Navigating Climate Science in the Classroom: Teacher Preparation, Perceptions and Practices

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ABSTRACT

Results from a series of surveys describe dimensions of middle and high school science teachers' preparation for and practices around climate science instruction in the classroom. Descriptions are drawn from 877 respondents to four surveys of US middle and high school science teachers from 2009–2011. Most respondents had engaged in self-directed learning or short duration workshops to prepare for climate instruction while a third had received professional development in sustained undergraduate or graduate level courses. Controversy was cited as the top climate education concern in 2011, followed by the need for resources, alignment with standards and needs for professional development. Some respondents perceive the existence or human-attribution of recent climate change to be false, some accept and wish to teach the evidence that the climate is changing due primarily to human activities, and some describe a desire to teach "both sides" without describing the motivation. The most commonly used strategy to address controversy and misinformation is to promote learning about the nature of science, evidence, and data. Recommendations for supporting teachers in climate science instruction are made based upon the findings of these studies, the evolution literature, and the Next Generation Science Standards. © *2014 National Association of Geoscience Teachers*. [DOI: 10.5408/12-304.1]

Key words: climate education, professional development, middle and high school science teachers, climate change, controversy

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. The Framework for K12 Science Education (NRC, 2011) and the resulting Next Generation Science Standards (Next Generation Science Standards, 2014) include concepts about climate change, especially within the *Earth and Human Activity* and *Earth's Systems* Disciplinary Core Ideas. In order to implement these climate concepts, teachers will need support, high quality teaching resources, and professional development. At present, there is a great need for better understanding; 77% of the American public would receive a grade of "D" or "F" for the state of their climate science knowledge (Leiserowitz et al., 2010), and American teens would receive similar grades (Leiserowitz et al., 2011). The situation was not improved in 2012 (Leiserowitz et al., 2012).

Education is an essential piece of the puzzle as society decides how to address a changing climate, and teachers are the means by which today's students will become tomorrow's informed citizens. 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 another educational goal is to teach students about scientific issues in a personal and social context (NSTA, 2011), and to equip students with the civic literacy skills necessary to engage with issues in the social arena (Miller, 2000). According to the Essential Principles of Climate Science (USGCRP, 2009), comprehensive climate literacy education should result in learners who "understand the essential principles of Earth's climate system, know how to assess scientifically credible information about climate, communicate about climate and climate change in a meaningful way, and are able to make informed and responsible decisions with regard to actions that may affect climate." Researchers find that adults with a "just world" view are more accepting of facts about anthropogenic climate change when the facts are paired with information about climate mitigation and adaptation (Feinberg and Willer, 2011). As an added consideration, children have been shown to be distressed by topics inherent in climate change impacts, such as species extinction and changing landscapes (Sobel, 1996; Barraza, 1999; Strife, 2008). These emotional aspects must be handled with sensitivity and a future-oriented mindset (Pruneau et al., 2003).

Given the links between student achievement and teacher preparation (Supovitz and Turner, 2000; Yoon et al., 2007), teachers must possess the requisite climate content knowledge, be able to find or develop appropriate learning resources for their situation, and must practice within a sufficiently supportive professional context. Studies of teachers within the climate education literature focus primarily on misconceptions, and usually on pre-service teacher audiences rather than those who are practicing in the classroom (Groves and Pugh, 1999; Khalid, 2001; Boon, 2010). A few published and informal studies have focused on the climate education needs, practices, and perceptions of classroom teachers (Pruneau et al., 2006; Wise, 2010; National Earth Science Teachers Association, 2011).

Within a 2007 Colorado sample, Wise (Wise 2010) found that lack of alignment with standards and curriculum was the largest barrier for Colorado teachers, followed by the need for more climate science content knowledge, with

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concern about controversy a distant third. Kastens and Turrin found that 30 out of 49 states with science education standards mentioned any aspect of anthropogenic climate change in summer 2005 (Kastens, 2006). The impacts of climate change are mentioned within all of these, but the connection between the use of fossil fuels as a cause of climate change is mentioned or implied by only seven, and the mitigation or prevention of climate change is mentioned vaguely in seven of the eight states that mention it at all. Any topic must be aligned with standards for the course. 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). Wise also found that middle and high school science teacher preparation in climate education was variable and often the result of independent study. Wise found in 2007 that 85% of Colorado teachers addressed controversy by accommodating "both sides", with reasoning ranging from scientifically savvy (use controversy as a teachable moment) to reasoning inconsistent with the scientific consensus view ("both sides are valid") (Wise, 2010). At that time, 35% of Colorado teachers agreed that "science that goes against global warming theory is being suppressed" (Wise, 2010), and 85% of Colorado teachers supported some mechanism for teaching "both sides".

Whether these state findings also exist at the national level is unknown in the peer-reviewed literature. The purpose of this study helps to address this need. This study describes patterns among national samples of science teachers, most of whom do include formal climate science lessons within their classes and courses. Teacher perceptions of climate change, instructional patterns, top concerns, and strategies used to address controversy are described. Conclusions and recommendations are drawn from these descriptions.

CONTEXT

This study relies upon surveys and open-ended comments from national samples of middle and high school science teachers. These surveys were conducted in 2009, 2010, January 2011, and December 2011 as part of the needs assessment and evaluation for two federally-funded climate education projects. The 2009 study (Survey 1) was conducted as a needs assessment for the NASA-funded Inspiring Climate Education Excellence (ICEE) project, with a national sample of science teachers. The second study (Survey 2) was conducted in 2010 as a needs assessment and application to be part of the informant network for the NSF-funded Climate Literacy and Energy Awareness Network (CLEAN) Pathways project. The informant network is a group of 150 teachers and instructors of grades 6–16 assembled to inform the project and gauge its reach and utility over time. The January 2011 (Survey 3) and December 2011 (Survey 4) surveys were conducted by invitation only among teachers chosen to be part of the informant network. Most study participants received an incentive for participation, as the project budget allowed, in an effort to increase response rate (Warriner et al., 1996; Jackle and Lynn, 2008). All surveys were administered online.

Demographic data (e.g. gender, ethnicity) was collected for respondents on Survey 3 and 4, who are predominantly female and white. Because demographic data was not collected consistently across all the surveys, no demographic information is reported, no comparisons are made and responses are not disaggregated by demographic information. The informants chosen to be part of the network in Surveys 3 and 4 were representative of the applicant pool responding to Survey 2 by states represented, career stage and inclusion of climate science in the most commonly taught class at each level. Thus Survey 2, 3 and 4 are comparable in these respects, though the results are reported per survey, and not as an aggregate sample. Informant network teachers (Survey 3 and 4) were chosen in part because they do teach formal lessons on climate or energy topics.

Table 1 describes the number of middle and high school educator respondents, the number of states represented, and the percentage of respondents that teach climate lessons in the classroom. Respondents to the 2009 and 2010 Needs Assessment surveys were a convenience sample who received the online survey through a link forwarded through science education networks. There is no way to calculate a response rate because the invitation was sent through various open-ended online communication methods. Survey 1 respondents taught climate topics to a lesser extent than those responding to the 2010–2011 surveys (Surveys 2 to 4), though as teaching assignments change within the informant network cohort fewer of the respondents teach climate topics in the classroom.

Geographic location information was collected for all surveys. Survey 1 respondents reflect rough correspondence with United States population density, but for Surveys 2 to 4 the states in which the project teams reside (Massachusetts, Minnesota and Colorado) are over represented relative to the expected distribution based on population density. States represented in each survey ranged from 33–48 states. See the online supplemental material for distribution of states for the surveys (available at http://dx.doi.org/10.5408/12-304s1) and Surveys 1 to 4 (available at http://dx.doi.org/10.5408/12-304s2).

The survey items overlapped in themes but not in exact wording on each question, thus the data is not aggregated or treated longitudinally. Surveys ranged from 24 to 94 individual items, all of which are included in the instruments in the online appendices. Survey items covered knowledge of climate science, teaching practices, degree of support, needs, barriers, and use of digital resources. The results section includes data from Survey 1, 3 and 4, while Survey 2 is provided in the table and in the supplemental material to increase context. Results were analyzed using Excel and SPSS descriptive statistics. The data in the Results section pulls from each survey individually, and the survey from which the data is drawn is noted. Because the survey samples are not a scientific sample of the U.S. teacher population, these results should be considered a snapshot of perceptions and practices by middle and high school climate educators rather than as a generalizable description. The instruments and states charts are available in the online supplemental material.

TABLE I: Survey and Respondent Characteristics.

Survey Number	Year Data Gathered	Project	Number of U.S. Middle and High School Science Respondents	Number of States Represented (Middle and High School Science Respondents)	Percentage Who Teach Formal Climate Lessons	Pertinent Items on Survey
Survey 1	2009	ICEE Needs Assessment	284 (response rate unknown)	41	61%	28
Survey 2	2010	CLEAN Invitational Survey	325 (response rate unknown)	45	88%	24
Survey 3	January 2011	CLEAN Informant Network	145 (97% response rate)	37	80% middle school 88% high school	94
Survey 4	December 2011	CLEAN Informant Network	123 (82% response rate)	33	71% middle school, 59% high school	53

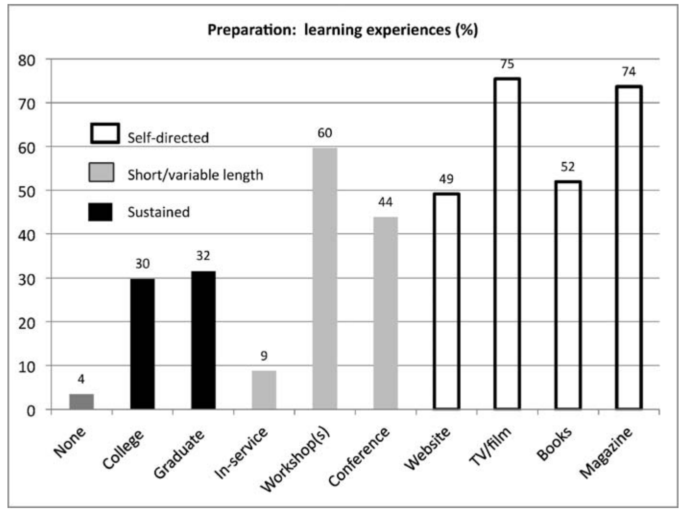


FIGURE 1: Types of climate science professional development experienced by teachers in Survey 1 sample ($n = 269$).

RESULTS

Preparation

Survey 1 respondents engaged in climate professional development through variable delivery methods and of variable duration, and have often prepared themselves through self-study, as described in Figure 1. While few respondents in Survey 1 (2009) had received no learning experiences in climate science, the most frequently-cited learning experiences were self-directed (e.g., reading magazine articles, books, and websites, viewing television or film programming). Many respondents participated in short-duration professional development workshops and conference learning experiences. A third of respondents attended more sustained college classes or graduate level classes that included climate science. Only one in ten cited in-school or district-sponsored learning experiences. For Survey 3 respondents (January 2011), 29% of respondents learned mostly or entirely through informal self-directed means while another 48–61% by grade-band learned through a mix of formal and self-directed approaches.

Research on effective professional development indicates that at least 80 hours of professional development is required to support meaningful changes in teaching practices, while 160 hours and more is required to establish an integrated and inquiry-based classroom (Supovitz and Turner, 2000). More than half of the Survey 3 (2011) respondents have had more than a week of formal professional development in the last three years, while 16–20% by grade band have received over a month of professional development training in climate science instruction.

Survey 3 respondents most frequently hold their highest degree in education, followed by biological and Earth sciences, followed by environmental sciences. As shown in Figure 2, when asked if their highest degree is relevant for climate instruction, those who hold geoscience and environmental sciences degrees answered "Yes", those who held

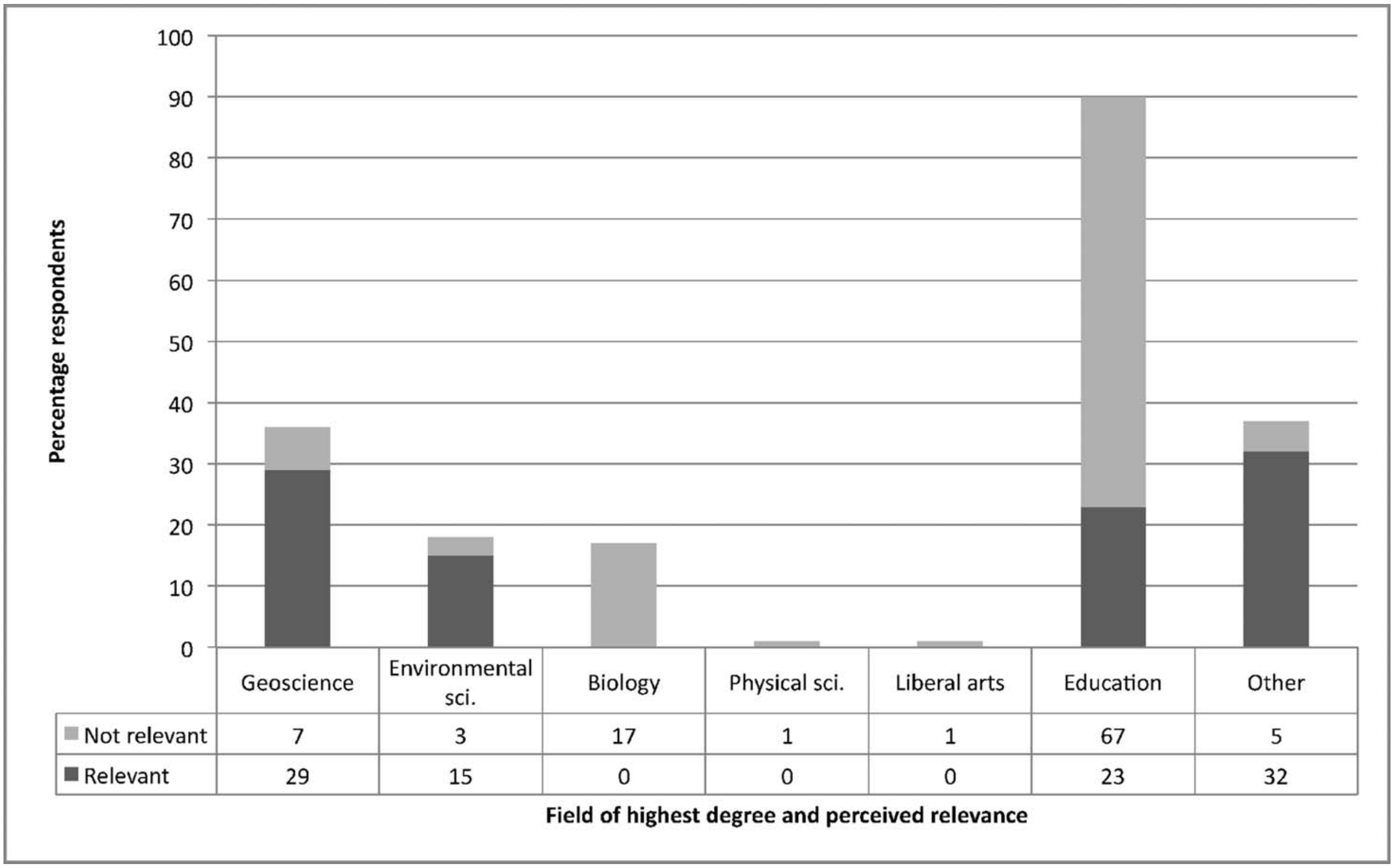


FIGURE 2: Highest degree held by middle and high school science teachers responding to Survey 3 and perceived relevance to climate and energy topics ($n = 125$).

education degrees were mixed in their perception of relevance, and those who held biology degrees answered that their degree was not relevant to climate instruction, as shown in Figure 2. Since many climate impacts that students perceive as relevant to them are about human health, ecosystems, and species, and since 95% of high school students do take biology courses, efforts to communicate the biological aspects of climate science to teachers may be one way to engage more students in this topic.

Community Engagement

Survey 3 respondents are active in many roles, such as district science coordinator, team lead, or provider of professional development or curriculum. Most (80%) report having some or a great deal of institutional support for teaching climate topics. Survey 3 respondents report being perceived as a climate sciences resource by colleagues within their institutions. Most (55% of high school respondents and 70% of middle school respondents) have contacts with climate scientists, whom they describe as providing research experiences, answering questions, and providing lectures and curriculum collaboration. This sample of Survey 3 respondents participate in national-scale science and education professional organizations such as the American Geophysical Union, the Geological Society of America, and the National Science Teachers Association. One in ten of these educators also participate in local or regional communities focused on climate or energy topics. Thus, these teachers who do teach formal climate science lessons are engaged leaders who have developed sufficient support systems. These support relationships bridge climate science and education, and span multiple scales (school site, local and regional, national). These networks help teachers engage in a complex, publicly controversial topic in a more confident manner.

Perceptions

Concerns and Barriers

Controversy was cited as the top climate education concern in 2011 by Survey 3 and Survey 4 respondents, followed by the need for resources, alignment with standards and needs for professional development. Survey 3 respondents answered an open-ended question about the challenges they face in climate instruction and responses were coded for themes. Survey 4 respondents answered a Likert scale question about various challenges, where one of the choices was "Student and/or parent beliefs about the nature and causes of climate change, particularly skepticism about the role of human activity in climate change". This same period has seen an increasing number of battles over "balanced" climate education (Louisiana Science Education Act, 2008; South Dakota House Concurrent Resolution No.

TABLE II: Survey 1 respondents' comments along a continuum of stances towards teaching climate change science.

Leaning Towards or Committed to View that Climate Science is Suspect or Wrong	Desire to Teach Both Sides, Personal View Unclear	Evidence is Clear; Students Helped to Think Scientifically
"...global climate change is both premature and over-hyped, too much media, too little long term science investigation other than recent trends..." "I was taught...in late 1960 that we were in fact entering into another "ice age" and today... I am to teach the other end of that continuum?" "Right now I am very concerned over the global warming emails and the implication that data has been changed...How can I teach about global change if scientists are not being honest about their results?" "Climate change is a normal earth process. Welcome to earth, carbon based bipod."	"Teaching both perspectives of the issue within time constraints." "More support materials-from both sides of the argument are needed-in order to give this topic the time and depth needed to really inform and educate students."	"I want to objectively present the scientific data that presents climate change is real and an issue of immediate concern." "I am learning to rely on the science (evidence) and let the facts speak for themselves." "I now know that there are clear easy to understand graphs that show evidence that shows fact. This makes it easier to present to students...and to other teachers."

1009, 2010) and U.S. public opinions have become more polarized and politicized (McCright and Dunlap, 2011). Though this increase in concern about controversy is consistent with other indicators, it is not possible to ascertain from these data whether actual classroom controversy experiences have increased in frequency or force over the years or if these engaged and energetic teachers have solved the other problems of curriculum alignment and content knowledge.

Survey 1 respondents, those who responded to the first national needs assessment survey in 2009, display a continuum of perceptions of the state of climate science. As demonstrated by comments in Table 2, some perceive the existence or human-attribution of recent climate change to be false, some accept and wish to teach the evidence that the climate is changing due primarily to human activities, and some describe a desire to teach "both sides" without describing the motivation. In a previous study (Wise, 2010) described in the context section, motivation to teach both sides ranged from a desire to represent all perspectives, a desire to engage students in their own decision-making regarding the credibility of evidence, or a perception that the evidence for human causation for recent climate change was not solid.

Climate Science Content Knowledge

In open-ended comments, teachers within Survey 1 describe comfort with familiar Earth system science topics such as the global circulation system and the reasons for the seasons, but may lack understanding of other climate concepts. Examples include the difference between reflectivity/albedo and the greenhouse effect, the degree of relationship between the ozone layer and recent climate changes, or the qualities that distinguish a molecule as a greenhouse gas in contrast to other molecules.

Survey 1 respondents were asked about their interest in, knowledge of and teaching of the seven essential principles topics within the Essential Principles of Climate Science. Respondents described more interest *and* more lack of knowledge about newer topics such as the local impacts of climate change, the evidence for the scientific basis of human-caused climate change, and "options for reducing or adapting to impacts of 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".

Survey 4 respondents, who were chosen because they do teach climate science topics, are more knowledgeable about climate science than the American public in general (Leiserowitz et al., 2012). For example 60.2% of Survey 3 respondents agree or strongly agree that "recent climate change is happening mostly because of human activities". In March 2012 only 46% of the U.S. public agreed with a similar statement (Leiserowitz et al., 2012). When asked to describe the Earth's climate system, 52% of middle school consultants and 69% of high school consultants correctly identified the climate system as characterized by "Theshold: Stable within certain limits", compared with 34% nationally in 2010 (Leiserowitz et al., 2010).

Practices

Climate Topics Alignment within Curriculum

Teachers are more readily able to include climate concepts within curriculum when the district content standards include climate explicitly. Survey 1 respondents who did not teach climate topics cited lack of alignment with standards and curriculum as their main barrier. Survey 3 teach climate lessons across the science curriculum, including earth science, environmental science, life science, physical science, chemistry, physics and general or integrated science. Figure 3 describes the extent to which respondents teach climate science within particular courses.

Among Survey 3 respondents, 71% of middle school and 66% of high school teachers spend less than 25% of their instructional time on climate topics, with 20–30% by grade band spending 10% or less of course time. Most (~80%) integrate climate science with other subjects and topics, while 20% teach climate science as a stand-alone topic mostly or always.

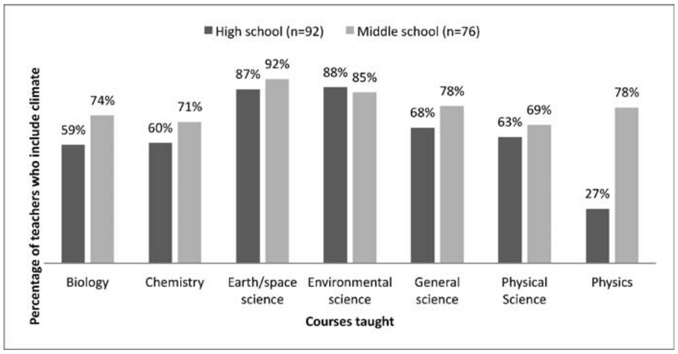


FIGURE 3: Subjects in which Survey 3 respondents include climate topics (high school teacher $n = 92$, middle school teacher $n = 76$).

Evidence-Based and Student Centered Instruction

The most commonly used strategy to address controversy and misinformation is to promote learning about the nature of science, evidence, and data. Survey 3 respondents seek resources that exhibit credible science, real world applicability, and opportunities for students to use real data and to have hands-on engagement. Respondents indicate that students are more engaged by information introduced as a relevant problem or issue, such as changing water resources, ski seasons, or landscapes. However, while Survey 3 informants say that students are most likely to want to engage with hands-on lab activities, field trips, local issues or problems, and visualizations or simulations, instructional approaches used in the classroom center around discussion and lecture as two of the top three approaches as described in Figure 4.

Integrating Science with Society and Climate Mitigation and Adaptation

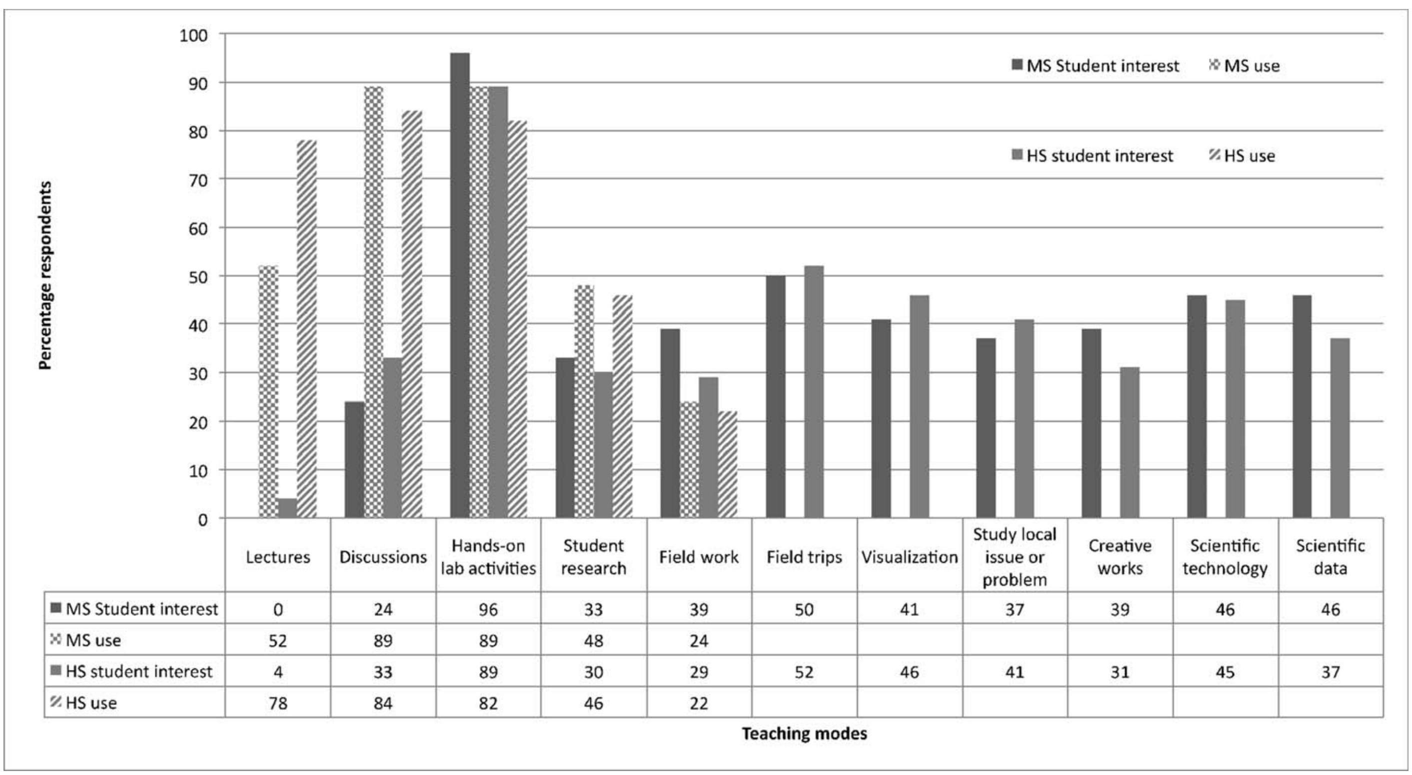
More than 80% of Survey 3 respondents consider climate mitigation and adaptation in their instruction in some way. Among these respondents, approximately 40% teach mostly or only science, approximately 50% teach an equal mix of science and social aspects, while less than 10% teach mostly or only the social aspects of climate science. These aspects are described in Figures 5 and 6.

DISCUSSION AND IMPLICATIONS FOR TEACHER SUPPORT

If the major issues in climate instruction include concern about controversy, alignment with standards, and needs for professional development and resources, how should those of us who prepare and support teachers respond? How may the factors that help teachers engage in high quality climate instruction be broadly implemented so as to reach more teachers? These issues intersect and require cohesive approaches to support teachers on all of these fronts.

Forestalling or Mitigating Controversy

Climate controversy in the classroom is complex, influenced by student and teacher understanding of climate science, affective responses to a changing climate, cultural



	Lectures	Discussions	Hands-on lab activities	Student research	Field work	Field trips	Visualization	Study local issue or problem	Creative works	Scientific technology	Scientific data
MS Student interest	0	24	96	33	39	50	41	37	39	46	46
MS use	52	89	89	48	24						
HS student interest	4	33	89	30	29	52	46	41	31	45	37
HS use	78	84	82	46	22						

FIGURE 4: Teaching modes perceived by Survey 3 respondents to engage students compared to modes that are commonly used ($n = 123$).

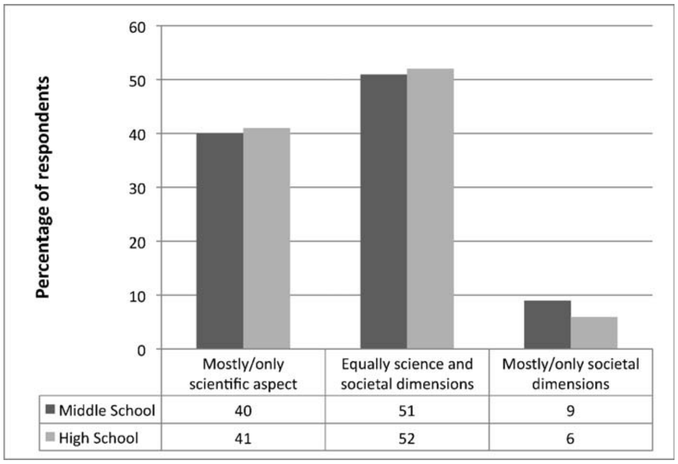


FIGURE 5: Extent to which Survey 3 middle and high school science teachers integrate climate science with societal dimensions (n = 76 high school teachers, 43 middle school teachers).

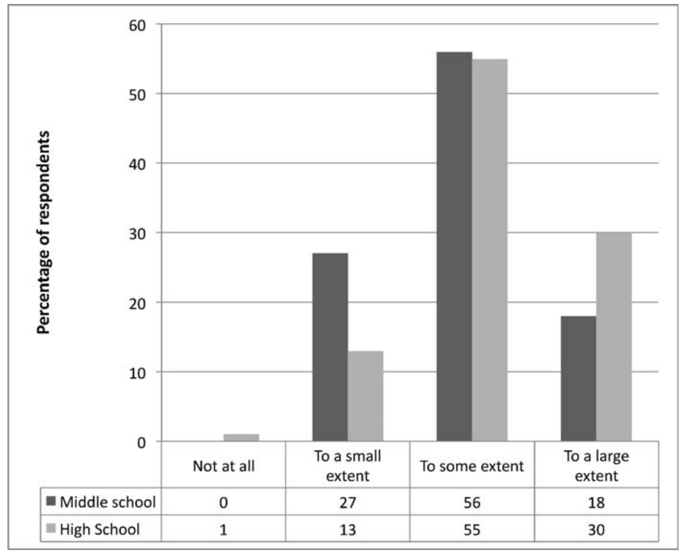


FIGURE 6: Extent to which Survey 3 respondents consider climate change mitigation and/or adaptation as part of climate science instruction (n = 75 high school teachers, 43 middle school teachers).

context, and local and state educational policies. Some parallels can be drawn between strategies used in the teaching of evolution (Griffith and Brem, 2004; Nelson, 2008; Sinatra et al., 2008), and the strategies described by these respondents. As in evolution education, a false "both sides" contingency arises wherein the scientific viewpoint is contrasted with a pseudoscience viewpoint based in a cultural context.

Some of the respondents to Survey 1 describe a desire to teach "both sides", either because the teacher indicates a perception that both sides are scientifically valid, or to teach critical thinking skills, or without describing their motivation. Referring to the evolution education literature, Griffith and Brem (2004) described three categories of evolution teachers, including "Scientists" who see no place for social controversy in the science classroom, "Selective" who limit discussion and avoid difficult topics and situations, and "Conflicted", who thoroughly explore the issues related to teaching evolution with their students and with themselves. Griffith and Brem found that teachers within the "Scientist" category tend to have high content knowledge and love for science. Such educators would be unlikely to teach both sides from a lack of understanding of the scientific basis. While Survey 2 to 4 respondents answered knowledge questions that reflect a scientific understanding that exceeds that of the U.S. public, knowledge questions were not asked of Survey 1 respondents, so it is not possible to objectively determine whether a respondent's knowledge correlated with the desire to teach both sides. On the other hand, a "Scientist" teacher may be inclined to teach both sides as a means to teach critical thinking. Since the social dialogue on climate science presents as a disagreement about which scientific narrative is most credible, the line between claims based in religious ways of knowing and those based in sciences is not relevant within climate instruction. Anecdotally, climate science teachers sometimes have students purposely research claims from all voices in the climate dialogue in order to determine scientific credibility and validity. Teachers who use this strategy could be within either the "Scientist" category or the "Conflicted" category, who use all viewpoints as a way of increasing harmony and decreasing the potential for conflict. Teachers who teach both sides are unlikely to be among the "Selective" category, which characteristically limits topics or discussion in order to avoid conflict. Applying these categories drawn from evolution education to climate education would be a useful future step for study.

These respondents cite strategies to forestall conflict that promote learning about the nature of science, evidence, and data. Furthermore, respondents seek resources that are credible, relevant, and use data and hands-on engagement. These strategies are similar to those called for within the evolution education community (Nelson, 2008; Bybee, 2004), including the extensive use of structured active learning, a focus on scientific and critical thinking, and directly addressing misconceptions and student resistance. Using conceptual change models within evolution instruction is suggested as a positive strategy for changing misconceptions and for addressing deeply held personal commitments counter to evolution (Sinatra et.al, 2008), and would likely be positive for climate education as well.

Lastly, Wise found that encouragement has a greater effect on climate science instruction than discouragement (Wise, 2010). Since more than 80% of Survey 3 respondents express confidence in their ability to teach climate science and to get the support they need, it is worth examining what they have done to become so confident. As described earlier, these respondents participate in interdisciplinary climate and energy learning communities across multiple scales (school district, local, regional, and national). Professional development intended to support teachers with social controversy around climate instruction would include ways to build community across scales (national, regional, local) and disciplines (climate science, social sciences, education). These communities should then be accessible on an as-needed basis for different teaching and learning needs.

Alignment with Standards

At the time of this writing, 11 states and the District of Columbia have adopted the Next Generation Science Standards, which were released in April 2013 (Next Generation Science Standards, 2014). These new standards represent climate sciences much more thoroughly than did the 1996 National Science Education Standards, on which many state and district content standards are based. For example, the word "climate" appears 11 times in the National Science Education Standards (National Research Council, 1996). Two appearances in the NSES Professional Development chapter refer to the school climate for learning. The remaining nine refer to the role of climate in the Earth System. Modern climate change and the human influence on the climate system is not addressed. In contrast, searching the Next Generation Science Standards for the word "climate" results in 17 Performance Expectations that include Earth's climate in some way, of which 11 include some aspect of climate change or human activity. The climate-relevant standards occur primarily within the Disciplinary Core Idea (DCI) sections of *Earth and Human Activity* and *Earth's Systems*, with some representation in the Life Sciences DCI.

Relevant Earth science concepts progress from foundational observations of weather in early grades through sophisticated climate modeling, data synthesis, and design solutions in high school. For example, the high school level NGSS Performance Expectation HS-ESS3-6 states "Students who demonstrate understanding can use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified because of human activity." The NGSS includes a number of performance expectations concerned with natural hazards, human influence on and by the climate system, and human sustainability. Thus, the teachers within this study who integrate societal aspects, mitigation and adaptation into climate instruction are on the way to alignment with the new standards.

On the other hand, life sciences teachers will continue to benefit from standards alignment support. Survey 3 respondents with a terminal degree in biology perceived their degree to be of less relevance to climate science. This is important because climate change impacts ecosystems, biodiversity and humans, and because many more high school students traditionally take biology courses compared to earth sciences courses (Gonzales and Kean, 2011).

The teacher respondents within Survey 3 are engaged nationally and locally in geoscience and education organizations. In order to achieve the intention of these standards, the geosciences community, including national geoscience and education societies and organizations, will need to offer support to states and districts which are considering adoption of NGSS. The National Science Teachers Association is providing this guidance through a series of webinars, training workshops and a curated collection of learning resources (NSTA, 2014). In addition, teachers will require a great deal of support regionally in order to implement the NGSS in locally relevant ways.

Professional Development

Respondents within these surveys described a need for more professional development, including a need for more content knowledge. Many have engaged in self-directed learning about climate change on the internet, which can lead to an inaccurate perception of the state of the science. Respondents to Survey 1 describe interest in regional climate impacts and "options for reducing or adapting to impacts of climate change" but describe relatively low confidence in their knowledge in this topic. Professional development can respond to these needs, and at the same time equip teachers to deal with controversy, respond to new climate science standards and to teach in student-centered ways.

Since the "Scientist" category of evolution teachers feel the least internal stress around controversy (Griffith and Brem, 2004), based on their robust content knowledge, increasing teacher content knowledge about climate science would likely also decrease fear of controversy in the classroom. Professional development, especially that in which participants have access to and develop relationships with climate scientists, should decrease the number of teachers who teach both sides as if both were scientifically valid.

Some teacher support needs may be met through national-scale professional development (e.g., action plans to counter controversy or to develop knowledge of common misconceptions). However, some needs are locally contingent; curriculum and standards-alignment advice given by a knowledgeable local teammate is more credible than that given by a well-meaning outsider. Relatively few teachers have received climate science professional development through school in-service opportunities, but these nationally-engaged respondents are seen as credible resources by their peers. Thus, models of national/district/building partnerships may be effective, with support and professional development offered nationally for on-site local climate science "coaches". One example of a project which provides community support to teachers teaching climate topics is the NASA-funded PLC project, Lifelines, (Gould 2012), which supports twenty PLC sites across the country. A PLC is defined by a focus on student learning, a culture of collaboration, and an emphasis on results (DuFour, 2004). Another example is the Climate Ambassadors project, in which the Cooperative Institute of Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison works with science teachers to advance climate literacy in Wisconsin and beyond (Mooney, 2012). The complete program combines an on-line course with a teacher workshop and an educator's forum to equip G6-12 teachers to be climate education resource agents in their local schools and communities. Participation in professional development opportunities such as these provides the encouraging support networks in which many of these respondents are situated, and which have been shown by Wise to be motivating.

While 70–80% of Survey 3 respondents indicate that resources for teaching climate are generally available, only 20% indicate these are of excellent quality. Teachers indicate that students are most interested in hands-on lab activities, followed by field trips, working with visualizations, real scientific technology, or data, followed by studying a local issue or problem. However, there is a need for more learning resources to cover a greater breadth of the fundamental concepts within the Essential Principles of Climate Science (USGCRP, 2009), especially in areas relevant to the Guiding Principle for Informed Climate Decision: Humans can take actions to reduce climate change and its impacts (CLEAN, 2013). These respondents seek resources which are personally relevant to learners, just as evolution educators seeks resources of relevance to learners (Sinatra et al., 2008). In areas of emerging science such as the impacts of climate change on ecosystems or local/regional areas, teaching resources are needed. Professional development can provide the opportunity and support to use existing excellent resources such as those in the Climate Literacy and Energy Awareness Network (CLEAN) collection (CLEAN, 2014), and to develop new resources where needs exist.

LIMITATIONS OF THE STUDY

The self-reported nature of the data, based upon teachers perceptions of their own practices is a limitation of the study, as the results in this study were not verified by classroom observation or other independent measures. In addition, this population is not generalizable to the entire population of U.S. educators. While efforts were made to increase the representative nature of the respondents in the Informant Network who formed the basis of Surveys 3 and 4 by selecting among the respondents to Survey 2 as described in the Context section, these respondents were chosen because they were teaching climate science in their classrooms, and in addition, they self-selected to participate in an informant network about climate instruction. This fact alone makes them non-representative of the teaching population at large. Also, the respondents for Survey 1 and Survey 2 were recruited through a snowball sampling technique, in which a smaller group of contacts engages more respondents through networks of colleagues and friends. Thus, no effort was made to ensure the sample represented the demographics of the U.S. teacher population and the response rates are unknown. There is some ambiguity in the levels of professional development preparation received by participants in Survey 3 in that the survey item asked about "total days of professional development" whereas the response items were given in terms of days, weeks or "more than a month". There is no way of knowing if respondents thought of the time spent in terms of work days, weeks and months or the full unit (e.g. five-day work week versus seven days). The geographic distribution of the respondents does not consistently reflect the population density of the United States, especially for Surveys 2 to 4. As a result, these results should be viewed as a snapshot of teacher perceptions and practices around climate education and as a starting place for discussion and further investigation.

CONCLUSION

These results confirm and extend descriptions of climate instruction patterns previously observed at the state level in Colorado (Wise, 2010). U.S. climate instruction has been burdened by the present state of alignment with state and district standards, teacher perceptions about the state of the science, and concerns about controversy and content knowledge. However, the Next Generation Science Standards provides an opportunity for more and deeper climate instruction, and the professional development and learning resources to go with the performance standards. Teachers who are confident in their ability to teach climate science have developed practices that are grounded in strategies for teaching about socially controversial topics as described in the evolution education literature, and are ripe for adoption by those engaged in teacher preparation and support in climate sciences. These strategies include development of networks of trans-disciplinary and cross-sector communities, increasing knowledge through professional development, using active learning methods, and developing and disseminating engaging teaching resources that foster student learning within a personal and societal context. While there are many real challenges, there are also many master teachers who spend their time taking professional development and who craft relevant learner-centered instruction. For every one of these climate-engaged master teachers there are others ready to take the same path if we can make the way clear.

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