Climate Change in the Classroom: Patterns, Motivations, and Barriers to Instruction Among Colorado Science Teachers

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ABSTRACT

A large online survey of Colorado public school science teachers (n=628) on the topic of climate change instruction was conducted in 2007. A majority of Earth science teachers were found to include climate and climate change in their courses. However, the majority of teachers of other science subjects only informally discuss climate change, if at all. Teachers are motivated to include this topic in the curriculum when they perceive it is represented in their standards and when they receive direct encouragement from members of their school and wider communities. At the time of this study, only a small minority of teachers had experienced pressure to avoid teaching climate change. Certain misconceptions about climate change are widespread among teachers, as is the belief that "both sides" of the public controversy over human causes of climate change should be presented to students. The patterns of instruction, knowledge gaps, and a lack of learning experiences for teachers documented here suggest that all science teachers would benefit from professional development focused on climate science, best practices in climate instruction, and climate communication.

INTRODUCTION

Climate Literacy and Formal Education

Thirteen U.S. government agencies recently voiced their support for the development of a 'climate literate' public by endorsing the publication Climate Literacy: The Essential Principles of Climate Science (U.S. Climate Change Science Program, 2009). Climate literacy involves understanding how people influence the climate, and in turn how the climate influences people. Gaining an understanding of this simple statement is difficult, however, because climate systems and human impacts upon them are inherently complex (Intergovernmental Panel on Climate Change, 2007; U.S. Climate Change Science Program, 2009). The complexity of climate systems cannot adequately be conveyed using mass media (Dunwoody, 2007). Furthermore, given the interactions of climate with human systems, climate science would ideally be conveyed via an interdisciplinary instructional approach (Fortner, 2001; Hansen, 2009; Rebich and Gautier, 2005). In effect, to generate a climate literate public, students are likely to require comprehensive formal instruction about climate change.

A number of countries have developed strategies to promote climate change instruction. For example, in England, instruction about climate change is a mandatory part of the geography curriculum for students aged 11-14 (Qualifications and Curriculum Authority, 2007) and has been supported by free curricular resources (DirectGov, 2007). Specifically, this curriculum requires students study weather and climate, the impact of human activity on climate, and sustainable development. Climate change related concepts also appear frequently in the U.S. National Geography Standards (Boehm and Bednarz, 1994), though implementation of those standards is voluntary. Mandatory curricula related to global warming or climate change are outlined for teachers in Singapore (Singapore Ministry of Education, 2007), Scotland (Scottish Government, 2008), and Norway (though limited to non-vocational students) (Hansen, 2009), among others.

In United States, national and state science education standards are important drivers of educational change (Finn et al., 2006; Roseman and Koppal, 2008; Scherer, 2001). However, climate change is inconsistently addressed in these curricular guidelines. Coverage of the historical mechanisms, recent human causes, and impacts of climate change science appear in the standards of only 11 U.S. states; only 3 of these also mention mitigation strategies (Kastens and Turrin, 2008). The term 'global warming' appears in the National Science Education Standards as an exemplar for an area 'where data or understanding [is] incomplete' (National Research Council, 1996). However, climate change related benchmarks do appear in Project 2061's recent Atlas of Science Literacy, Volume 2 (American Association for the Advancement of Science, 2007a, 2007b). Given such variable treatment of the topic, U.S. state and national science education standards currently provide weak guidance for climate change instruction.

Climate science instruction also faces challenges related to disciplinary 'siloing' (Gayford, 2002). Climate-related topics naturally fall within Earth science classes, but the effects of climate change on humans and other species fall more naturally within biology and social science classes. Furthermore, Earth science education in the United States has traditionally been marginalized (Hoffman and Barstow, 2007; McCaffrey and Buhr, 2008; Metz, 2008). While state recommendations for the inclusion of Earth science courses are increasing, less than a quarter of high school students take Earth science (American Geological Institute, 2009).

Current science standards and patterns in course enrollment generate a dilemma for many U.S. science teachers. They face a choice over whether to leave the topic of climate change out of their courses, or to incorporate instruction not explicitly supported by standards into curricula that are frequently criticized as overstuffed (American Association for the Advancement of Science, 2001; Bentley et al., 2007). In this light, it is not surprising that students report learning more about climate change from the media than from school (Gowda at al., 1997).

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Climate Change Education Research: Status and Gaps

The nascent literature on climate change education has focused around three areas of study: the relationship between instruction and environmental action or activism, misconceptions about climate, and classroom activities to teach climate concepts.

The first group of studies has demonstrated that instruction about climate change can result in student conceptual and attitudinal change (Cordero et al., 2008; Devine-Wright et al., 2004; Lester et al., 2006; Pruneau et al., 2003). The second and larger group of studies has catalogued dozens of misconceptions (Gautier et al., 2006; McCaffrey and Buhr, 2008) and their persistence following instruction (Chi, 2005). These include the ideas that burning destroys matter, the hole in the ozone causes warming, and individual weather events provide evidence for climate change. Similar misconceptions have been documented among school students (Andersson and Wallin, 2000; Gowda et al., 1997; Hansen, 2009; Henriques, 2002; Meadows and Wiesenmayer, 1999; Rule, 2005; Rye et al., 1997), college students (Cordero, 2001; Gautier et al., 2006; Jeffries et al., 2001; Madsen et al., 2007; Schneps and Sadler, 1985), teachers (Groves and Pugh, 1999; Khalid, 2003; Rule, 2005; Summers et al., 2003), and the general public (Pruneau at al., 2001).

Misconceptions studies reveal an important reason why instruction about climate change is inherently challenging. However, further research is needed into other barriers to climate instruction. It can be hypothesized that science education standards and disciplinary 'siloing' may affect the incidence of instruction. Furthermore, some teachers may not feel they have enough preparation to teach the topic well (Fortner, 2001).

Still other teachers may fear that public controversy around climate change could cause disruption to their classroom. While public controversy around climate change was not focused on schooling at the time of this survey, anecdotal evidence exists that incidents of controversy at that time did affect school communities (Robbins, 2008).

Evidence suggests that teachers' instructional choices may be influenced by the general presence of controversy, even when public attention to climate change education is not salient. One qualitative study documented that teachers can be concerned about how to teach about climate change 'in a rational manner so that the balance of arguments can be appreciated' (Gayford, 2002).

Public controversy around climate change likely generates confusion about the state of the science for teachers and students. Over a third of the U.S. public thinks that scientists disagree about the topic (Curry et al., 2007) and that climate change is primarily related to non-human causes (Leiserowitz et al., 2008). As a result of controversy, some teachers may fear objections about the content of their instruction, or be unsure about what content to present.

Patterns of Climate Change Instruction are Unknown

Perhaps surprisingly, no studies have yet surveyed the incidence of instruction about climate change in U.S. schools. Such studies could provide insight into the extent of student exposure to this topic as well as the factors teachers assess when considering whether to voluntarily incorporate this topic into their curriculum. A number of open questions exist, including: What fraction of science and social studies teachers include lessons about climate change in their curricula? In which subjects are students learning about the topic? How well do teachers understand climate change, and what kinds of learning experiences have they engaged in around this topic?

Public controversy and misconceptions around climate change bring additional questions to the fore. How do the views of teachers about climate change compare with those of scientists? Do teachers hold misconceptions about climate change that may be passed on to students? What proportion of teachers accept the scientific consensus that recent climate change is caused by human activities? Do teachers experience community pressure either for or against the teaching of climate change?

To explore these questions, I undertook a large survey of K-12 public school science teachers working in the state of Colorado. The aim was to collect and compare descriptive data on the views and instructional practices of teachers on two publicly controversial topics, climate change and evolution. In this paper, I examine the data from secondary science teachers on their teaching of climate change. The results reveal a number of characteristics of climate change instruction that provide insights for both secondary science teachers and those providing professional development to these teachers.

METHODS

Survey design and recruitment

Nearly 950 K-12 public school teachers from all regions of Colorado responded to the 'Teaching About Publicly Controversial Science' survey during the 2007-2008 school year. Data presented here are drawn from the subset of secondary (middle level and high school) science teacher respondents (n=628) with responses to survey items related to climate change. The survey was administered using a third-party secure online platform, www.surveymonkey.com. In order to moderate the length of the survey, participants received questions relevant to their subject area. As climate is included in Colorado secondary Earth science standards, Earth science teachers received a full set of questions related to climate change instruction, including items related to their general opinions about climate change, their knowledge of climate change, and their approach to climate change in the classroom. Other science teachers were asked a smaller subset of climate related questions. For this reason, analysis in this report focuses on Earth science teacher data, augmented when relevant by data from other science teacher subsets.

The survey was grounded in qualitative data from a set of semi-structured interviews with 22 elementary and secondary science teachers. Themes from these interviews (Denzin and Lincoln, 2000) included how teachers choose whether to incorporate formal lessons for climate change, or use informal discussion to address the topic; the amount of class time devoted to the topic of climate change, and topics covered; the impact of learning experiences and community pressure on curricular choices around climate change; and the choice over whether to discuss the public controversy around the existence or causes of climate change with the class. These themes were used to develop specific question items on the survey and informed the use of the term 'global warming' in the survey. One bank of questions included items similar to those found in public opinion polls about climate change (Nisbet and Myers, 2007), in order to assess participant agreement with common statements about global warming. The draft survey was reviewed for face validity by five practicing teachers and other educators and revised based on their feedback. The final survey included demographic questions, a set of Likert-scale items, multiple-choice items, and free response items and can be retrieved from http://cires.colorado.edu/education/k12/people/wise/index.html. The internal consistency of the Likert scale items was assessed by calculating Cronbach's alpha, which with a value of .75 indicated satisfactory reliability.

The convenience sample of participants was initially recruited by direct contact at the fall NSTA conference in Denver, Colorado, and via email solicitations distributed to two science educator electronic mailing lists. Phone contacts to school districts around the state led 41 districts to send an email requesting participation to their teachers; 6 sent this email twice. Teachers in additional districts were identified from school websites and emailed directly by the author, or received an email solicitation from a colleague. Responses were received from 73 (41%) of the 178 districts in Colorado.

Self-selection bias, whereby participants highly interested in the survey topic respond at a greater rate, is of particular concern for publicly controversial topics. The impact of incentives on bias is not well understood (Jackle and Lynn, 2008). Nevertheless, a $5 gift card incentive was offered to each participant completing the survey in an effort to increase the response rate (Warriner, 1996) and to potentially obtain a wider variety of viewpoints on the survey topics.

Where participants provided names and addresses, duplicate entries were able to be identified and removed. Entries that were more than 50% incomplete were also removed. The resulting sample was reflective of the proportion of teachers residing in different regions of Colorado, and of urban and rural teachers (Table 1). Within the secondary science teacher subset, the sample was roughly split between middle level (46%) and high school (54%) teachers. These teachers identified a main science subject; 35% (n=220) of this subset identified life science; 29% (n=183) identified Earth science; and 36% (n=225) identified an environmental science, general/integrated science, or physical science subject, referred to below as the 'all other' science group.

When possible, responses were converted into numerical values to facilitate analysis. Free response data was categorized and coded by the author (Denzin and Lincoln, 2000); categories are described with the results of these responses in the next section. For questions related

TABLE 1. COMPARISON OF SURVEY SAMPLE WITH COLORADO TEACHER POPULATION

Geographic category	teacher population[1] (%, n=46,665)	survey sample (%, n=628)
Regions[2]		
Metro Denver	51	53
Metro Colorado Springs	19	19
North central	13	14
North west	4.8	4.3
West central	4.7	4.3
South west	3.3	2.6
South east	2.1	1.6
North east	2.1	1.2
Settings[3]		
Urban/suburban/outlying city	85	89
Outlying town/rural	15	11

[1] Colorado Department of Education, 2006c
[2] Colorado Department of Education, 2006a
[3] Colorado Department of Education, 2006b

to instructional practices, data were analyzed separately for the life science, Earth science, and 'all other' science groups, to investigate potential disciplinary drivers of instruction. Descriptive statistics and statistical tests were conducted using STATA. The raw data are archived at http://cires.colorado.edu/education/outreach/people/wise/.

Limitations of study

The response rate to the survey was not possible to estimate precisely due to the fact that recruitment was extended by email-based networking. However, the response rate for teachers in 29 districts which the author contacted directly was only 26%, lower than the generally accepted rate of 60% for generalizability (Moore, 2008; Warriner et al., 1996), but similar to other Web-based surveys (Kaplowitz et al., 2004). Therefore, this non-random convenience sample does not represent all secondary science teachers across Colorado. On the other hand, the sample can be appropriately used to identify key trends for use by professional development providers and researchers.

The sample surveyed here may differ from the population of all teachers in Colorado in several important ways. First, teachers who are actively teaching the topic of climate change may have been more likely to respond, causing an inflation of estimates of the incidence of climate change instruction. Secondly, teachers who feel uncomfortable due to the controversy around climate change, or unsure of their opinion about the topic, may be underrepresented in the sample. Therefore, the proportions of teachers in this sample having views favorable to teaching climate change may be higher than the state or national average. Next, the presence of questions about evolution in the larger survey could have encouraged a greater participation by life science teachers. However, actual patterns of participation did not indicate this occurred. Finally, social studies teachers were not included in the survey even though they may teach about climate change, limiting the ability of this study to estimate overall exposure of students to instruction about this topic.

Despite these possible biases, results suggest that the sample captures the perspectives of teachers with wide-ranging opinions and instructional practices around climate change. It was observed that for every survey item, participants selected the full range of choices available. Free responses to selected items indicate the sample includes a number of teachers skeptical about the presence or human cause of climate change, a number of teachers committed to teaching the latest consensus of climate scientists, and many teachers with intermediate views. Therefore, the diversity of Colorado teachers' perspectives on climate change is likely included in the sample.

RESULTS

General Views about Climate Change Education

Teachers responded to several items related to their general support for the inclusion of climate change in school curricula (Table 2, section A). The secondary science teachers in this sample overwhelmingly supported teaching the topic of global warming and teaching about solutions to global warming. A majority of participants thought that global warming should be discussed in Earth science, life science, environmental science, and social studies classes. On average, teachers chose five school subjects in which they thought the topic of global warming should be discussed.

Public controversy about global warming has become increasingly focused on whether the phenomenon is caused by human activity. Therefore, participants were asked specifically about whether teachers should discuss "both sides" of this public controversy (Table 2, section A). Support for this idea was high (85% overall). Because such a discussion could be steered in many ways, a follow-up question was posed: "If you replied yes, please explain your reasoning for why. Please also explain how you think teachers should discuss 'both sides'. If you replied no, please explain your reasoning for why not." Free responses (n=627) to this question varied greatly, but

Because there is science to support both sides of the argument, both sides should be presented. …………………… There is always evidence that supports both sides and students need to be exposed to all so...they may make an informed decision....	A teacher's personal opinion should never be taught exclusively. Global warming caused by human activity is a theory…Students should have enough information presented to them that would show doubt on 'both sides'.	Students should have facts in order to develop their own thinking. If only presented with one side of an issue, then they are not given the tools to develop their own thinking. That is our primary job.	I think students should be able to listen and discuss both sides in order to form their own conclusions. ……………….. Teachers should let students debate if global warming is caused by humans.	Teachers should always mention other sides of an issue, if for no other reason, just to acknowledge that they exist. ………………….. Again, students need to see their teachers as being willing to listen, read and learn about current events.	I feel that teachers should be prepared to discuss counterarguments, but most data seems to point toward human involvement, so that should be presented first and foremost.	I am not sure what 'both sides' there are. In my view, we teach what scientists of note are discovering... some new information is just being explored... students just need to be informed of the uncertainty of the findings…	It is our job to teach science concepts that are accepted in the scientific community. We provide the data and the science. Students are still, of course, allowed to come to their own conclusions.

reasoning promoting 'both sides' as valid science → **reasonings leaving validity of each side unclear** → **reasonings promoting validity of human-caused climate change**

Discussing both sides allows students to see scientific evidence supporting both sides of this issue. This is an important skill in science, and all classes really. .... …it is important to remain unbias[ed] and give students both sides of the argument.	You cannot be a fair teacher by teaching only one theory about a controversial topic. ……………….. Again, in order to not be biased, one must present varying views on such controversial toics.	Part of teaching is allowing students to make an argument for what they believe... Teachers could present both sides by having the students have a debate, using primary sources and summarizing what they say... analyzing [TV] programs, etc…	It is always important to show a balanced view of topics. Even if you have an opinion it is important to let the kids decide what they think and draw conclusions from the evidence. ……................…….. As with all topics, if students are not informed… myths become truth.	I think it should be discussed because students have preconceived ideas not based on fact. I think it is important to show them the research and look at opinions out there...I think they will see that the research points to human causes.	Students need to know the facts behind the issues. Introducing the confusion and argument that is unfounded only serves to confuse students who are not critical thinkers, thus introducing misconceptions.	I think that the focus should be on the scientific consensus. Addressing the fact that most people do not understand the science… is worthwhile. Students should …address their understanding, then challenge it using scientific data.

FIGURE 1. Continuum of secondary science teacher responses to the question 'About 20% of the U.S. population does not think that recent global warming is caused primarily by human activity, according to a recent poll by TIME. In general, do you think Colorado teachers should discuss 'both sides' of this public controversy with students? (Explain why and how).

TABLE 2. RESPONSES RELATED TO CLIMATE CHANGE EDUCATION PRACTICES

A. General Climate Change Education	**Earth science** (n=183)	**Life science** (n=220)	**All other** [1] (n=225)
In general, do you think that Colorado students should learn about global warming in school? Answering yes:	99%	98%	99%
In general, do you think that Colorado students should learn about individual and/or societal solutions to global warming in school? Answering yes:	98%	97%	94%
In which school subject(s) should Colorado students learn about global warming? (check all that apply)			
environmental science	93%	88%	89%
earth science	91%	85%	89%
life science	65%	67%	69%
social studies	55%	50%	61%
geography	54%	43%	54%
physical science	43%	40%	55%
chemistry	44%	37%	48%
economics	36%	29%	42%
physics	26%	9%	28%
language arts	23%	17%	25%
About 20% of the U.S. population does not think that recent global warming is caused by human activity, according to a recent poll by TIME. In general, do you think Colorado teachers should discuss "both sides" of this public controversy with students? Answering yes:	86%	83%	85%
B. Participants' Instructional Practices			
Do you teach about or discuss global warming in any of your classes?			
yes, formal lessons	65%	33%	36%
yes, informal discussions	27%	50%	50%
no	8%	17%	14%
Do you use any specific strategies when teaching about global warming, due to the fact that it is publicly controversial?[2]	(n=118)	(n=73)	(n=80)
emphasize the nature of science aspect of the topic	87%	77%	86%
acknowledge and/or allow discussion of ideas expressed by global warming skeptics	76%	66%	80%
offer to talk with students outside of class	24%	7%	11%
send a letter home to parents	14%	3%	16%
bring in guest speakers	13%	7%	21%
offer to talk with parents outside of class	10%	4%	4%
follow the controversial topics policy of my district	2%	14%	0%
allow students to opt out of portions of class	2%	4%	1%
I do not use any special strategies around global warming	25%	59%	23%

[1] Includes environmental, integrated, physics, chemistry, physical science, and general science teachers
[2] Participant subsets teaching formal lessons about global warming

generally fell into three groups that can be roughly organized along a continuum (Figure 1). At one end of the continuum, about 25% of the sample of teachers reasoned that 'both sides' should be taught because both constitute valid scientific viewpoints. In the middle of the continuum, about 50% of the responding teachers reasoned that 'both sides' should be taught because it would be more fair or promote independent decision-making or critical thinking. This group of teachers' reasonings seemed to leave unclear the scientific validity of each of the sides of the public controversy around human causes of climate change. At the other end of the continuum, approximately 25% of teachers generally reasoned that allowing student discussion of 'both sides' is appropriate, but that teachers and curricula should emphasize the scientific consensus that humans are primarily responsible for recent climate change.

Patterns of Instruction About Climate Change

Secondary science teachers show great variability in their approaches to teaching about climate change (Table 2, section B). Overall, 87% of respondents address the topic in some way, but many do so only through informal discussion in class. Earth science teachers most frequently approached the topic using formal (planned) lessons. Significantly more high school science teachers than middle level science teachers in the sample reported teaching formal lessons about global warming ($t=-3.6$, $p<.01$).

The subset of teachers using formal lessons to instruct about global warming were asked to identify teaching strategies they employ (Table 2, section B), from a list composed of strategies anecdotally used by teachers in handling the publicly controversial topic of evolution (Scott and Branch, 2008). Two-thirds of the sample reported using one or more of the strategies on the list when teaching about global warming. The most common strategies reported were emphasizing the 'nature of science' (e.g., how scientists gather evidence, arrive at explanations, and engage in peer review) in their teaching of global warming, and acknowledging or discussing the presence of public controversy and skepticism around the topic of global warming with their students.

Factors Influencing Curricular Inclusion of Climate Change

Motivating Experiences - Secondary science teachers who include formal lessons about global warming in their curriculum were asked what motivates their teaching (Table 3). Top reasons such as 'it is in my curriculum/ standards' were similar to what would be expected for any topic. Many teachers also cited student interest as a motivating factor, but only a minority cited encouragement from someone else. Two survey items explored possible community motivators to instruction in more depth (Table 3). First, most secondary science teachers reported that their students expressed interest in learning about global warming. Secondly, about a third of Earth and "other" science teachers identified adults in their community who had directly encouraged them to teach about global warming. Most of these encouraging experiences originated from within the teachers' professional communities, such as other teachers and administrators.

The effect of encouragement on instruction was explored further by asking teachers to describe one experience in which they had been encouraged to teach about global warming. These free responses (n=106) were coded as shown in Table 4; the sum of the codes showed that most teachers encouraged in this way enhanced their teaching of global warming as a result (Figure 2).

Barrier Experiences - Patterns of climate change instruction documented above (Table 2, section B), indicate that 63% of the overall sample either marginalize the topic (by limiting it to informal discussion) or avoid it altogether. This suggests that most science teachers face barriers to including formal lessons about climate change in their curriculum. Several survey items explored such barriers. When science teachers not teaching about global warming were asked to choose reasons why, they most frequently chose a structural factor: it doesn't fit into their curriculum or standards (Table 3). Many teachers who wrote an "other" choice for this item cited the related structural factor of time limitations on their curriculum.
On the other hand, community-related barriers affecting the inclusion of climate change in the curriculum appear minimal. Very few teachers reported their students uniformly object about learning about global warming. Similarly, only a small minority of Earth and "other" science teachers reported being directly discouraged from teaching about global warming by someone in their community (Table 3).

Free responses describing a discouraging experience (n=48, Table 4) were coded with respect to effects on instruction. Calculating the fraction of responses for each type of code revealed that discouraging experiences hindered teaching very infrequently. Moreover, discouraging experiences appeared to have a smaller overall effect on teaching than did encouraging experiences (Figure 2).

Knowledge and Perceptions of Climate Change

Teachers' responses to questions about why they do or do not include formal lessons about climate change (Table 3) revealed that for many teachers, their level of knowledge about climate change acts as a motivating

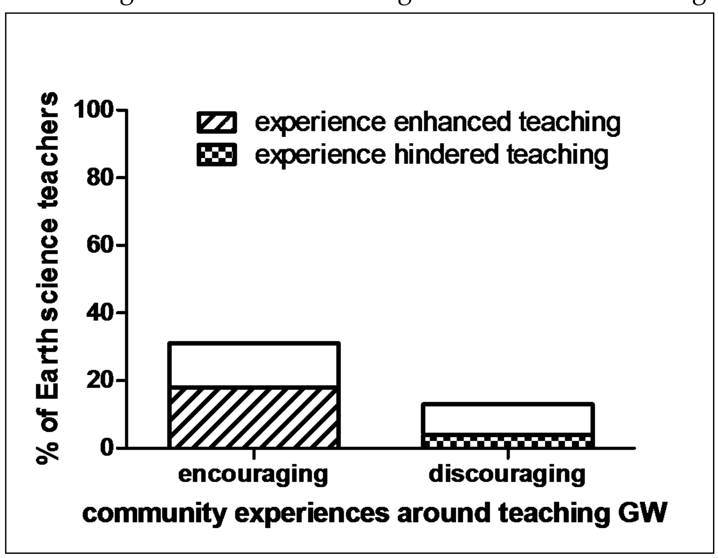

FIGURE 2. Proportions of Earth science teachers in sample reporting community experiences encouraging or discouraging their teaching of global warming. Patterned areas show the subset of teachers whose experiences led to an enhancement or hindering of their teaching. GW = global warming.

TABLE 3. RESPONSES RELATED TO CHOICE TO TEACH CLIMATE CHANGE

Survey Question	Earth science (n=183)	Life science (n=220)	All other [1] (n=225)
Do your students express opinions about learning about global warming in school?			
some express interest in it	59%	54%	61%
some express interest, others object	28%	21%	21%
some object to it	1%	0%	0%
they haven't expressed opinions about it	12%	25%	18%
Has anyone suggested to you, that you should NOT teach about global warming? [2]			
no one	87%		90%
parent(s)	6%		7%
teacher(s)	7%		2%
administrator(s)	2%		1%
acquaintance(s)	1%		2%
family member(s)	4%		1%
Has anyone suggested to you, that you SHOULD teach about (or teach more about) global warming? [2]			
no one	69%		72%
parent(s)	7%		7%
teacher(s)	26%		21%
administrator(s)	5%		3%
acquaintance(s)	7%		9%
family member(s)	10%		10%
Have you engaged in any learning experiences specifically about global warming? [2]			
none	17%		19%
college class(es)	26%		20%
graduate-level class(es)	21%		16%
conference session(s)	30%		22%
professional development workshop(s)	22%		16%
school inservice(s)	5%		2%
global warming-specific website	60%		42%
reading a magazine	58%		65%
reading a book	39%		32%
Please indicate which of the following factors impact your choice to teach formal lessons about global warming. (check all that apply) [3]	(n=118)	(n=73)	(n=80)
it fits within my curriculum and/or standards	89%	85%	91%
it is important for students to understand the topic	89%	90%	93%
I know enough about this topic to teach about it	72%	68%	64%
my students bring up the topic	52%	47%	41%
I have been encouraged to teach this topic	17%	11%	10%
Please indicate which of the following factors impact your choice to not formally teach about global warming. (check all that apply) [4]	(n=64)	(n=143)	(n=146)
it doesn't fit into my curriculum or standards	66%	76%	71%
I don't know enough about this topic to teach about it	16%	14%	18%
it isn't an important topic	2%	1%	1%
it isn't solid science	3%	2%	3%
I am unsure whether or how to present "both sides"	8%	14%	13%
the topic is too controversial	5%	3%	4%
I am concerned about objections from students/parents/administrators	6%	9%	6%
it conflicts with my religion/faith	0%	1%	0%
other	31%	25%	26%

[1]Includes environmental, integrated, physics, chemistry, physical science, and general science teachers.
[2]Question not asked to life science participant subset
[3]Participant subsets teaching formal lessons about global warming
[4]Participant subsets not teaching formal lessons about global warming

factor for instruction, while for some teachers it acts as a barrier. I explored Earth and "other" science teachers' knowledge by asking them to identify learning experiences they had about the topic from a list (Table 3). Most teachers reported they had learned about climate change in two to three different ways. Overall, more teachers reported learning about climate change independently (from web sites, books, and magazines), compared to learning through professional development (conference sessions, workshops, and school inservices) or a college-level course. A sizeable minority of teachers reported no learning experiences about climate change at all.

To further explore teachers' perceptions of climate change, I asked the subset of Earth science teachers to indicate their agreement with eight factual or opinion statements on a Likert scale. Several of these statements were worded to reflect the scientific consensus on climate change (Figure 3, upper three statements) as reported by the Intergovernmental Panel on Climate Change (2007). A strong majority of Earth science teachers agreed or somewhat agreed with each of these statements. However, these teachers were the least certain about the statement 'recent global warming is caused mostly by things people do', with the majority choosing "somewhat agree" or "somewhat disagree" as their response.

Additional statements in this item set were worded in reverse, to reflect common misconceptions or skepticism about climate change (Figure 3, lower five statements). A majority of Earth science teachers disagreed or somewhat disagreed with three of these statements. However, over half of these teachers agreed or somewhat agreed with the misconception that the ozone hole contributes to global warming, and nearly a majority agreed with the statement that 'there is substantial disagreement between scientists about the cause of recent global warming'.

DISCUSSION

Patterns of instruction are highly variable

Science teachers participating in this study show strong support for teaching about climate change, teaching about solutions to the problem, and for including instruction about climate change in a variety of science and social studies classes. However, formal curricular

TABLE 4: SAMPLE TEACHER EXPERIENCES WITH COMMUNITY MEMBERS AROUND TEACHING CLIMATE CHANGE

Experience	Effect on teaching	Coded as
Classes at the Denver Science Museum	I gained personal knowledge and confidence to teach. I developed many resources.	Enhanced teaching
Had a conversation with a family member about it	I talked about it in class with a news article, but not a formal lesson	Enhanced teaching
My brother (who is a scientist) sent me an email with the latest position statement from the American Geophysic[al] Union	This encouraged me to share the results with others	Enhanced teaching
I received an email from another teacher on staff, not a science teacher, with resources on teaching global warming.	I was validated and more aware of how widespread the concern is among teachers.	Enhanced teaching
A parent suggested that it is important for my students to learn the data and science behind global warming.	Verified what I already do.	No effect
Parents, other teachers and acquaintances have encouraged me through conversations about a news article or TV program.	Trying to maintain an open mind…and gain new perspectives.	No effect
Discussions with colleagues of the topic at work.	No effect other than to heighten my awareness of how others may feel.	No effect
Through email, a parent said I should show films that say global warming isn't real	It didn't; I always tell my students I am open to research that shows different things.	No effect
My spouse said that I should not teach that human activity is the only cause for global warming.	I try to present the possibility that humans tend to take too much credit for their impact on the earth and there is a possibility that global warming could be the result of a natural cycle.	Hindered teaching
My parents and coworkers said it is too controversial.	It hindered me from teaching it.	Hindered teaching

inclusion of the topic by study participants lags significantly behind these general levels of support.

Disciplinary divisions and enrollment trends appear to generate barriers to providing students with comprehensive instruction about climate change. High school Earth science teachers in this sample were most likely to teach formal lessons about climate change and perceive the topic falls within their curricular standards. However, a minority of U.S. high school students take Earth science at the high school level (American Geological Institute, 2009). In comparison, 91% of high school students take biology (National Center for Education Statistics, 2002) but nearly half of the life science teachers in this sample perceive climate change to fall outside of their curricular standards. It would be interesting to track changes in instructional practices in states such as Colorado, which recently adopted revised science standards that more explicitly included climate change for both middle and high school classrooms (Colorado Department of Education, 2009).

In addition to these barriers to the *inclusion* of instruction about climate change, the data provide insight into the possible *content* of climate change instruction. When teachers provided their perspectives on statements about climate change (Figure 1, Figure 3), they agreed with most scientifically-supported statements, such as the fact that the Earth is warming, but supported other statements which contradict the views of the scientific community (Intergovernmental Panel on Climate Change, 2007; Doran and Kendall Zimmerman, 2009). Strikingly, only about 25% of the sample appears to hold the opinion that teachers should emphasize the scientific consensus that human activities cause climate change, and a substantial minority of teachers perceive disagreement about the cause of recent climate change among scientists.

Misconceptions about climate change abound in the general public (Leiserowitz, 2007). While their presence in this sample of teachers is not surprising, they are cause for concern as they may lead some to misrepresent the content and nature of climate science. However, much further research is needed to characterize the extent to which teachers hold known climate-related misconceptions, to document ways in which misconceptions are included in instruction, and to assess the impact of instruction on student knowledge and perceptions of climate and climate change science. A concept inventory for the greenhouse effect (Keller, 2006) combined with qualitative classroom observations could further our understanding of how climate misconceptions may be reinforced through instruction.

Does public controversy influence instruction?

While many science-related topics inspire public controversy, most of these (e.g., human reproduction, cloning, nuclear energy, and policy around carbon dioxide emissions) are related to questions about how to *apply* scientific knowledge. Many science teachers appropriately treat these 'science and society' topics as rich forums for student debate and discussion. In contrast, the cause of recent climate change is a topic for which public controversy involves questions about the *validity* of the science itself. It stands to reason that teachers could feel 'caught in the middle' when objections arise about the validity of climate change, as has been documented for the topic of evolution (Griffith and Brem, 2004).

Results of this study indicate that, at the very least, most science teachers are sensitive to the public controversy around climate change. Many teachers in this

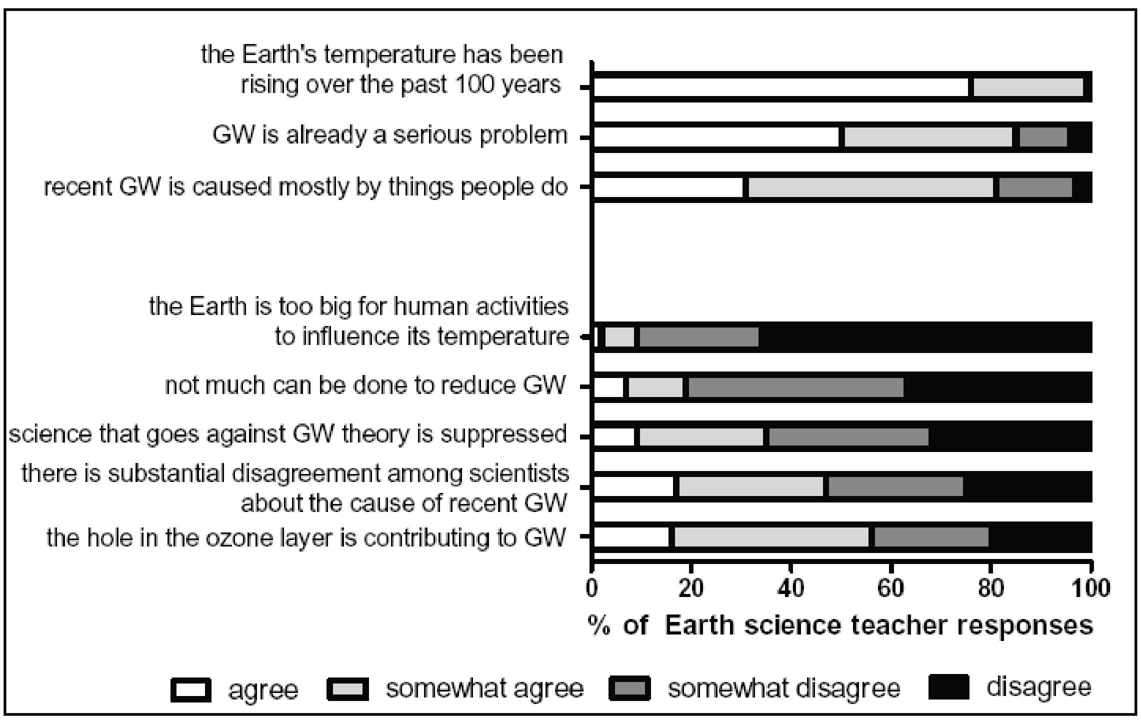

FIGURE 3. Proportions of Earth science teachers reporting agreement, some agreement, some disagreement, and disagreement with common statements about global warming (GW).

sample acknowledge the existence of public controversy as one strategy they use in teaching about climate change (Table 2, section B). Furthermore, participants' free responses to the 'both sides' question reveal that about 7 out of 10 would approach a discussion of human causes of climate change in ways that could be argued to undermine student perception of the validity of the science (Figure 1). Ironically, within the same sample of teachers, 8 out of 10 personally agree at some level with the statement that 'recent global warming is caused mostly by things people do' (Figure 3). Therefore, public controversy appears likely to affect the *content* of instruction about climate change, particularly with respect to the question of human attribution.

On the other hand, it appears that at the time this survey was administered, public controversy was not an important factor affecting the *inclusion* of instruction about climate change. The proportion of teachers receiving community pressure against teaching about climate change was quite small. Similarly, only a small minority of teachers cited concerns about objections or controversy in their classroom. The most prevalent reason for teachers excluding climate change was that 'it does not fit in my curriculum or standards', indicating that concerns over authorization or time currently drive patterns of instruction about climate change across different science subjects.

However, it will be important to monitor whether the effect of public controversy on the inclusion of climate change education remains small over time, as school-related climate controversy appears to be on the rise. Between 2008 and 2010, "Academic Freedom" bills aimed at influencing instruction of global warming and other controversial topics were introduced in a number of states (Kaufman, 2010), a publication promoting skepticism about climate change science was mailed to nearly 14,000 public school board presidents in Colorado and other states (Nova, 2009), and the nonprofit group "Balanced Education for Everyone" attracted national press by petitioning a school board in western Colorado to prevent teaching about global warming (Lofholm, 2010).

Lastly, while prior studies have focused on the potential negative impacts of public controversy on instruction, this study reveals a potentially positive effect of the attention and discussion generated by controversy. A number of teachers have been directly encouraged to teach about climate change, and a larger proportion of such "encouraged" teachers enhance their teaching of climate change, compared to the proportion of teachers for whom direct discouragement hinders teaching (Figure 2). However, additional research is needed to further test the idea that controversial topics lead teachers to receive more encouragement or discouragement, compared to other topics, and to examine whether encouragement to teach about controversial issues can outweigh the influence of discouraging experiences or other barriers to instruction on a teacher's decision to instruct about climate change.

Implications for policy and professional development

Because teachers in this sample generally support climate change education, it is possible that thoughtful policy and professional development efforts to encourage the incidence of instruction will be well received. Given the patterns, motivations, and barriers to instruction documented here, efforts should be focused in three areas: supporting interdisciplinary professional development, targeting professional development to help teachers overcome misconceptions and appropriately frame the public controversy, and explicitly including climate change in national, state, and district science standards for all science subjects.

Science teachers of all stripes in this study reported teaching about climate change. Therefore, opportunities for comprehensive professional development around climate change should ideally be directed to all science teachers. For example, biology teachers may currently feel comfortable instructing only about ecosystem-level impacts of climate change. Given many students could encounter climate change only in a biology classroom, these teachers would ideally understand and be able to instruct about the physical basis of climate change as well. A second strategy for professional development could provide needed support for teachers across science and social studies departments to divide and sequence climate subtopics appropriately. It may be possible to meet such an ambitious professional development objective, as teachers increasingly engage in local district or school professional learning communities (Nelson 2009). Professional development providers may find that working with existing interdisciplinary teams could result in a greater and lasting impact on students.

A reliance on independent forms of learning has likely led many teachers to hold misconceptions about climate science. Professional development providers must take care to specifically target misconceptions that are the most prevalent among teachers. Results from this study would suggest a focus on the role of uncertainty in climate change science and science in general, the processes by which scientists come to consensus about the collective knowledge of climate science, and the attribution of climate change to human activities. In this latter area, where teachers diverge most strongly from scientists, teachers not only need information about how human activities can cause climate change (U.S. Climate Change Science Program, 2009), but also how alternative explanations (e.g., natural cycles, solar activity, volcanic activity) do not sufficiently explain the onset and rate of the warming trend of the last century (Crowley, 2000; Intergovernmental Panel on Climate Change, 2007; Landstrom, 2008).

Teachers also need support targeted toward understanding how to appropriately acknowledge and frame the public controversy. Teachers may not realize that they can be fair to both science and the public by instructing about the 'single side' of the scientific consensus while later giving students ample opportunity to debate the *applications* of science to public policy and individual decision-making. Campaigns by scientific and educational groups to 'first, teach the science' around climate change could further teacher awareness of this important distinction. Such campaigns would maintain the topic as an active point of discussion among teachers, possibly heightening the 'encouragement effect' identified here.

If education leaders and the public wish to catalyze instruction around climate change, encouraging and preparing teachers to include climate change in their curriculum will be necessary, but likely not sufficient, components of the process, because science teachers who marginalize or avoid the topic of climate change clearly indicate that they perceive that this topic does not fall within their curriculum or educational standards (Table 3). This likely explains why climate change is most likely to be taught by Earth science teachers. While it is difficult to argue for an expansion of science standards given the critical need to reduce the overstuffed curriculum (Scherer, 2001), compelling arguments have also been made for the interdisciplinary educational value and societal need for instruction on this topic (Fortner, 2001; Gautier et al., 2006; McCaffrey and Buhr, 2008; Hansen, 2009; U.S. Climate Change Science Program, 2009). Therefore, explicit and thorough inclusion of the causes, impacts, and solutions of climate change in national, state, and district science standards is likely to be an important lever for change (Kastens and Turrin, 2008). In the short term, professional development providers can focus teacher attention on the fact that newer standards do include climate change (see the Atlas of Science Literacy, American Association for the Advancement of Science, 2007b). In the long term, climate scientists and educators will need to make their perspectives on climate education known to the state committees that review and update science education standards, and to the growing movement for a new set of national science standards.

CONCLUSIONS

This study documents patterns in climate change instruction that suggest a substantial fraction of science teachers may not provide entirely accurate formal instruction about this important topic. Policymakers and professional development providers can use insights about the barriers and motivators of instruction from this study to guide their efforts towards supporting interdisciplinary training and collaboration, the reduction of misconceptions about climate science, and the explicit inclusion of climate change in educational standards.

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