LESSONS LEARNED THROUGH OUR CLIMATE CHANGE PROFESSIONAL DEVELOPMENT PROGRAM FOR MIDDLE AND HIGH SCHOOL TEACHERS

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Abstract: The National Center for Atmospheric Research in Boulder, Colorado has been offering professional development on climate change for middle and high school teachers since the summer of 2001. Our experience with educators has shown that teachers feel ill-prepared to share the science and implications of climate change research with their students. As a result of the extensive exposure of this topic in the media and the controversy that sometimes surrounds it, teachers are highly motivated to engage in professional development on this subject. A variety of professional development approaches are needed to reach a wide spectrum of educators whose learning preferences and personal and professional constraints may preclude participation in some professional development opportunities. This paper provides lessons learned from successful climate change professional development for teachers, including the importance of inquiry-based curriculum activities, the importance of an opportunity to “learn by doing” and to share their perspectives with their colleagues. Finally, development and continuation of the learning community, both among participants as well as with instructors and scientists, provides critical support to classroom educators, who can at times experience a sense of professional isolation. [Key words: climate change, professional development.]

INTRODUCTION

The National Center for Atmospheric Research (NCAR) in Boulder, Colorado is a major U.S. research facility focused on better understanding Earth’s weather and climate, and the interaction of the complex and coupled Sun-Earth system. NCAR has been the source of many advances in the atmospheric and related sciences, and supports the scientific community through management and maintenance of major community models (e.g., the Community Climate System Model) as well as community research facilities (e.g., the new National Science Foundation’s Gulfstream-V aircraft for atmospheric research). NCAR was deeply involved with the development of the recent Intergovernmental Panel on Climate Change reports (United Nations Environment Programme, 2007), including extensive modeling, authorship, and review. In addition to its activities in climate change research, NCAR is at the forefront of many areas of research such as weather modeling, atmospheric chemistry and dynamics, and biogeochemical cycles. NCAR is managed by the University Corporation for Atmospheric Research (UCAR), representing over 73 Member and Affiliate universities around the world.
Since the founding of the lab in 1960, NCAR and UCAR have recognized not only their research role, but also their roles in service and education (NCAR, 2006; UCAR, 2007a). In view of the increasing consensus about the need for improved science education and literacy, particularly in the geosciences, UCAR formed the Office of Education and Outreach (UCAR EO) in 2000. The purpose of this office includes providing: education and outreach support and services to programs under way across UCAR and in the broader university community; developing new programs in priority areas (identified in the UCAR Education and Outreach Strategic Plan, 2007–2012); and promoting the importance of improved science education and literacy nationally and internationally.

Considering NCAR's focus on climate change research, UCAR EO immediately initiated an effort to increase the emphasis on climate change education at NCAR for the public, students, and educators. This paper documents lessons learned through the professional development component of these activities, targeting middle and high school educators. Because of the increasingly integrated nature of UCAR EO's activities, resources initially designed for one purpose (e.g., climate change content on the Windows to the Universe™ website) are frequently used successfully in other applications (e.g., in our online Climate Discovery courses). Our workshops and presentations are based on best practices associated with professional development from the educational research community and outlined in the National Science Education Standards (NSES; NRC, 1996; Loucks-Horsley et al., 2003). The NSES document acknowledges the challenge of continual professional development for a content area with a “rapidly changing knowledge base and expanding relevance to societal issues,” such as the atmospheric and climate sciences.

**CLIMATE CHANGE PROFESSIONAL DEVELOPMENT AT NCAR**

*Summer Climate and Global Change Professional Development Workshops at NCAR*

Following the completion of UCAR's first Strategic Plan for Education and Outreach (UCAR, 2001), UCAR EO began an effort to increase emphasis on climate change education. With the support of NCAR, in 2001 UCAR EO initiated the development of a two-week long summer workshop on climate and global change for middle and high school teachers offered on-site at NCAR. The workshops were offered annually from 2002 to 2005 to 20 teachers drawn from a national pool of over 100 applicants each year. The workshops interwove background lectures on the components of the Earth system and their interaction (provided by leading scientists at NCAR and neighboring research facilities) with training on easy-to-use inquiry-based classroom activities (Fig. 1), field experiences, extensive discussion, and social interactions with each other as well as with scientists and EO staff. Participating teachers were required to develop an activity that they could use in their classroom based on the resources provided through the workshop. Participants were also required to provide professional development to teachers in their home school, district, or state. Workshop evaluations demonstrated that participants highly valued the workshop experience.
In the third year of our climate and global change workshop (2004–2005 academic year), a review of our NCAR-supported education and outreach program, while very positive, provided guidance that we should seek to reach larger numbers of teachers with a professional development experience. The EO team subsequently shifted focus to a two-pronged approach to climate change professional development: online courses and smaller workshops offered at other professional development venues.

**Online Courses**

From 2005 to 2007, EO staff worked to develop a set of three online *Climate Discovery* courses including: *An Introduction to Earth’s Climate; Earth System Science: A Climate Change Perspective*, and *Understanding Climate Change Today*. These three courses, each of six or seven weeks duration, build on the content and resources developed for the original summer workshop, but provide the opportunity to go into more depth than is possible in a two-week, in-person workshop.

The online courses were rolled out during this two-year period, as they were developed, and built iteratively on the expertise gained from previous offerings of the courses. For instance, our first course, *An Introduction to Earth’s Climate*, first...
offered in a pilot phase in 2005, was revised and improved using suggestions from course evaluations, prior to offering the full course in 2006. This cycle of development, testing, evaluation, revision, and improvement has been used throughout the online course development process, allowing lessons learned in the first courses to transfer to our more recently developed courses. All three courses are now being offered multiple times on an annual basis, and we anticipate between 110 and 180 enrolled teacher participants during the coming year. Figure 2 shows the total number of teachers by state that have participated in our in-person on-site summer workshops as well as our online courses to date. Overall, we have had 209 teachers involved in these intensive professional development efforts.

Our online courses are grounded in best practices combining effective instructional strategies adapted for distance education (Clark and Mayer, 2003; Woods and Ebersole, 2003). This includes descriptive text and images, downloadable video clips, simulations, interactives, and both asynchronous and synchronous communication tools. The courses are designed with many different forms of media to meet the needs of different learning styles and preferences.

We have built the courses using the web-based Moodle courseware system (open-source software similar to Blackboard and webCT), utilizing its features to promote dialogue as well as provide rich online content and media. A key element of the online courses is the development and support of an online learning community, an essential component in successful online courses (Berger Ehrlich, 2002). Interactive learning techniques are built into the course designs with assignments that encourage active participation. Educators (both formal and informal) use the

Fig. 2. Two hundred nine teachers have participated in our extended climate change professional development activities, including both in-person workshops and on-line courses, since 2002. Numbers indicate the total number of teachers in each state that have participated.
courses as a venue to exchange ideas and teaching resources. A unique feature of the courses is the emphasis on hands-on activities, a hallmark of our professional development efforts. To encourage this in an online format, we send participants a kit of supplies early in the course. We ask the participants to use the supplies to test the activities and provide feedback to other participants.

Our online courses include internal self assessments, assignments, interim evaluations, final exams, and final evaluations. Based on these results, the team is able to assess weaknesses in the courses and modify the courses, if necessary, to provide an optimal experience for participants. The following quote, from an online course participant, documents his/her appreciation for the course structure and resources:

I teach two different science courses (Earth science and environmental) and information that I’ve been presented with in the NCAR courses has worked its way into my classrooms. The diagrams, video clips, and overall content can be applied to supplement a wide variety of topics. What I loved the most about these courses is that we are given easy-to-use activities and demonstrations to try out first as students. This way, we were able to share tips and extension ideas with each other before actually using them with our kids. The NCAR courses have increased my personal knowledge about the topic of climate change and, in turn, have increased my students’ knowledge as well. (High school Earth and environmental high school teacher, Chicago, IL)

The courses are supported by one or more course instructors who facilitate participants’ progress in the course, answer questions, encourage discussions, and grade participants work in the course. The course fee for each course of $225 covers the cost of supporting activity kits mailed to participants as well as partial support for the efforts of course instructors. Two units of graduate recertification credit are available for each course from the Colorado School of Mines for a small additional fee.

Workshops at Other Venues

By far, our largest reach in providing climate change professional development to teachers has been attained by leveraging professional development opportunities offered by other organizations. By offering workshops and short courses at professional development venues supported by other organizations (e.g., the National Science Teachers Association [NSTA] and the American Geophysical Union [AGU]), providers avoid the expense of travel, food, and lodging required for participants (and reduce the carbon footprint of the activity as well). The downside of this approach is that, by necessity, the depth of the training possible in workshops incorporated in such venues is usually significantly shorter than what is possible in a dedicated multiday workshop (although some venues offer more extended formats that are conducive to extended contact with participants).

UCAR EO staff has offered numerous workshops on climate change at NSTA area and national conferences. Since fall 2004, we have offered 10 hour-long workshops
and 2 three-hour short courses on climate change at NSTA venues, reaching 664 teachers. In recent years, we have frequently found that our NSTA workshops are full to overflowing, at times with almost twice the number of participants as were anticipated for the session. In addition, we have been asked to offer climate change workshops at a number of other venues (twice at the University of Texas at Austin, at the University of Michigan Exhibit Museum, at the Mexican VII and VIII National Conventions of Natural Sciences Teachers, and twice at American Geophysical Union Geophysical Information for Teachers workshops). These additional venues have allowed us to provide training to well over 500 additional teachers. The workshop format at these professional development opportunities has ranged from standard one-hour workshops to multiple-day workshops. In all of these events, we focus on combining background content with a variety of easy-to-use, inquiry-based classroom activities for the classroom teacher. Workshop evaluations indicate that participants appreciate our format, as well as the resources provided.

Exhibits

While working on the development of the climate change workshops, we simultaneously initiated a review of our public exhibits in the NCAR Mesa Laboratory to determine where to prioritize our efforts in coming years. Our exhibit advisory board completed a review of the exhibits, and identified the need to include climate change content as a priority. During the 2002–2006 time frame, UCAR EO worked with NCAR scientists, educators, and exhibit designers to develop and install a new Climate Discovery exhibit, which was brought out on the floor in two phases, in 2004 (Climate Now and Climate Timeline) and 2006 (Climate Future). In 2005, after the first phase of exhibit development, the team worked to develop a Teacher’s Guide to the Climate Discovery exhibit, which was subsequently made available to the public online (at http://www.eo.ucar.edu/educators/ClimateDiscovery/), in the Windows to the Universe Teacher Resources section, and incorporated into the suite of classroom activities used in our professional development workshops.

Website Development

Parallel to these professional development and exhibit development efforts, education designers working on the Windows to the Universe website (http://www.windows.ucar.edu) began development of an extensive section of the website on Climate and Global Change (http://www.windows.ucar.edu/climate_change). Windows to the Universe, which spans the Earth and space sciences with integrated interdisciplinary content on the arts and humanities, is a very popular science education website composed of over 8000 interlinked webpages (available at three levels of sophistication as well as in English and Spanish). It is accessed by ~20 million users annually from around the world. The Climate and Global Change content on the website receives ~100,000 page views per month. Beginning in 2007, the team began development of a new section of the website, Earth’s Polar Regions, with support from NCAR and the NSF Division of Atmospheric Science. This new content area significantly enriches the content in the Climate and Global Change area of the
Table 1. Climate and Global Change Classroom Activities Available on the Windows to the Universe Website

<table>
<thead>
<tr>
<th>Activity Description</th>
<th>Activity Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students make a model of glacier motion and then experiment with it.</td>
<td>Model a moving glacier</td>
</tr>
<tr>
<td>Students compare photographs of glaciers to observe how Alaskan glaciers have changed over the last century.</td>
<td>Glaciers: Then and now</td>
</tr>
<tr>
<td>Through an online game, students learn how carbon cycles through the Earth system.</td>
<td>Using the carbon cycle interactive game in the classroom</td>
</tr>
<tr>
<td>Students experiment with the carbon cycle.</td>
<td>Carbon dioxide–Sources and sinks</td>
</tr>
<tr>
<td>Students discover how thermal expansion of water affects sea level.</td>
<td>Thermal expansion and sea level rise</td>
</tr>
<tr>
<td>Students explore bathymetric contour lines and sea level change.</td>
<td>Mapping ancient coastlines</td>
</tr>
<tr>
<td>Students conduct a classroom paleoclimate study.</td>
<td>Paleoclimates and pollen</td>
</tr>
<tr>
<td>Students make a model of sedimentary rock layers to understand how rocks form layers and represent ancient environments.</td>
<td>Making sedimentary rocks!</td>
</tr>
<tr>
<td>Students plan towns and learn how planning affects the environment and the larger community.</td>
<td>The land plan challenge</td>
</tr>
<tr>
<td>Students graph weather and climate data to learn the difference.</td>
<td>The difference between weather and climate</td>
</tr>
<tr>
<td>Students play a game to learn about indirect evidence, like those that record ancient climate changes.</td>
<td>Natural records of climate change: Working with indirect evidence</td>
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<tr>
<td>Students discover how modest climatic cooling changed life for Europeans during the Little Ice Age.</td>
<td>Living during the Little Ice Age</td>
</tr>
<tr>
<td>Students compare “then and now” photographs to see how much glaciers have changed over the last century.</td>
<td>Where have all the glaciers gone?</td>
</tr>
<tr>
<td>Students check the pulse of the seasons, compare opposite hemispheres, and see whether long-term trends in ice cover are changing as global temperatures rise.</td>
<td>Graphing sea ice extent in the Arctic and Antarctic</td>
</tr>
<tr>
<td>Students collect and analyze tree ring data to discover when the Little Ice Age occurred.</td>
<td>Trees: Recorders of climate change</td>
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<tr>
<td>A graphing activity that allows students to discover how the timing of blooming has changed as climate changed.</td>
<td>Blooming thermometers</td>
</tr>
<tr>
<td>Students investigate data to discover how Earth’s climate is affected by changing quantities of sunspots.</td>
<td>Sunspots and climate</td>
</tr>
<tr>
<td>Students discover how volcanoes can alter the Earth’s climate.</td>
<td>Dark skies: Volcanic contributions to climate change</td>
</tr>
<tr>
<td>Students investigate multiple pieces of data to learn about the Little Ice Age.</td>
<td>The Little Ice Age</td>
</tr>
<tr>
<td>Students investigate how color affects heat absorption.</td>
<td>Looking into surface albedo</td>
</tr>
</tbody>
</table>

website. The website includes over 100 classroom activities on the Earth and Space sciences, with ~30 on climate change topics. Table 1 lists activities related to climate and global change available on the Windows to the Universe website. These activities are freely available on the website, and are used throughout our climate change professional development program in UCAR EO. Our classroom activities
appear to be accessed by large numbers of teachers—resources within the Teacher Resources section of the website received an average of ~83,000 pages view per month during the 2007–2008 school year. Additionally, the website hosts content used in our online courses, so that individuals who wish to develop a deeper understanding of climate change but cannot take our online course can still access the information for free (but without the additional support of a class instructor).

EVALUATION

Evaluation is an integral component of our workshops and online courses. To capture the most complete picture, multiple data collection methods have been used. Several team members have expertise in program evaluation and work with other staff to implement and analyze surveys, feedback questionnaires, and assessments. The goals, objectives, and anticipated outcomes of the workshops and online courses provide the necessary reference for determining success. We make extensive use of formative evaluation through daily feedback from face to face workshops and weekly surveys from online courses. The formative evaluation helps us determine if the workshop or online course is proceeding as planned, and allows us to make adjustments if necessary. Summative evaluation data is collected through graded assignments and teacher self-reports. Overall, teacher self-reports on content knowledge strongly suggest enhanced understanding of the scientific foundation of climate and global change from an Earth system science perspective at the conclusion of our workshops and online courses.

In our face-to-face workshops, evaluation data are collected using daily feedback forms, reflective journals, pre- and post-questionnaires, focus group discussions, and teacher self-reports. Analysis of the data collected pre- and post-workshop strongly supports that the goals and outcomes of our workshops have been met repeatedly, including the central goal of increasing teachers’ content knowledge in the area of the climate system and climate change and having them become proficient in the use of hands-on classroom activities intended to increase student understanding of the science concepts.

For example, the 2004 summer climate workshop had 18 participants in the two-week event held in Boulder. Workshop participants were asked to fill out a pre-workshop survey questionnaire covering their knowledge of, and experience in, teaching topics related to climate and global change as well as their understanding of climate models. We also asked that they develop a pre-workshop concept map of climate change and the climate system. At the conclusion of the workshops, the pre-questionnaire and concept maps were returned to participants. They were then asked to make changes to their original answers on the questionnaire and to enhance their concept maps based on learning and understanding as a result of the two-week workshop.

This approach allowed us a useful pre- and post-assessment of content knowledge. To analyze the differences in the pre- and post-responses, we identified a list of key words and concepts associated with the science content underlying the climate system and climate change. Of the 18 teachers, 17 submitted pre- and post-concept maps. All but one (94%) of these teachers showed moderate or significant
gains in knowledge related to climate systems and climate change (64% had significant gain). All 18 teachers demonstrated significant gains in content knowledge on the questionnaires with notable achievements in their understanding of climate change from an Earth system science perspective.

Another indication of enhanced content knowledge is reflected in the grades earned by online course participants. The online courses are graded based on rubrics developed for assignments, tests, and participation. We have found the participants are generally highly motivated learners as evidenced by the overall high grades earned, which reflect increased content knowledge and understanding. Of the 150 participants to date, 116 (78%) have achieved an A, 18 (12%) B, 4 (3%) C, and 12 (7%) have failed. Those who choose to take the online course for credit (approximately 75%) must achieve an A or B. To earn a certificate of completion, a minimum of a C grade is required.

LESSONS LEARNED

As noted above, in the past eight years, our team has had extensive experience sharing climate change science with middle and high school teachers in the United States. We have identified a set of observations that we hope are valuable to others who are interested in providing similar training for teachers.

(1) Teachers have a critical need for credible climate change science content and age-appropriate, hands-on activities that can be readily used in today’s real science classrooms (rather than the ideal science classroom of tomorrow). In order to effectively use these resources in the classroom, teachers need to have experience using them in professional development contexts to build confidence with the material.

(2) Teachers from many disciplines and levels are interested in covering climate change in their classrooms. Climate change science is highly interdisciplinary, and is relevant not only in the Earth science classroom, but also in biology, chemistry, and physics as well as in geography, history, and ethics. Although the emphasis of instruction may change, students can learn about climate change in age-appropriate ways from elementary school through graduate study. Teachers report that their students are very motivated to learn about climate change, and to do something about it, at all levels.

(3) Teachers value local perspectives on climate change, rather than only focusing on global averages. This helps teachers make the impacts of climate change concrete to their students, and also provides an opportunity for student engagement through observations. What is likely to happen in their community? In other communities that they are connected to or are concerned about?

(4) We feel very comfortable in providing instruction and materials related to climate change from a scientific perspective. However, we recognize that climate change as a topic in secondary classrooms can be challenging. To get a better understanding of this classroom challenge, we solicited input from 25 teachers in our online course. To help inform our own professional development instruction, we asked what resources or approaches they find most useful in the instruction of challenging topics such as climate change with their students. Interestingly, they felt they had ready access to credible science content related to climate science.
Common ideas included the need for “real” data in user-friendly formats; encouraging students to think and act like a scientist; making the topic relevant to students personally; address potential solutions; provide examples of success; and empower students to believe they can make a difference.

(5) Like everyone else, being part of a community of learners and practitioners is very important to teachers. Once the professional development activity is over, teachers often go back to isolated classroom environments, without access to colleagues. Online tools, such as discussion forums and listserves, are helpful to maintain connection to a community. Peer mentoring during online courses is another helpful approach to building community.

(6) Teachers are concerned about scaring students by focusing only on the gloom and doom aspects of climate change. It is critically important to include emphasis on the actions students and communities can do to have a positive impact. Examples of instances where human intervention has successfully changed the anticipated outcome (e.g., the Montreal Ozone Protocol) are helpful to demonstrate the power of positive actions by people. Teachers can also stress the importance of students’ education and career decisions, which will determine their ability to help solve the problems of the future.

(7) Increasingly, professional development efforts with teachers no longer require as much emphasis on “proving” that climate change is actually occurring. Even so, it remains important to provide evidence, in terms of climate change observations and model results, so that teachers can explain the science accurately. It is also very important to keep ideology and politics out of the classroom—just focus on the facts, and what steps we can take to improve future climate scenarios.

(8) Teachers can use climate change science to help develop higher-order thinking skills in their students, such as critical thinking, interpreting information from a variety of sources, the meaning of uncertainty and its application in real life, as well as developing an understanding of systems and models.

(9) Online professional development should include a variety of content delivery resources to keep participants engaged, such as video, websites, readings, activities, polls, and discussion forums.

(10) Because community building is a hallmark of effective professional development programs, we struggled initially with how to build and support the virtual community of learners. After trying several approaches, we decided on an approach that has our facilitators provide responses that encourage additional interaction. It can be tempting to simply answer a question that is asked, but oftentimes we found that reposing the question to the community resulted in more robust learning and discussion.

(11) Detailed structure and clear performance expectations and due dates are critically important for online workshops. It is extremely helpful to build in interim deadlines into online interactions (e.g., discussion forums) to ensure that participants do not complete the required work at the last minute.

(12) Professional development programs should include a cycle of improvement between offerings, so that programs can continuously improve based on evaluation results and science and technology advancements.
Climate change professional development offers an opportunity to help teachers become comfortable in teaching a topic that has constant breakthroughs in scientific knowledge. As a result, what is “known” at one point may change at some later point as science advances. By being aware of the progress in climate change science, students and teachers can see the scientific process in action.

CONCLUSIONS

Our experience with middle and high school educators has shown that teachers feel ill prepared to share the science and implications of climate change research with their students. Nonetheless, they are highly motivated to engage in professional development on climate change because of the prominence of this topic in the media and resulting student interest. In order to reach a wide spectrum of educators with professional development on this (and other topics), a variety of approaches are needed that meet participants’ personal and professional constraints and learning preferences.

REFERENCES