entire class.  The video resumes at the **4:07** mark. The video teacher shares some of her questions:   * How is carbon dioxide introduced and removed into and out of the Earth’s atmospheric system? * How can we know whether the **patterns** observed are just the natural cycles of matter on Earth or whether these **patterns** of carbon dioxide concentrations are abnormal in some sense? * What **effect** does increased carbon dioxide have on weather or climate?   At the **5:45** point of the video the video teacher pauses the following prompt:   * Decide with your group which part of the process your samples represent. Then begin to develop your carbon cycle models.   The teacher provides student groups with the following:   * [Carbon Cycle Model Blank](https://blossoms.mit.edu/sites/default/files/video/download/Carbon-Cycle-Model-Blank.pdf) * [Carbon Cycle Process Signs](https://blossoms.mit.edu/sites/default/files/video/download/Carbon-Cycle-Process-Signs.pdf) * [Carbon Cycle Product Signs](https://blossoms.mit.edu/sites/default/files/video/download/Carbon-Cycle-Product-Signs.pdf)   Students use the [Carbon Cycle Product Signs](https://blossoms.mit.edu/sites/default/files/video/download/Carbon-Cycle-Product-Signs.pdf) and the [Carbon Cycle Process Signs](https://blossoms.mit.edu/sites/default/files/video/download/Carbon-Cycle-Process-Signs.pdf) to create a **model** t**(**see evidence bullets in the teacher column) hat shows which product is connected to which process. Their **model** should specifically demonstrate how CO2 enters into and exits from our atmosphere. The students can use the [Carbon Cycle Model Blank](https://blossoms.mit.edu/sites/default/files/video/download/Carbon-Cycle-Model-Blank.pdf)  to help them develop their model. The boxes on the model blank represent the products and the clouds represent the processes. |
| **[Reason Phase](#bookmark1)** | |
| **In the Classroom (Teacher):**  At the **5:55** point the teacher resumes the video and discusses some of the processes and how CO2 enters into and exists from our atmosphere. At the **7:09** mark the video teacher prompts the students to:   * Evaluate and refine your models to show what **causes** CO2 to move into and out of the atmosphere.   Teacher should emphasize that students are looking for possible **causes** of CO2 moving into and out of our atmosphere. Once the groups have finished, teacher then asks students to share their **models** and **causes** for CO2 movement as a whole class. This portion of the lesson should take **12 minutes**.  *Teachers should “look for” evidence of the following when students are using the practice of* ***Arguing***  ***from Evidence:***  ***Evidence Bullets (Look Fors):***   * Use models to understand arguments * Use evidence to generate or support explanations * Reflect on the best evidence supporting an explanation * Listen and make sense of other’s explanations * Evaluate and share weaknesses in one’s own arguments and collaborate to seek better   evidence.  Resuming the video at the **7:10** mark, the video teacher then relates sources and absorbers of CO2 sharing the following reactions:  Combustion reaction of gasoline  2C8H18 + 25O2 🡪 16CO2 + 18H2O  Photosynthesis  6CO2 + 6H2O 🡪 C6H12O6 + 6CO2  The video teacher also shares the Monthly Mean CO2 Graph from Mauna Loa Observatory. She also asks the question, “How does an increased concentration of CO2 **effect** atmospheric temperature?”. The classroom teacher may want to write the reaction equations and the question on a white board or poster paper.  The video teacher then describes the experiment that models and investigation into the question posed earlier on the effect of increased concentration of CO2 on atmospheric temperature. At the **11:24** mark, the classroom teacher should pause the BLOSSOMS video in order for the students to turn to a partner and make a prediction about what will happen in the model when the heat lamps are turned on. The classroom teacher should provide **5 minutes** for the students to make their predictions. | **In the Classroom (Students):**  Students observe the video from **5:55** to **7:09**. At the **7:09** mark the video teacher prompts the students to:   * Evaluate and refine your models to show what **causes** CO2 to move into and out of the atmosphere. * Student groups revise their models showing possible **causes** of CO2 moving into and out of our **system i**nto and out of the atmosphere. * Students then share their **models** and **causes** for CO2 movement as a whole class using **evidence** **(**see evidence bullets in the teacher column) from their **models** to support their claims**.**   Once the video resumes the students are exposed to two reaction equations:  Combustion reaction of gasoline  2C8H18 + 25O2 🡪 16CO2 + 18H2O  Photosynthesis  6CO2 + 6H2O 🡪 C6H12O6 + 6CO2  They are also challenged with a question from the video teacher:  “How does an increased concentration of CO2 **effect** atmospheric temperature?”. The students then observe an experimental setup to test the question posed.   * At the 11:24 mark the video is paused and the students are asked:   *Turn to a partner and make a prediction about what will happen in the model when the heat lamps are turned on.* |
| **[Communicate Phase](#bookmark2)** | |
| **In the Classroom (Teacher):**  The classroom teacher then resumes the video. The video teacher begins the demonstration. At the **11:56** mark the video teacher asks students to:   * Create a **graph** and **analyze and interpret** the data from the demonstration.   The teacher hands out the [Data Blossoms Experiment - Activity4](https://blossoms.mit.edu/sites/default/files/video/download/Data-Blossoms-Experiment-Activity4.pdf).  This activity should take **10 minutes**  *Teacher should “look for” evidence of the following when students are engaged in the practice of* ***Using Mathematical and Computational Thinking such as:***   * *Make and use measurements as evidence.* * *Compare evidence from measurements.* * *Organize and analyze simple data sets for patterns that suggest relationships.* * *Use graphs to find patterns and/or relationships in data.*   *Teacher should “look for” evidence of the following when students are engaged in the practice of* ***Analyzing and Interpreting Data*** *such as:*   * *Compare data to make sense of and explain phenomena.* * *Compare data and use comparisons as evidence.* * *Use graphical displays to analyze data in order to identify linear and nonlinear relationships.*   *Teachers should “look for” evidence of the following when students are using the practice of* ***Arguing from Evidence:***  ***Evidence Bullets (Look Fors):***   * Use models to understand arguments * Use evidence to generate or support explanations * Reflect on the best evidence supporting an explanation * Listen and make sense of other’s explanations * Evaluate and share weaknesses in one’s own arguments and collaborate to seek better   evidence.  The classroom teacher resumes the BLOSSOMS video at the **12:05** mark. The video teacher shares that the CO2 rich environment had a significantly higher rate of temperature increase as well as sharing some perspective of the effects of climate change.  NOTE: As an extension, the classroom teacher may want to ask the students to research ways to mitigate greenhouse gas emissions. | **In the Classroom (Students):**  The students then observe the resumed video and watch the demonstration in progress.   * At the **11:56** mark the video teacher asks students to:   *Create a* ***graph*** *and* ***analyze and interpret*** *the data from the demonstration.*   * The classroom hands out, to each group, the [Data Blossoms Experiment - Activity4](https://blossoms.mit.edu/sites/default/files/video/download/Data-Blossoms-Experiment-Activity4.pdf) * Student groups create a **graph** **(**see evidence bullets in the teacher column) of the data. * Student groups then **analyze and interpret** **(**see evidence bullets in the teacher column) the data from the demonstration looking for **patterns** and possible **causes** for the **patterns** in their **graphs**. * Once finished student groups share out their analyses and provide explanations for **causes** for the **patterns** as a whole class. Groups then **argue from the evidence (**see evidence bullets in the teacher column) in their data to support their explanations.   At the **12:05** mark the BLOSSOMS video is resumed. Students observe the video teacher’s findings from her experiment and relates some of the possible impacts of climate change over time. |

**The Gather, Reason, and Communicate Performance Sequence (Moulding & Bybee, 2017)**

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| **Gather** | Students are provided with a relevant phenomenon or problem that acts as the launching point for them to (1) obtain information by asking questions and defining problems for causes of the phenomenon within and among systems; (2) investigate the interactions of components of systems to determine the changes in terms of flow of energy and cycling of matter; and (3) determine the proportion of components in systems and interactions/feedback among systems. Gathering may include reading, listening, investigating, and using models. |
| **Reason** | Students use information they gathered to make sense of phenomena. Reasoning includes analyzing data and information, constructing explanations for the causes(s)of the phenomenon, engineering solutions to problems, and developing arguments for how the evidence supports or refutes explanations or solutions. Reasoning occurs in our brains, but may utilize models, speaking, and writing to organize the relationship between the causes of phenomena and the evidence supporting the explanations. |
| **Communicate** | Students communicate their reasoning by developing arguments for how evidence supports explanations. Communicating includes speaking, writing, and/or models to present explanations and arguments to themselves and others. |

Moulding, B. & Bybee, R. (2017). *Teaching Science is Phenomenal.* ELM Tree Publishing: Washington, UT. ISBN:978-0-8890674-0-6