An Earth System Science Teacher Professional Development Toolkit for Climate Science

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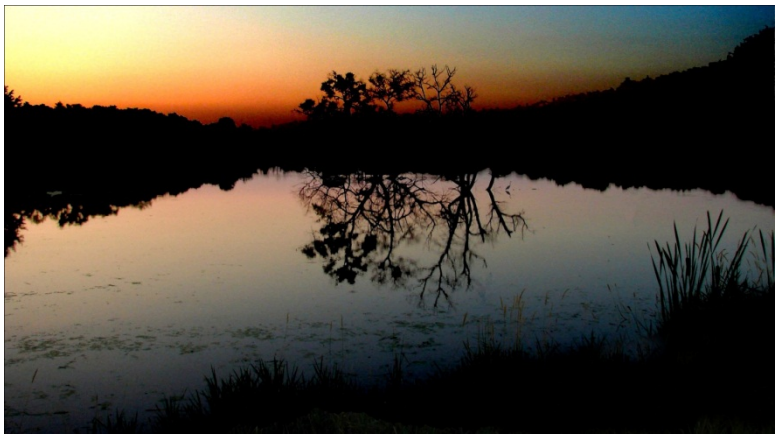
Introduction



The Intergovernmental Panel on Climate Change (IPCC, 2007) has concluded that global warming is unequivocal and that human activity is likely the main cause. The National Research Council's *Grand Challenges in Environmental Sciences* (NRC, 2000a) identified four "grand challenges" that are directly linked to climate and climate change. Additionally, the National Science Foundation has identified climate prediction and variability as a core study area. Hence, it is vital that adults and students learn about climate and climate change. Areas especially relevant to the educational needs of students and adults include: understanding climate variability, the interactions of natural and human systems, and the role of climate data and modeling in decision-making (NRC, 2000b). Teaching about climate and climate change, however, is conceptually challenging. Although individuals can collect local weather data and relate this data to local climate, they cannot monitor climate change due to time and scale issues. Thus, in order to learn about climate change it is necessary for individuals to interpret, analyze, explain and evaluate historical data and model-based data projections.

The Earth System Science toolkit is designed to support those interested in implementing professional development that prepares teachers to both understand the science of climate and climate change and the pedagogy for effectively teaching about climate and climate change. The toolkit consists of rich data sets and visualization activities that are model learning experiences and that address the major misconceptions students and adults hold about climate, global warming and climate change. The toolkit was designed to align with a conceptual framework and is: 1) grounded in the research on students' and adults' conceptions of climate and climate change, 2) based on instructional activities and experiences that engage participants in analyzing and interpreting climatic data sets and visualizations and that require the application of scientific concepts, and 3) designed in accordance with the research on effective teacher professional development. Pedagogically, the toolkit promotes active learning and collaboration.

About the Toolkit

The toolkit was developed and field tested by a team composed of teachers, scientists, and professional educators with expertise in pedagogy and climate science. Included in the toolkit are: PowerPoint slides, participant activities, supporting materials that visualize scientific concepts, presenter guide, and background and educational resource links. This toolkit may be downloaded and copied for use at no cost, but may not be sold. For more information and additional resources visit our web site at: http://www.agry.purdue.edu/climate/ccc/ClimateEdu/index.html

The toolkit is designed to promote active learning, viewing participants as active thinkers who construct their own understandings. Constructivism emphasizes that 1) knowledge is actively constructed by the individual and not passively received from others; 2) prior understandings influence knowledge construction; 3) knowledge is constructed by physically and mentally acting on phenomena and ideas and by integrating new experiences into existing knowledge structures (assimilation) or by creating new knowledge structures (accommodation); and 4) knowledge construction is influenced by social interaction with other learners. The program and toolkit, therefore, require that participants:

- interpret, visualize, and transform scientific data and apply scientific concepts
- analyze, evaluate, and explain scientific evidence and information
- discuss different perspectives and represent ideas
- work collaboratively to make decisions and draw conclusions

Student and Adult Conceptions about Climate and Climate Change

A summary review of the research on students' conceptions about climate and climate change is presented in Table 1. Many of these conceptions are also held by adults. For a more detailed review visit our web site at: http://www.agry.purdue.edu/climate/ccc/ClimateEdu/index.html.

Student Conceptions about Climate and Climate Change	Author(s)
Confusion between climate and weather	Pruneau, Gravel, Courque, & Langis (2003) Growda, Fox, & Magelky (1997)
Climate change is caused by the sun's rays getting trapped in the ozone; the sun's rays hitting more places on the Earth	Pruneau, Gravel, Courque, & Langis (2003)
Climate change is caused by general air pollution	Boyes & Stanisstrret (1997) Growda, Fox, & Magelky (1997)
Climate change is caused by the ozone hole	Rebich & Gautier(2005) Pruneau, Gravel, Courque, & Langis (2003) Österlind (2005)
Confusion between the greenhouse effect and global warming	Rebich & Gautier(2005)

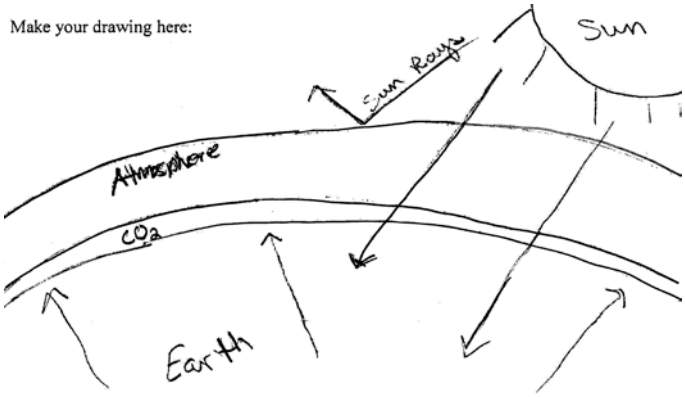
Table 1: Summary Review of the Research on Students' Conceptions

Our work and others have shown that secondary school students lack an understanding of:

- The relationship between the biogeochemical cycles, greenhouse effect and the Earth's energy budget (e.g. Boyes & Stanisstreet, 1993; Fisher, 1998; Shepardson et al., 2009)
- The impact of the greenhouse effect on global warming and its effect on climate (e.g., Fisher, 1998; Growda, Fox & Magelky, 1997; Pruneau et al. 2003; Shepardson et al., 2009), and
- The impact of climate change on the Earth's spheres (e.g., oceans, weather, animal and plant distributions/diversity, land) (e.g., Boyes & Stanisstreet, 1993; Kilinc, Stanisstreet, & Boyes, 2008; Shepardson et al. 2009).

Furthermore, our research has shown that students' conceptions about the greenhouse effect include the following ideas:

- Carbon dioxide as the only greenhouse gas; students do not realize that methane, nitrous oxide, and water vapor are greenhouse gases.
- Carbon dioxide is seen only as an air pollutant and not as naturally occurring in the atmosphere.
- Carbon dioxide forms a layer in the atmosphere which traps heat.
- All radiated heat is trapped by the atmosphere; that is, no heat is radiated into space.



Student drawing of the greenhouse effect

Thus there is a need to prepare both teachers and formal and informal staff developers to address these essential topics of Earth and climate literacy in their classrooms. This research on students' conceptions served as the building block for the teacher professional development program and toolkit.

Similarly, teachers lack the pedagogical content knowledge to address these student misconceptions, as well as basic climate science. Only 3% of secondary teachers have a degree in the geosciences (AGI, 2010). This further highlights the need to enhance science teachers' knowledge and abilities to teach about climate and climate change. Teacher content knowledge is a critical component of teacher quality (Schmidt, 2001). Teachers who lack science content knowledge tend to rely more on science textbooks, ignore student conceptions, and often misrepresent the science (Gess-Newsome, 1999), essentially reinforcing students' misconceptions. Our review of existing science textbooks and laboratory manuals found few instructional materials that foster students' conceptual understanding about climate and climate change, and in fact promote misconceptions, for example about the greenhouse effect (Choi et al. 2010; Shepardson et al. 2009). Many of these textbooks isolate climate and climate change, providing no more than worksheet activities. Thus, teachers need access to and preparation in using inquiry-based, data driven instructional activities.

Conducting an Effective Climate Change Workshop: A Climate System Approach

Implementing a workshop on climate change is challenging. First, it is a complex topic that requires an understanding of the interactions among components of a system, requiring system-based thinking. Second, it is an abstract topic in the sense that there are few "concrete" concepts and because it requires the ability to handle and interpret data, to understand variation and trends over time. Third, it is a heated social and political debate as to its existence or extent, which polarizes individuals and stakeholders. Thus, to address these challenges, this toolkit presents climate change from a climate system approach. The toolkit presents the science of climate in a simple and compelling manner, stressing the science and the evidence of a changing climate system. As with any workshop there is a delicate balance between presenting the science of climate without overwhelming the audience with scientific vocabulary, boring them with prolonged talk, or exacerbating the disagreement among individuals and stakeholders. At the same time, it is essential to present the data, evidence, with scientific certainty; 97% of climate scientists agree that the Earth's climate is changing (ICLEI-Local Governments for Sustainability USA, 2011). The toolkit presents the science of climate in a way that is consistent with that proposed by the ICLEI (2011):

- Avoids gloom and doom comments and scenarios
- Stresses the certainty, evidence, of how our climate system is changing and why
- Keeps the science simple and free of scientific jargon
- Presents images and graphics that visualize the science and the changes to the climate system
- Addresses solutions—how people can adapt and mitigate a changing climate
- Acknowledges and respects alternative views and disagreement

It is also important to be aware of how Americans view global warming and climate change (Figure 1). According to the Yale/George Mason (2009) study only the Alarmed (18%) and the Concerned (33%) are convinced that global warming is occurring and that it is a serious environmental issue. Only the Alarmed, however, have taken personal steps or actions to address global warming. Although the Cautious (19%) believe in global warming they are less likely to see it as a problem. The Disengaged (12%) are unsure about global warming. The Doubtful (11%) is a mixed group of believers, nonbelievers, and those who do not know. They tend to see global warming as a natural process, with little human impact, and that nothing further needs to be done to solve the problem. The Dismissive (7%) do not believe in global warming. The Alarmed and Concerned are more likely to pay attention to information about global

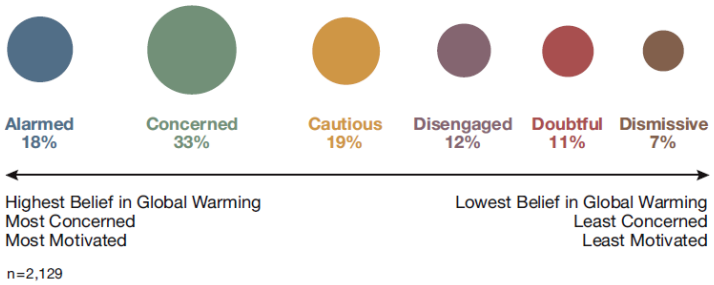


Figure 1.FromYale/George Mason (2009).*Global Warming's Six Americans 2009: An Audience Segment Analysis*

warming and to actively seek out information about global warming than the Cautious, Disengaged, Doubtful, and Dismissive (Yale/George Mason, 2009).

Leiserowitz et al. (2011) identified the top questions Americans would ask an expert about global warming. Of these questions, the toolkit addresses the following:

How do you know that global warming is caused mostly by humans?
How do you know that global warming is happening?
What causes global warming?
What harm will global warming cause?
What can I do to reduce global warming?

Checklist for Conducting Effective Workshops

The following checklist serves as a guide for conducting effective workshops. Facilitators may modify the approach based on time and the experience or needs of the workshop participants. Preparation is the number one key to a successful workshop. Practice presenting the workshop. Flexibility is the second key to a successful workshop. Agendas may not always go as planned, be prepared to adjust activities and experiences as needed.

<u>Opening the Workshop</u>

√ Introduce yourself and the focus of the workshop
√ Overview the goals, objectives, and outcomes of the workshop
√ Indicate how the workshop will be of benefit to teachers/participants, how the workshop will positively affect their classroom/situation
√ Summarize the workshop agenda
√ Explain your role as facilitator:

- guide instruction and activities
- model an activity
- respond to questions, and engage participants in helping answer questions
- keep the workshop on time, pace instruction, adapt as needed

√ Explain the role of participants:

- focus on the instructor
- actively participate in activities and discussion, ask questions
- collaborate with and help others, respect others
- work efficiently, stay on task

Facilitating and Managing the Workshop

√ Demonstrate procedures and processes
√ Encourage participants to work collaboratively
√ Manage time, it is important to start and end as scheduled
√ Engage participants with questions
√ Reflect back on workshop goals, objectives, and outcomes along the way
√ Pre distribute handouts and resources as needed, ask for assistance in distributing materials
√ Promote hands-on exploration, reduce lecture
√ Allow time for individual thought and reflection
√ Pair/group participants to enable interaction, consider participant backgrounds, expertise and comfort level
√ Move around the room, interacting with and coaching participants
√ Encourage the sharing of ideas and perspectives, answering of questions
√ Record questions on flip chart or board, encourage others to answer questions, revisit questions at the end of the workshop

Closing the Workshop

√ Reflect back on workshop goals, objectives, outcomes, and activities
√ Allow time for participants to share what they learned
√ Provide additional materials/resources, website addresses
√ Obtain feedback
√ Thank individuals for participating

Effective Teacher Workshops

The most effective teacher professional development connects to the teachers' classroom and models appropriate teaching practices (Reys et al. 1997). Furthermore, when teachers learn science content in a fashion similar to classroom instruction it increases their content and pedagogical confidence and understanding (Radford, 1998). Successful teacher professional development programs integrate the two dimensions: the *science content* and the *pedagogy*; what teachers need to learn and how they should teach it (Bybee & Loucks-Horsley, 2001). Effective teacher professional development programs:

- promote science as inquiry, involve teachers in investigating phenomena, interpreting results, and making sense of findings,
- introduce teachers to scientific literature, media and technological resources,
- build on teachers' existing understandings, abilities, and attitudes,
- use modeling and guided practice to build understanding of content and teaching, and
- develop teachers' understandings of science learners and science learning (NRC, 1996).

Climate Education Websites

The websites listed in Table 2 provide both classroom-based instructional activities and materials and climate science content background. In addition, the following websites provide information on climate literacy and climate change:

Climate Literacy: The Essential Principles of Climate Science
http://www.climatescience.gov/Library/Literacy/

Intergovernmental Panel on Climate Change (IPCC)
http://www.ipcc.ch/

Website	Link
Activities for Conceptualizing Climate and Climate Change	http://climate.agry.purdue.edu/climate/ccc/
CoCoRaHS observing network for precipitation reports (rain, hail, snow, drought, significant weather)	www.cocorahs.org
NOAA Education	http://www.education.noaa.gov/index.html
NOAA Climate Education Resources	http://www.education.noaa.gov/Climate/
The USGS and Science Education	http://education.usgs.gov/
NASA Education	http://www.nasa.gov/offices/education/about/index.html
US Environmental Protection Agency	http://www.epa.gov/climatechange/index.html
Digital Library for Earth System Education	http://dlese.org/library/index.jsp
Climate Change at the National Academies	http://dels.nas.edu/climatechange/ecological-impacts.shtml
NASA Earth Observatory	http://earthobservatory.nasa.gov/
PBS	http://www.pbs.org/now/classroom/globalwarming.html
Center for Integrated Study of the Human Dimensions of Global Change	http://hdgc.epp.cmu.edu/teachersguide/teachersguide.htm
Global Warming: Understanding the Forecast	http://geoflop.uchicago.edu/forecast/docs/lectures.html
Climate Literacy Catalog	http://serc.carleton.edu/climatechange/climate_literacy_search.html
Smithsonian Institution-Climate Change	http://www.smithsonianconference.org/climate/teachers/
The Globe Program	http://classic.globe.gov/
Earth Watch Institute	http://www.earthwatch.org/aboutus/education/lessonideas/
Global Climate Change-Climate Kids	http://climate.nasa.gov/kids/index.cfm
The Ultimate Guide to Weather and Climate Resources Online	http://www.guidetoonlineschools.com/library/weather-resources
Climate Prediction Center, Educational Materials	http://www.cpc.ncep.noaa.gov/products/outreach/education.shtml

Table 2. Educational Resources for Teachers

Climate and Climate Change Resources

The following websites provide: 1) answers to the most often asked questions about climate and climate change, 2) links to short video casts and other media resources, and 3) access to climate data for individual analysis or classroom use.

Answers to Frequently Asked Questions about Climate and Climate Change

- Climate FAQs (NCDC): http://www.ncdc.noaa.gov/faqs/index.html
- UCAR (University Corporation for Atmospheric Research) Global Warming and Climate Change FAQs: http://www2.ucar.edu/climate/faq

Multimedia Resources

- UCAR Podcasts (brief 3-5 min general descriptions by experts on main questions): http://www.ucar.edu/webcasts/voices/#
- Additional UCAR multimedia: http://www2.ucar.edu/news/understanding-climate-change-multimedia-gallery
- NOAA Climate Services (videos and articles of updated topics): http://www.climate.gov/#climateWatch

Access to Climate Data

- National Climatic Data Center (NCDC). National station specific temperature and precipitation data: http://www.ncdc.noaa.gov/oa/ncdc.html
- NCDC Climate Program Office data and products (quick access to NCDC data and climatological normals, i.e. Climate-At-A-Glance): http://www.climate.noaa.gov/index.jsp?pg=./data_products/data_index.jsp&data=catalog
- Climate Prediction Center (CPC):
  - monitoring and data index: http://www.cpc.ncep.noaa.gov/products/MD_index.shtml
  - monitoring and data product descriptions: http://www.cpc.ncep.noaa.gov/products/monitoring_and_data/
  - weather and climate data: http://www.cpc.ncep.noaa.gov/products/precip/CWlink/
  - global regional climate maps (temp and precip): http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/
  - monthly atmospheric and SST indices: http://www.cpc.ncep.noaa.gov/data/indices/
  - regional climate maps: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/usa.shtml
  - U.S. temperature and precipitation trends: http://www.cpc.ncep.noaa.gov/charts.shtml
  - Northern hemisphere snow cover: http://www.cpc.ncep.noaa.gov/data/snow/
  - climate glossary: http://www.cpc.ncep.noaa.gov/products/outreach/glossary.shtml
  - GIS datasets for U.S. daily temp, SST: http://www.cpc.ncep.noaa.gov/products/GIS/GIS_DATA/
- Southern Climate Impacts Planning Program (SCIPP):

- data tools: http://www.southernclimate.org/data.php
- annual monthly graphs: http://www.southernclimate.org/products/temp_precip.php
- graphs by season: http://www.southernclimate.org/products/trends.php
- graphs by station: http://www.southernclimate.org/products/climo_graph.php

Background Readings on Climate and Climate Change

The following NASA Earth Observatory articles provide excellent background reading on climate and climate change:

- Climate and Earth's Energy Budget : http://earthobservatory.nasa.gov/Features/EnergyBalance/
- Global Warming: http://earthobservatory.nasa.gov/Features/GlobalWarming/global_warming_2007.pdf
- The Carbon Cycle: http://earthobservatory.nasa.gov/Features/CarbonCycle/carbon_cycle2001.pdf
- The Greenhouse Effect: http://earthobservatory.nasa.gov/Experiments/PlanetEarthScience/GlobalWarming/GW_Movie3.php
- Oceans and Climate: http://earthobservatory.nasa.gov/Features/OceanClimate/

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