CIRES EDUCATION AND OUTREACH GROUP UNIVERSITY OF COLORADO BOULDER

Navigating Climate Science in the Classroom

Teacher Preparation, Practices, Perceptions and Professional Development

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I. Introduction

Classrooms are a microcosm of society. As such, climate education in the classroom is subject to the same social complexities as the rest of the public dialogue on climate change. Desirable climate education should result in learners with a robust understanding of the climate system and climate change, the skills to engage with climate change as a societal issue, an understanding of the practices of science, and the ability to discern between credible scientific claims and those based in misinformation. To achieve this end, teachers must possess the requisite knowledge, skills and dispositions, be able to find or develop appropriate learning resources, and would practice within a supportive professional context.

This paper describes the current preparation of classroom climate instructors in terms of knowledge and practices; outlines characteristics of useful professional development and lists some challenges inherent to meaningful professional development. Since public controversy influences climate instruction, teacher perceptions and practices around climate controversy are described throughout.

SUMMARY

Context of this work-selected from four different data samples
How well (or not) are teachers prepared to teach CC?
- Content Knowledge (self-directed PD, fundamentals vs. emerging topics, fragmented)
- Views on climate change (adherence to the academy view)
- Alignment within curriculum (standards, integration cross discipline)
- Strategies to Address controversy (both sides, transferred from evolution, solutions)

What are characteristics of helpful PD?
- Sustained within a supportive community
- Deep-builds a cohesive mental framework
- Relevant-tied to student and teacher needs

What are challenges of training and support?
- Place in the curriculum
- Difficulties of scale
- Reaching the unengaged

Conclusion

II. Context of this work

Any discussion of teachers requires a caveat; there is no more a uniform group of “the nation’s teachers” than there is a uniform group called “the general public”. In fact the teacher population varies widely in content knowledge, attitudes and dispositions towards climate science and comfort with public controversy.

Source material for these remarks include a descriptive research study and evaluation data derived from climate education projects, with respondents ranging from secondary science teachers (middle and high school) through undergraduate faculty. Respondents range from those hostile to climate science to those deeply engaged in climate education. These remarks are further informed by discussions with science teachers and professional development practitioners.

Sources include a descriptive study of Colorado science teachers from data gathered in 2007 (Wise 2010), a national-scale needs assessment conducted in 2009 (Lynds, 2009), a workshop evaluation report comparing gains before and after a week-long workshop (Lynds, 2010), and survey results from a national informant network of faculty from middle school through upper level undergraduate levels. (Hirabyashi, 2011). Samples vary by geographic scope, sample size, level of instruction and degree of engagement in climate instruction, but themes and findings are consistent throughout.

Source	Year data gathered	Number of respondents	Scope of sample	Level of instruction	Degree of engagement (% formal climate lessons)
Wise, 2010 (Wise, 2010)	nstr	628	Colorado science teachers	Middle and high school	33-65% (varies by subject)
CIRES /ICEE project Needs Assessment (Lynds, 2009)	2009	284	National sample, science teachers	Middle and high school	61%
CIRES ICEE Workshop evaluation (Lynds, 2010)	2010	25	National, competitive application	Middle and high school	72%
CLEAN Informant Network (Judy Hirabyashi, 2011)	2011	213	National, competitive application	Middle and high school, upper and lower UG	80-94% (varies by level)

III. How well prepared are teachers to teach climate change?

Secondary teacher preparation is variable and often the result of independent study (Wise, 2010) (Lynds, 2009) (Judy Hirabyashi, 2011). This results in fragmented content knowledge and less confidence with current science. Teacher views reflect those common among the public and students; understanding is somewhat inconsistent with the academy view of climate science and reflects similar prior conceptions to those observed among students and the public. Barriers to climate instruction include lack of alignment with curriculum, lack of content knowledge, and the views of students, parents and colleagues. Strategies around controversy range from those that are inconsistent with the scientific view to seasoned and savvy, informed by experience with other controversial topics such as evolution.

A. Content Knowledge

Self-directed professional development Few respondents to the ICEE Needs Assessment have had no learning experiences about climate change whatsoever. However, secondary science teachers surveyed most frequently cite independent study such as reading magazine articles, or viewing television programs and documentaries. Many respondents participated in short duration professional development workshops and conference learning experiences while many also cite other independent study such as reading climate change specific websites and books. A third of respondents attended more sustained college classes or graduate level classes including climate change. Only one in ten cite in-school learning experiences (Lynds, 2009).

Among CLEAN informants, which are the data sample with the most engagement in climate education, most secondary science teachers do not hold a degree related to climate science (Judy Hirabyashi, 2011). This finding is consistent with data on "out of field teaching" in which relatively few teachers have degrees or certifications in physical sciences or geoscience, especially at the middle school level. The picture is brighter for climate impacts concepts within life sciences and social studies, because a higher percentage of teachers are "in-field" in those disciplines (U.S Department of Education, National Center for Education Statistics, 2004).

Fragmented content knowledge Teachers describe looking for climate change background knowledge and resources within a bewildering landscape of blogs, articles, press releases, websites, and curriculum repositories, each with varying provenance, currency and point of view. Thus, many describe feeling their knowledge is fragmented, and are unsure what is credible. Practitioners who use concept map assessments in climate science professional development anecdotally describe teachers unwilling to make connections between climate concepts, even when specifically directed to do so. In general, pre-service teacher knowledge about climate change reflects similar misconceptions and preconceptions as found among the U.S. public, resulting in generalized ideas of environmental issues, such as thinking that global warming causes skin cancer because of the conceptual linkage between global warming and the ozone hole. Researchers in the field have identified the same misconceptions among in-service and pre-service teachers as among secondary students and the public (Boon, 2010) (Khalid, 2001) (Pugh, 1999). Answers to questions about climate change reflect a range of agreement with the established scientific view, and also reflect common misconceptions, such as "the ozone hole is a significant cause of recent climate change" (Wise, 2010).

The major barriers flow from this lack of coherence, making teachers less confident in their abilities to make curricular connections, choose authoritative resources and deal with controversy. These remarks do not apply to all teachers, as some have sophisticated levels of climate science knowledge, and some do not accept the evidence for human-caused climate change.

Fundamentals versus newer concepts Teachers describe comfort with some long-familiar Earth system science topics such as the global circulation system and the reasons for the seasons, but lack understanding of other physics and chemistry concepts which gain greater prominence within climate science. Examples include the difference between reflected and absorbed/re-emitted radiation, or the qualities that distinguish a molecule as a greenhouse gas. Teachers describe more interest *and* more lack of knowledge about newer topics such as the local impacts of climate change, and the evidence for the scientific basis of human-caused climate change. Despite increased interest, fewer teachers teach about "what is predicted to happen where you live" or "how scientists know what they know about climate" (Lynds, 2010). This mismatch is understandable, since in science education there is a lag time between the emergence of new science and the advent of professional development and classroom-ready learning activities.

B. Views on Climate Change

Teachers profess a range of views on climate change. While most teachers agree that the Earth's climate is warming, there is less agreement on human-causation, and less understanding of the degree of scientific consensus (Wise, 2010) (Lynds, 2009) (Judy Hirabyashi, 2011). This may result from teachers having learned climate science from the public media, or because teachers are situated within communities that exhibit a similar variance in attitudes towards climate change.

Forty percent of the U.S. public thinks "there is a lot of disagreement among scientists about whether or not global warming is happening" and 32 percent do not know enough to say what proportion of climate scientists think that global warming is caused by human activities (Leiserowitz, 2011) Assuming global warming is happening, 35% think it is caused mostly by natural changes in the environment (Leiserowitz, 2011). Wise (2010) found that in 2007 approximately 20% of Colorado Earth science teachers disagreed that "recent global warming is caused mostly by things people do", while nearly half agreed that "there is substantial disagreement among scientists about the cause of recent global warming". Approximately 35% agreed that "science that goes against global warming theory is suppressed". In a national needs assessment (Lynds, 2009), similar proportions disagreed that "recent global warming is caused mostly by things people do" while 30-40% (by instructional level) disagreed that "there is substantial agreement among climate scientists about the cause of recent global warming". More polarization occurs as instructional level increases; within the CLEAN informant group the least adherence to the academic scientific view is evident in the upper division university sample. Among all college-level instructors, geology was the most commonly taught topic followed by environmental science and atmospheric science. This pattern is consistent with studies that show greater scientific literacy and numeracy corresponds to increased cultural polarization and less likelihood to see climate change as a serious threat (Kahan, 2011).

C. Alignment within and across the curriculum

Aligning climate concepts within the curriculum requires either explicit inclusion of climate science within standards or the ability to identify and make connections based on the teacher's own content knowledge. Half of CLEAN informants are aware of and influenced by the Essential Principles of Climate Science (EPCS) (USGCRP, 2009), a conceptual framework built upon AAAS Benchmarks for Science Literacy (AAAS, 1993). Among those who do not teach climate lessons, curricular alignment is the greatest barrier (Wise, 2010) (Judy Hirabyashi, 2011). Most secondary respondents teach climate lessons within life science, earth science and environmental science, followed by physical science and general or integrated science (Lynds, 2010; Lynds, 2009; Judy Hirabyashi, 2011). When asked where climate topics fit into the school curriculum, Colorado teachers most often cited Earth science, life science, environmental science and social studies classes (Wise 2010).

Time on task Among CLEAN informants, the majority spend less than 25% of their instructional time on climate and energy topics. Wise (2010) found that science teachers spend more time on climate "fundamentals" concepts and less time on concepts with human implications. Since a critical task of formal climate education is to equip students with a robust understanding of the climate system, it is appropriate to ensure an understanding of the fundamentals. But it is also desirable to teach students about issues in a personal and social context (National Science Teachers Association, 2011) , and to equip students with the civic literacy skills necessary to engage with issues in the social arena. However, science teachers may see this as the purview of the social studies curriculum rather than the science class.

Connecting across the curriculum Among engaged secondary instructors, most (~80%) integrate climate science with other subjects and topics, while ~ 20% teach climate science as a stand-alone topic mostly or always (Judy Hirabyashi, 2011). Integration is considered a best practice for several reasons; learning climate science through the lens of Earth Systems throughout a course makes climate change topics more resistant to controversy-based challenges. Also, integration with other subjects such as social studies introduces the opportunity for more thorough treatment of human aspects such as economics and societal practices. Doing this integration requires sufficient content knowledge to make curriculum connections and a sufficiently supportive school community to build cross-discipline bridges.

D. Addressing controversy

Half of CLEAN informants say the biggest challenges they face are student beliefs (along with parents' and colleagues' beliefs), misconceptions, pre-conceived ideas, political views, and religious views. Strategies employed to address controversy fall along a continuum of sophistication and scientific validity. From 2007 to 2011, controversy has overtaken lack of curriculum alignment and lack of content knowledge as the major concern (Wise, 2010) (Judy Hirabyashi, 2011)

Teaching "both sides" Colorado teachers overwhelmingly (85%) indicate a willingness to teach "both sides" (Wise, 2010). Explanatory comments fell into three categories; a minority who see "both sides" as valid scientific viewpoints, a majority who describe teaching "both sides" as more fair or as promoting independent decision-making, and a minority who reason that allowing student discussion of controversy is appropriate but that formal instruction should emphasize the academic scientific view. Those who teach "both sides" as a way to promote critical thinking may undermine the scientific consensus by implying that both viewpoints are considered scientifically valid (Wise, 2010). Our work at CIRES outreach promotes formal climate science lessons reflecting the consensus view, the practices by which scientists come to consensus, and accommodating student discussion on controversial points. Additionally when policy or social decisions are under discussion we promote an environmental education model that weighs competing social values and viewpoints. The content of issues and proposed solutions may change but the value of learning to make informed decisions is perennial.

Learning from evolution Workshop participants anecdotally describe transferring strategies learned from evolution education to climate science. Parallels to evolution are most common, but parallels to learner (and parent) readiness for such topics as sex education or the Holocaust have also been drawn by workshop participants. Wise (Wise, 2010) found that the most common strategies used by educators include reliance on scientific evidence and data, accommodating discussion of ideas expressed by global warming deniers, and offering to talk with students outside of class. Workshop participants anecdotally describe those strategies and also cite strategies such as using educational standards to indicate institutional accountability, citing the norms of science class, securing support from administrators, and highlighting the views of opinion leaders who accept the scientific evidence for human-caused climate change, such as faith leaders or the military. Other strategies include hosting outside speakers and educating adults (parent and colleagues at school).

Student-centered instruction Teachers seeks resources that exhibit high quality science, real world applicability, and opportunities for students to use real data and to have hands-on engagement. Introducing climate change framed in terms of relevant local issues or impacts, such as water resources or pine bark beetle damage, helps students access the topic in a way that is not as “hot button” as the words “global warming”. Furthermore, teachers indicate that students are more engaged by information introduced as a relevant problem or issue (Judy Hirabyashi, 2011). However, while informants say that students are most likely to want to engage in hands-on lab activities, field trips, studying a local issue or problem, and working with visualizations/simulations, instructional approaches that are used in the classroom do not track closely, centering around discussion and lecture as two of the top three approaches (Judy Hirabyashi, 2011).

Integrating solutions Climate change realities can be emotionally challenging to learners, and students may develop apocalyptic fears or disengage from climate topics under the strain. This anxiety-based disengagement from environmental topics has been described in environmental education literature (Sobel, 1996), and educators anecdotally describe students home crying because of climate change. Thus, integrating climate science with the social aspects of climate change (including solutions) is intuitively understood as a best practice in climate education. The NSTA supports teaching science in a personal and societal context (National Science Teachers Association, 2011) and student engagement increases if topics are socially or personally relevant. Solutions information offered in concert with climate science information has been shown to help adults accept the evidence (Willer, 2011). CLEAN informants uniformly consider solutions in their teaching of climate science (Judy Hirabyashi, 2011). Different models exist; anecdotally most focus on energy efficiency and use. Teachers host environmental clubs, students conduct energy audits at school, individuals calculate family greenhouse gas emissions, and some students research and recommend emissions-sensitive strategies to municipalities.

IV. What sort of professional development is helpful?

Valuable climate change professional development (PD) is sustained, deep, and relevant and should take place within a supportive professional network of communities. PD with these characteristics address the biggest barriers-alignment with standards and curriculum, coherent and robust content knowledge, ability to withstand controversy and the ability to find or develop useful teaching resources.

A. Sustained within a supportive community

The best professional development is sustained; it takes at least 80 hours of professional development experience to result in reform-based impacts on teaching practices (Corcoran, 2003) and to result in more inquiry based practices (Supovitz, 2000) . At the secondary level, more than half of CLEAN informants have had formal PD in climate science, and over half have had one week to a month of professional development over the last three years (Judy Hirabyashi, 2011). Engaged teachers participate in multiple climate and energy learning communities and participate in multiple professional development opportunities. Teachers form loose networks of learning partners from multiple communities who are accessed on as-needed basis. Teachers recommend PD to one another (or warn one another away), bring colleagues from one community to another and “cross-pollinate” communities with resources, questions and news. The majority of CLEAN Informants are engaged in climate-relevant science and education communities. These are overwhelmingly national-scale science organizations (American Geophysical Union, Geological Society of America) or science education organizations such as NSTA, NAGT, NESTA or NMEA. A majority of informants have connections with scientists working in climate science. Many participate in local or regional climate and energy groups outside of their professional life (Judy Hirabyashi, 2011).

Wise (2010) found that encouragement from a teacher’s local community had a greater effect on instruction than did discouragement. When teachers experienced encouragement for climate instruction, teaching was enhanced and teachers were more committed to the topic, whereas discouragement hindered teaching to a lesser extent. The majority describe being a resource to their colleagues in climate science but the relationship is not entirely reciprocal, as they do not receive resources from their local colleagues to the same extent (Judy Hirabyashi, 2011). The majority of secondary teachers feel supported “to some extent” or “to a great extent” by their institutions (Hirabyashi, 2011). Because informants do participate in communities at multiple scales, and because they are viewed as a resource among local peers, valuable PD provides ways to build community across scales (national, regional, local) and disciplines (science, policy, education).

Support to address controversy We treat our CIRES online communities as an extension of our classroom. CIRES online norms are such that dialogue is evidence-based, respectful and moderated so that the community remains free of vitriol and off-topic controversy canards. These communities are used often to counter classroom climate controversy. A teacher who posts to our email list with a challenge has scientists and master teachers offering help within hours. Teachers ask for scientific input on questionable information brought to school, ask for clarification on scientific points, ask for learning resource suggestions and warn of biased professional development offerings. Valuable climate PD provides a safe environment to ask questions and get support in a timely and respectful manner.

Ability to stay up with the field –connections with scientists and master teachers

The consistently most valuable part of professional development is time with climate scientists. Teachers value the opportunity to ask whatever is foremost on their minds of people who are clearly expert. This opportunity is valued most when each party's expertise is valued going both ways; when climate science presenters speak at the appropriate relevant level, mention teachers who were influential to them, stay for lunch and invite their students to attend, it sends a message of mutual respect. The majority of climate-engaged CLEAN secondary informants have connections with climate scientists and all are interested in developing such connections. Valuable PD includes opportunities to develop meaningful connections with scientists, and to access expert scientist input on an as needed basis.

The second most cited valuable element of PD is time with master teachers; time for collaboratively developing implementation plans, strategizing and identifying good teaching resources. There is never enough time in a workshop to fully satisfy this need-again, sustained means to communicate and follow up with professional colleagues after a personal connection has been made is desirable.

B. Deep: A cohesive mental framework

Teachers build confidence as they build mastery of climate science content. The Essential Principles of Climate Science (USGCRP, 2009) describes a framework of big ideas in climate science, built upon the evidence-based learning progressions of the Benchmarks for Science Literacy (AAAS, 1993). Newer learning progressions research extends what we know about how students progress in climate science. Helping teachers use these progressions can help them understand how to include climate concepts throughout the curriculum. A coherent mental framework includes an understanding of Earth systems ideas applied to the climate system, such as feedback loops, inter-connected spheres, varying scales in time and space, and tipping points. Deep learning requires professional development that focused on higher level learning goals (application and synthesis vs. recall) and inherently models the nature of science (inquiry-based projects, research experiences).

C. Relevant: student and teaching needs

Climate change PD structured around identified teaching needs is most immediately useful to teachers. Teacher express interest in practice addressing controversy, gaining access to high quality resources and anticipating difficult concepts. Teacher express a need for climate teaching resources to address particular student groups, such as English Language Learners, low reading or mathematics skills or honors/Advanced Placement level students.

PD at different scales: Some of these needs may be met through national scale PD such as practice responding to common contrarian arguments or uncovering common misconceptions. However, some needs are locally contingent-an opinion leader who knows a teacher's students, district standards and community provides more credible advice about is suitable in that teacher's classroom. Teachers are more credible brokers of information about curriculum than are scientists. Thus models of national/district/building partnerships may be effective, with some PD offered nationally and local communities of practice or climate science “coaches” being developed on site.

D. Professional Development viewed as valuable

CLEAN informants were asked to describe which organizations provided particularly high quality PD experiences. Responses varied, however experiences with NEED (energy) and ICEE/CIRES (climate) were mentioned most often while GLOBE, NOAA, and NSTA were also mentioned repeatedly. Teachers cited connections to scientists, greater understanding of research, learning about curriculum and time planning classroom implementation as the most valuable elements. Teachers who participated in ICEE/CIRES PD described greater confidence in their ability to teach climate science post-workshop (Lynds, 2010). Many participants also expressed one or two levels greater agreement with the statement “there is substantial agreement among climate scientists about the cause of recent global warming”. Content knowledge questions demonstrated greater mastery before and after the workshop (Lynds, 2010). Teacher implementation reports are coming in with a range of new classroom products ranging from lessons and units to semester-long courses and professional development for other teachers.

V. What are the challenges and barriers for training and support?

Professional development in climate science is subject to the same challenges and barriers as within other areas of geosciences education, with the added barrier of public controversy. Some of these challenges and barriers are noted below. However, since those who engage in climate education must draw upon some measure of optimism to persist, some strategies for addressing these are suggested.

Most climate science instruction ends in middle school Climate science does not occupy the same priority in the school curriculum as it does in the public dialogue. Many administrators and teachers consider climate science to be at best a relatively narrow topic in what is at the high school level a relatively low-priority subject. Some but not all states include climate science in their content standards at present . Few states require Earth science as a graduation requirement. Concepts within the EPCS fall from middle school through professional levels, with most clustered around high school. But of the courses considered most closely aligned with climate concepts, only life science is widely subscribed by high school students. More than 90% of graduating high school students take life science, while less than 25% take an Earth science class in high school (AGI, 2011). For high-achieving college-bound students, the Advanced Placement Environmental Science course is the only likely avenue for climate change science learning (NAGT, 2011). Ties should be built between Earth science, life science and social sciences (perhaps through PD that includes interdisciplinary teams from one district), and the community should push for greater requirements and rigor in Earth science courses. In the meantime, more life science and social science PD and resources should be developed.

Scale: Best practices PD takes money, time and inclination The best PD includes real relationships between teachers, scientists and professional development providers. Building and maintaining relationships with teachers takes time whether in real or virtual space. Engaging those who are at present disengaged or even hostile to the topic is non-trivial in terms of sheer numbers and requires even more relationship-building to overcome the barriers. Developing skills and retaining knowledge is best done with repeated exposure and practice. This can only happen over an extended amount of time. Eighty hours of contact time over a year is better than 80 hours of contact time over two weeks. Research experiences for teachers are transformative professionally and personally. Teachers enjoy a greater understanding of the nature of science and gain credibility in the eyes of their students when they have themselves conducted research. However, these in-depth experiences reach only the most motivated and engaged of teachers. Greater connections and partnerships between PD providers may help alleviate the time crunch, especially those that fill niches within the climate PD ecosystem and those that increase dissemination.

Reach the rest: District-based climate PD is rare Relatively few teachers have received climate science professional development through school in-service opportunities, and a relatively small percentage seek extensive formal PD through outside organizations. Evolution education researchers have suggested that a greater emphasis on evolution be made part of pre-service licensure requirements (Berkman, 2011), a strategy which could be transferred to the climate topic. But, since teachers need PD that is tied to the learner needs and standards of their own schools, and since the best opinion leaders are those that understand the local district and building context, school and district-based opportunities are the best way to provide that opportunity to teachers already in the classroom who are not otherwise engaged in climate PD. Those who are engaged in climate instruction identify climate contrarian colleagues as a barrier, though CLEAN informants are also seen as a resource among their local colleagues. PD that helps teachers act as ambassadors and coaches within their districts may take advantage of the community dynamics already in play.

Mismatch between needs and scientific culture Teachers value face to face time with scientists, the ability to ask questions and have them answered personally, and the ability to ask for backup or resources when needed. However, the scientific culture offers only modest rewards to scientists who support education. PD providers who can act as bridges and buffers can repurpose previous communications, can develop efficient ways to engage scientists and may recruit a broader swath of scientists.

VI. Conclusion

The climate education scene contains reason for both discouragement and for hope. While one could expect that the scientific view would always prevail among science teachers, that is not the case. Our learning resources are in some ways adequate and in other ways unequal to the challenges of equipping students for the tasks ahead. The best professional development is expensive and difficult to scale up. Teachers cope with all the challenges with which they have always wrestled, and struggle with added burdens of controversy.

But despite the challenges, hope abides. The new conceptual framework for science education standards (Board on Science Education, NAS, 2011) includes climate science explicitly. One hopes the framework will result in national standards containing equally strong language about climate science and climate change that will influence state and district standards. Some states require Earth science as part of the graduation requirement, and more educators are looking for ways to build bridges across the school curriculum. Students are generally interested in the topic from one perspective or another, and scientists feel a personal responsibility to engage. A great upwelling of climate education projects has emerged, compared to the landscape even ten years ago.

An optimistic observer may envision professional development in which partners each take a niche, share resources and participants, and devote themselves to different aspects of climate education at different scales. Teachers who already act as district resources could be better equipped and supported. Online, local and face to face modes of professional development could be established cross-project and cross-agency, as long as the needs of all parties are respected. A good understanding of the changing climate education landscape may result in projects and resources that squarely meet teacher and student needs. This workshop is one example of the kind of cross-discipline and cross-agency dialogue that could lead to more effectively meeting the needs of climate educators.

There are two ways (at least) of blazing a path forward. We as a community could look at the failures and problems and some of that is no doubt informative. Or we could look at the successes, determine what is different, and replicate that to whatever extent possible. While there are many real challenges, there are also master teachers who spend their time taking every professional development opportunity they can get, who craft relevant learner-centered curriculum, and who change the lives of their students. They have told us what they need, and for every master teacher there are others ready to take the same path if we can make the way clear.

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For more information see:

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  http://cires.colorado.edu/education/outreach/
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Climate Literacy and Energy Awareness Network
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Works Cited

AAAS. (1993). *Benchmarks for Science Literacy.* Oxford University Press.

AGI. (2011). *Status of the Geoscience Workforce 2011.* Alexandria VA: American Geological Institute.

Berkman, M. P. (2011, January). Defeating Creationism in the Courtroom, But Not in the Classroom. *Science* , 404-405.

Board on Science Education, NAS. (2011). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* National Academies Press.

Boon, H. J. (2010). Climate Change? Who Knows? A Comparison of Secondary Students and Pre-service Teachers. *Australian Journal of Teacher Education , 35* (1), 104-120.

Corcoran, T. M. (2003). *Getting it right: The MISE approach to professional development.* Philadelphia PA: Consortium for Policy Research in Education.

Judy Hirabyashi, J. H. (2011). *CLEAN Pathways Informant Survey #1.* Inverness Research Associates, Inc.

Kahan, D. M. (2011). *The Tragedy of the Risk-Perception Commons: Culture Conflict, Rationality Conflict, and Climate Change.* Cultural Cognition Project Working Paper No. 89.

Khalid, T. (2001). Pre-service teachers' misconceptions regarding three environmental issues. *Canadian Journal of Environmental Education , 35* (1), 102-120.

Leiserowitz, A. M.-R. (2011). *Climate change in the American Mind: Americans' global warming beliefs and attitudes in May 2011.* New Haven CT: Yale Project on Climate Change Communication.

Lynds, S. (2010). *ICEE (Inspiring Climate Education Excellence) Summer Workshop 2010 Internal Evaluation Report.* Boulder, CO: CIRES Education and Outreach, University of Colorado.

Lynds, S. (2010). *ICEE Summer Workshop 2010 Evaluation Report.* Boulder CO: CIRES Education and Outreach, University of Colorado.

Lynds, S. (2009). *Inspiring Climate Education Excellence (ICEE) Program Needs Assessment Survey Report.* Boulder, CO: CIRES Education and Outreach, University of Colorado.

NAGT. (2011). Draft Position Statement: High School Earth Science Instruction. National Association of Geoscience Teachers .

National Science Teachers Association. (2011, November). *Teaching Science and Technology in the Context of Societal and Personal Issues.* Retrieved August 26, 2011, from http://www.nsta.org/about/positions/societalpersonalissues.aspx

Pugh, F. H. (1999). Elementary Pre-Service Teacher Perceptions of the Greenhouse Effect. *Journal of Science Education and Technology* , 75-81.

Sobel, D. (1996). *Beyond Ecophobia: Reclaiming the Heart in Nature Education.* Nature Literacy Series.

Supovitz, J. a. (2000). The effects of professional development on science teaching pracgtices and classroom culture. . *Journal of Research in Science Teaching* , 963-980.

U.S Department of Education, National Center for Education Statistics. (2004). *Qualifications of the Public School Teacher Workforce; Prevalence of Out-of-Field Teaching, 1987-88 to 1999-2000, NCES 2002-603.* Washington, D.C.: National Center for Education Statistics.

USGCRP. (2009). *Essential Principles of Climate Science: A Guide for Individuals and Communities.*

Willer, M. F. (2011). Apocalypse Soon? Dire Messages REduce Belief in Global Warming by Contrdicting Just-World Beliefs. *Psychological Science* , 34-38.

Wise, S. (2010). Climate change in the classroom: Patterns, motivations and barriers to instruction among Colorado science teachers. *Journal of Geoscience Education , 58* (5), 297-309.

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