

Climate change: confronting student ideas

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Students bring prior knowledge about science to our courses, yet sometimes their information is inaccurate. The Beedlow *et al.* article in this issue (p 315–322) provides a foundation for addressing several incomplete, naïve, or erroneous ideas that have been identified in students' thinking about the carbon cycle (Carlsson 2002; Ebert-May *et al.* 2003), what scientists know about the relationship between plant growth and rising atmospheric CO₂ concentrations, and the relationship between carbon and nitrogen cycles.

The scientific teaching approach for this article involves three components: learning goals, instructional strategies that are inquiry-driven and student-centered, and assessment (ie obtaining data that measure student achievement of learning goals). The learning goals are based on the question: "What do students need to know to demonstrate a genuine understanding of the carbon cycle and its relation to global climate change?" The instructional strategy chosen for this example is based on the *learning cycle*, an instructional model that enables students to address misconceptions and develop more accurate understanding (Posner *et al.* 1982; Kennedy 2004). In this case, students actively confront their current ideas about global warming by exploring the question "Where does the carbon go?" (a section in Beedlow *et al.* 2004) and ultimately come to a deeper understanding of the carbon cycle. Assessments probe students' understanding and misconceptions before, during, and after instruction, to evaluate the effectiveness of teaching and learning.

■ Learning goals

In this example, students will:

- Predict how the carbon cycle responds to elevated atmospheric CO₂
- Explain the pathways and processes involved in the movement of carbon
- Illustrate how nitrogen limits plant growth in response to elevated CO₂
- Determine if elevated CO₂ could increase forest carbon sequestration
- Use scientific methods to predict the effect of human activity on climate change

Further goals that are relevant to the course can be included.

■ Instructional strategy

The *learning cycle* is a teaching model, based on cognitive psychology research, which shows that people learn best by interactively constructing understanding (Bransford *et al.* 1999). This approach has several phases. First, students are engaged with a question or activity probing prior knowledge and focusing their thinking. Then they explore and share

their ideas or concepts, after which the instructor explains scientific concepts and processes to bring order to the students' explorations.

Engagement (*last 10 minutes of prior class*): With this article we use pop culture to engage students in thinking critically about the science of climate change, as portrayed in a current disaster film (*The Day After Tomorrow*) and by doing so, build understanding about the carbon cycle. Engage students as the preceding class ends by assigning Beedlow *et al.* as homework and announcing: "Next class we will discuss climate change and "where the carbon goes" based on this paper". Also, show a 30-second trailer for the movie *The Day After Tomorrow* (www.thedayaftertomorrow.com) and ask students who saw the movie to describe major scientific points on climate change that it addresses.

Explain that before the next class you need to learn what they currently understand about carbon cycling, and administer a two-question quiz (Panel 1). Collect the responses, without providing correct answers; instead, ask students to consider as they read how elevated CO₂ might influence the ultimate outcome of *The Day After Tomorrow* (Peplow 2004). In addition, ask students to draw a simple model of a forest ecosystem, using arrows to indicate carbon and nitrogen flow, and to bring two copies (one to turn in and one to use in class). Announce a graded quiz on the reading at the start of the next class.

Exploration (*15 minutes at the beginning of class*): Administer the same quiz (Panel 1) as class starts and collect individual responses for assessment. Using the same quiz after the assignment holds students accountable for reading, and assesses changes in misconceptions held before and after reading. Results help direct the exploration and explanation phases of instruction.

After the quiz, have students explain their responses to their neighbor ("Think/Pair/Share" in Johnson *et al.* 1998). Walk around, listening to students. After 5 minutes of discussion, call on students to create a list of answers and justifications on the overhead or board. We predict you will still hear some of the misconceptions listed in Panel 2. In this phase, students wrestle with prior and new ideas to gain understanding (Posner *et al.* 1982; Bransford *et al.* 1999). This exploration helps delimit the explanation phase of instruction.

Explanation (*30 minutes*): Explain the basic elements of the carbon cycle required to understand relationships between the carbon cycle and global climate change. Lectures, as explanation, can help clarify students' thinking when ongoing feedback is provided (McKeachie 2002). For example, ask students to identify the incorrect reasoning in the misconceptions presented in the quiz,

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Panel 1. Quiz (Pre-test)

This example pre-test is designed to check students' prior knowledge before any instructional intervention. It can be conducted with paper and pencil or electronic scoring devices, but should be short and relevant to the *Where does the carbon go?* section in Beedlow *et al.* Accurate conceptions are noted as "answers" and the incorrect choices represent known student misconceptions

- (1) The majority of actual weight (biomass) gained by plants as they grow comes from which of the following substances: [answer b]
- organic substances in soil that are taken up by plant roots.
 - carbon dioxide in the air that enters through leaf stomata.
 - minerals dissolved in water taken up by plant roots.
 - energy from the sun captured by leaves.
 - carbon from decomposed leaf litter in soil.
- (2) What are the different pathways that a carbon atom can take once it is inside a plant? Choose all that are correct. [answer a, b, c, d]
- It can exit the plant as CO₂.
 - It can become part of the plant cell walls, protein, fat, DNA.
 - It can be consumed by an insect feeding on the plant and become part of the insect's body.
 - It can exit the soil as CO₂ as plant tissue decomposes.

Results from this quiz will allow you to prepare your lecture using students' prior knowledge. Save these data for future reference and to share with others.

explaining how someone might think they were correct. Since research indicates the attention span of most students is 10–15 minutes in a lecture setting (Johnson *et al.* 1998), the instructor can augment student explanations when necessary, rather than lecturing at length.

Have small groups of students use their forest ecosystem models to predict how carbon in various pools (ie oceans, atmosphere, plants, detritus; Figure 2, Beedlow *et al.*) would change with increasing atmospheric CO₂. Challenge students to write predictions based on specific questions such as: (1) How will changes in atmospheric CO₂ alter photorespiration rates? and (2) Under what conditions does elevated CO₂ increase forest carbon sequestration (storage)? Ask them to include scientific reasoning to support their predictions. Ask a few groups to explain their model predictions to the class.

Panel 2. Common misconceptions held by undergraduates about the carbon cycle

Misconceptions are linked to pages in Beedlow *et al.* (2004) for explanations

- Global warming will make all parts of the earth warmer
- Increased atmospheric CO₂ will always increase productivity (p 317)
- Carbon moves through different pools at the same rate (Figure 3)
- The largest pools of carbon are on land and in living organisms (Figure 2).
- Photosynthesis provides energy for uptake of carbon and nutrients through plant roots (Figure 3; p 317)
- Plants get their biomass from nutrients in the soil (p 315–316)
- Soil respiration means the soil is respiring rather than the organisms living in the soil (p 315–316)
- Plant cells do not undergo respiration; only animal cells respire (p 315)

This provides an opportunity for the instructor to dispel persistent misconceptions.

Assessment

As class ends, assess students' progress in achieving the defined learning goals (5–10 minutes). Use a quick writing assignment (eg "minute paper", Angelo and Cross 1993) to further probe students' understanding. You might ask one of the following: (1) Predict whether increased CO₂ will increase plant growth, giving one or two supporting reasons; (2) List three locations where you might find C atoms from CO₂ taken up by plants. Briefly describe one forest management practice that could affect carbon storage or release; (3) Describe two factors that might limit forest carbon sequestration; (4) What is the scientific evidence that humans either do or do not influence climate change? By asking these questions before, during, and after the learning cycle, we can assess how many, and perhaps why, students still have misconceptions about the carbon cycle.

Summary

Beedlow *et al.* provides a rich conceptual background and synthesis of interrelations of the carbon and nitrogen cycles and the effects of air pollution on carbon sequestration. The instructional potential of this paper is broad and how it is used depends on the learning goals for your students. Clearly, this example will be interpreted and implemented differently by faculty with diverse teaching and disciplinary expertise.

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References

- Angelo TA and Cross KP. 1993. Classroom assessment techniques: a handbook for college teachers, 2nd ed. San Francisco: Jossey-Bass.
- Bransford JD, *et al.* (Eds). 1999. How people learn: brain, mind, experience, and school. Washington DC: National Academy Press
- Carlsson B. 2002. Ecological understanding 1: ways of experiencing photosynthesis. *Int J Sci Edu* **24**: 681–99.
- Ebert-May, *et al.* 2003. Disciplinary research strategies for assessment of learning. *Bioscience* **53**: 1221–28.
- Johnson DW, *et al.* 1998. Active learning: cooperation in the college classroom. Edina, MN: Interaction Book Company.
- Kennedy D. 2004. Climate change and climate science. *Science* **304**: 1565.
- McKeachie WJ 2002. Teaching tips: strategies, research, and theory for college and university teachers, 11th ed. Lexington, MA: Heath and Co.
- Peplow M. 12 May 2004. Disaster movie makes waves: but could the climate crash "the day after tomorrow"? Nature Science Update. www.nature.com/nsu/040510/040510-6.html. Viewed June 2004.
- Posner GH, *et al.* 1982. Accommodation of a scientific conception: toward a theory of conceptual changes. *Sci Educ* **66**: 211–27.