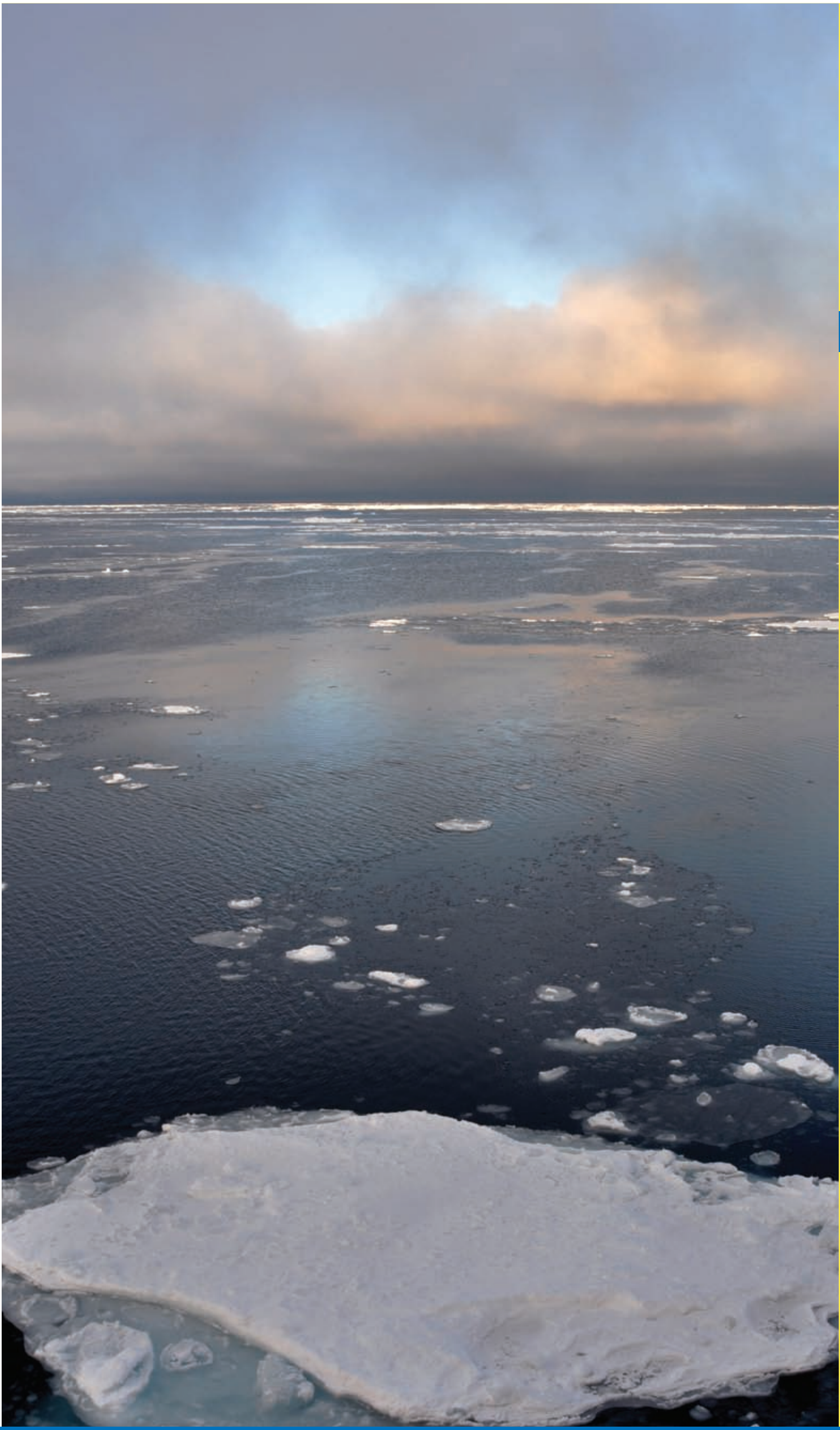
THE EARTH SCIENTIST

NATIONAL EARTH SCIENCE TEACHERS ASSOCIATION

Volume XXVIII • Issue 3 • Fall 2012

$10.00*



FREE POSTER INSIDE!
From the American Geosciences Institute
2012 Earth Science Week Poster

INSIDE THIS ISSUE

The Arctic Ocean has lost more than 30 percent of its summer ice cover in the last thirty years. Scientists have long thought that climate change is to blame, and recent study provides more evidence for that idea. Credit: Patrick Kelley, U.S. Coast Guard

*ISSN 1045-4772

This special Climate Change issue is sponsored by the National Science Foundation

NESTA'S MISSION

To facilitate and advance excellence in Earth and Space Science education.

NESTA Contacts

From the President

by Ardis Herrold, NESTA Past-President

Happy New (*school*) Year!

The Next Generation Science Standards (NGSS) will be a reality before we know it! If you haven't taken a peek at them, now is a good time to get a handle on how they will impact you in your profession as a science educator. Make it your New (school) Year's resolution to develop an awareness of the NGSS.

For many of our states the Next Generation Science Standards (NGSS) will be adopted in the near future as they are slated to be completed late in 2012 or early in 2013. Even if your state is not one of the 26 lead states scheduled to adopt the NGSS, use this New (school) Year to develop or join a Professional Learning Community (PLC) focused on unpacking the NGSS so that you are ready for the implementation. The framework that guided the creation of the NGSS can be downloaded for free from the National Academies Press website and a draft of the NGSS is available from the Achieve website. Both of these documents can serve as the foundation for a rich dialogue among you and your science education colleagues.

The creation of the *Framework for K-12 Science Education: Practices, Cross-cutting Concepts, and Core Ideas* began in the summer of 2010. The National Research Council organized an exemplary committee to create this document, who then used the latest research on how children learn science. After extensive vetting through science, engineering, and education organizations as well as thousands of people organized in focus groups, the document was completed in the summer of 2011 and published in its final form in 2012. The purpose of this document is to provide the foundation upon which the NGSS were to be constructed. Everything you see in the NGSS can be traced back to the *Framework,* and therefore starting your grasp of the NGSS should start with a grasp of the *Framework*.

Let the table of contents of the *Framework* serve as your PLC agenda. For instance, the table of contents is divided into three parts, Part 1: A Vision for K-12 Science Education; Part II: Dimensions of the Framework; and Part III: Realizing the Vision and the chapters within these three parts, can be a topic for each meeting. Pay special attention to chapters 1 and 2 as they provide the philosophy behind the *Framework* and chapters 3 and 4 as they include key dimensions grounding the paradigm shift of what will be expected of science educators when the NGSS are implemented. The scientific and engineering practices as well as the crosscutting concepts are now married to our content, and students are expected to actively integrate all three dimensions (practices, crosscutting concepts, and disciplinary core ideas) in future assessments.

The discussion in your PLC should include ways you can integrate these three dimensions and ways you can successfully implement the NGSS in your classrooms. Once your PLC has digested the *Framework*, you are ready to view the NGSS to see how they will assist you in your curricular and instructional decisions. Have a wonderful New (*school*) Year and may you be successful with all your resolutions!

Missy Holzer

NESTA President, 2012-15

From the Executive Director and Guest Editor

Dear NESTA Members,

Greetings from NESTA at the beginning of another school year! I hope you have had a great and restful summer, and are reinvigorated for the school year to come. And I hope to see you at our events this year, if your schedules allow!

This very special fall issue of The Earth Scientist (TES) has a focus on climate change education. We're very excited about it, for several reasons. First of all, we'd like to thank the National Science Foundation (NSF) (GEO-1246254 from the Geoscience Education program of NSF) for their financial support of this issue. This support has made it possible for NESTA to implement a peer-review process for articles submitted to TES! For NESTA, peer-review involves feedback from leading teachers across the country as well as domain experts – in this case, specialists in climate change education. We're delighted that 16 of these individuals agreed to serve as peer-reviewers for the articles submitted to the issue. Moving forward, ***we will continue to provide peer-review for all articles submitted to TES, providing a valuable service for both authors and subscribers.***

As many of you already know, this year has been exceptionally warm. According to NOAA, this spring was the warmest on record in the US since record keeping began in 1895, with tens of thousands of records falling to date. The last 12 months have been the warmest on record. According to NASA, the global average surface temperature in 2011 was the ninth warmest since 1880, continuing a trend in which nine of the 10 warmest years in the modern meteorological record have occurred since the year 2000. On a daily basis, we hear about extreme events and changes in our environment. In mid July, NASA discovered a surprising sudden melting of the Greenland ice sheet, with melting underway across 97% of its surface. The Alaska Highway, which was built on permafrost (and relies upon it for its stability), is starting to buckle as the permafrost below it melts. This year we had a record number of tornadoes very early in the year, causing massive damage in the midwest and southern states. We are in the middle of the worst drought in 50 years, which brings with it significant ripple effects in society – lowering water levels in reservoirs endangering recreation and energy production, withering crops impacting food production and the cost of food, and lowering water levels on major rivers impacting shipping to name only a few. Clearly, we live in a deeply interconnected system bringing together the environment, the economy, and our social system – the three pillars of society. As the climate warms – which observational evidence clearly shows ***is*** happening – there will be impacts throughout society because of these interconnections.

From the perspective of an Earth and space science teacher, climate change offers a particularly compelling case study demonstrating the interconnectedness of systems and the opportunity to develop an understanding of and apply unifying concepts and processes of science. This issue provides you with five articles describing resources for you to use in the classroom for climate change education, as well as an article that looks into the problems caused by the "teach the controversy" approach. We hope these articles are helpful to you in the coming year as you delve into this difficult and compelling topic. In this issue, we also provide a list of particularly useful, online, climate change education resources for you.

Also included in this issue is an article announcing the 2012 Earth Science Week celebration sponsored annually by the American Geosciences Institute (AGI). In the hard copies of this Fall issue, the AGI has graciously provided, for use in your classroom, the 2012 Earth Science Week Poster, entitled *Discovering Careers in the Earth Sciences.*

As usual, NESTA will hold our signature events - the NESTA Share-a-Thon and Rock and Mineral Raffle - at each of the fall NSTA Area Conferences in addition to multiple workshops and short courses in Louisville and Atlanta on planetary science (see the list of our fall events in this issue). We hope to see you at our events, and invite you to participate as a presenter at one of our Share-a-Thons. If you are interested in presenting at one or more of our upcoming Share-a-thons, please apply at https://www.nestanet.org/cms/content/conferences/nsta/shareathons/apply , and NESTA's Share-a-Thon Coordinator, Michelle Harris, will be in touch with you soon.

Best Regards,

Dr. Roberta Johnson, Executive Director, NESTA
And Guest Editor of this special, NSF sponsored, Climate Change issue of TES

TES Editor
Tom Ervin

Twenty Five Years Ago in TES

Twenty Five years ago, in 1987, TES was in its fourth year of publication. The cover of Volume 4, issue 3 featured photos of four volcanoes: (clockwise from lower left they are Crater Lake, Oregon, Polomolak, Philippines, Sunset Crater, California and Mauna Loa, Hawaii. These were fitting photos since the first 19 pages of the issue were devoted to five articles regarding volcanoes.

These articles were followed by an article on behavioral objectives and how they relate to Earth science lesson planning. This article was followed by an article listing computer programs for use in Earth science classroom which were either free (public domain) or "low cost" (up to $100 commercially available).

HELP WANTED!

NESTA needs you to help us run our events at the NSTA Fall Conferences in Louisville, Atlanta and Phoenix. At the 2013 spring NSTA in San Antonio, we need volunteers to help with our Share-a-thons, Rock Raffle, and at our Exhibit Hall booth. If you feel that you can help, contact Joe Monaco, NESTA Volunteer Coordinator: monacoj@aol.com

Particularly useful online resources for climate change education

- **Our Changing Planet** – a collaboration of NBC Learn and NESTA (Windows to the Universe) with support of NSF, providing beautiful short videos and associated classroom activities on over a dozen topics at http://www.windows2universe.org/earth/changing_planet/changing_planet.html
- **Windows to the Universe** – hundreds of pages of content on climate and global change at upper elementary, middle, and high school levels, presented in English and Spanish at http://www.windows2universe.org/earth/climate/climate.html as well as over 50 classroom activities on climate change topics in the Teacher Resources/Activities section at http://www.windows2universe.org/php/teacher_resources/activity.php#6
- **CO2Now.org** – with daily updates on the level of CO_2 in the atmosphere, and supporting resources at http://co2now.org/
- **National Snow and Ice Data Center** – with regular updates on conditions in polar regions, reports, and images at http://nsidc.org/
- **Scripps Institute of Oceanography** (home of the Keeling curve) http://scrippsco2.ucsd.edu/home/index.php
- **Skeptical Science** – continuous updates on arguments regarding global warming and climate change at http://www.skepticalscience.com
- **Real Climate** – updates from climate scientists at http://www.realclimate.org/
- **NOAA Climate Portal** – with resources for teachers at http://www.climate.gov/#education
- **NASA Global Climate Change**: Vital Signs of the Planet – with background information and resources for teachers and students at http://climate.nasa.gov/
- **NASA Goddard Institute for Space Science** – with links to multiple programs, including the EdGCM and the GISS Surface Temperature Analysis Program at http://www.giss.nasa.gov/
- **Alliance for Climate Education (ACE)** – a program with student leadership opportunities at http://www.acespace.org/
- **Environmental Protection Agency (EPA) Climate Change** – resources for students, teachers, and administrators at http://www.epa.gov/climatechange/wycd/school.html
- **National Academies of Science Climate Change Education Roundtable** – reports from NAS Roundtable on issues in climate change education at http://www7.nationalacademies.org/bose/Climate_Change_Education_Homepage.html

The Earth Scientist

EDITOR
Tom Ervin

PUBLICATIONS COMMITTEE
Linda Knight, Chair
Tom Ervin, TES Editor
Parker Pennington IV
Howard Dimmick
Ardis Herrold
Missy Holzer
Richard Jones

CONTRIBUTING AUTHORS
Steve Ackerman, Erin Bardar, Melinda Bell, Geoff Camphire, Joëlle Clark, Tanya A. Dewey , Katherine Ellins, Nick Haddad, Carol Haden, EdD, George Starr Hammond, Louise Huffman, Bruce Hungate, PhD, Tommy Jasmin, Andrew Kwok, Tamara Shapiro Ledley, Julie Libarkin, Jane Marks, PhD, Mark S. McCaffrey, Galen A. McKinley, Karen McNeal, Margaret E. Mooney, Jean Pennycook, Vanessa L. Peters, Frank Rack, Nancy Butler Songer, Betsy Youngman, Tom Whittaker

The Earth Scientist is the journal of the National Earth Science Teachers Association (NESTA).

The Earth Scientist is published quarterly (January, March, June, September) and distributed to NESTA members. Back issues of The Earth Scientist are available for sale through the NESTA Office for $10 per copy.

Advertising is available in each issue of *The Earth Scientist*. If you wish to advertise, visit http://www.nestanet.org/cms/content/publications/tes/advertising.

To become a member of NESTA visit www.nestanet.org.

To get more information about NESTA or advertising in our publications, or to get copies of back issues, contact the NESTA Office at 720-328-5351 or marlene.dimarco@gmail.com

DESIGN/LAYOUT
Patty Schuster, Page Designs

Printed and bound by Scotsman Press, Syracuse, NY on recycled paper using soy ink.

RECYCLED PAPER | PRINTED WITH SOY INK

Article Reviewers for this Fall *TES*

Lisa Alter
Michael Chandler
LuAnn Dahlmann
Teresa Eastburn
Lisa Gardiner
Rebecca Hatheway
Sandra Henderson
Ardis Herrold
Linda Knight
Nicole LaDue
Jean May-Brett
Bruce Moravchik
Heather Pacheco
Margaret Turrin
Wendy Van Norden
Janet Warburton

NESTA Workshops at the fall 2012 NSTA Area Conferences

NESTA is pleased to announce our sessions at the NSTA Area Conference for fall 2012.

Want to present at one or more of our Share-a-Thons? Sign up to present at a NESTA Share-a-Thon at www.nestanet.org/cms/content/conferences/nsta/shareathons/apply.

NESTA sessions in Louisville

Friday, October 19

All events on Friday are in the Kentucky International Convention Center, L15

8:00 – 9:00 am - Activities from Across the Earth System
9:30 - 10:30 pm - Let's Get Well Grounded!
11:00 am - noon - Climate Change Classroom Toolkit
12:30 – 1:30 pm – Our Changing Planet
2:00 - 3:00 pm - Share-a-Thon
5:00 – 6:00 pm - Rock and Mineral Raffle

Saturday, October 20

Short Course: *Exploring Planetary Science and Astronomy: What Would Galileo Do?* Louisville Marriott, Kentucky C/D, 9:00 am – noon. Ticketed Event: $57 advance; $62 on-site. Purchase tickets when you register online for NSTA or on the Louisville Advance Registration Form.

NESTA sessions in Atlanta

Friday, November 2

All events on Friday are in the Georgia World Congress Center, B401/B402

8:00 – 9:00 am - Climate Change Classroom Toolkit
9:30 - 10:30 pm - Let's Get Well Grounded!
11:00 am - noon – Activities from Across the Earth System
12:30 – 1:30 pm – Our Changing Planet
2:00 - 3:00 pm - Share-a-Thon
3:30 – 4:30 pm - Rock and Mineral Raffle

Saturday, November 3

Short Course: *Exploring Planetary Science and Astronomy: What Would Galileo Do?* Georgia World Congress Center, B404, 9:00 am – noon. Ticketed Event: $55 advance; $60 on-site. Purchase tickets when you register online for NSTA or on the Atlanta Advance Registration Form.

NESTA sessions in Phoenix

Friday, December 7

All events on Friday are in the Phoenix Convention Center, 132 A-C

8:00 – 9:00 am - Climate Change Classroom Toolkit
9:30 - 10:30 pm – Activities from Across the Earth System
11:00 am - noon – Let's Get Well Grounded!
12:30 – 1:30 pm – Our Changing Planet
2:00 - 3:00 pm – Share-a-Thon
3:30 – 4:30 pm – Rock and Mineral Raffle

Discovering Careers in the Earth Sciences

By Geoff Camphire

Celebrate Earth Science Week 2012

Jobs and employment issues are important to everyone -- especially students. Has there ever been a better time to promote awareness of the many exciting careers opportunities available in the Earth sciences?

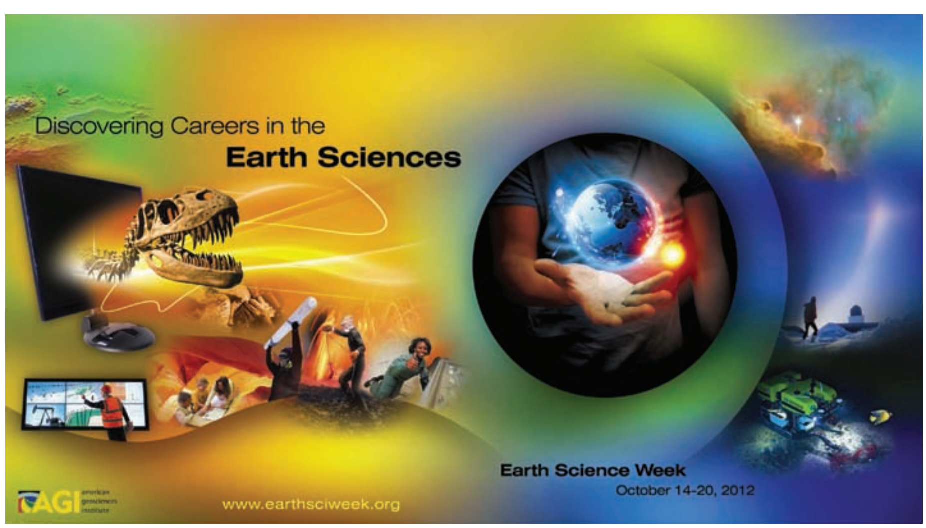
That's why Earth Science Week 2012 will focus on the theme of "Discovering Careers in the Earth Sciences." During the 15th annual Earth Science Week (Oct. 14-20, 2012), millions of people, in all 50 states and around the globe, will learn about the work of geoscientists by conducting classroom activities, preparing competition projects, ands well as visiting parks, museums, and science centers. Each year, the American Geosciences Institute (AGI) reaches more than 48 million people through its Earth Science Week campaign promoting better understanding of Earth science and stewardship of the planet.

AGI american geosciences institute

Day by Day

Join in activities emphasizing different areas of the geosciences on different days:

- Sunday, Oct. 14, EarthCachers worldwide will take part in geocaching "treasure hunts" for on International EarthCache Day (www.earthcache.org), on Sunday, Oct. 14.
- On Monday, Oct. 15, Earth Science Literacy Day will focus on videos illustrating the field's "Big Ideas" (www.earthsciweek.org/forteachers/bigideas/main.html).
- Tuesday, Oct. 16, No Child Left Inside Day invites young people to go outdoors and learn about Earth science firsthand (www.earthsciweek.org/ncli).
- Wednesday, Oct. 17, The National Park Service and AGI are collaborating to conduct the third annual National Fossil Day (http://nature.nps.gov/geology/nationalfossilday/).



About the Author

Geoff Camphire is Earth Science Week Program Manager, American Geosciences Institute, 4220 King Street, Alexandria, VA 22302, gac@agiweb.org.

- Thursday, Oct. 18, The Association for Women Geoscientists urges you to share the excitement of geoscience careers with young women, on Women in the Geosciences Day.
- On Friday, Oct. 19, celebrate the first-ever Geologic Map Day. Hosted by the U.S. Geological Survey and the Association of American State Geologists along with AGI, this event promotes awareness of the importance of geologic mapping for education, science, business, and public policy. A poster, activities, and additional resources can be found online (www.earthsciweek.org/geologicmap).

Get Involved

How can you participate? This year's educator kit and web site provide more than one hundred lessons, materials, and links on Earth science. To receive the $6.95 kit, including the Geologic Map Day poster and dozens of other resources, order online (www.earthsciweek.org/materials/index.html) or call 703-379-2480. The 2012 Earth Science Week Poster (enclosed in this issue of The Earth Scientist) features a learning activity designed to help young people think about careers in the Earth sciences. Visit the Earth Science Week web site (www.earthsciweek.org) to find out about ways to get involved, events and organizations in your community, educational activities, the monthly electronic newsletter, and much more.

Students can enter AGI's Earth Science Week contests. The photography contest, open to all ages, focuses on the theme "Earth Science Is a Big Job." Students in kindergarten through grade five may enter the visual arts contest, "Imagine Me, an Earth Scientist!" In addition, students in grades six through nine can enter the essay contest, which highlights "Geoscientists Working Together." Information on rules and prizes is online (www.earthsciweek.org/contests). Have a great Earth Science Week!

The Carbon Cycle Game: A Regionally Relevant Activity to Introduce Climate Change

Joëlle Clark, Jane Marks, PhD, Carol Haden, EdD, Melinda Bell, Bruce Hungate, PhD

Illustration by Landis Bahe, Navajo artist http://artofthepeople.org/LandisBahe.html

Abstract

The "Carbon Cycle Game" is introduced as a regionally relevant activity for students to experience the carbon cycle. In the game, students behave as carbon molecules moving between reservoirs (hydrosphere, biosphere, lithosphere, and atmosphere). Students select cards that instruct them to take on the role of a carbon molecule. The cards provide information about a carbon cycling process and direct students how to move from one carbon reservoir to another. Students conduct ten rounds of cycling while recording where they went and how long they stayed. The game concludes with a discussion of student experiences and a review of the carbon cycle. Teacher feedback on the implementation and impact on learning in the classroom indicates high levels of student engagement and effective strategies to learn about carbon and its role in climate change. Although the lesson is regionally based, it can easily be adapted to other regions of the globe, if needed.

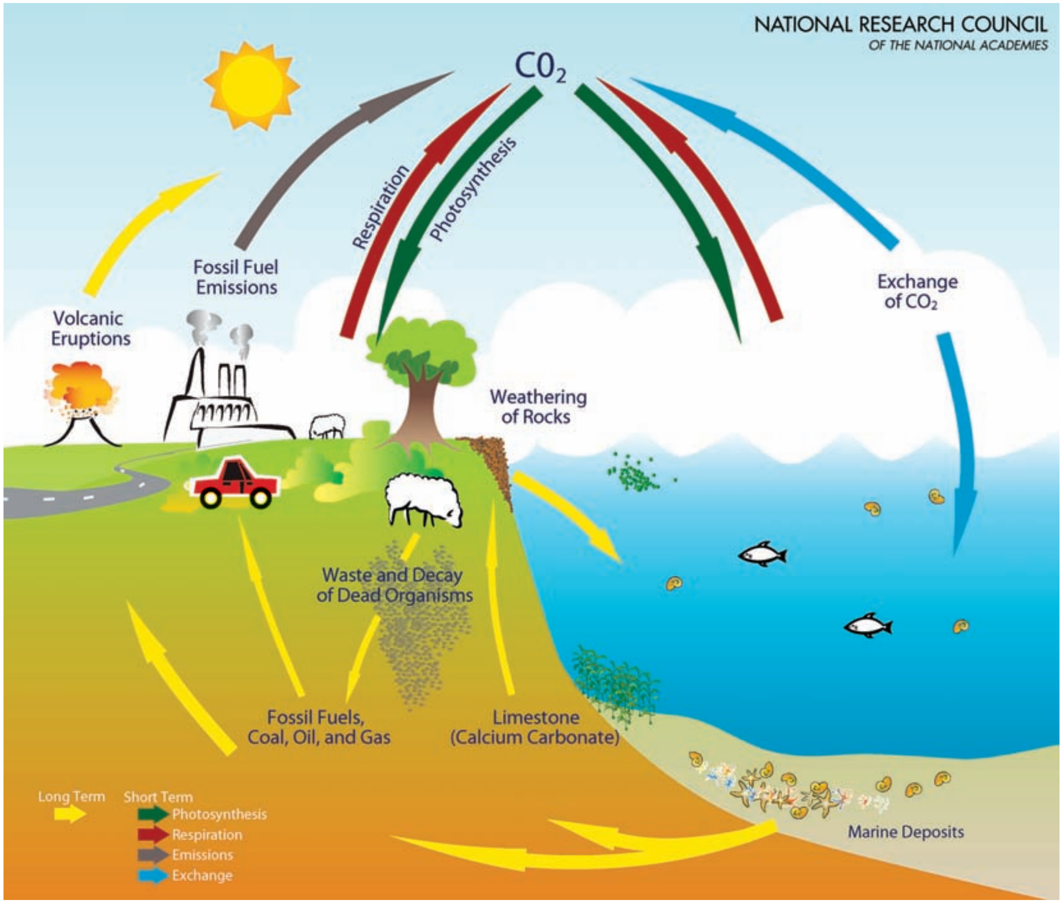
The Carbon Cycle Game: A Regionally Relevant Activity to Introduce Climate Change

According to the 2007 synthesis report prepared by the Intergovernmental Panel on Climate Change (IPCC), the main drivers for climate change are increased concentrations of greenhouse gases and aerosols and increased global radiation in the atmosphere and on the Earth's surface (IPCC 2007, p. 15). Human activities have increased the concentrations of greenhouses gases in the Earth's atmosphere, particularly carbon dioxide. Students are challenged to understand the role of carbon in global climate change.

Students need to know how carbon cycles through Earth's systems. The Framework for K-12 Science Education (National Research Council 2012) outlines a vision for student learning that emphasizes the Earth as interconnected systems involving the atmosphere, hydrosphere, geosphere, and biosphere. Students are typically introduced to a carbon cycle in elementary or middle grades as a part of how matter cycles. Often, a diagram with arrows showing the flow of carbon is used to illustrate this process (See Figure 1: Example of Carbon Cycle Diagram). Research on student misconceptions indicates that students see the parts of this cycle, yet see the connections among the systems as fragmented. They think the cycle involves cause and effect events with matter being created or destroyed during those events. To them, each part of the cycle represents a new, not continuous, event (Driver, Squire, Rushworth, & Wood-Robinson 1994). This disjointed view of how carbon moves, makes it difficult to apply the carbon cycle to environmental issues, such as

Figure 1. Carbon Cycle example

(Source: National Research Council of the National Academies Ocean Acidification: Starting with the Science booklet, http://oceanacidification.nas.edu/?page_id=29)



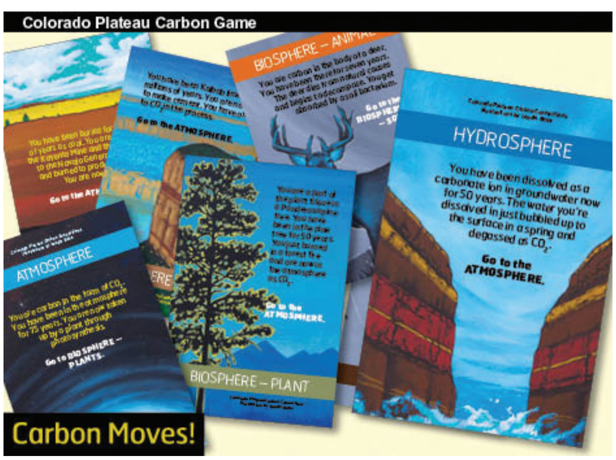


Figure 2. The Carbon Cycle Game, teaches the carbon cycle by engaging students to behave as carbon molecules and move between reservoirs (hydrosphere, biosphere, lithosphere, atmosphere), stationed around the classroom. Students conduct ten rounds of cycling while recording where they went and how long they stayed. The game concludes with a discussion of student experiences and review of the carbon cycle.

(Source: The *Climate Change Science and Solutions: Creating Innovative Education Tools for Native Americans and Other Rural Communities on the Colorado Plateau,* a Climate Change Education Partnership grant funded by the National Science Foundation to Northern Arizona University.)

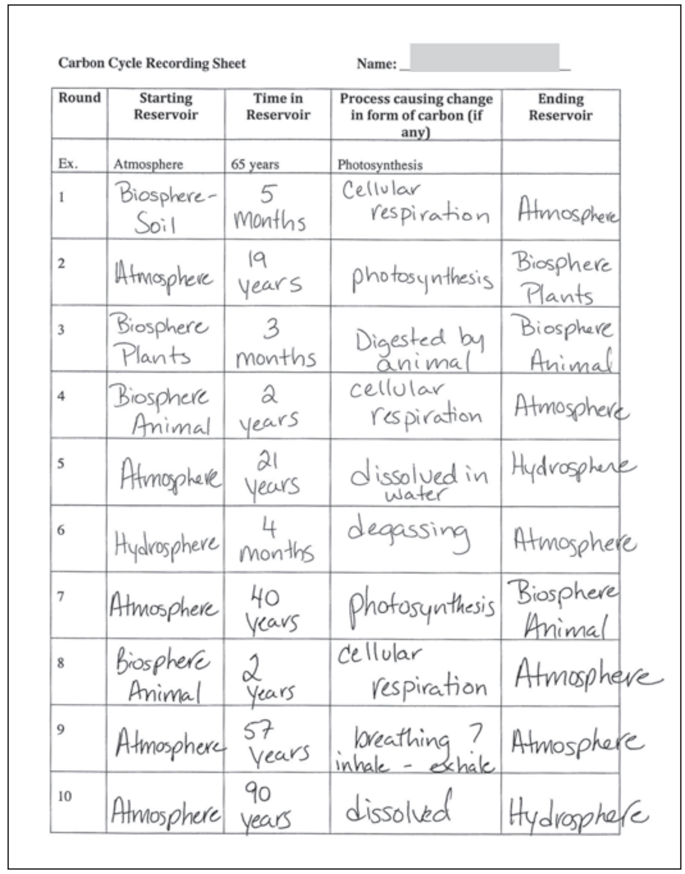
climate change. To the students, the word "cycle" infers that every carbon molecule follows the same series of events over and over again, thus students underestimate differences in frequencies of some processes, as well as different rates of storage among the reservoirs.

In an effort to deepen understanding of the carbon cycle, students can play a carbon cycle game (See Figure 2: The Carbon Cycle Game) . The learning goal of the game is for students to experience how carbon molecules are transferred between carbon reservoirs, what's the relative amount of time carbon remains in any given reservoir, and which processes initiate a change in carbon from one form and reservoir to another. A carbon reservoir is defined as a natural storage place for carbon. The game involves students physically moving from one carbon reservoir to another, based on information provided by the carbon cycle game cards. Students record their carbon molecule's journey for later discussion of the carbon cycle (See Figure 3: Carbon Cycle Recording Sheet). For example, students learn that carbon can move from the atmosphere to the biosphere through the process of photosynthesis. Afterwards, carbon can move from the biosphere to the lithosphere where it can be buried for millions of years as a fossil fuel.

The *Carbon Game* senario is situated on the Colorado Plateau, a geographic region in the western United States that includes the Four Corners states of Arizona, New Mexico, Utah, and Colorado.

This semi-arid region is known for its dramatic landscapes consisting of canyons, plateaus, and colorful rock formations. The Grand Canyon is the most famous landmark in the region. For geographic authenticity, the carbon cycle represented in the regional game does not include the ocean nor the cryosphere although students learn about these during the post game discussion. The game was adapted and modified by a team of educators and climate scientists as part of a larger climate science and solutions curriculum supplement for students on the Colorado Plateau. The ideas for the Colorado Plateau carbon cycle game originated from other carbon cycle games available on the Internet (Gardiner & Genyuk , 2006 and Kreger 2004).

Prior to playing the game, a teacher must create seven reservoir stations spread around the room. Each station contains a poster and a set of game cards (See Figure 2). To play the game, students are initially assigned to one of the seven stations: hydrosphere, lithosphere–limestone, lithosphere–fossil fuels, biosphere–soils, biosphere–animals, biosphere–soils, and atmosphere. At their station, students select a card, read and record the pertinent information regarding their carbon molecule including a description of the form of carbon and the process of transformation (See Figure 3). Regional examples of rock formations, plants, animals, and locations are used to help students recognize the dynamic nature of the carbon cycle in the past, present, and future. After recording the information from the card, the student moves to the station (or maybe stays put) as indicated by the information presented. The student selects a different card and continues the process until he/she has played 10 rounds. One round consists of a carbon game card played from the initial reservoir to the ending reservoir. The number of cards available at each reservoir is shown at the right. It takes an average of 20 minutes to play ten rounds depending on the age and background knowledge of the students.


Carbon Cycle Recording Sheet Name: ______

Round	Starting Reservoir	Time in Reservoir	Process causing change in form of carbon (if any)	Ending Reservoir
Ex.	Atmosphere	65 years	Photosynthesis	
1	Biosphere-Soil	5 Months	Cellular respiration	Atmosphere
2	Atmosphere	19 years	photosynthesis	Biosphere Plants
3	Biosphere Plants	3 months	Digested by animal	Biosphere Animal
4	Biosphere Animal	2 years	cellular respiration	Atmosphere
5	Atmosphere	21 Years	dissolved in water	Hydrosphere
6	Hydrosphere	4 months	degassing	Atmosphere
7	Atmosphere	40 Years	Photosynthesis	Biosphere Animal
8	Biosphere Animal	2 Years	cellular respiration	Atmosphere
9	Atmosphere	57 Years	breathing ? inhale - exhale	Atmosphere
10	Atmosphere	90 years	dissolved	Hydrosphere

Figure 3. Carbon Cycle Game Recording Sheet

(Source: the *Climate Change Science and Solutions: Creating Innovative Education Tools for Native Americans and Other Rural Communities on the Colorado Plateau,* a Climate Change Education Partnership grant funded by the National Science Foundation to Northern Arizona University.)

Each student has a unique experience playing the game. Students begin at different reservoirs and each card leads to different reservoir destinations. Examples of a set of three Colorado Plateau Carbon Game cards illustrate both the process of carbon moving and how regional information is incorporated into learning (See Figure 4). Students do not get to choose where to begin. Instructions recommend that the teacher randomly assign students to start at a particular reservoir. The students then follow the journey of a carbon molecule to other reservoirs as indicated on the cards.

Reservoir	Number of Cards
Lithosphere – Fossil Fuels	4 Cards
Lithosphere – Limestone	4 Cards
Biosphere - Plant	11 Cards
Biosphere – Animal	5 Cards
Biosphere	5 Cards
Atmosphere	11 Cards
Hydrosphere	8 Cards

Table 1. Number of Carbon Game Cards for Each Reservoir

(Source: Author)

Students analyze their findings from the cards, responding to the following questions individually in their science journals/notebooks:

1. In which reservoirs did you remain for millions of years before you were able to go to a new reservoir?
2. Which processes move carbon fairly quickly from one reservoir to another? For example, what process moves carbon between the atmosphere and the biosphere? What process moves carbon from the biosphere to the atmosphere?

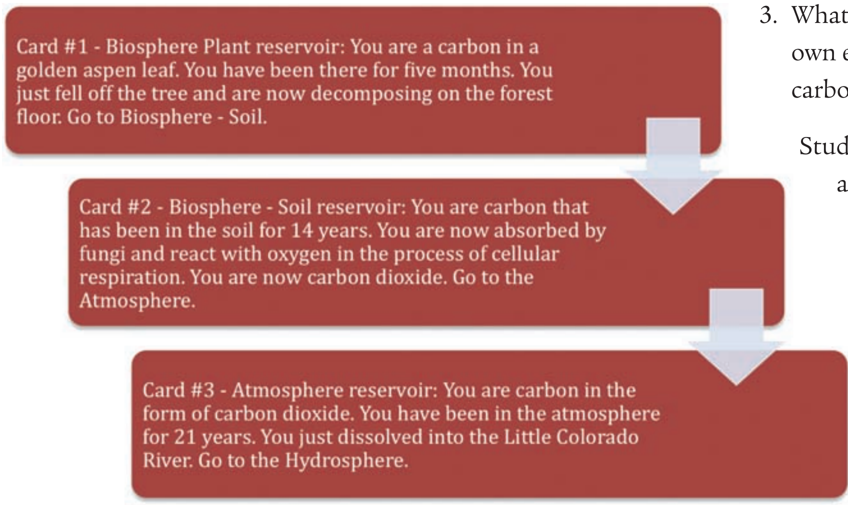


Figure 4. Example of the start to a possible carbon molecule journey a student may follow using the *Carbon Game* cards.

(Source: the *Climate Change Science and Solutions: Creating Innovative Education Tools for Native Americans and Other Rural Communities on the Colorado Plateau,* a Climate Change Education Partnership grant funded by the National Science Foundation to Northern Arizona University.)

3. What evidence do you see, from the game or from your own experience, regarding how humans are changing the carbon cycle?

Students find that they remain longest in the lithosphere and return most often to the atmosphere. Some lithosphere cards indicate to students that the carbon is still buried and so remains in the lithosphere. Students then select a different lithosphere card and collect new information. Eventually, students will obtain a card in which the carbon is released and students then can move to a different reservoir. Students can become frustrated initially by being "stuck" in the lithosphere. However, the game is a simulation and therefore models how carbon moves through the various reservoirs including the relative length of time carbon is sequestered in each reservoir. In addition, the model allows students to begin to explore the idea that human activities can release increased carbon dioxide into the atmosphere. More students, and thus more carbon, move through the atmosphere reservoir.

To conclude the lesson, students draw and label their own diagrams of a carbon cycle based on their experience with the game. They compare their diagram with other examples of carbon cycle diagrams from more conventional sources, such as textbooks, to reinforce the learning. This game-style introduction to climate change sets a foundation for students to learn more about carbon dioxide and other greenhouse gases, the greenhouse effect, carbon dioxide changes over time in the atmosphere, and the evidence for current global temperature increases.

The *Carbon Game* was intentionally designed to incorporate multiple learning styles and to capitalize on student interest through regional references. Teachers using the *Carbon Game*, specifically mentioned the activity as a great example of providing students the opportunity to gain a deeper understanding of carbon and the biogeochemical cycle that occurs as carbon moves from one reservoir to another. The teachers also noted high student engagement and found that the game was an effective manner to introduce the role of carbon in climate change. One teacher commented about her students, "*They loved the Carbon Game. To me, learning about carbon was the bread and butter of the content.*"

The *Carbon Game* presented here is one example of a regionally relevant approach to teaching students about climate change. The benefit of this approach to learning is that it allows students to build conceptual understanding by providing a relatable context. Cognitive brain research on how people learn provides evidence that people develop new learning based on previous experiences and knowledge (Bransford, Brown, & Cocking 2000). It makes sense that students can construct their understanding of scientific concepts, like the carbon cycle, with new information that incorporates familiar regional examples. This instructional approach can easily be adapted and expanded to other regions of the world. One simply needs to use scientific information about how carbon moves through reservoirs while referring to regional places, animals, plants, bodies of water and geological formations. If you modify the Colorado Plateau version of the game to fit your region, then oceans, glaciers and ice sheets may need to be included in your version.

References

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind, experience, and school*. (Expanded ed. ed.). Washington D.C.: National Academy Press.

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science: research into children's ideas*. London: RoutledgeFalmer.

Gardiner, L., & Genyuk, J. (2006, November 6). *The carbon cycle game*. Retrieved from http://www.windows2universe.org/earth/climate/carbon_cycle.html

Intergovernmental Panel on Climate Change (IPCC).(2007).*Climate change 2007: synthesis report*. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Core Writing Team: Pachauri, R.K, &Reisinger, A. (eds.)]. Geneva, Switzerland: IPCC. 104 pp.

Kreger, C. (2004, November 10). *Exploring the environment: Global climate change*. Retrieved from http://www.cotf.edu/ete/modules/climate/GCcarbon1.html

National Research Council. (2012). *A framework for K-12 science education: practices, crosscutting concepts, and core ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards.Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Summers, M., Kruger, C., Childs, A., &Mant, J. (2001). Understanding the science of environmental issues: development of a subject knowledge guide for primary teacher education. *International Journal of Science Education*, *23*(1), 33-53.

About the Authors

The authors are partners on a "Phase I - Climate Change Education Partnership" grant funded by the National Science Foundation to Northern Arizona University. The goal of *"Climate Change Science And Solutions: Creating Innovative Education Tools For Native Americans And Other Rural Communities On The Colorado Plateau"* was to develop and implement a middle school through high school climate change curriculum serving primarily Native American and rural students on the Colorado Plateau. Together with BSCS (Biological Sciences Curriculum Study), a nonprofit curriculum study committed to transforming science teaching and learning, the project created the *Colorado Plateau Carbon Connections* curriculum, a 10-lesson high school curriculum based on understanding the carbon cycle and its relevance to climate change. The Carbon Cycle game is part of Lesson 2.

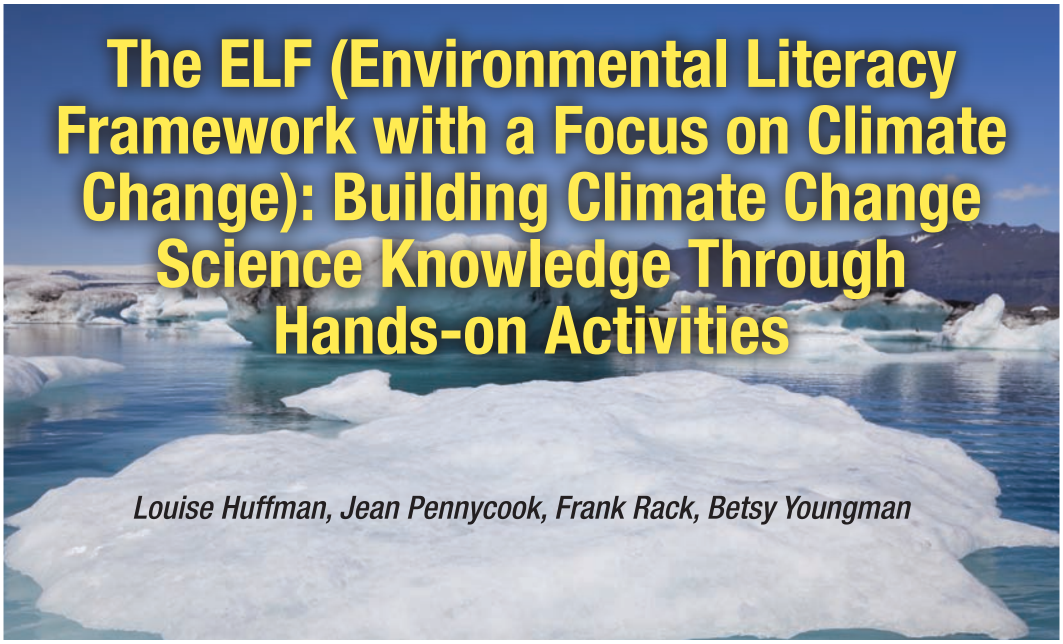
Joëlle Clark, MA, is a Professional Development Coordinator for the Center for Science Teaching & Learning, Northern Arizona University. She is a science educator and an applied anthropologist who has designed, written, and taught science and culture curricula and professional development programs. Joëlle can be reached at Joelle.Clark@nau.edu

Jane Marks, PhD, is the principal investigator for the project, a fresh water biologist and professor with the Biology Department, Northern Arizona University. Her leadership developed the partnership and created the vision for the climate science and solutions educational materials for the Colorado Plateau. She has also co-produced a PBS documentary titled "A River Reborn" directed by Emmy award winner Paul Bockhorst and narrated by Ted Danson. The film tells the story of the restoration of Fossil Creek and was aired on over 200 PBS stations. Dr. Marks can be reached at Jane.Marks@nau.edu

Carol Haden, EdD, is a senior consultant with Magnolia Consulting, LLC, an evaluation and research company. She is a former science educator and the evaluator for the project. As a teacher, Carol taught on the Navajo reservation. Her current work focuses on designing and implementing formative and summative evaluation studies of programs in K-20 STEM education in formal and non-formal settings. Dr. Haden can be reached at Carol@magnoliaconsulting.org

Melinda Bell, MAT, is a former high school biology teacher and is the curriculum developer for the project. She is a science curriculum developer and professional development provider. She has traveled as a teacher researcher, most notably as a PolarTREC Teacher in Antarctica. Melinda can be reached at Melinda.Bell@nau.edu

Bruce Hungate, PhD, is a climate scientist and professor in the Biology Department and Merriam-Powell Center for Environmental Research, Northern Arizona University. His research focuses on ecosystem processes, especially carbon, water, and nutrient cycling. He studies biogeochemical responses to global changes, such as rising atmospheric CO_2, climate change, nitrogen deposition, and altered land use.



The ELF (Environmental Literacy Framework with a Focus on Climate Change): Building Climate Change Science Knowledge Through Hands-on Activities

Louise Huffman, Jean Pennycook, Frank Rack, Betsy Youngman

Abstract

The ANDRILL (ANtarctic geological DRILLing) Science Management Office at the University of Nebraska-Lincoln and other members of our team, with funding from a NOAA (National Oceanic and Atmospheric Administration) Environmental Literacy grant (NA09SEC46900009), have created a series of hands-on activities that give middle and high school students a foundation in understanding the basics of climate change from an Earth systems approach to the topic. The entire series, entitled *Environmental Literacy Framework (ELF), with a focus on climate change* provides educators with a 5-unit collection of activities aimed at creating climate change science knowledge among students. The 5 units are organized around the idea of "a system of systems," with energy exchanges providing the connections among the systems. Individual activities in each unit provide engaging entry level experiences intended to motivate students to ask questions and to build a strong base for scaffolding climate change knowledge through a careful construction of climate science concepts. This article focuses on one of the ELF activities, entitled *Earth's Albedo*.

The ELF

Constructing learning and scaffolding experiences with new concepts is important to building the broad cognitive framework necessary for understanding the complexities of the climate system. Initial results from recent studies indicate that a constructivist and experiential approach to teaching climate change concepts builds students' knowledge and ideas about the multiple and diverse dimensions of climate change issues. (Pruneau, 2010) With funding from a NOAA Environmental Literacy grant, the ANDRILL Science Management Office at the University of Nebraska-Lincoln and other members of our team, have created a series of hands-on activities that give middle and high school students a foundation for understanding the basics of climate change from an Earth systems approach to the topic. The *"Environmental Literacy Framework (ELF), with a focus on climate change"* provides educators with a 5-unit collection of activities aimed at creating climate change science knowledge organized around the idea of "a system of systems," with energy exchanges providing the interactions between and within systems. Activities provide engaging entry level inquiry experiences intended to motivate students to ask questions and to build a strong base for scaffolding climate change knowledge through a careful construction of climate science concepts.

The ELF activities are modeled after ANDRILL's earlier resources titled Antarctica's Climate Secrets, (Dahlman, 2007) or "Flexhibits." (FLEXible exHIBITS). Students learn from building and manipulating the models and engaging in the activities, then using their materials to teach a different audience. Students take on the role of "teachers" and "scientists" as they teach concepts of climate science to audiences like younger students, community groups, or museum visitors. Taking part in a Flexhibit is a powerful learning experience and extends and cements the learning, because "No one...learns as much as the individual teaching [it] for the first time." (Bodner, 2003)

The ELF has been field tested by classroom teachers for two years with an extremely positive response from educators in grades 5 to AP Environmental science courses.

> "My department is loving the activities in the *ELF* curriculum. It has been very useful to have this *ELF* material with the background reading, materials lists, and procedures in one place. It is meaty content that meets our needs. .... (in) our 9th grade curriculum, the biology classes and environmental science classes have selected activities to enrich their content as well. Our school has greatly benefited from your efforts."
>
> — Jennifer H., Seattle, Washington

Each activity in the *ELF* includes background materials for the teachers, links to powerpoints for presenting the information to students, a glossary of terms, all data sheets, extension ideas, links to additional resources, and a correlation guide to National Science Standards. There is a close correlation to the draft of the Next Generation Science Standards, and those will be posted online when the NGSS is finalized. The activities are intended to be extremely flexible and directions are written at a middle school reading level making it accessible to students whether the activities are used independently in class, for homework, in a lab setting or in an after school club or program. All activities are freely available for download at www.andrill.org/education/elf. This article will focus on one of the *ELF* activities.

Earth's Albedo

In this hands-on activity, learners develop their conceptual knowledge of the term *albedo* (the ability of a surface to reflect energy) and create a model to illustrate the relationship between the albedo of various Earth surfaces and the energy balance of our planet. Students propose a relationship between the albedo of these surfaces and climate patterns observed around the world.

Some of the questions learners are expected to address are:

- How do ice and snow help regulate the overall energy balance of the Earth?
- How will the impact of climate change and reductions in the amount of snow and ice affect the Earth's ability to reflect incoming solar energy?

As with all the activities in the *ELF*, this one begins with thoughtful focus questions for the learners, followed by background information and a description of the activity. For *Earth's Albedo,* the students are given a common example of albedo from their everyday experience: "Think back to a hot summer day and the feeling of walking barefoot on grass and then a sidewalk or paved surface." From there they are led to a conceptual understanding of albedo before working with the activity. The activity demonstrates and models how albedo varies with different Earth surfaces.

Students gather their own data so group results may vary. Students then analyze the data using simple math processes and draw conclusions about how various Earth surfaces contribute to the

ACTIVITY 1D-Earth's Albedo Unit-1 ENERGY

Print out a copies for the Albedo activity

Earth's Albedo Data Table							
Land surface type	Round 1	Round 2	Round 3	Average Of 3 rounds	Albedo	Number Reflected (Average x albedo)	Number Absorbed (Average – number reflected)
Taiga and Boreal Forest					0.20		
Deserts and Shrubs					0.30		
Inland Water					0.10		
Coniferous Forest					0.10		
Deciduous Forest					0.20		
Grassland					0.20		
Ocean					0.10		
Tundra					0.20		
Ice and Snow					0.80		

67

Figure 1. Earth's Albedo Data Table

Source: http://www.andrill.org/education/elf/activities/1D

overall Earth energy budget. They are then asked to predict how changes in the overall amount of some surfaces like ice and snow will affect the Earth's temperature and climate patterns.

Addressed in this activity are these National Science Education Standards 5-8:

1. Physical Science Standard B
2. Earth Science Standard D
3. History and Nature of Science Standard G

Materials

Materials for each team of students: All reproducible materials (maps, data table, etc.) can be found at http://www.andrill.org/education/elf/activities/1D

1. 17" X 22" Global Biomes Map placed in a copy paper box top or similar tray with an edge to keep the popcorn kernels from falling off the work surface
2. Plastic bag of 100 kernels of unpopped popcorn (representing 100% of the sun's energy)
3. Sorting tray (ice cube trays or egg cartons work well) labeled with the biomes from the map key
4. Data table for recording results

Directions

1. Randomly sprinkle the popcorn kernels out of the bag over the entire surface of the map
2. Collect and sort the kernels into the sorting tray, according to the nine different surfaces on which they landed
3. Count the popcorn kernels in each section of the sorting tray; record the number of kernels counted onto the corresponding sections of the data table (See Figure 1)
4. Return all popcorn to the original plastic bag
5. Repeat steps #1-4 three times
6. Average the number of kernels on each land surface type.
7. Multiply the average number of popcorn by the albedo factor as shown on the data table.
8. Complete the calculations and compare how much incoming solar radiation is absorbed by each type of surface

Figure 2 (top). Working as a team to sort popcorn kernels according to the biome on which the kernals landed. Photo: Louise Huffman

Figure 3 (bottom). Calculating Earth's albedo. Photo: Louise Huffman

Students will observe that solar radiation falling on surfaces such as snow and ice contributes less to the overall energy budget of the Earth than radiation falling on forests, water or deserts. Students then do a second round of the activity using the map without Arctic summer sea ice and compare how the loss of ice may affect Earth's energy budget.

Figure 4. Comparing Earth's albedo today with the albedo of Earth without any Arctic summer sea ice.

Photo: Louise Huffman

Questions for students to ponder and discuss in their groups or as a class:

1. What land surfaces reflect the most incoming radiation?
2. What land surface types absorb the most incoming radiation?
3. How would the total amount of the sun's radiation absorbed by the Earth change if all of the tundra/taiga was covered year round with snow and not just in the winter as it is now? How would this change affect the Earth's average temperature?
4. How would the total amount of the sun's radiation absorbed by the Earth change if there were fewer forests or more deserts? How would this affect the Earth's average temperature?
5. How would the decrease in the amount of snow and ice on the Earth's surface change the amount of total energy absorbed by Earth? How would this affect the Earth's average temperature?

Student conclusions from this activity include:

1. The amount of solar radiation absorbed (or reflected) by the Earth varies with the type of surface.
2. The more solar radiation the Earth absorbs (the less reflected), the warmer the Earth will be.
3. Any changes in the amount of solar radiation absorbed by the Earth affects the Earth's climates.
4. As the amount of ice and snow covering the Earth's surface changes, the Earth's temperature may also change.

Conclusion

The climate system is extremely complex. By actively engaging in hands-on inquiry activities, students construct scientific knowledge and develop a conceptual framework for building climate change knowledge. *Earth's Albedo* is one such activity in which students create a model to illustrate the relationship between the albedo of various Earth surfaces and the energy balance of our planet. Students propose a relationship between the albedo of these surfaces and climate patterns observed around the world. As they manipulate their model, they observe that solar radiation falling on surfaces such as snow and ice contribute less to the overall energy budget of the Earth than radiation falling on forests, water or deserts. They conclude that if climate change affects the amount of ice and snow covering the Earth's surface, Earth's temperature may also change.

References

Bodner G. *Eternal verities: how the results in learning can improve the way we teach.* Purdue University Workshop, 2003.

Dahlman, L. *Antarctica's climate secrets.* 2008. *http://www.andrill.org/flexhibit/flexhibit/materials/activities/index.html*

Pruneau, D. Gravel, H. Bourque, W. Langis, J. *Experimentation with a socio-constructivist process for climate change education.* Taylor Francis online, 2010.

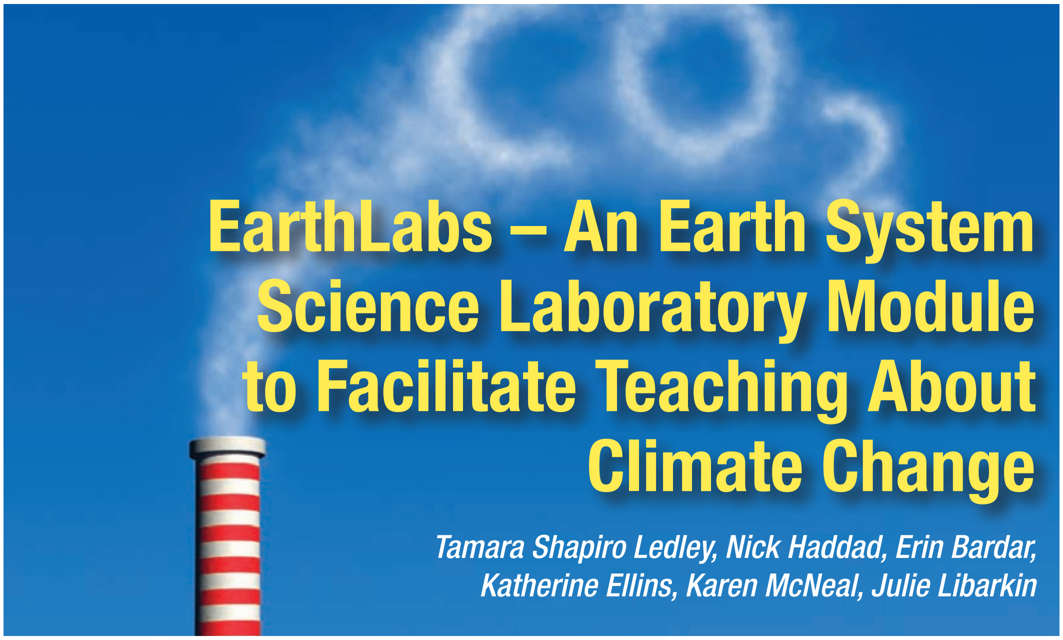
About the Authors

Louise Huffman, MS Ed, a former teacher with over 30 years of public school experience, is ANDRILL (ANtarctic geological DRILLing) Coordinator of Education and Public Outreach at the University of Nebraska-Lincoln (UNL). Besides teaching children, Huffman has worked with the Golden Apple Foundation providing professional development workshops on science inquiry for teachers. She is a Fellow in the Golden Apple Academy and was also twice recognized for Excellence in Teaching by the Illinois Science Teachers Association. She spent two research seasons in Antarctica including coordinating the ANDRILL ARISE (ANDRILL Research Immersion for Science Educators) program in 2007. During the International Polar Year (IPY) she served as the Chair of the Formal Education Subcommittee of the IPY Education and Outreach Committee. Louise can be reached at lhuffman@andrill.org

Jean Pennycook, MS Ed, has been a secondary science teacher for more than 20 years in California. In that time she has promoted science education and excellence at all levels encouraging students to continue in higher education and pursue STEM related careers. Her first trip to Antarctica was in 1999 when she joined a team doing research on Mt Erebus. Since then she has focused her education and outreach on Adelie penguins, bringing Antarctic science research to classrooms worldwide. She is currently serving a second fellowship year with the Albert Einstein Distinguished Educator Fellowship Program at the National Science Foundation in Washington, DC. Jean can be reached at jean.pennycook@gmail.com

Frank Rack, PhD, is the executive director of the ANDRILL Science Management Office at the University of Nebraska-Lincoln. His responsibilities include: strategic planning, project development, research, education and outreach and administrative oversight of the U.S. ANDRILL Program. Rack is also an associate professor in the Department of Geosciences at UNL. He participated in the ANDRILL McMurdo Ice Shelf Project deployment to Antarctica in 2006 and the Coulman High Site Survey Project in 2010-11. Prior to joining UNL and ANDRILL, Rack was director of ocean drilling programs at Joint Oceanographic Institutions, a non-profit corporation representing 20 U.S. academic institutions. Before that, he was assistant director, ocean drilling programs, and associate director of the U.S. Science Support Program. Dr. Rack can be reached at frack2@unl.edu

Betsy Youngman, MS Ed, is a curriculum developer for a variety of educational projects across the nation including multiple EarthLabs modules. She has taught middle and high school science for 25 years, most recently in Phoenix. Youngman worked as a freelance writer, and is an active outdoorswoman, participating in cycling, hiking, skiing, and canoeing as a class 4-5 kayaker. She has worked on science research teams in Antarctica and Greenland. Betsy can be reached at betsy.youngman@gmail.com



EarthLabs – An Earth System Science Laboratory Module to Facilitate Teaching About Climate Change

Tamara Shapiro Ledley, Nick Haddad, Erin Bardar, Katherine Ellins, Karen McNeal, Julie Libarkin

Abstract

Climate science has emerged as an important domain of education because of the implications of climate change for society, the need to train future scientists to continue to increase our understanding of the climate system, and the need for citizens to make informed and responsible decisions about their environment. Yet climate science presents real challenges in cognition, perception and pedagogy, especially as it applies to understanding the Earth as a dynamic system of components interacting at local to global spatial scales and over multiple and embedded time scales.

To facilitate student understanding of the complex interactions among the components of the Earth system and how that system changes over time, we have developed and implemented in classrooms,numerous high school level curriculum modules which make up *EarthLabs*. The currently available *EarthLabs* modules focus on *Hurricanes*, *Drought*, *Corals*, *Fisheries*, *Climate and theCryosphere*, and *Earth System Science*. In this article we focus on the implementation of *EarthLabs* in Texas classrooms and in particular the *Earth System Science* module. The *Earth System Science* module has been developed to guide students to understanding Earth system dynamics. This includes facilitating a deeper understanding of how the components of the Earth system interact to shape the climate system, and how this system can change over time. Students begin the modules by investigating the interactions among the components of the Earth system on scales they are familiar with – their own local environment. Once these concepts have been grasped, the scope is extended to regional and global spatial scales.

Introduction

Humans are modifying Earth without fully understanding how our actions affect the atmosphere, hydrosphere, biosphere, and geosphere. However, research indicates that increases in globally averaged temperatures of a few degrees this century will likely cause drought, floods, extreme weather, and sea-level rise (IPCC, 2007a, 2007b, 2007c). For society to develop strategies to address climate change there is an urgent need for the inclusion of climate literacy in public education. Yet climate literacy demands cognitive and perceptual leaps for students and teachers (Grotzer & Lincoln, 2007) with respect to understanding the complex interactions among the components of the Earth System.

EarthLabs (Teacher Guide: http://serc.carleton.edu/earthlabs, Student Portal: http://serc.carleton.edu/eslabs) is an online curriculum for rigorous, quantitative lab science courses in Earth and environmental science. An *EarthLabs* module is comprised of six to nine sequenced labs intended to build on the knowledge and skills learned in the previous labs. With funding from the National Oceanographic and Atmospheric Administration (NOAA, NA05SEC4691004), the National Science Foundation (NSF, EAR-0807575), and the National Aeronautics and Space Administration (NASA, NNX09AL90G) there are six live *EarthLabs* modules: *Hurricanes*, *Corals*, *Fisheries*, *Drought, Climate and the Cryosphere,* and *Earth System Science*. Under current funding from the NSF (DUE-1019721, DUE-1019703, DUE-1019815) we are developing two additional modules: *Climate, Weather and the Biosphere*, and *Carbon and the Earth System*. In this article we describe the *Earth System Science* module and its implementation in Texas, provide teaching tips on module use, and describe evidence of impact on student learning about Earth system science.

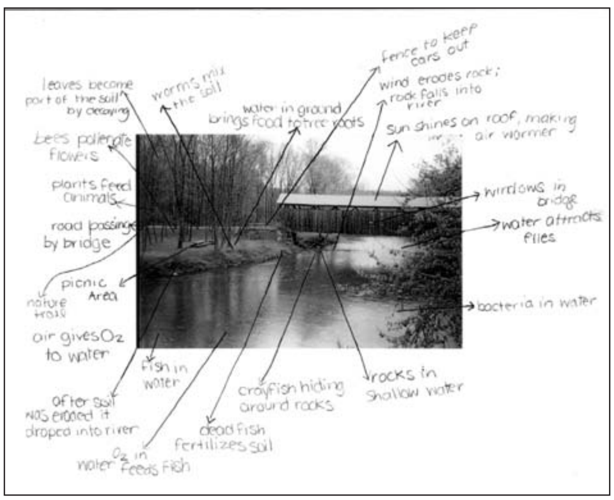


Figure 1. Photograph of GLOBE study site in Greenville, Pennsylvania USA annotated with interactions between components of the Earth system.

Source: EarthLabs ESS Lab 2A http://serc.carleton.edu/dev/eslabs/climate/2a.html and Earth as a System chapter of GLOBE Teachers Guide: Exploring the Connections activity LC2: Representing the Study Site in a Diagram, http://www.globe.gov/documents/356823/356868/earth_la_connections_lc1.pdf, page 9.

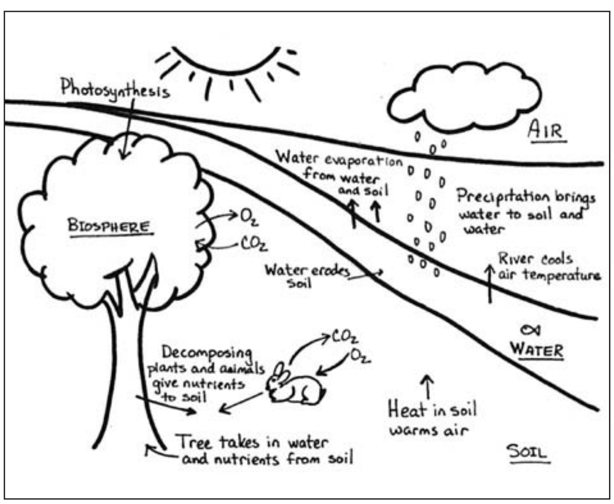


Figure 2. Simplified diagram of the interactions of the components of the Earth system at a GLOBE study site in Greenville, Pennsylvania USA.

Source: EarthLabs ESS Lab 2B http://serc.carleton.edu/dev/eslabs/climate/2b.html and Earth as a System chapter of GLOBE Teachers Guide: Exploring the Connections activity LC2: Representing the Study Site in a Diagram, http://www.globe.gov/documents/356823/356868/earth_la_connections_lc1.pdf, page 10.

EarthLabs: Earth System Science (ESS) Module

In the *EarthLabs ESS* module (http://serc.carleton.edu/earthlabs/climate) we begin by examining Earth systems processes on the time and space scales that are most familiar to students. The first few labs focus on the local scale – the scale that students experience every day; familiar places, such as the schoolyard, a park, or a common area in their community can be the focus at the local scale.

The *EarthLabs ESS* Teacher Portal provides background information, lists of required materials, whether an internet connection is required, and the online tools that will be used. In this module, online tools include Google Earth, the GLOBE graphing tool, the NASA Ocean Motion Ship Drift Model, NEO (NASA Earth Observations tool and data), and ImageJ (a public domain Java image processing program that can read many image formats including tiff, gif and jpg and can display, edit, analyze, process, save and print results, is available at http://rsb.info.nih.gov/ij/download.html). Instructions are provided for using these tools to complete the activities.

In the first lab, *Think Globally, Act Locally*, students learn about the different components of the Earth system and explore a local site for those connections. They visit the site, photograph and identify various components of the Earth system, and describe these components within the context of the local environment. Students are then asked to predict how changes in one component might impact others.

In the second lab, *Drawing Local Connections*, students annotate their photographs of the site with the interconnections they observed or inferred (Figure 1) , and consider how energy and matter are transferred between different components of the Earth system. The students are then asked to use their annotated photograph to create a simplified diagram of their site that highlights the most important interactions that define their local environment (Figure 2). This place-based approach results in highly localized responses with expected answers being different for temperate environments versus either desert or tropical environments.

In the third lab, *Discovering Local Data*, students examine how the interactions between the components of the Earth system they have been exploring are reflected in observational data. This involves students looking at the relationships among four different variables measured at the local study site over the course of a year. While it would be ideal for students to work with observations taken locally, these data are not always available. In these cases, students can use data from a school in Greenville, Pennsylvania USA that has several continuous years of data. Students examine maximum surface air temperature, soil moisture at 10 cm and 90 cm below the surface, and precipitation and see that as surface air temperatures rise in the spring, the 10 cm, and later the 90 cm soil moisture, decrease. They also see that precipitation events cause short-term increases in the 10 cm soil moisture (Figure 3).

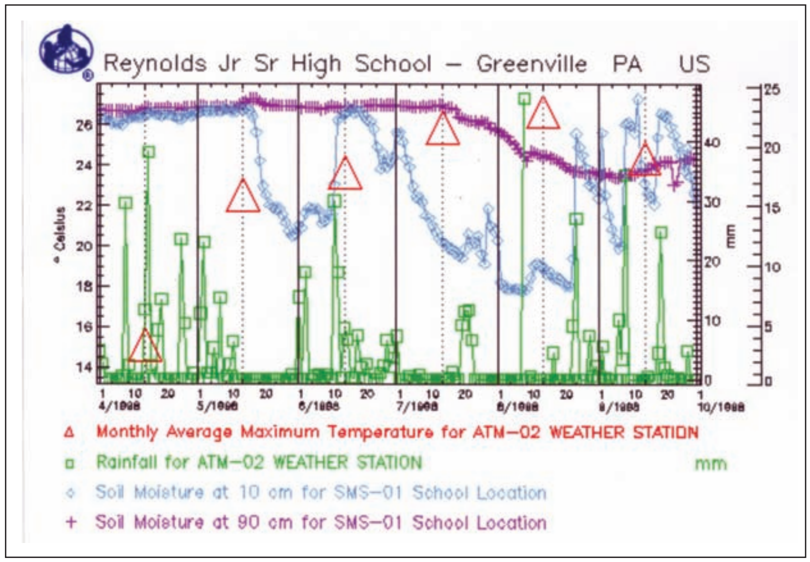


Figure 3.Monthly averaged maximum air temperature, rainfall, and soil moisture at 10cm and 90cm below the surface from April through June 1998 in Greenville, Pennsylvania USA.

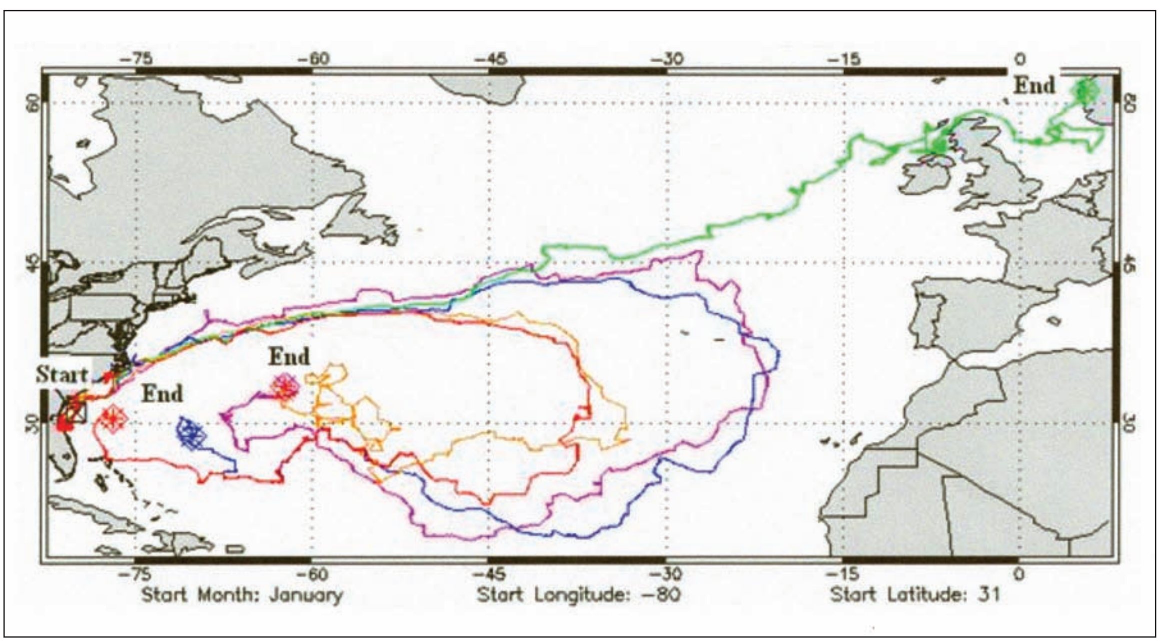
Source: EarthLabs ESS Lab 3 http://serc.carleton.edu/dev/eslabs/climate/lab3.html and Earth as a System chapter of GLOBE Teachers Guide: Exploring the Connections activity LC3: Using Graphs to Show Connections, http://www.globe.gov/documents/356823/356868/earth_la_connections_lc3.pdf , page 10.

In the fourth lab, *A Bird's Eye View: Exploring Your Region*, students focus their attention on an area significantly larger than their study site, applying their developing knowledge of local Earth system interactions to a regional scale. Although the scale being examined changes, the questions remain the same. For example: *How does organism, process or event "A" influence, or become changed by, organism, process or event "B"? Specifically, in what ways is my local region interconnected with adjoining regions? What types of matter and energy cross regional boundaries to help define and shape neighboring regions?* Although students investigate the region in which they live, the concept of a "site" changes: instead of focusing their attention on an actual plot of land, students investigate their region by combining their personal knowledge of the region with information they can learn from Google Earth.

Students begin the fifth lab, *It's All Connected: Global Circulation*, by looking at average wind and water patterns across the globe to explore how different regions of the world are connected. Onto a world map, they trace pathways of wind and water into and out of their region, and across an ocean to other regions on Earth. The ideas of movement of matter and energy across Earth are reinforced as students first predict where a bottle, dropped in the ocean, will go as a result of surface ocean currents over a period of time, and then use a computer model of ocean currents to test their predictions (Figure 4).

Figure 4. Model simulations of the path over five years of a "bottle" dropped in the ocean off the southeast coast of the United States. The five tracks show the approximate effects of the ocean surface current variability.

Source: EarthLabs ESS Lab 5b http://serc.carleton.edu/dev/eslabs/climate/5b.html and NASA Ocean Motion and Surface Currents, Ship Drift Model, http://oceanmotion.org/html/resources/drifter.htm.



In the sixth lab, *Air, Water, Land, & Life: A Global Perspective*, students review a variety of images and maps of the whole Earth using global NASA datasets to identify the major components of the Earth system at the global scale. The maps show solar energy, average temperature, cloud cover, precipitation, soil moisture, and vegetation, and the images are of Earth from space. Students discuss ways that individual components interact to form the whole Earth system. After engaging in a role-playing game, students are able to describe the water cycle at the global scale in greater detail, identify the components of the Earth system through which water passes and the processes that move water, and draw an abstract diagram of the water cycle at the global scale.

In the seventh and final lab, *A Year in the Life of the Earth System*, students consider change over time. *How do the atmosphere, hydrosphere, pedosphere (soil), and biosphere change over the course of a year? What relationships exist between components of the Earth system at the global scale?* Students use *ImageJ* to make a global map-based animation depicting monthly changes in one component of the Earth system, allowing exploration of how Earth changes over time at the global scale. Students then make a similar animation of two datasets, providing opportunities to investigate relationships between different components of the Earth system over time.

On completing the *EarthLabs ESS* module students are asked to reflect on what they have learned by describing the Earth as a complete system and giving specific examples of the ways that each component of the system impacts other components.

Implementation of EarthLabs in Texas

Seven high school teachers aided in the review of this EarthLabs ESS module as it was being developed and presented the module to 42 other Texas teachers at a professional development workshop. This was part of a larger University of Texas Institute for Geophysics-led TeXas Earth and Space Science Revolution (TXESS) Revolution program. This program (Ellins et al. 2011) is focused on developing the content knowledge and skills teachers need to enable them to teach the state's current offering of a number of high school level Earth science courses, including: Earth and Space Science, Environmental Systems, Aquatic Science, Astronomy, and AP Environmental Science.

Teaching Tips from the EarthLabs Teacher Partners

The *EarthLabs* teachers implemented this *EarthLabs ESS* module in their classrooms as part of the research on the student learning component of the project. These teachers have provided useful teaching tips to help other teachers implement this module. These include:

- In the progression of studying Earth system interactions at local, regional, and global scales, the regional scale may be the most difficult. Highlighting the characteristics of your region is a good way to start; what differentiates your area from neighboring areas in terms of natural features, biomes, or human-constructed features? Drawing the borders for your "study region" within that greater region can be more arbitrary.
- Ideally the local "study site" is close enough to the school to allow students to make return visits for additional observations.
- Posting the learning objectives for each lab in a visible place within the room can help students stay in touch with the key ideas.
- If your students are unfamiliar with Image J (Lab 7) get them familiar with it in another context before using it in the module. One suggestion is have them complete the investigation *Measuring Distance and Area in Satellite Images* (http://serc.carleton.edu/eet/measure_sat2/index.html) from the Earth Exploration Toolbook (Ledley et.al, 2011).

- Book a computer lab in advance; have the software needed installed in advance; and go through the labs yourself to assure that you have access to all the websites with data, animations, visualizations, etc. included, and ample bandwidth for all students.

Effectiveness of the EarthLabs ESS Module for Student Learning

We examined the effectiveness of the *EarthLabs ESS* module through a number of mechanisms including student pre- and post-instruction tests, classroom observations, and teacher interviews.

The pre- and post- tests showed that students significantly ($p<0.05$) improved their understanding of key concepts after instruction. An example is one student's responses to the question "Describe and define Earth system science in your own words." In the pre-test the student responded *"The research of the way that the Earth operates. This shows us how the earth is changing as a whole"* indicating an understanding of the individual words without a real understanding of the interactions of the different components of the Earth. After instruction, this student wrote, *"[Earth system science is the] biosphere, pedosphere, atmosphere, and hydrosphere used to find information and solve facts for future use and help us find out more about the way our planet works."* This shift to articulation of aspects of the planet that make up the Earth system, as well as the notion that this science deals with understanding how the planet works, is indicative of overall student learning.

Classroom observations were focused on documenting the nature of student activities during classroom instruction. Results indicated that students were rarely off-task (<2% of the time), spending most of their time working in the online environment (61%), and about 30% discussing the materials or engaging in hands-on activities.

Teacher interviews indicated that generally, teachers felt strongly that the *EarthLabs* materials were promoting student learning about Earth systems. Teachers also felt that the modules played an important role in improving students' conceptual understanding of the dynamic nature of Earth processes and their ability to connect concepts to personal experience. One teacher noted, *"In AP environmental courses, we try to look at Earth as system,... but the EarthLabs tied in the big picture much better than I have been able to do in the past."*

Summary

The *EarthLabs ESS* module was designed to help students, through inquiry-based activities, develop a deeper understanding of Earth as a system. This understanding is "key" for students to be able to explore and understand the complex issues that society must deal with in the face of climate change. Our work with teachers and students in Texas indicates that the *EarthLabs ESS* module is engaging and effective in helping students develop an understanding of the Earth as a system in the context of recognizable ideas and experiences and possibly helps them to make the more abstract concepts in climate change more relevant to their lives.

References

Ellins, K.K., Olson, H.C., Snow, E., Willis, M., Odell, M., Stocks, E., and Manganella, K., 2011, Characteristics of the Texas Earth and Space Science (TXESS) Revolution Model of In-service Teacher Professional Development, Geological Society of America Abstracts with Programs, V. 43, No. 5, Paper No. 216-8.

Grotzer, T., & Lincoln, R. (2007). Educating for "Intelligent Environmental Action" in an Age of Global Warming. In S. M. a. L. Dilling (Ed.), Creating a Climate for Change (pp. 266-280). New York: Cambridge University Press.

Hoffman, M., & Barstow, D. (2007). Revolutionizing Earth System Science Education for the 21st Century. Washington DC: NOAA.

IPCC (Ed.). (2007a). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press, http://www.ipcc.ch/ipccreports/ar4-wg2.htm

About the Authors

Dr. Tamara Shapiro Ledley is a senior scientist and chair of the Center for Science Teaching and Learning at TERC, and is chair of the Climate Literacy Network. She received her PhD from MIT in 1983 and conducted a research program in climate change for 15 years before moving into science education. Her efforts focus on bridging the scientific and educational communities to make Earth science data accessible and usable in educational contexts, and on improving the climate literacy of teachers, students, and citizens. Dr. Ledley can be reached at Tamara_Ledley@terc.ed

Mr. Nick Haddad is a Senior Curriculum Developer and Project Director at TERC. He holds degrees in both engineering and education and was a classroom teacher for 24 years before switching his focus to support curriculum and teacher professional development. His work at TERC is a natural extension of his life-long interest in the natural and physical sciences. Nick can be reached at nick_haddad@terc.edu

Dr. Erin Bardar is a curriculum developer, professional development specialist, and project director at TERC. She has a Ph.D. in astronomy, but dedicates much of her time to Earth, environmental, and climate science education. She is always looking for new ways to bring technology and authentic research experiences for students into the classroom. Dr. Bardar can be reached at erin_bardar@terc.edu

Dr. Katherine Ellins is a program manager at the University of Texas at Austin Institute for Geophysics where she specializes in geoscience education. She received a PhD from Columbia University in 1988. The focus of her work is to provide science professional development for K-12 teachers and in the development of earth science curriculum for grades 8-12. Dr. Ellins can be reached at kellins@ig.utexas.edu

Dr. Karen McNeal is an Associate Professor in the Department of Geosciences at Mississippi State University. She spends her time teaching and conducting research in the biogeochemistry and geoscience education research fields. Her research in geoscience education explores questions concerning the human understanding of complex and dynamic earth system and their interactions. Dr. McNeal can be reached at ksm163@msstate.edu

Dr. Julie Libarkin is an Associate Professor of Geological Sciences and Associate Director for Educational Research in the Center for Integrative Studies at Michigan State University. Her work focuses on helping teachers and curriculum developers collect data that can document the impact of their work. Dr. Libarkin can be reached at libarkin@msu.edu

IPCC (Ed.). (2007b). Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, http://www.ipcc.ch/ipccreports/ar4-wg3.htm

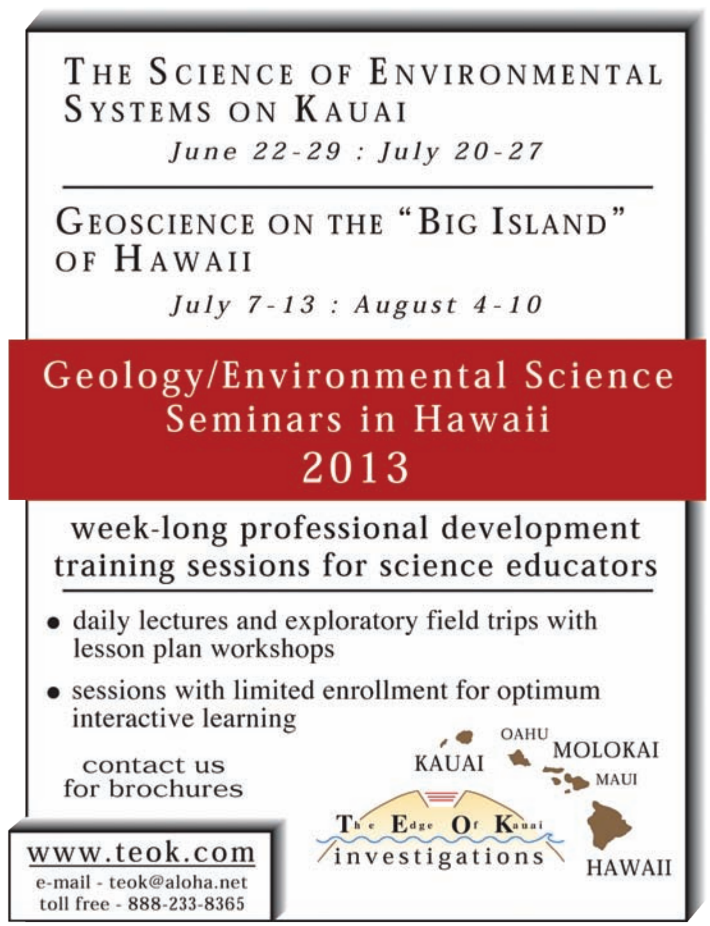
IPCC (Ed.). (2007c). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, http://www.ipcc.ch/ipccreports/ar4-wg1.htm

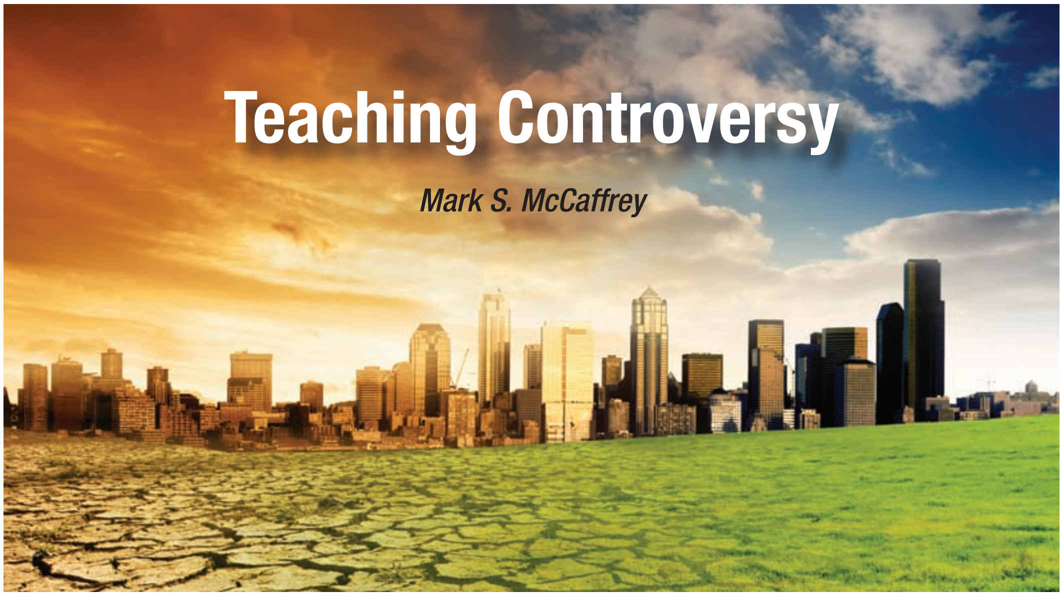
Ledley, T.S, Dalhman, L., McAuliffe, C., Haddad, N., Taber, M.R., Domenico, B., Lynds, S., Grogan, M. (2011). Making Earth Science Data Accessible and Usable in Education, Science, 333(6051), 1838-1839, http://www.sciencemag.org/content/333/6051/1838.summary.

Libarkin, J. C., & Kurdziel, J. P. (2006). Ontology and the Teaching of Earth System Science. Journal of Geoscience Education*, 54*, 408-413.

Schuster, D. A., Filippelli, G. M., & Thomas, C. W. (2008). Secondary Students' Subject Matter Representations of Climate Change. Journal of Geoscience Education*, 56*, 307-316.

Singer, S. R., Hilton, M. L., & Schweingruber, H. A. (Eds.). (2005). America's Lab Report: Investigations in High School Science: National Academies Press, http://www.nap.edu/catalog.php?record_id=11311





Teaching Controversy

Mark S. McCaffrey

Abstract

What could be wrong with presenting in a science class "both sides" of controversial topics like evolution or climate change, or having students debate the topics, using argumentation to improve their critical thinking skills? In the case of evolution, presenting supposed alternatives, such as intelligent design or young-earth creationism, is not only considered bad practice, but also unconstitutional in public schools due to the separation of church and state. However, in the case of climate change, the practice of teaching it as controversial and presenting "both sides" as if they are equally valid, is a too common practice among science teachers. This paper examines the reasons why teachers may be encouraged or drawn to "teach the controversy" about climate change, why it is ***not*** an effective practice and leaves students more confused, and how the Next Generation Science Standards may help to transform how we teach about climate and global change science and solutions.

Teaching Evolution and Climate Change: similar but different

Teaching evolution in classrooms has been a bone of contention for years, dating back to the Scopes trial in Tennessee in 1925, after the Butler Act outlawed the teaching of "any theory that denies the divine creation of man and teaches instead that man has descended from a lower order of animals." There have been numerous court cases since then, and efforts to teach "both sides" of evolution in public schools have been promoted. In the *Kitzmiller v. Dover* case, tried in 2005 in a Harrisburg, Pennsylvania, federal district court, it was found that intelligent design was a form of creationism, and therefore unconstitutional to teach in American public schools.

In the legal arena, climate change education is substantially different from the teaching of evolution. It isn't unconstitutional to teach "both sides" of climate change, and many teachers do this, although in instances where climate change is explicitly included in school district curriculum, teachers who don't teach to the curriculum could be accused of insubordination.

There are some similarities between evolution and climate change in how they are taught or not taught. Like evolution, climate change often isn't taught at all or isn't taught well. By and large, climate change has been missing from science education for many decades, in part because it is complex and doesn't fit neatly into traditional science education disciplines, in part because the science has been politicized and framed as uncertain and controversial.

Unsurprisingly, then, a study (Leiserowitz 2011) entitled "American Teens' Knowledge of Climate Change" conducted by the Yale Project on Climate Change Communication found that most adults and teens get a D or an F in terms of their basic climate and energy literacy. Fewer than 1 in 5 said they are "very well informed" about how the climate system works, or the different causes of, consequences from, or potential solutions for global warming, and only 27 percent said that in school they have learned "a lot" about global warming.

Importantly, in the study, 70 percent of teens said that they would like to know more about global warming. But they may be disappointed. For today, when climate change is taught at all, it is often not well taught, due to the lack of background in the subject content and pedagogical experience of the educator and/or the lack of inclusion of the topic in the curriculum and science standards.

Challenges and Opportunities: teach current science, not a phony debate

There are certainly substantial challenges to teaching climate change. The science itself is complex, crossing many scientific disciplines, particularly when the human societal dimension is included. For students, the science can be particularly challenging and non-intuitive. Even well-prepared teachers may struggle to help students overcome naïve ideas or misconceptions about climate dynamics.

Also, the topic has historically not been adequately or systematically addressed in most science standards. Even in college textbooks about environmental science, the subject of climate change may be only part of a chapter out of the entire book. In the classroom the topic might be covered in just one day out of an entire semester or skipped altogether. When the human dimension is added to the equation, the psychological and sociological aspects of climate change add to the complexity of teaching about climate change science and solutions. Clearly, in some communities and schools, one of the biggest obstacles to teaching climate change, for many teachers is that the topic has become extremely polarized politically, particularly in recent years. Largely because of this political polarization, a substantial number[1] of teachers who do cover the topic are opting to teach "both sides" of climate science. Most commonly this takes the form of presenting the "theory" that climate change is caused by human activities, and then attempting to balance it by presenting the counter-"theory" that climate change is simply due to natural cycles.

The reasons that teachers may employ the "both sides" approach vary. In some cases, they have experienced overt external pressure from other teachers, administrators, parents, or even students. In other instances, educators may opt to present "both sides" of climate change to students because they aren't confident or comfortable with the content, haven't mastered the pedagogy, or because of their own opinions or worldviews.

In some cases, teachers are swayed by deliberate efforts that promote "teaching the controversy", but this teaching only fosters confusion and denial of climate change. This approach is similar to the efforts to have evolution taught side-by-side with supposed alternative theories, like creation science, or more recently, intelligent design. Unlike efforts to "teach the controversy" of evolution,

1 Over a third—36%—of K-12 educators responding to a 2011 NESTA survey reported that they "have been influenced in some way (directly or indirectly) to teach 'both sides' of climate change." Although only 5% reported that they were required to teach "both sides" of climate change, 47% reported that they taught "both sides" because they thought that "there is validity to both sides." NESTA's survey was informally conducted on-line, however, and cannot be considered scientifically rigorous. See: http://www.nestanet.org/cms/sites/default/files/documents/ExecutiveSummaryClimateChangeEducationSurveyDecember2011.pdf

which is driven primarily by religious ideology, efforts to "teach the controversy" in climate change education are primarily motivated by political and economic ideological perspectives.

In both cases, those promoting "teaching the controversy" claim that it will foster student's critical thinking skills, ultimately teaching "more science not less." In both instances, the claim is made that the science is bad ("Climate change is a hoax!"), the societal implications of the science are bad ("Fixing the climate will destroy free market capitalism!"), and proponents insist that it is only balanced and fair to grant equal time to present "both sides" of "the debate" to let students decide for themselves. But students need to master the content before they can engage in meaningful argumentation.

To many Americans, "teaching the controversy" appeals to an ideal of fairness and balance. But when it comes to evolution, gravity, the laws of thermodynamics and, yes, climate change, there is no "other side" for students to learn about in a science class. Simply put, climate change is happening, and humans, having become a force of nature through our sheer numbers and technological impact, are responsible.

The bottom line is that while climate change certainly is a social and political controversy, it is not a scientific controversy. This is not to say there aren't a few scientific unknowns, in some cases substantial ones, regarding the details of how climate and the global environment will change and over what time scales. *Should we be preparing for three feet or six feet of sea level rise along our coasts? Will wildfires along the Colorado Front Range increase 300% or 600% as temperatures increase?* Within the community of climate and global change experts, there are areas of scientific disagreement such as these. But the biggest wild card is how humans are going to respond to the evidence presented by the scientific community.

The concept of human activities leading to climate change—specifically, the burning of fossil fuels, the warming of the atmosphere, and the resulting melting of the ice sheets, the rise of sea level, and the alteration of ecosystems—is not new to science education. Over fifty years ago, science education materials—including the booklet *Planet Earth: The Mystery with 100,000 Clues*, published by the National Academy of Sciences (1958), and related television programs and educational films—featured such information. Since then, however, with few exceptions the topic has largely been missing from K–12 science education.

What science educators ought to recognize is that for climate science, as for science in general, students need to master the content before they can engage in meaningful argumentation. True, argumentation can be a powerful way to engage students in learning science and debating the societal relevance of science and technology. But having students engage in a "phony" debate about whether climate change is happening, and whether humans are responsible, is counterproductive. Research has shown, and experience confirms, that teaching "both sides" of ***climate change*** is not sound, and can lead to more student confusion, not less.

For your classroom, here are a few tips on how best to address the controversy and denial of climate change. The tips are from the National Center for Science Education (http://ncse.com/climate/teaching/addressing-doubt-denial), which has been defending the teaching of evolution in public schools for many years and recently launched a new climate change education initiative:

> Science teachers have a responsibility to help their students understand, to the extent appropriate, the central methods and results of contemporary science. There is substantial scientific agreement around climate change: 97% of scientists who have published peer-reviewed scientific articles on climate change agree that humans have caused most of the increase in global temperature over the last 150 years … Science teachers thus have a responsibility to help their

students understand climate change, the evidence for climate change, and the fact that the scientific community agrees that the evidence is convincing.

Science teachers **should** therefore:

- be prepared, by understanding the content of climate science, using the most effective pedagogical methods for conveying it, and understanding the claims of climate change deniers
- be ready to cite the consensus of the scientific community on the reality of climate change and the consensus of the science education community on the importance of climate change education
- be respectful of student concerns (which are likely to reflect those of their parents or other trusted adults), while not engaging them in fruitless debate

By the same token, science teachers should:

- **not** misrepresent the scientific consensus by suggesting that climate change is a matter of scientific controversy or by presenting "the other side" as though it were scientifically credible
- **not** conduct "phony" debates in class about whether climate change is happening (as opposed to issues about which there is a genuine scientific debate or policy issues that aren't able to be decided by the science alone)
- **not** use supplementary materials (such as DVDs produced by climate change deniers) or invite guest speakers who may misrepresent climate science

Integrating Science and Solutions

One of the biggest complaints about climate change education efforts is that they alarm students, make them feel guilty, and convey a sense of gloom and doom. There's some truth to this. Climate change has an undeniable psychological and emotional dimension that must be acknowledged in order to effectively communicate or teach this challenging topic.

An emerging "best practice" that requires skill and creativity by the practitioner is for the teacher to weave a wide range of technological, engineering, behavioral and societal solutions into the mix. Students thus learn about possible ways to mitigate or adapt to climate change, at the same time and in the same educational context that they are learning about climate change. For example, when focusing on how the Sun is the primary source of energy for the Earth's climate system, teachers could augment their lessons on the Earth's energy budget with discussions of the effective solar design of buildings.This is not always easy since it requires true balance and critical thinking to avoid advocacy for a particular policy or technological solution. But it is the science teacher's responsibility to be an advocate for helping the learners become literate with the current science, ideally integrating climate and energy topics throughout the curriculum.

Next Steps

In science classrooms, we don't debate "both sides" of astrology or alchemy or whether the Earth is flat. Our duty as educators is to convey the complex, often challenging, and sometimes counter-intuitive consensus of current scientific research so that students can master the content and gain proficiency to help them to become more scientifically literate individuals, as well as better informed and better prepared citizens.

The proposed Next Generation Science Standards, which 26 states have been involved in drafting, include 30 standards from kindergarten to 12th grade that relate to understanding the basics of climate and energy concepts. These standards will help learners to examine the impact of human activities on climate and Earth's ecosystems, and engage them to develop technological, engineering and societal solutions in order to minimize human impacts on the Earth system, and become more resilient as individuals and communities when required to deal with local and global changes. The potential is enormous for these proposed science standards to help improve how climate and global change are taught and advance civic science literacy. But achieving this potential will require commitment, creativity, the development and deployment of new curriculum, and professional development programs that can prepare educators to effectively convey 21st-century science to learners. No small task, but crucial to preparing society for changes that are already well underway.

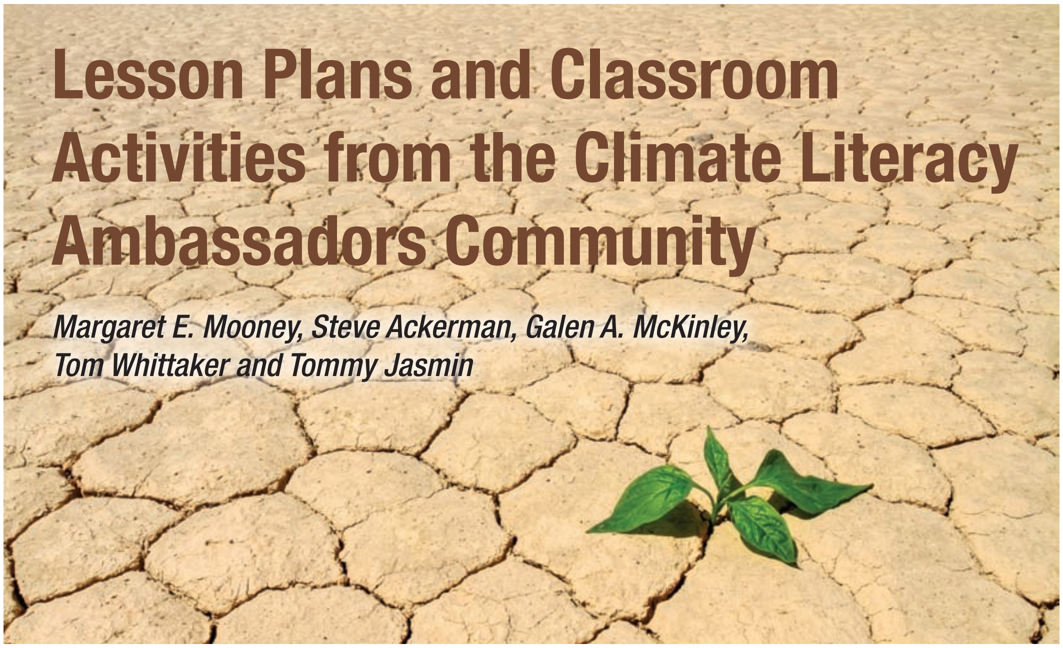
References

Leiserowitz, A., Smith, N. & Marlon, J.R. (2011).American Teens' Knowledge of Climate Change. Yale University. New Haven, CT: Yale Project on Climate Change Communication, p. 5.

http://environment.yale.edu/climate/files/American-Teens-Knowledge-of-Climate-Change.pdf

About the Author

Mark McCaffrey is the Programs and Policy Director of the National Center for Science Education's climate change education initiative. Before coming to NCSE, he helped spearhead the development of the Climate Literacy and Energy Literacy frameworks, available through the U.S. Global Change Research Program (http://globalchange.gov/resources/educators), presented and taught about climate, energy, water and environmental science at many grade levels, and was a Principal Investigator of the Climate Literacy and Energy Awareness Network (http://cleanet.org). He has a Masters in Education from the University of Northern Colorado, where he focused his studies on water as an interdisciplinary and integrating theme in education. Mark can be reached at mccaffrey@ncse.com



Lesson Plans and Classroom Activities from the Climate Literacy Ambassadors Community

Margaret E. Mooney, Steve Ackerman, Galen A. McKinley, Tom Whittaker and Tommy Jasmin

Background

In 2007, the Intergovernmental Panel on Climate Change (IPCC) published its fourth assessment of Earth's Climate. Stating clearly that "warming is unequivocal" and documenting observed warming, the IPCC laid the foundation for actions to address the impacts of climate change but left a chasm between evidence presented in the report and the public's ability to make meaningful responses or even comprehend climate mechanisms. To bridge this gap, educators at the University of Wisconsin-Madison (UW) developed an on-line resource for educators clarifying graphs and tables presented in the IPCC Summary for Policy Makers. The *Global and Regional Climate Change* course debuted in 2008 (http://cimss.ssec.wisc.edu/climatechange/). Teachers from Wisconsin and California worked through the content and provided feedback via embedded questionnaires and telephone interviews. Revisions followed and in 2010, with support from NASA award number NNX10AB52A, the UW began offering *Global and Regional Climate Change* as a professional development opportunity for middle and high school science teachers as part of a Climate Literacy Ambassadors project, the idea being that teachers would take the course and then promote climate awareness in their schools and communities. Since then, dozens of teachers have designed and submitted grade-specific lesson plans that support teaching and learning around climate change. This article highlights a few of the more robust lesson plans available for download, including a district-wide community action plan and numerous shorter activities suitable for classroom instruction.

The UW Global and Regional Climate Change course and activities for the classroom

There are 16 lessons grouped into five units in the UW Global and Regional Climate Change course. The content in each of the 16 lessons is freely available on-line, and each lesson includes several learning activities that reinforce the main concepts presented. Most of these activities are perfect for classroom instruction. While there is the option to take the entire course and print out a certificate of completion, users are free to skip the log-in option and go directly to course content. To get to your favorite activity or lesson plan, simply use the navigation bar along the top of the home page. A list of 48 activities can be found under the "Resources" tab. While several of the activities are from NASA or NOAA, most, such as the Carbon Projections Applet to explore future carbon emission scenarios and the Milankovitch Cycles Applet to explore past climates, were developed at the UW.

Lesson Plans

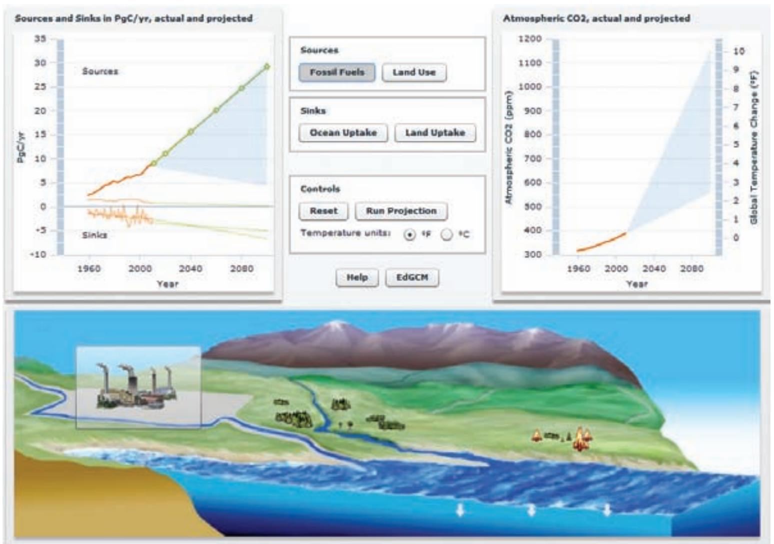


Figure 1. Carbon Projections Applet

Source: Tommy Jasmin

There are two lesson plans and one worksheet to guide learning with the Carbon Projections applet and one lesson plan associated with the Milankovitch Cycles applet. These were developed by teachers, tested in classroom settings and iteratively refined. They can be found under the "Lesson Plans" tab in the navigation bar. Materials required are computers and Internet access. (http://cimss.ssec.wisc.edu/climatechange/nav/lessonplans/).

The **Carbon Projection Applet** is an interactive computer exercise where students can model future projections of CO_2 sources and sinks and associated temperatures based on climate models used in the IPCC report. The graphs and graphics provide a visually appealing and powerful illustration of how choices can make a difference in future climate scenarios. The applet, like real life scenarios, is somewhat involved, so the screen shots and sequences laid out in the **Carbon Projection Applet Worksheet** provide an excellent guide for teachers and students to familiarize themselves with this learning tool. For teachers who have more than one class period to devote to this topic, there is also a **Global Dilemma Scenario** lesson plan where middle school students make choices about energy generation options, and a **Stabilization Wedges** lesson plan to engage high school students around strategies to reduce carbon levels from worldwide annual emmision totals.

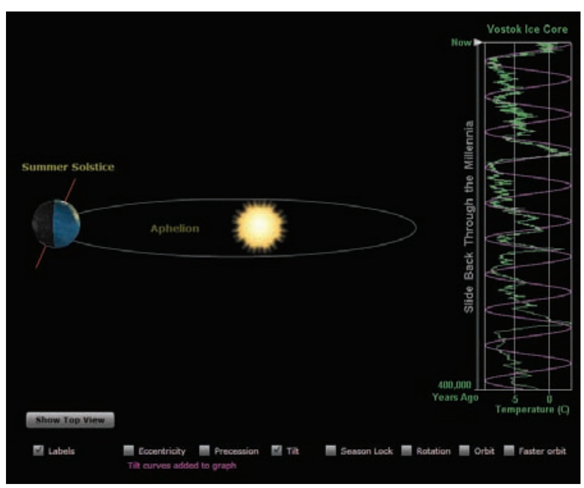


Figure 2. Milankovitch Cycle Applet

Source: Tom Whittaker

The **Milankovitch Cycles Applet** lesson plan was developed for high school students to complete in one class period. If you're familiar with the Milankovitch Theory, you'll remember that it involves cyclical variations in three elements of Earth-Sun geometry. Traditionally hard to teach, this applet enables teachers and students to visualize these elements and compare different configurations to temperatures derived from the Vostok ice core. This is another powerful teaching tool made easier by the lesson plan freely available for download.

Another set of popular lesson plans on the website evolved from an activity on probability and uncertainty. Several teachers have adapted and used the **Simple Statistics Exercise on Uncertainty** lesson plan to have students analyze a historical climate dataset of seasonal ice cover qualitatively and quantitatively. Instructions complete with screen shots are available for Excel 2003, Excel 2007 and Mac 2011. There is even a simplified version of this activity at the middle school level requiring students to plot data and make graphs, rather than use Excel.

About the Authors

Margaret Mooney is a former National Weather Service meteorologist who leverages early career experience with a more recent degree in public policy to promote weather and climate education as avenues towards stewardship and sustainability. Margaret can be reached at margaret.mooney@ssec.wisc.edu

Steve Ackerman is a professor in Atmospheric and Oceanic Sciences and the Director of the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin-Madison. His teaching often highlights the use of technology to convey information and address misconceptions. Dr. Ackerman can be reached at steve.ackerman@ssec.wisc.edu

Galen McKinley is an Associate Professor in the Department of Atmospheric and Oceanic Sciences at the University of Wisconsin-Madison. Dr. McKinley's research involves carbon cycling in the global oceans and the Great Lakes. Dr. McKinley can be reached at gamckinley@wisc.edu

Tom Whittaker has been writing software related to the atmospheric sciences since the 1960s. While his degrees are in meteorology, he focuses on visualization, analysis, and understanding of earth science data and information. He is the author of many of the interactive applets found at: http://profhorn.aos.wisc.edu/wxwise Tom can be reached at tom.whitakker@ssec.wisc.edu

Tommy Jasmin is a Systems Developer at the University of Wisconsin Space Science and Engineering Center (SSEC), in Madison. At SSEC, Tommy works primarily with scientific data processing systems and visualization tools. Tommy can be reached at tommy.jasmin@ssec.wisc.edu

A District-wide Community Action Plan

For Educators that have longer than a week and seek broader community engagement, there are two, district-wide action plans available for download. The **10-10-10** plan breaks activities down into elementary, middle and high school level with grade-appropriate opportunities and incentives for students to investigate the size of their individual and household carbon footprint and identify actions to reduce carbon pollution. The **2011 Moving Planet** plan encourages students to reduce fossil fueled trips. Both were coordinated with **350.org**, an international organization working to raise awareness of human-induced climate change.

Summary

There are over three dozen climate-related lesson plans created by science teachers freely available for download from the UW Global and Regional Climate Change course. And the list is growing! An internal survey conducted in the fall of 2011 revealed that 28% of teachers in the Climate Literacy Ambassadors Community tend to only use the lesson plan they created while 45% have also used other teachers' lesson plans. We're confident that there is a lesson plan available that will help improve your students' understanding of climate change.

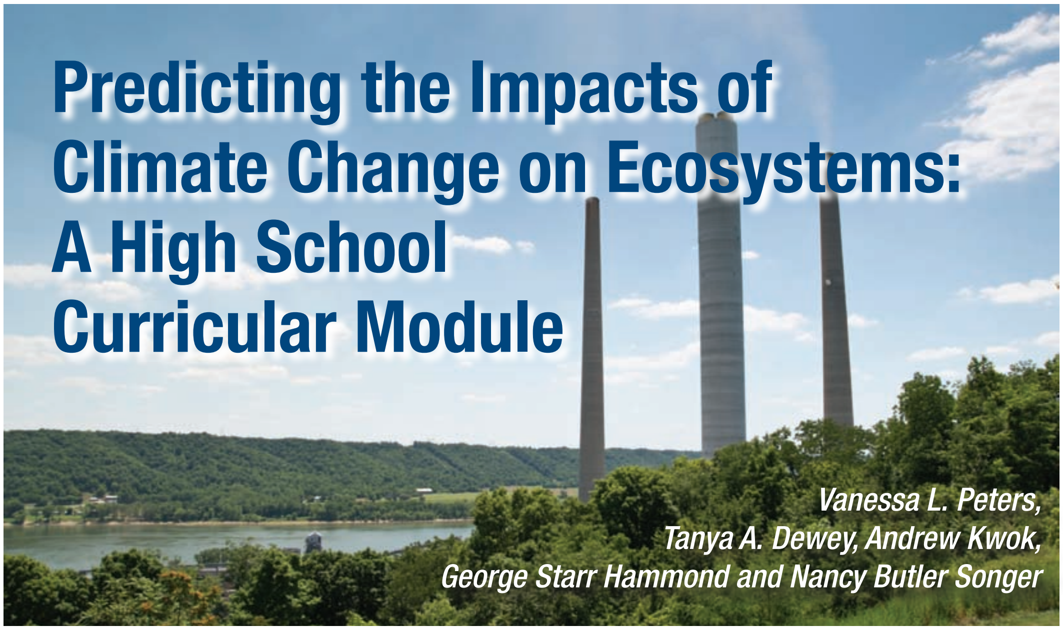
Bibliography

UW-Madison Global and Regional Climate Change Course (http://cimss.ssec.wisc.edu/climatechange/)

CIMSS Education and Outreach (http://cimss.ssec.wisc.edu/education/

UW-Madison Carbon and Climate Website (http://carboncycle.aos.wisc.edu/)

350.org (http://350.org/)



Predicting the Impacts of Climate Change on Ecosystems: A High School Curricular Module

Vanessa L. Peters, Tanya A. Dewey, Andrew Kwok, George Starr Hammond and Nancy Butler Songer

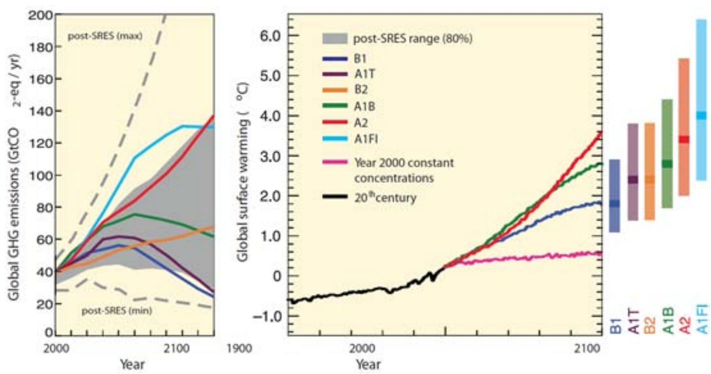
Abstract

There is growing consensus among educators about the importance of teaching students the necessary science skills to address some of today's most pressing environmental concerns. The Center for Essential Science (CES) at the University of Michigan (www.essentialscience.umich.edu) has developed an eight to twelve-week climate change curriculum for teaching middle and high school students about the ecological impacts of global climate change. In this article, we describe a four-day module from that curriculum. We begin by discussing the science behind the module, including the data and technologies that climate scientists use for studying the impacts of climate change on local ecosystems. We then describe how the module guides students in predicting the effects of climate change on species distribution. Finally, we conclude with tips for classroom implementation and information on how teachers can gain immediate access to our activities and resources.

Predicted Distribution Modeling and Climate Change

Predicted Distribution Modeling (PDM, also known as Ecological/Environmental Niche Modeling, Predictive Habitat Distribution Modeling or Climate Envelope Modeling) is a method used widely in ecology and conservation biology. This approach uses environmental data, primarily climate variables, combined with species occurrence data, to produce a model that explains how climate variables influence where a species is found across landscapes. Scientists use PDM to predict where a species occurs under current environmental conditions (i.e., predict where else the species may be found, based on a limited set of observed occurrences) and where a species might occur if environmental factors changed, such as under future climate change scenarios. This makes PDM a powerful tool for exploring how climate change may influence ecosystems as species respond individually to changes in environmental factors (Beach et al., 2002).

Predictions of future species distributions are based on sophisticated climate change models defined by the Intergovernmental Panel on Climate Change (IPCC). Because these climate change models and the graphs used to represent them are complex (see Figure 1), we created simplified versions of these scenarios. In this simplification process, we used a brief narrative to explain that IPCC scenarios are based primarily on three socioeconomic factors: global population size, energy



	Population Growth Rate	Energy Use Per Person	Proportion Clean Energy	CO_2 Emissions by 2100 (Gt)	Climate Scenario
Future 1	higher	lower	lower	1862	A2
Future 2	lower	higher	higher	1499	A1B
Future 3	lower	lower	higher	983	B1

Figure 1 (top). Surface warming temperatures for IPCC future climate scenarios, shown as continuations from 20th century temperature simulations

Image source: IPCC, 2007

Figure 2 (bottom). Simplified comparison table of three IPCC future climate scenarios. The possible futures illustrate how global population size, consumption practices, and the proportion of clean energy use impacts future carbon emissions.

Source: the Authors.

consumption practices, and the proportion of energy use from clean sources (IPCC, 2007). A subset of the scenarios, A2, A1B and B1, were renamed as Future 1, Future 2 and Future 3 and summarized in a comparison table (Figure 2). Having this resource available to students allows them to make connections between human impacts on the global carbon budget, resultant climate change and its impact on ecosystems.

Predicting the Impacts of Climate Change on Ecosystems: A High School Curriculum Module

Predicting the Impacts of Climate Change on Ecosystems is a selected module from the semester-long climate change curriculum that has been developed for high school students. All activities in the curriculum were developed in close collaboration with scientists to ensure that students are learning accurate, peer-reviewed science content. All content in the curricular activities aligns with the Framework for the K-12 Next Generation Science Standards. Both the module and full curriculum are delivered through SPECIES (Students Predicting the Effects of Climate In EcoSystems), a password-protected, online learning environment where students use a variety of digital media to learn about climate change and the impacts of climate change on ecosystems. Below, we describe the activities in a module where students explore the scientific question: "Will climate change impact the distribution of a species?"

Activity 1: Students begin the module with a reading about how environmental factors influence where species are found (i.e., its distribution). This is an important content foundation; students should understand that: (a) species are found in places where the environmental conditions are appropriate for them, (b) that different species have different environmental needs, and (c) there are many kinds of factors (abiotic and biotic) that influence where a species is found.

Students then use the "focal species chooser" to select a species on which to focus when making predictions about the impact of the climate change scenarios on a species' distribution. The focal species chooser uses content from the Critter Catalog (www.biokids.umich.edu), an online animal encyclopedia that provides students with natural history information about their chosen species, including habitat, social behavior, diet and ecosystem roles. Students use this resource to understand the biology of their focal species and the conditions that influence where it can live. This background information allows students to make predictions about the impact of ecosystem changes on the distribution of their focal species under future climate change scenarios.

Next, students overlay maps of environmental conditions (temperature and precipitation, both of which are aspects of climate) and a map of their focal species distribution to understand how those environmental conditions influence the distribution. Students are asked to focus their attention on the areas of the map where their focal species occurs. The area where the distribution and temperature/precipitation overlap indicates the range of temperature/precipitation that occurs where their focal species is found (Figure 3). This information provides a foundation for students' understanding of how climate change will influence the future distributions of their focal species.

Activities 2 and 3: Students begin activity 2 with a background reading on possible future climates predicted under three human energy use and population scenarios, using the Futures 1, 2, and 3 comparison table in Figure 2. Students learn that the impact of human-induced climate change depends largely on greenhouse gas emissions and that greenhouse gas emissions are strongly influenced by socioeconomic factors. In Activity 3, students are led through an example of PDM using simplified grids that represent map cells. Observations of species are overlaid with information on precipitation and temperature. Students combine this information to develop their own predicted distribution on a simple grid. This exercise helps students understand the process behind the more complex, algorithm-driven modeling they will work with in the final module activity.

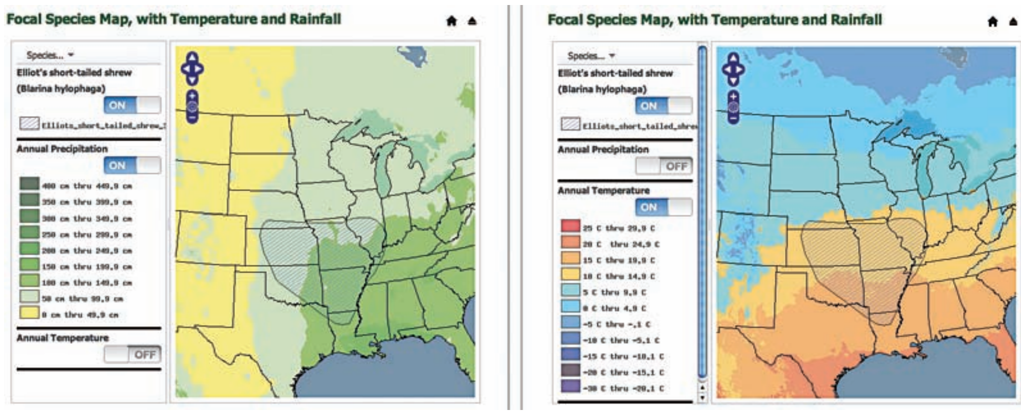
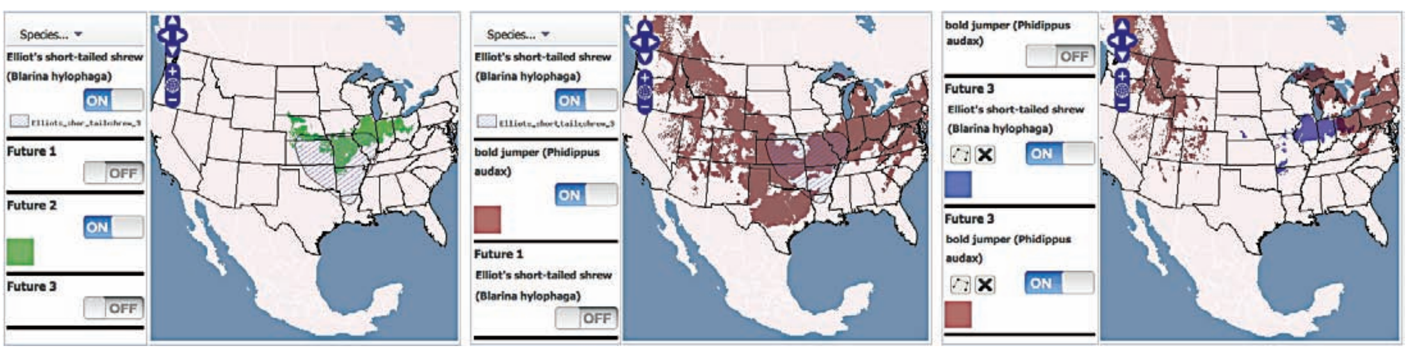


Figure 3. Map resource showing the current distribution of Elliot's short-tailed shrew (hatched area in center of map) overlaid with average annual precipitation (left) and average annual temperature (right).

Source: the Authors.

Activity 4: In the culminating activity, students use the PDM tools in SPECIES to make and justify predictions about how climate change will influence their focal species and its prey. Students begin the activity by comparing the current distribution of their focal species with its predicted distribution under the three future climate scenarios (left panel in Figure 4). They examine predicted changes in their focal species distribution under two scenarios, while also examining the human population and energy uses that define those scenarios. Students are then asked to describe the human population and energy uses under a third scenario based on how the distribution of their focal species changes. By examining a prey distribution, students can explore how changes in ecological interactions will impact their species. Students also use the PDM tool to overlay current



distribution maps of their focal species and a prey species to see how their distributions overlap under the predicted climate futures (center and right panels in Figure 4). By comparing the models and their data, students can make a justified prediction about the impact of a single prey species or multiple prey species under different climatic conditions. Collectively, these observations reinforce the important understanding: that not all species will respond to climate change in the same way, that ecological interactions among species are likely to change, and that changing ecological interactions will influence whether species can survive the multiple stresses of climate change in the future.

Figure 4. Map resource showing current and predicted future distributions of a focal species (left), current distributions of a focal species overlaid with a prey species (center), and predicted future distributions of both a focal species and prey species (right).

Source: the Authors.

Students conclude the module by synthesizing the information gathered throughout the activities to explain how biological communities may respond to climate change. A valuable addition to this module is to follow up with a classroom discussion in which students or student groups present their predictions for their focal species. This provides a collaborative opportunity for students to compare results and discuss the varying responses of species and their ecological interactions to climate change.

Teacher Tips

For practitioners, each curricular module provides 'Teacher Notes' prior to each lesson that include supplemental information for difficult concepts, links to supporting resources, and suggestions for extending the activities using different learning modalities. Lessons are typically designed for 50-minute class periods; however, they consist of smaller sub-sections that are flexible for varying amounts of instructional time. Because students' information is saved on the web, students can resume progress where they left off the day before.

All modules in the curriculum are designed for teachers who are unfamiliar with climate change or predicted distribution modeling. To improve accessibility, all curricular data and resources are presented in a user-friendly web environment that includes various media such as animations, videos and web articles. Hands-on activities include greenhouse gas and albedo labs, where students use infrared thermometers to measure temperature across surfaces. In addition, the curriculum includes student-accessible resources relevant to climate change, such as pollen and ice core data, so that students can use these as evidence when constructing scientific explanations. For instance, our simplified IPCC scenarios eliminate the guesswork of deciphering what the scenarios present, so teachers and students can focus their attention on conceptual learning and prediction making. Finally, the curriculum includes both embedded assessments and pre/post-tests that focus on core science content fused with explanations, predictions, and data analysis as emphasized in the upcoming Next Generation Science Standards.

Demonstrated Success with Impacts of Climate Change Curriculum Unit

A research study of the full curriculum conducted in spring 2012 realized strong learning in two areas. First, there was a high degree of student engagement across both middle and high school audiences. Second, many students created high quality research papers about the impacts of climate change on ecosystems. In addition, teachers noted the emphasis the lessons placed on guiding students to create evidence-based predictions and explanations about climate change impacts. Teachers also found they could adapt the lessons by either expanding discussions when the class period was longer, or omitting information that was already covered when class time was more limited. Initial pre/post-test data indicate students understand that climate is changing rapidly due to anthropogenic causes. Students comprehended the consequences of a warming global temperature and its potential impacts on species distribution and ecosystems. On balance, while many positives were observed, many students continued to struggle with the complexity of factors that contribute to global climate change.

Using Predictions About the Impacts of Climate Scenarios on Ecosystems

We invite all interested teachers to visit our web site to learn more about our program. While access to the full-featured curriculum requires teacher registration, the module described in this article is freely available at the following link: http://tinyurl.com/7fm2g5r. The Center for Essential Science is pleased to offer full or partial support to teachers wishing to implement our curricular activities in their classrooms. If interested, please contact Vanessa Peters at essentialscience@umich.edu

References

Beach, J.A., Stewart, A.M., Voronstov, Y.G., Scachetti Pereira, R., Stockwell, D.R.B., Vieglais, D.A., &Downie, S. R. (2002). The future of biodiversity: Mapping and predicting the distribution of life with distributed computation. *Proceedings of the ESRI User Conference.* Retrieved from http://proceedings.esri.com/library/userconf/proc02/pap0769/p0769.htm

References (cont.)

BioKids (2012).*BioKIDS: Kids' Inquiry of Diverse Species.* Retrieved from http://www.biokids.umich.edu/critters/

Intergovernmental Panel on Climate Change. (2007). Summary for Policymakers. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, & H.L. Miller (Eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK: Cambridge University Press.

University of Kansas Biodiversity Institute (2011).Lifemapper [Software]. Available from http://www.lifemapper.org

About the Authors

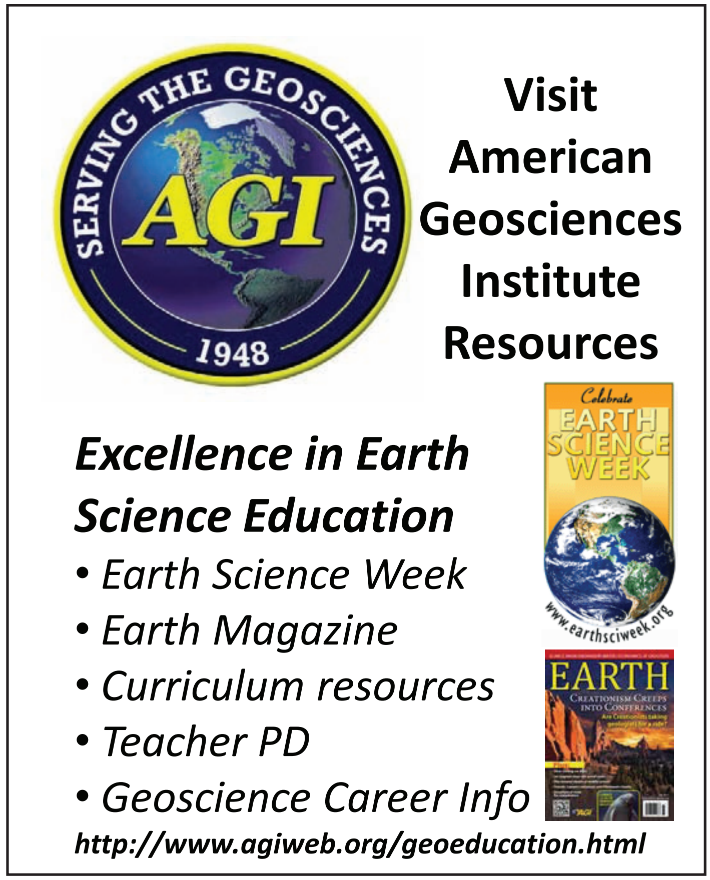
Vanessa Peters is a postdoctoral research fellow at the School of Education at the University of Michigan, where she works on the Change Thinking Climate Change Education project. Her research focuses on the use of technology for promoting a deep understanding of interdisciplinary science. Vanessa has an M.A. in Educational Technologies and a Ph.D. in Curriculum Studies from the University of Toronto. Dr. Peters can be reached at vlpeters@umich.edu

Tanya Dewey is a biologist interested in expanding opportunities for authentic science experiences in K-20 classroom settings. She acts as a science content consultant for the Climate Change Biology Team and is excited about helping students explore their inner scientist. Dr. Dewey can be reached at tdewey@umich.edu

Andrew Kwok is a doctoral student at the University of Michigan at Ann Arbor focusing on Teaching and Teacher Education. Previously, he taught high school science in Oakland, CA, which helped to shape his current interests of urban secondary teacher preparation, particularly in classroom management. He has a B.S. in Brain, Behavior, and Cognitive Science from The University of Michigan. Andrew can be reached at kwok@umich.edu

George Starr Hammond is an editor and content specialist for the Animal Diversity Web, a project based at the Museum of Zoology of the University of Michigan. He has a Masters Degree in Biology from the University of Michigan. George can be reached at gstarrh@umich.edu

Nancy Butler Songeris a faculty member in the School of Education at the University of Michigan, where she has been designing and studying science learning environments that utilize emerging technology for many years. Nancy has a Ph.D. in Science Education from the University of California, Berkeley, an M.S. in Molecular/ Developmental Biology from Tufts University, and a B.S. in Biological Sciences from the University of California, Davis. Dr. Songeris can be reached at songer@umich.edu



Advertising in the NESTA Quarterly Journal, *The Earth Scientist*

NESTA will accept advertisements that are relevant to Earth and space science education. A limited number of spaces for advertisements are available in each issue.

Artwork

We accept electronic ad files in the following formats: high-res PDF, TIFF or high-res JPEG. Files must have a minimum resolution of 300 dpi. Ads can be in color.

Advertising Rates

Full-page	7.5" w × 10" h	$500	Quarter-page	3.625"w × 4.75"h	$125
Half-page	7.25" w × 4.75" h	$250	Eighth-page	3.625"w × 2.375"h	$75

Submission Deadlines for Advertisements

Submission dates given below are the latest possible dates by which ads can be accepted for a given issue. Advertisers are advised to submit their ads well in advance of these dates, to ensure any problems with the ads can be addressed prior to issue preparation. The TES Editor is responsible for decisions regarding the appropriateness of advertisements in TES.

Issue	Submission Deadline	Mailing Date
Spring	January 15	March 1
Summer	April 15	June 1
Fall	July 15	September 1
Winter	October 31	January 1

For further information contact
Howard Dimmick
Treasurer
dimmick@esteacher.org

The Earth Scientist (TES) MANUSCRIPT GUIDELINES

NESTA encourages articles that provide exemplary state-of-the-art tested classroom activities and background science content relevant to K-12 classroom Earth and Space Science teachers.

- Original material only; references must be properly cited according to APA style manual
- Clean and concise writing style, spell checked and grammar checked
- Demonstrates clear classroom relevance

Format Specifications

- Manuscripts should be submitted electronically – Microsoft Word (PC or Mac)
- Length of manuscript should not exceed 2000 words.
- All submissions must include a summary/abstract.
- Photos and graphs: may not be embedded, but must be submitted as separate files, of excellent quality and in PDF, EPS, TIFF or JPEG format. 300 dpi minimum resolution. Color or black and white are both accepted.
  - References to photo/chart placement may be made in the body of the article identified with some marker: <Figure 1 here> or [Figure 1 in this area].
- Figures should be numbered and include captions (Figure 1. XYZ.).
- Captions, labeled with a clear reference to their respective photo/chart/image, must be submitted in a separate file, or they may be placed at the end of the manuscript where they can easily be removed and manipulated by the editor.
- If using pictures with people, a signed model release will be required for EACH individual whose face is recognizable.
- Each article must include: author(s) names, the school/organizations, mailing address, home and work phone numbers (which will not be published), and e-mail addresses.

Review

Manuscripts are to be submitted to the Editor, via the email address at the bottom of the page. Manuscripts are reviewed by the Editor for content and language. The Editor is responsible for final decisions on the publication of each manuscript. Articles will then be submitted to our Article Reviewers. Manuscripts may be accepted as is, returned for minor or major revisions, or declined, based on the decision of the Editor. The Editor reserves the right to edit the manuscript for typographical or language usage errors.

Page Charges

A fee of $100 per page is charged to authors who have institutional, industrial, or grant funds available to pay publication costs. Authors without access to such funds are strongly urged to assist in defraying costs of publication to the extent their resources permit, but payment of page charges is not required from such authors. Payment of page charges has no bearing on the decision to accept or reject a manuscript.

Copyright Transfer Waiver

The lead author of the article shall submit a signed NESTA Copyright Transfer Waiver.

The waiver form may be obtained from the NESTA web page. When completed AND signed it should be sent to the Editor. It may be sent as a printed original by US mail (address below), or as a pdf attachment via e-mail.

We cannot begin the production process until this signed waiver has been received. Please help us to expedite the publication of your paper with your immediate compliance. If you have any questions, please e-mail the NESTA Editor or Executive Director as listed below.

Submission Deadlines

Issue	Submission Deadline	Mailing Date
Spring	December 15	March 1
Summer	March 15	June 1
Fall	June 15	September 1
Winter	September 30	January 1

For further information contact:

Tom Ervin, EDITOR
tomervin@mchsi.com
21799 282nd Ave., LeClaire, IA 52753

Roberta M. Johnson, Executive Director
rmjohnsn@gmail.com

NESTA Membership Dues Structure

Basic Membership (US and International) – includes access to online versions (only) of The Earth Scientist (not including posters), monthly NESTA, E-News, access to TES archives online, NESTA Special Alert e-mailings, access to member-only sections of the website, and full voting privileges.

- One year – $20
- Two years – $40
- Three years – $60

Membership with Print Supplement* – includes a printed copy of TES mailed to you quarterly, frequently including poster inserts, in addition to Basic Membership benefits (US rates):

- One year – $35
- Two years – $68
- Three years – $100

* in Mexico and Canada, our rates for Membership with Print Supplement are slightly higher, because of mailing costs:

- One year – $45
- Two years – $88
- Three years – $130

Domestic Library Rate – includes print copies of The Earth Scientist only, and does not include NESTA membership

- One year – $70

Add Windows to the Universe Educator Membership Subscription to your NESTA membership (50% discount from non-NESTA member rates) – provides access to special capabilities and services on NESTA's premier Earth and Space Science Education website available at http://www.windows2universe.org

- One year – $10
- Two years – $18
- Three years – $24

NATIONAL EARTH SCIENCE TEACHERS ASSOCIATION

NESTA
P.O. Box 20854
Boulder, CO 80308-3854

PLEASE INFORM US IF YOU ARE MOVING

CHANGE SERVICE REQUESTED

Determined parents - Adult Adelie penguins do not leave the nest even when faced with floods. Here several adults are sitting on eggs which are, in turn, awash in glacial melt water and will thus not survive. It is unknown how long these adults continued to nest these eggs. Credit: Photograph taken by Jean Pennycook on Dec 20, 2007 at Cape Bird, Ross Island, Antarctica.