Ways to Include Global Climate Change in Courses for Prospective Teachers

By Emily H. van Zee, Deborah Roberts-Harris, and Emma Grobart

What responsibility do we as science teacher educators have for engaging students in learning about global climate change in our courses? What stance should we take in introducing this topic? How can we add the topic of global climate change within an already packed course curriculum? These are the issues with which we have been grappling. We have begun assembling instructional resources and informing ourselves about ways others have incorporated global climate change in their courses. For now, we are choosing an incremental approach, thinking about ways to extend what we are already doing to help our students to understand at least some of the scientific concepts and reasoning underlying the claims being made, potential social impacts, and relevant educational policies. Here we reflect on ways we are modifying our curriculum as instructors in an introductory physics course and an elementary science teaching methods course for prospective teachers.

Will the dire predictions of the consequences of global climate change actually occur? A view of history suggests that societies have flourished and then perished throughout human existence (Diamond, 2005; Linden, 2006). From our perspective, certainty is not required. Given even the possibility of extreme outcomes, we feel responsible for educating our students about the potential causes and effects of global climate change as well as actions that could modify such consequences. How, we wondered, can we include aspects of global climate change in our already packed courses?

Aspects articulated in U.S. national documents

To what extent have national documents emphasized educating students about the topic of global climate change? The *Next Generation Science Standards: For States, by States* (NGSS Lead States, 2013), based on *A Framework for K–12 Science Education* (National Research Council, 2012), makes explicit the expectation that students should learn about global climate change. The framework includes this topic as one of 12 disciplinary core concepts in Earth and space sciences (ESS) that students should understand:

> ESS3.D Global climate change: (Grades 6–8): Human activities affect global warming. Decisions to reduce the impact of global warming depend on understanding climate science, engineering capabilities, and social dynamics. (Grades 9–12): Global climate models used to predict changes continue to be improved, although discoveries about the global climate system are ongoing and continually needed.

These standards not only highlight global climate change with its own entry, but also include the contribution of human activities within topics U.S. science teachers should be teaching. The first author's university is responsible for preparing teachers to implement these standards as her state Department of Education has adopted the *NGSS* as the state's science standards.

Instructional resources

A wide variety of resources are available. The National Science Teachers Association, for example, maintains an extensive list of climate science resources at http://www.nsta.org/climate/. In 2010, the U.S. government launched a major educational effort, the National Science Foundation's Climate Change Education Partnerships (http://www.nsf.gov/news/news_summ.jsp?cntn_id=117685&org=NSF&from=news), to assist teachers in learning and teaching about climate change. The U.S. National Climate Assessment (http://nca2014.globalchange.gov) reports on ways that climate change impacts our country. The Intergovernmental Panel on Climate Change (http://www.ipcc.ch) provides a detailed account of current knowledge across scientific disciplines and methodologies reported by the international community of scientists. The Global Learning and Observations to Benefit the Environment (GLOBE) program (http://www.globe.gov/home) has fostered collaboration among scientists, teachers, citizens, and students in developing and implementing a wide array of science learning opportunities worldwide.

Instructional approaches

Some courses focus entirely on aspects of global climate change (Clary & Wandersee, 2012). Others use this topic as a context for developing argumentation skills (Crippen, 2012; Golden, Grooms, Sampson, & Oliveri, 2012), demonstrating the nature of science (Matkins & Bell, 2007), and considering ethical and moral issues (Hestness, McGinnis, Riedinger, & Marbach-Ad, 2011). Others have explored how students think about climate change (Lambert & Bleicher, 2013) and willingness of students to take action (Herman, 2015; Skamp, Boyes, & Stanisstreet, 2013).

Questions

Given the limited time available, our already packed curricula, the daunting array of resources yet to be examined, as well as our own initial hesitations and still evolving understandings about climate change, we have chosen an incremental approach, a way simply to start attending to this topic. We are pondering several questions: What science would be accessible to our students, particularly those with little knowledge and high anxiety about teaching and learning science? How can we extend what we are already doing to include in our courses some of the science underlying global climate change? How might we also include social impacts of climate change and relevant educational policies in these courses?

Curricular modifications

Emily teaches a physics course for prospective elementary and middle school teachers. Emma is a graduate of this course and currently serves as a peer instructor, helping students understand not only the content but also the inquiry-based instructional approach. In designing the course, Emily and colleagues also developed ways to integrate literacy and science learning in this setting (http://physics.oregonstate.edu/coursewikis/ph111/doku.php; van Zee et al., 2013a).

TABLE 1

Revision of physics course.

Focus	Prior physics course	Current physics course
Explorations of the nature of light phenomena	3 weeks: light and shadows, reflection, refraction, dispersion; use in developing explanation for pinhole phenomena and rainbows	2 weeks: omit extensive exploration of mirrors and lenses
Explorations of the nature of thermal phenomena	3 weeks: distinction between heat and temperature; development of concepts of equilibrium, thermal conductivity, specific heat, energy transfer, changes of state, conservation of energy	2 weeks: omit extra practice with mathematical representations of conservation of energy in context of mixing hot and cold water
Explorations of the influence of light and thermal phenomena on local weather	Not included	1 week: exploration of aspects of the water cycle and differences between sand and water in thermal conductivity, specific heat, and reflectivity; use in developing an explanation for sea breezes
Participation in teaching children during Discovery Day on campus; Midterm	Same	Same
Explorations of the influence of light and thermal phenomena on global climate	Not included	2 weeks: exploration of aspects of the greenhouse effect and rising sea levels
Exploration of graphical representations of motion	2 weeks; position, velocity, and acceleration versus time graphs for stopped, moving with steady speed, speeding up, slowing down, and turning around, (moving toward and away from a motion detector)	1 week, omit practice in translating from one graph to another; apply to interpreting graphs related to global climate issues, including melting glaciers.
Exploration of the nature of astronomical phenomena within the Sun/Earth/Moon system	Throughout the term: Observations of Sun and Moon; development of explanations for phases of the Moon and seasons on Earth	Same
Field trip to teach science at local elementary school Review for final	Same	Same

Initially Emily used the question "Why does the moon seem to have different shapes at different times?" as a context for developing understandings about the nature of science, as well as for fostering scientific ways of speaking such as asking thoughtful questions and discussing evidence in support of claims. Although encouraging a global perspective—what does the moon look like in other places?—this theme did not raise or address climate change issues.

Recently Emily changed the guiding question for the course to "What happens when light from the Sun shines on the Earth?" Each unit engages the prospective teachers in identifying resources on which to build, developing powerful ideas based on evidence, using those powerful ideas to develop an explanation for an intriguing physical phenomenon, developing mathematical representations for the phenomenon, and then using those mathematical representations to estimate a quantity of interest.

As shown in Table 1, the physics course still starts with explorations of the nature of light phenomena and the nature of thermal phenomena and ends with explorations of the nature of astronomical phenomena within the Sun/Earth/Moon system. In between, however, Emily added units on the influence of light and thermal phenomena on local weather and global climate change.

Emily has chosen to focus on exploring causes of a familiar weather-related experience: the role of the properties of thermal conductivity, specific heat, and reflectivity in causing hot sand, cool water, sea breezes, and clouds in the sky during an afternoon at the beach. For the unit on global climate change, she focuses on developing understandings about energy transformations during the greenhouse effect and rising sea levels.

Students also consider ways in which their explorations involve relevant core disciplinary ideas, scientific and engineering practices, and crosscutting concepts articulated in the *NGSS*. The physical science (PS) disciplinary core ideas that Emily has identified as relevant to her modified curriculum include PS3.A, Definitions of energy; PS3.B, Conservation of energy and energy transfer; and PS4.B, Electromagnetic radiation. The ESS disciplinary core ideas include ESS2.D, Weather and climate, and ESS3.D, Global climate change.

Example physics activities relevant to climate change

Emily begins and ends the unit on climate change with a diagnostic questionnaire in which she asks students to record their initial and current knowledge about the greenhouse effect and rising sea levels. She uses internet resources to introduce the electromagnetic spectrum (http://science-edu.larc.nasa.gov/EDDOCS/Wavelengths_for_Colors.html), the nature of infrared radiation (http://www.youtube.com/watch?v=2--0q0XlQJ0), and the greenhouse effect (https://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1-3.html). The students observe a model of the greenhouse effect by noting temperature changes within two plastic containers, covered and uncovered, under identical lamps. They also model causes of rising sea levels by observing trays of ice melting in water and ice melting on rocks, as well as by holding thermometers with liquid bulbs in their hands. The students also explore internet resources about climate change with friends and family, make connections to the *NGSS*, reflect on changes in their understandings as documented in their responses to the diagnostic questionnaires, and design a 5E lesson (engage, explore, explain, elaborate, evaluate; Bybee, 2014) for teaching aspects of climate change with children of the age they want to teach. The learning progression for K–2 students, for example, for NGSS PS3.B Conservation of energy and energy transfer is "Sunlight warms Earth's surface," which is an appropriate preparation for later studies of climate change. In reflecting on these instructional decisions, Emily asked her peer instructor what had been the most interesting aspects of the global climate change unit. Emma identified two important aspects that seemed important:

> I thought that the activity that had the most powerful impact on my learning experience of global climate change was the activity about how melting ice on land is affecting rising sea levels. I thought it was a very simple, and straightforward way to model what is happening on our earth.
>
> I also enjoyed talking with my friend about the material that we went over. She is getting her degree in environmental studies with a focus on atmospheric science so it was interesting to hear her thoughts on what we were learning. She also found the way we were going about understanding the material as a way to help adults understand it as well. Many people don't have basic knowledge of what global climate change is so she saw the activities and lecture material that we went over as a good way to help the general population who is unaware of current environmental issues become educated. (personal communication, January 6, 2015)

Figure 1 shows excerpts from Emma's writings about "simple, straightforward ways of modeling what is happening to our earth" in the rising sea level explorations.

As Emma noted, the students identify, explore, and critique websites that present diagrams of the greenhouse effect, select the diagram that they find most useful, engage a friend or family member in trying to understand the diagram, and reflect on what they have learned about science learning and teaching from this experience. A graduate assistant and former museum educator invented our "friend and family assignments" (Crowl, Devitt, Jansen, van Zee, & Winograd, 2013). Such assignments now occur roughly every other week to give the students experience in teaching, in a nonthreatening environment, the science they have just learned.

An in-class activity and homework assignment involves exploring an additional series of websites relevant to global climate change. In class, small groups explore and report on interesting aspects drawn from a website they select from a list that includes websites developed by our university, state, nation, and international agencies. Emily also asks students to explore websites that focus on the seriousness of these issues from the U.S. military's perspective, social implications of climate change, and educational policies (Table 2). For homework, the students report something that they found interesting in each of these reputable websites. Emily's intent is that the students become aware of information available within contexts that directly relate to their own settings. This also models making connections to other curricula areas such as social studies.

In addition to documenting student understandings, Emily requests feedback on anonymous questionnaires monitoring students' attitudes. A major goal is to increase students' interest in science. On the last day of class, students rate various aspects from 1 (*not interesting*) to 5 (*interesting*). Mean ratings (n = 25) for exploring the influence of light and thermal phenomena on local weather (4.3 ± 0.9) and global climate change (4.0 ± 1.0) were similar to other topics in being somewhat positive. Students self-reported a statistically significant increased interest in science (from 2.7 ± 1.2 initial to 4.0 ± 1.0 final mean ratings, p = .001, paired t-test) as well as a statistically significant increased intention to teach science through inquiry in their own classrooms (from 2.4 ± 0.9 initial to 4.3 ± 0.8 final mean ratings, $p < .001$, paired t-test). See the appendix for the questions asked.

FIGURE 1

Emma's report about activities modeling causes of rising sea levels.

Rising sea levels due to melting ice on land. In class, we did an experiment where we put the same amount of ice cubes in a tray with rock and in a tray that was empty. We then poured water to the brim of the tray, making sure not to pour any water on the ice cubes on top of the rock. After about 20–30 minutes (or as long as it takes for the ice to melt), we checked back in and observed the changes. The water in the tray with the rock had over flowed, while the water in the tray without a rock did not.

This experiment was meant to mimic the difference between glaciers melting on land and icebergs melting in the water. What we are able to conclude from this is that sea levels will rise significantly if ice on land melts. . . . Here is a website that illustrates the areas of land that contain melting ice: http://www.nasa.gov/topics/earth/features/grace20120208.html.

Rising sea levels due to thermal expansion of oceans. When observing alcohol thermometers, we can see the red liquid rise when it is reading a hot object and falls when it is reading cold objects. The reason why we see the alcohol rise when it is reading a warm object is because when liquids warm up, they expand. Thermal expansions of oceans can be explained the same way; sea levels will rise if the ocean warms up. Here are two links that discuss how this relates to rising sea levels: http://ocean.nationalgeographic.com/ocean/critical-issues-sea-level-rise/ and http://www3.epa.gov/climatechange/kids/expeditions/sea-level/index.html.

Curricular modifications

Deborah teaches a course on methods of teaching science in elementary school at a different institution. Unfortunately, a common outcome of her students' prior science learning experiences in lecture-based introductory science courses has been an attitude ("I hate science") and anxiety ("I can't teach science"). Therefore, one of her goals is to shift their perceptions toward seeing science as comprehensible and interesting; she also wants them to perceive teaching science as a feasible enterprise of fostering children's active explorations of natural phenomena.

In deciding how to teach this course, Deborah wants her students to experience learning science in ways that she hopes they will eventually teach science in their own classrooms. In particular, she wants them to experience the coherent development of understandings about a science topic through inquiry. Therefore, she has chosen to embed discussion of methods of teaching science within students' explorations of a specific topic, the water cycle. Water figures prominently in the disciplinary core ideas for earth and space sciences (ESS) articulated in the *NGSS*. These include ESS2.A, Earth materials and systems, ESS2.C, The roles of water in Earth's surface processes, and ESS2.D, Weather and climate.

Deborah has found that her students typically know little about water, its properties, uses, distribution, and role in Earth's systems and processes. They even seem unaware that a nearby river, the Rio Grande, is on a list of the top ten endangered rivers throughout the world (http://wwf.panda.org/about_our_earth/about_freshwater/freshwater_problems/river_decline/10_rivers_risk/). *Evaporation*, *condensation,* and *precipitation* are vocabulary the students come to class using but they are not sure how those processes relate to the water cycle nor how complex the water cycle can be. Some seem unaware that clouds are made of liquid water droplets; that plants give off water through transpiration; or that the water cycle includes groundwater, runoff, and melting glaciers.

In exploring the focus question "What happens to water in the world around us?" Deborah involves the students in a series of brief investigations. To model evaporation, they observe water boiling in a container on a hot plate. To model condensation, they observe the clear water drops forming on the outside of a cup of water with green food coloring and a cup of green ice cubes. To consider a molecular model of changes in state, they watch a video simulating molecules moving in ice, liquid water, and a gas. Through drawing their observations, writing interpretations, discussing in small groups, reading relevant materials, analyzing water cycle curricula, as well as microteaching with their peers, her students become more familiar with the processes related to the water cycle and its complexity.

As a result of our conversations and ponderings, Deborah identified several ways to extend this focus on the water cycle to include aspects of global climate change. She now engages her students in talking about what climate change is, what they believe about it, and ways that changes are affecting their state such as the drought and recent severe weather. They also explore internet resources such as a U.S. government website about the effects of increased temperature on rates of evaporation and precipitation, impacts on droughts and floods, and seasonal patterns of ice, snow, and rain that influence availability of freshwater (e.g., http://water.epa.gov/scitech/climatechange/Water-Impacts-of-Climate-Change.cfm). They also explore a European Union website about the Water and Global Change (WATCH) programme (http://www.eu-watch.org). As an assessment, she uses a website that challenges students to identify the effects of climate change as shown in a modified water-cycle diagram (see http://www.epa.gov/climatechange/kids/scientists/clues.html).

On the last day of class, her students rated various aspects from 1 (*not interesting*) to 5 (*interesting*). Mean ratings ($n = 30$) were 4.3 ± 0.6 for exploring the water cycle and 4.5 ± 0.6 for global climate change. Students also self-reported a statistically significant increased interest in science (from 2.8 ± 1.2 initial to 4.3 ± 0.7 final mean ratings, $p < .001$, paired t-test), as well as a statistically significant increased intention to teach science through inquiry in their own classrooms (from 1.8 ± 0.9 initial to 4.2 ± 0.7 final mean ratings, $p < .001$, paired t-test). See the appendix for the questions asked.

Reflection

What have we learned from this initial effort to think about ways to include global climate change in our courses? An amazing array of resources exists already—online, in our own institutions, and within ourselves. Each website we explore, article we read, conference session we attend, and person with whom we share ideas helps move us forward, even if only incrementally, step by step. We need to do this. The first author's state Department of Education expects this. The students in our courses, now in their late teens or early 20s, will find out what the next 50 years or so will bring. Their children and grandchildren will live with the reality of whatever happens. We can sit back and watch, or we can act, at least to educate ourselves as well as our students and with them to try to make a difference. ■

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TABLE 2

Small group explorations of internet resources relevant to global climate change.

Question	URL
What is our university doing to study climate change and take action?	Oregon Climate Change Research Institute http://occri.net
What is our state doing to study climate change and take action?	Oregon Department of Energy: Climate Change in Oregon http://www.oregon.gov/ENERGY/gblwrm/climhme.shtml
What is our country doing to study climate change and take action?	Third National Climate Assessment http://nca2014.globalchange.gov
How are countries collaborating to study climate change and take action?	Intergovernmental Panel on Climate Change Fifth Assessment Report, http://www.ipcc.ch/report/ar5/index.shtml Physical Science Basis, 13.6.5, p. 1198, chart of projected sea level rise for coastal cities in meters
How does the U.S. military regard global climate change?	National Security and Accelerating Risks of Climate Change https://www.cna.org/cna_files/pdf/MAB_5-8-14.pdf
What are some social implications of climate change?	http://www3.epa.gov/climatechange/impacts/society.html
What educational policies address climate change issues?	Next Generation Science Standards (PS3.B, ESS2,D, ESS3.D) http://www.nextgenscience.org
What can one do oneself to take action?	Ways to take action: http://www.epa.gov/climatechange/wycd

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References

Bybee, R. (2014). The BSCS 5E instructional model: Personal reflections and contemporary implications. *Science and Children, 51*(8), 10–13.

Clary, R. M., & Wandersee, J. H. (2012). Mandatory climate change discussions in online classrooms: Promoting students' climate literacy and understanding of the nature of science. *Journal of College Science Teaching, 41*(5), 70–79.

Crippen, K. J. (2012). Argument as professional development: Impacting teacher knowledge and beliefs about science. *Journal of Science Teacher Education, 23,* 847–866.

Crowl, M., Devitt, A., Jansen, H., van Zee, E., & Winograd, K. (2013). Encouraging prospective teachers to engage friends and family in exploring physical phenomena. *Journal of Science Teacher Education. 24*(1), 93–110.

Diamond, J. (2005). *Collapse: How societies choose to fail or succeed*. New York, NY: Penguin.

Golden, B., Grooms, J., Sampson, V., & Oliveri, R. (2012). Generating arguments about climate change. *Science Scope, 35*(7), 26–35.

Herman, B. C. (2015). The influence of global warming science views and sociocultural factors on willingness to mitigate global warming. *Science Education, 99*, 1–38.

Hestness, E., McGinnis, J. R., Riedinger, K., & Marbach-Ad, G. (2011). A study of teacher candidates' experiences investigating global climate change education within an elementary science methods course. *Journal of Science Teacher Education, 22,* 351–369.

Lambert, J., & Bleicher, R. (2013). Climate change in the preservice teacher's mind. *Journal of Science Teacher Education, 24,* 999–1022.

Linden, E. (2006). *Winds of change: Climate, weather and the destruction of civilizations.* New York, NY: Simon and Schuster.

Matkins, J. J., & Bell, R. L. (2007). Awakening the scientist inside: Global climate change and the nature of science in an elementary science methods course. *Journal of Science Teacher Education, 18*, 137–163.

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

NGSS Lead States. (2013). *Next generation science standards: For states, by states.* Washington, DC: National Research Council.

Skamp, K., Boyes, E., & Stanisstreet, M. (2013). Beliefs and willingness to act about global warming: Where to focus science pedagogy? *Science Education, 97*, 191–217.

van Zee, E. H., Jansen, H., Winograd, K., Crowl, M. & Devitt, A. (2013a). Fostering scientific thinking by prospective teachers in a course that integrates physics and literacy learning. *Journal of College Science Teaching*, *42*(5), 29–35.

van Zee, E. H., Jansen, H., Winograd, K., Crowl, M., & Devitt, A. (2013b). Physics and literacy learning in a course for prospective teachers. *Journal of Science Teacher Education, 24*, 665–691.

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Appendix

Course Feedback

1. To what extent were you interested in science before this course?
   Not interested 1 2 3 4 5 interested

2. To what extent are you interested in science now?
   Not interested 1 2 3 4 5 interested

   Comments:

3. How likely would you teach science through inquiry in your own classroom before this course?
   Not likely 1 2 3 4 5 likely

4. How likely will you teach science through inquiry in your own classroom now?
   Not likely 1 2 3 4 5 likely

   Comments:

5. How interesting were these aspects of this course to you?

   Learning about the water cycle
   Not interesting 1 2 3 4 5 interesting

   Comments:

   Learning about global climate change
   Not interesting 1 2 3 4 5 interesting

   Comments: