The GLOBE Carbon Cycle Project: Using a systems approach to understand carbon and the Earth's climate system in K-12 classrooms

The global carbon cycle is a key regulator of the Earth's climate and is central to the normal function of ecological systems. Because rising atmospheric CO_2 is the principal cause of climate change, understanding how ecosystems cycle and store carbon has become an extremely important issue. In recent years, the growing importance of the carbon cycle has brought it to the forefront of both science and environmental policy. The need for better scientific understanding has led to establishment of numerous research programs, such as the North American Carbon Program (NACP), which seeks to understand controls on carbon cycling under present and future conditions. Presently, parallel efforts are needed to integrate state-of-the-art scientific research on the carbon cycle and its importance to climate with education and outreach efforts that help prepare society to make sound decisions on energy use, carbon management and climate change adaptation. In a similar vein, both popular media as well as some educational curricula move quickly through climate topics to carbon footprint analyses without ever addressing the nature of carbon or the carbon cycle. If students do not gain a concrete understanding of carbon's role in climate and energy they will not be able to successfully tackle global problems and develop innovative solutions in the future.

Furthermore, National Science Content Standards identify *systems* as an important unifying concept across the K-12 curriculum. While this standard exists, there is a recognized gap in the ability of students to use a systems thinking approach in their learning.

By participating in GLOBE Carbon Cycle, a joint project between NASA funded carbon cycle scientists and the international GLOBE education community, students learn to use a systems thinking approach, while at the same time, gaining a foundation in the carbon cycle and it's relation to climate and energy. Here we present the GLOBE Carbon Cycle project and materials, which incorporate a diverse set of activities geared toward upper middle and high school students with a variety of learning styles. A global carbon cycle adventure story and game let students see the carbon cycle as a complete system, while introducing them to systems thinking concepts including reservoirs, fluxes and equilibrium. Classroom photosynthesis experiments and field measurements of schoolyard vegetation brings the global view to the local level. And the use of computer models at varying levels of complexity (effects on photosynthesis, biomass and carbon storage in global biomes, global carbon cycle) not only reinforces systems concepts and carbon content, but also introduces students to an important scientific tool necessary for understanding climate change.

Learning Goals & Objectives

Through participation in the GLOBE Carbon Cycle project students will…

1. Learn why carbon is an important element in ecosystems, and how it cycles through ecosystems.

   They will be able to:

   - *Diagram the major pools and fluxes of the carbon cycle at a global scale.*
   - *Provide examples of the role of humans in the global carbon cycle.*
   - *Explain how carbon is stored in and passed between living and non-living things in terrestrial ecosystems.*
   - *Describe at least two ways in which changes to environmental conditions (i.e. temperature, precipitation, pollution) impact how carbon flows through ecosystems.*

2. Gain skills in current carbon cycle research techniques, such as:
   - *Perform field measurements used to assess carbon storage and plant growth at a local field site.*
   - *Scale local carbon storage to larger areas using Google Earth or other remotely sensed images.*
   - *Calculate carbon uptake by their vegetation and put it into the context of the global carbon cycle, carbon footprint analyses and more.*
   - *Use models to answer questions about the environment.*
   - *Make predictions about future environmental conditions by changing model inputs.*
3. Increase their critical thinking skills. This will be shown by their ability to:
   - *Design and perform an experiment on one aspect of the carbon cycle through construction of specific research questions.*
   - *Participate in small and large group discussions about the patterns in data and results from a variety of carbon cycle activities.*
   - *Use systems thinking diagrams to show the relationship between pools and fluxes in the carbon cycle, as well as apply this strategy to other systems.*
4. Understand the nature of science research, by their capacity to:
   - *Peer review another student's work and provide constructive comments for improvement.*
   - *Discuss why researchers may disagree on some science topics.*
   - *Provide examples of how carbon cycle research is important to society.*

Carbon Cycle Activities: 4 Categories

1. Introductory Activities
    - *Introduce students to the pools and fluxes of the carbon cycle*
    - *Provide opportunities to make connections between cycle components (biotic & abiotic)*
    - *Allow for conversations about humans' role in the global carbon cycle and the difference between human presence and human actions*
    - *Gain understanding of residence time, a key systems thinking concept*
    - *Connected to major scientific concepts such as the conservation of mass and energy laws*

2. Modeling
    - *Provides a context for how systems thinking is used to understand the world and solve problems*
    - *Introduces students to the use of modeling in science*
    - *Applicable to students around the world, regardless of where they live*
    - *A variety of models will allow students to understand how carbon is stored and transferred at the ecosystem and global level*
    - *Allows students to observe changes in carbon with changes in environmental conditions*
    - *Connection to field collected data*
    - *Enables individual investigations*

3. Plant-A-Plant Experiments
    - *Hands-on activities: range of cultivation experiments with real plants*
    - *Experiments are designed so you can increase the level of inquiry as students gain experience performing research*
    - *Exploration and validation of variables necessary for plant growth*
    - *Demonstration that CO_2 is incorporated into plant biomass*
    - *Understand changes in carbon storage at the ecosystem rather than global level*

4. Field Measurements
    - *Designed similarly to existing GLOBE protocols*
    - *Comparison of measurements between schools*
    - *Practice with basic field instruments (GPS, compass, meter tape, diameter/circumference tape, species ID guide)*
    - *Experience collecting, recording, and analyzing data*
    - *Promotes a high level of student-student collaboration*
    - *Allows students to make connections between the global C cycle and their own schoolyard*