

MIXED MESSAGES

HOW CLIMATE CHANGE IS TAUGHT IN AMERICA'S PUBLIC SCHOOLS



NATIONAL
CENTER
for
SCIENCE
EDUCATION

How do
teachers teach
about climate?

MARCH 2016

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a report from the National Center for Science Education
in collaboration with Eric Plutzer, Penn State University
& A. Lee Hannah, Wright State University

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<http://ncse.com/files/MixedMessages.pdf>

The average global temperature of the Earth is increasing at an unprecedented rate. The evidence is overwhelming that this increase is caused largely by the increase of greenhouse gases in the Earth's atmosphere due to society's accelerating consumption of fossil fuels. There is widespread agreement among climate scientists that consequences will include substantial sea level rise, increased incidence of extreme weather, gradual shifts in the ability of native plants and animals to thrive in their current locations, and increased risk of drought in many parts of the world.

While some individuals will have the ability and resources to minimize the impact of climate change on their own lives (e.g., by relocating, or by improving their property with sand dunes or flood mitigation systems), addressing the collective impact will require action by institutions — small ones such as neighborhood associations and local governments, and larger ones such as national governments and international organizations. In a democracy, the ability to participate in governance at all levels is a right and a responsibility. Scientific literacy will play an unusually important role as citizens participate in the crafting of policies designed to slow global warming or mitigate its effects.

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Although the mass media, informal education (such as museums and zoos), and advocacy organizations play important roles in promoting scientific literacy, a special responsibility lies with our public schools. Schools reach into all sectors of society and create environments that are better insulated from ideology and rancor than social media or political forums. Schools are well-positioned to create a foundation of scientific understanding that will equip all future citizens with an understanding of basic scientific concepts, as well as an appreciation of how scientists assess evidence and reach conclusions. So armed, they will be better prepared to critically assess arguments over and solutions to climate change proposed in the political sphere.



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Given the importance of climate literacy, we sought to determine how the public schools of the United States are educating the next generation of citizens about the science of climate change by asking the following questions:

- How many students receive instruction about recent global warming?
- What relevant topics and scientific principles are they taught?
- Are teachers well-equipped to teach effectively today and in the future, when enhanced attention to climate change will be required by new state content standards?

- And, finally, how much do non-scientific ideas and ideologically motivated reasoning find their way into public school classrooms?

Surprisingly, we found only a few research projects that have sought to answer these questions. Some were based on non-scientific opt-in polls,^{1,2} some sought to be representative but relied on social and institutional networks to recruit respondents,^{3,4} and some were surveys of small geographic areas.^{3,5} But even taken together, these previous efforts did not provide more than tentative and preliminary answers to these questions.

The National Survey of American Science Teachers

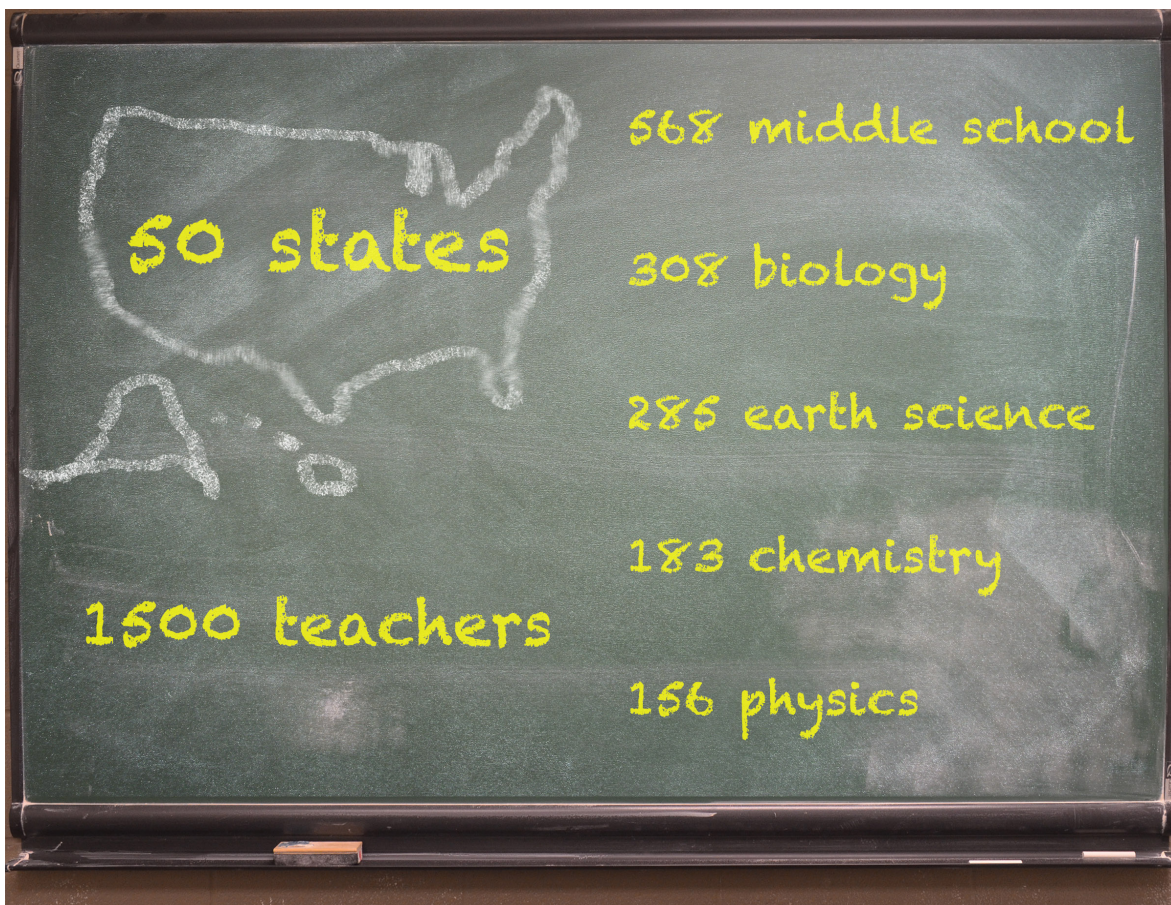
To fill this gap, we conducted the first nationally representative survey of science educators to focus on climate change. The results allow us to paint a national portrait of climate change education in the 2014–2015 academic year. The effort was the result of a partnership between the non-profit National Center for Science Education and the Penn State Survey Research Center.

The effort is characterized by employing best practices in survey research with a commitment to transparency — every table in this report contains the verbatim question wording from the questionnaire (either in the table itself or in the accompanying text). In addition, interested scholars and researchers will have access to replication data and documentation necessary to replicate the findings and explore their own research topics.⁶

Penn State and NCSE conducted the first nationally representative survey of science educators to focus on climate change.

Using a multiple-contact paper and web survey protocol and a disproportionate stratified sampling design, we collected data from 1,500 public school teachers from all fifty US states, including representative samples of middle school science teachers (n=568) and of high school teachers with primary responsibility in biology (n=308), earth science (n=285), chemistry (n=183), and physics (n=156).

We are grateful to the 1,299 teachers who took the time to complete the 12-page pencil-and-paper questionnaire and to the 201 who completed the web version.



Key Findings: Executive Summary

The report is divided into four parts, each with several key findings.

Part 1 focuses on what teachers do in their classrooms, and is based entirely on their own accounts of what they teach, how much time they devote to climate change, and how they teach it.

Finding 1: Climate change is widely taught in US public schools. Roughly 75% of public school science teachers devote time to climate change and almost all public school students are likely to receive at least some education about recent global warming.

Finding 2: Teachers are covering the essential topics. Teachers who devote one or more class hours to recent global warming typically discuss the greenhouse effect, carbon cycle, and several consequences of climate change, such as rising sea levels.

Finding 3: Teachers are linking science to action. While some have expressed concern that climate change curricula are all “doom and gloom,” our survey shows that many educators include discussions of positive steps that industry, government, or students themselves can take to alleviate recent global warming.

Finding 4: Many students are receiving mixed messages. As many as 30% of teachers who teach about climate change are emphasizing that scientists agree that human activities are the primary causes of

global warming while simultaneously emphasizing that “many scientists” see natural causes behind recent global warming.

Finding 5: Teachers take many approaches to managing conflict. While avoidance is rare, many other methods are used to manage conflicts arising from the politics of climate change. More than a quarter of teachers “give equal time” to perspectives that raise doubt about the scientific consensus.

Part 2 focuses on teachers’ educational background and scientific knowledge concerning climate change, recent global warming and the greenhouse effect in particular.

Finding 6: By their own account, many teachers are more knowledgeable about other science topics. Many teachers rate their expertise on climate models as below that of their peers and relatively less than their knowledge of other science topics.

Finding 7: Many teachers’ understanding of the greenhouse effect may be shaky. When asked to prioritize topics for a 2–3 day unit on the greenhouse gases and recent global warming, many teachers selected topics that are not especially relevant.

Finding 8: Most teachers are unaware of the scientific consensus on the causes of climate change. Less than half of all science teachers are aware that more than 80% of climate scientists think that global warming is caused primarily by human activities.

Finding 9: Prior training in climate science is limited. Fewer than half of all teachers had any formal coursework — even one class lecture — on climate change. Of those who did not study climate change during college, only one in five has obtained continuing education on the topic.

Finding 10: Many teachers are interested in professional development in climate science. Two thirds of teachers told us that they would take advantage of continuing education courses focused on climate change.

Finding 11: When asked about their personal acceptance of scientific conclusions, only two thirds see human activities as the primary cause of recent global warming. While few teachers doubt that average global temperatures are on the rise, many do not accept scientific conclusions regarding human energy generation and consumption as the critical cause.

Part 3 focuses on the political and cultural forces as well as the personal values that might influence how teachers negotiate socially controversial topics such as climate change.



<https://flic.kr/p/o5r8fy> / USDA NRCS South Dakota

Finding 12: Few teachers report explicit pressure from students, parents, or the community. In comparison to results of some prior studies, and in contrast to research on the teaching of evolution, very few teachers report explicit pressure to teach or not teach about the human causes of climate change.

Finding 13: Teachers' awareness of the scientific consensus is linked to their attitudes toward the role of government. The more that teachers question the role of government relative to individual responsibility, the less likely they are to know that most climate scientists believe that human activity is the major cause of global warming.

Finding 14: Most teachers are unaware of the degree of scientific consensus on the

causes of recent global warming. Even teachers who themselves attribute warming to human-caused greenhouse emissions tend to underestimate the extent to which climate scientists share their view.

Part 4 outlines policy implications of the data presented in the report. Our hope is that data-informed discussions of educational reforms and teacher development will contribute to more effective science education and, ultimately, increased science literacy.

Implication 1: Cumulative, coordinated climate change curricula are needed. Because climate change cuts across the curriculum, teachers need clear guidance about what concepts they can expect students to have been taught, and what lessons teachers in later grades will expect students to know.



Implication 2: Colleges that prepare students to be science teachers should provide more opportunities for them to gain a sound understanding of climate change, the evidence for anthropogenic causes, the approaches to forecasting its impact, and likely consequences for the natural and built environments.

Implication 3: Teachers who are already in the classroom need, and want, help to remain up to date with the current climate science via effective teaching materials and opportunities for professional development.

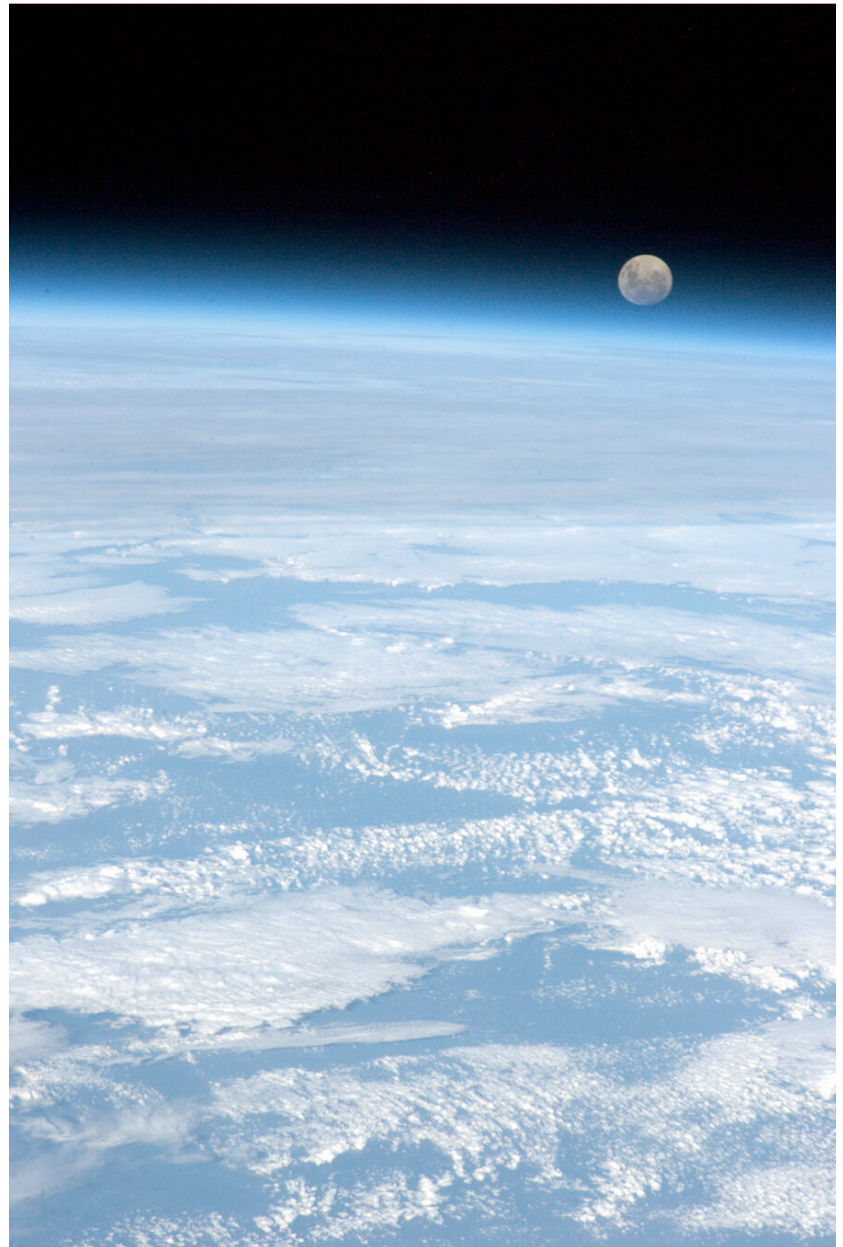
Implication 4: Authors of curricula, lesson plans, and online teaching resources should not assume that teachers adopting their materials have fully mastered the underlying science. Given how many teachers underestimated the scientific consensus or endorsed other misconceptions, publishers and authors should ensure that their materials supply enough background that all teachers can benefit from them.

Implication 5: Teacher education programs should anticipate, and equip future teachers to deal with, the politicization of science in general. Climate change, evolution, and other emerging and contentious topics polarize in different ways. Understanding how to respond to politicized attacks on science is an essential skill for teachers.

Implication 6: Teachers, administrators, and community members must remain vigilant against efforts to introduce denial into classrooms. Careful vetting of

classroom materials ensures that materials are accurate and aligned with curriculum and standards.

Implication 7: At all levels of instruction, effective climate change education will require recognizing the ideological diversity of educators and tailoring instruction to be inclusive.



<http://bit.ly/1RMLy8T> / NASA/Chris Hadfield

Understanding the survey data used in this report

Details on the sampling, questionnaire design, participant recruitment, response rates, and weighting are provided in the Supplementary Online Materials of our report published in the February 12, 2016, issue of *Science*.⁷ Here we provide a summary of that report.

Methodology Overview. The survey was designed and conducted by the Penn State Survey Research Center (SRC) in consultation with the National Center for Science Education, which provided the funding for the study. After the questionnaire was finalized, the SRC's professional staff worked independently until after the last questionnaire was received and the data sets compiled.

The data reported here are based on 1,500 surveys completed by teachers from fifty states — 1,299 pencil-and-paper surveys returned by mail and 201 completed online. Surveys were returned to the SRC between November 10, 2014 and February 18, 2015, when we officially closed the survey. (After February 18, questionnaires continued to arrive and the SRC subsequently logged the receipt of 13 additional paper questionnaires, not reported here.)

The samples were generated by Marketing Data Retrieval (MDR), a division of Dunn and Bradstreet that maintains a database of 3.9 million teachers containing name, job title, and contact information. Based on Penn State SRC specifications, MDR extracted a

disproportionate, stratified probability sample of 5,000 middle and high school science teachers and provided the SRC with their contact information. This sample is designed to represent all middle school science teachers and all biology, life science, earth science, chemistry and physics teachers in US public high schools.

Mailings and reminders. Following the recommendations of Dillman, Smyth, and Christian,⁸ this project used a five-contact postal mail implementation strategy, as well as two points of contact via e-mail.

1. A pre-notification letter was sent on October 20, 2014.
2. A survey packet (containing a cover letter, the survey, a postage-paid business reply envelope, as well as a \$2 bill as a token pre-incentive) was sent on October 31, 2014.
3. A reminder postcard was sent to non-respondents (n=3,908) on November 14, 2014.
4. Approximately 67% of the initial sample had valid e-mails. They received an e-mail reminder on November 19, 2014. These contained hyperlinks taking them directly to our web survey platform.
5. A second e-mail reminder was sent on December 4, 2014.
6. A replacement survey packet was sent on December 8, 2014.
7. A final postcard reminder was sent to teachers on December 15, 2014. This included directions to access the web survey.

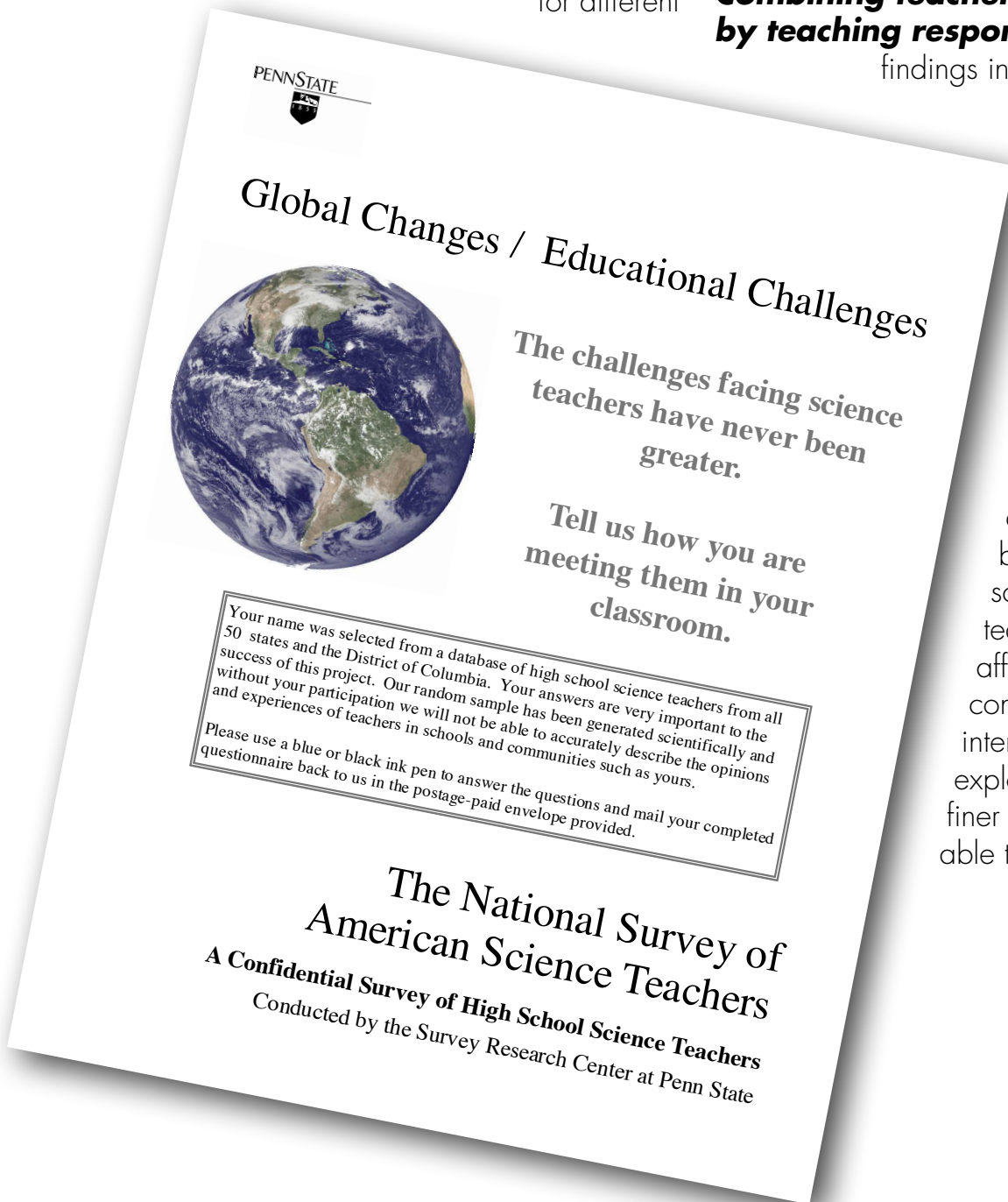
Response rate. After completed interviews were logged and data verified, we calculated a response rate of 37% (AAPOR response rate formula RR4 — details on the calculation are provided in citation 7).

Weighting. Before calculation of statistics reported in the paper, the SRC calculated inverse probability weights. The weighting is accomplished in two separate stages. The first stage of weighting adjusts for different

probabilities of selection associated with the number of teachers in each job title. In the second stage, sample demographics and school characteristics are used to model response propensity and rebalance the sample to correct for differential non-response (in particular, the lower response rates of teachers from majority-minority schools). All tables in this report contain weighted statistics. However, all substantive conclusions remain essentially the same when drawn from unweighted data.

Combining teachers or breaking out by teaching responsibility.

Some of the findings in this report break out teachers by their level of instruction (middle school versus high school) and by subject. Particularly later in the report, we group all respondents together as a sample of secondary science teachers. While there are small differences between, say, earth science and physics teachers, these do not affect our major conclusions. We invite interested scholars to explore the data and make finer distinctions than we are able to in this report.



PART 1: WHAT TEACHERS DO IN THEIR CLASSROOMS

Finding 1: Climate change is widely taught in U.S. public schools

In the first nationally representative probability survey on climate change education, we sought to determine the amount of time teachers devote to climate change in their regular classes. Each teacher was asked to report the number of class hours they devote to several topics common for their standard class.

Biology teachers, for example, were asked, “Thinking about how you lay out your Biology course for the year, please indicate how many class hours (40–50 minutes) you typically spend on each of the following broad topic areas.” After answering about cell biology, ecology, human health and disease, and two

topics related to evolution, they were asked about “recent global warming (last 150 years).”

The prior questions allowed teachers to calibrate and think about global warming in the context of standard topics. Teachers of earth science, chemistry, and physics, and middle school general science teachers received lists appropriate to their subject with global warming always the sixth or seventh item in their list. The results, adapted from Plutzer et al.,⁶ show that approximately 75% of all science teachers devote at least one class session to recent global warming, but that this varies considerably by subject. Over 95% of earth science teachers covered global warming and those who did devoted an average of nearly 6 hours.

Recent global warming was covered by about 70% of middle school teachers, half of whom allocated 4½ class hours or more. Physics and chemistry teachers were less likely to include the topic in their lesson plans, but when they did, half of them spent at least 3½–4 class hours.

Table 1. Formal class hours devoted to recent global warming

	Percentage of teachers devoting one or more class lessons to RGW	Mean and median number of hours devoted to recent global warming (among those with one or more class lessons)	
		Mean	Median
Middle School (<i>n</i> =568)	70.7%	4.4	1.5
Earth science (<i>n</i> =285)	95.6	6.0	4.0
Biology (<i>n</i> =308)	86.8	4.2	1.5
Chemistry (<i>n</i> =183)	54.0	3.5	1.5
Physics (<i>n</i> =156)	49.5	4.1	1.5
Total (<i>n</i> =1,500)	71.4	4.3	1.5

Our data suggest that most students will encounter formal instruction on recent global warming, and most will do so in their middle school science classes. For students who take only a single science course in high school, that course is likely to be biology (97% of all high school graduates complete general biology),⁹ so the odds of being exposed to recent global warming in either middle school or high school are very high.

Still, many teachers in our survey did not cover recent global warming at all. To assess whether students would have alternative opportunities to learn about climate change, we asked all teachers, “Whether or not you selected ‘Recent global warming’ above, please tell us if this topic is covered in any of the following classes at your school.” This was followed by a list of other types of science classes typically offered, and they could check one or more.

Of the roughly 30% of middle school teachers who did not teach about recent global warming, 63% were aware of the topic’s being taught by a colleague at their school; this allows us to estimate the coverage of climate change at the school level. Assuming these perceptions are accurate, we estimate that climate change is being taught in about 90% of all public middle schools. For high school science teachers who did not themselves address climate change, only 9% were unaware of the topic being taught in their school, suggesting that 98% of public high schools are teaching about recent global

Climate change is being taught in about 90% of all public middle schools

98% of public high schools teach about recent global warming in at least one class.

warming in at least one class.

These numbers are especially impressive because at the time of the survey only 13 states had adopted the Next Generation Science Standards, which expect students to learn about “the major role that human activities play in causing the rise in global temperatures” as early as

middle school.¹⁰ Moreover, most other states do not include recent global warming in their current science education standards,^{11,12} textbook inclusion is uneven,¹³ and our survey indicates that few teachers have extensive formal instruction in climate change themselves (see *Finding 9*).

Finding 2: Teachers are covering the essential topics

After ascertaining whether and how much recent global warming was taught, we then sought to get a detailed reporting of the topics covered during these hours. We asked all teachers,

Below is a list of more specific topics related to climate change. Did any of these come up in class? In answering, think about the entire last year that you offered this class.

Table 2 reports the percentage of teachers ticking off each topic.

Here we see that teachers who cover global warming typically cover many facets of climate change, though with slightly different emphasis across subjects. For example, nearly all

biology teachers discussed “Seasonal plant/animal life events (i.e., plant flowering, migration) that respond to climate,” while this was less common (but not uncommon) among physics and chemistry teachers.

As Figure 1 shows, most teacher address 4–11 topics in the course of a year (the mean is 6.7), suggesting that teachers devoting several class sessions to climate change discuss both the underlying scientific mechanisms as well as the consequences of climate change.

As indicated in Table 2, we also asked about two topics that are often introduced by those who reject the scientific evidence of climate change. One of these is the medieval warming period, which is established as a period of regional warming, but often invoked by those who wish to argue that the steady global rise

in temperature seen over the last few decades is not unprecedented. Interestingly, this is discussed by 29% of earth science teachers, but it does not appear to be diagnostic of any particular approach to pedagogy (such as those discussed in *Finding 4*).

We also asked about “Events described in the Bible such as Judgment Day or Noah’s flood.” We included this because this linkage has been explicitly made by a number of public figures, including creationist Ken Ham,¹⁴ and US Representative Joe Barton, who said, “I would point out that if you are a believer in the Bible, one would have to say the great flood was an example of climate change.”¹⁵

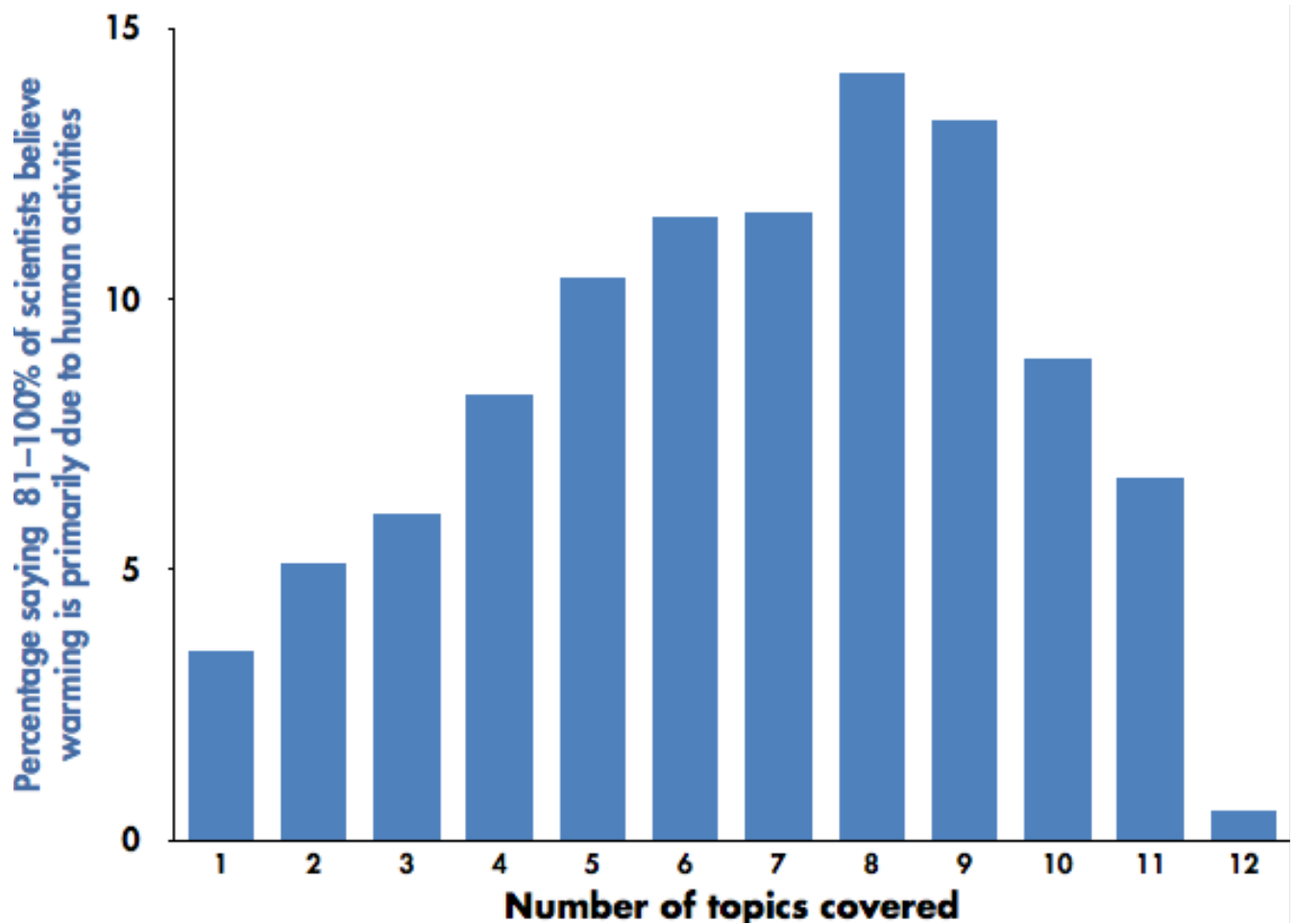
The results here show that unlike Biblical accounts of human origins being introduced into 10–15% of biology classrooms,¹⁶ we

Table 2: Percentage of teachers covering each topic, sorted from most to least common

(among those spending one or more hours on recent global warming)

	Middle School	Earth science	Biol.	Chem.	Physics	Total
Greenhouse effect	84%	97%	93%	82%	64%	86%
Carbon cycle	72	86	98	56	44	78
Sea level change	70	94	73	47	55	70
Changes in water quantity & quality	74	83	78	69	32	72
Seasonal plant/animal life events	71	64	83	37	34	68
Changes in ice and snow cover	63	87	63	44	51	62
Changes in precipitation	66	82	63	43	41	61
Ice ages	51	84	44	26	34	48
Solar variability	39	79	35	30	48	41
Ocean acidification	32	59	50	50	32	42
The medieval warming period	10	30	14	12	19	14
Events described in the Bible	3	5	2	1	5	3

Figure 1: Number of specific topics mentioned by those teachers devoting at least one class period to recent global warming



have virtually no evidence of Biblical perspectives intruding on climate science education.

Finding 3: Teachers are linking science to action

Global warming can seem like a daunting issue to students, and some observers have argued that the “doom and gloom” which can be evoked by discussions of climate change should be balanced by activities that inspire and empower students.¹⁷ Our survey reveals that many educators do in fact include discussions of positive steps that industry,

government, or students themselves can take to alleviate recent global warming.

We asked teachers, “Some curricula also include discussions about potential solutions or steps students can take to address challenges of climate change. Please indicate whether or not you discussed any of the following.” The percentages are reported in Table 3.

The data show that more than 85% discuss current technologies such as hybrid vehicles and alternative energy, and 88% discuss personal conservation. We also find that roughly two thirds reported discussing career opportunities in conservation, policy, or technology sectors.

The survey also shows that 47% discussed technologies geared to mitigation rather than prevention.

Not surprisingly, most science teachers stayed away from more political discussions of policy solutions, though these were discussed in a third of biology classes and 45% of earth science classes.

Finding 4: Many students are receiving mixed messages

Of course, a simple listing of course topics does not tell us how climate change is being taught. To better assess this, we adapted a question first used in Berkman and Plutzer’s 2007 survey of biology teachers.¹⁶ We asked teachers to agree or disagree with three statements that are printed verbatim in the Table 4. The statements reflect the key messages of effective climate science communication: the first question asks whether

teachers emphasize that temperatures *have risen*, and the latter two questions ask whether they emphasize that greenhouse gases are the *primary causes* of recent global warming, or if they deny that claim.

These questions reveal considerable diversity among teachers in how they approach climate science, and considerable ambivalence across the board. For example, while 63% emphasize that global temperatures have risen in the last 150 years (about 90% of those who teach about global warming), only about one in four teachers agrees strongly with this statement. A nearly identical pattern is seen for emphasizing the “scientific consensus that recent global warming is primarily being caused by human release of greenhouse gases from fossil fuels”: only a third agree “strongly.”

Emphasizing “both sides”

These data also provide our first indication that many students are being exposed to

Table 3. Percentage of teachers discussing potential solutions or steps students can take to address challenges of climate change

(among teachers covering recent global warming)

	Middle School	Earth science	Biol.	Chem.	Phys.	Overall
Policy solutions to address change incentives such as cap and trade or carbon taxes.	20%	45%	33%	24%	34%	29%
Efforts to make current technologies more efficient such as hybrid cars or alternative energy sources.	88	91	87	87	89	88
Technologies to mitigate and adapt to the effects of climate change such as geo-engineering.	45	59	45	49	47	47
Things students can do themselves such as walking to school, or turning off lights.	91	95	89	80	78	88
Potential career opportunities related to conservation, new energy technologies, or environmental policy.	67	78	62	69	73	67

contradictory assertions. About 30% of classroom teachers reported that they “emphasize that many scientists believe that recent increases in temperature are likely due to natural causes.” While only 4½% agree “strongly,” any emphasis on non-scientific conclusions can serve to legitimate the efforts of those who seek to undermine the conclusions of the scientific community.¹⁸

If we restrict consideration to those teaching about recent global warming and simplify by combining “agree” and “strongly agree” responses, we see in Figure 2 that 31% of teachers emphasized *both* points of view. In addition, fully 10% appear to be consistent advocates for the positions endorsed by those who reject climate science — they emphasize only the position that recent global warming is a natural phenomenon.

This suggests that many students are seeing political conflicts over the sources of climate change replayed in their classrooms, with their science teacher at times communicating the scientific consensus, while at other times conveying the idea that “many scientists” take a contrary view. We will return to the question

of the scientific consensus in the section of this report discussing *Finding 8*. But first, we move beyond teacher emphasis to a more nuanced exploration of how science teachers manage conflict and debate in their classrooms.

Finding 5: Teachers take many approaches to managing conflict

In the previous section, we saw evidence that ideologically and politically motivated efforts to cast doubt on the findings of climate scientists have found their way into many classrooms. But once broached, conflict and debate can take many forms. In this regard, classroom management and pedagogical philosophy can be of critical importance in science education — particularly when a scientific topic has been politicized and become controversial.

Some have argued that allowing students to explore controversial topics can be empowering, motivate students to research facts and communicate effectively, and build foundations for critical thinking.¹⁹ Others have argued that teachers should be authoritative when student exploration and discovery could

Table 4. Teacher approaches to climate science and scientific consensus

“When I do teach about climate change...”

	Strongly Agree	Agree	Disagree	Strongly Disagree	Not Applicable
I emphasize that average global temperatures have risen in the last 150 years.	25.8%	37.9%	6.8%	1.5%	28.0%
I emphasize the scientific consensus that recent global warming is primarily being caused by human release of greenhouse gases from fossil fuels.	29.3	36.6	8.7	3.0	22.8
I emphasize that many scientists believe that recent increases in temperature is likely due to natural causes.	4.5	26.4	30.2	13.7	25.2

lead students to conclusions at odds with settled science,^{20,21} as is the case with climate change, about which there is a great deal of easily available and highly misleading information.

We sought to understand how teachers navigated the potential mixture of debate, inquiry, and authoritative teaching through a series of questions that each addressed a different aspect of classroom management and pedagogy.

The first two questions were part of the same set of questions that asked about teacher emphasis; they are informed by previous research on the teaching of evolution. As Table 5a shows, a large majority of the science teachers we surveyed report that they encourage students to debate the likely causes of recent global warming (57% overall and 80% of those who teach about global warming). Likewise, a majority agreed with “I encourage students to come to their own

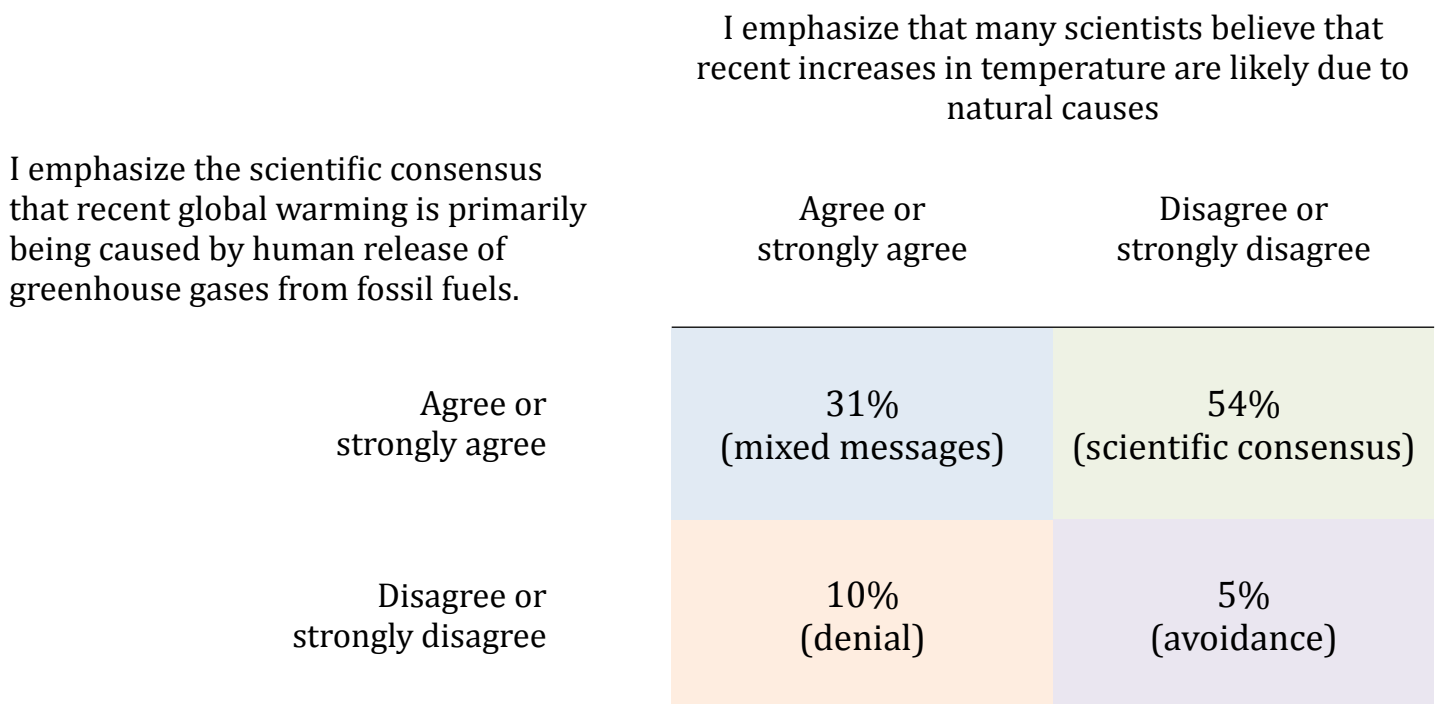
conclusions about the causes of global warming.”

Approaches to dealing with controversy

Of course, teachers are well aware that the science of climate change has been politicized, and that students, their parents, and members of the community may have strong feelings about claims that greenhouse gases are the primary cause of recent global warming. To get a sense of how teachers negotiated such controversies — both real ones and potential controversies they hoped to — we asked them a question that is adapted from earlier research by Sarah Wise:

Some teachers tell us that they acknowledge that human-caused climate change is controversial and adopt particular strategies to do so. Tell us about your approach to each of the following.⁵

Figure 2. Some teachers send contradictory messages about the consensus



Source: Adapted from “Climate confusion among U.S. teachers”⁷

Teachers then reported to us on nine commonly mentioned approaches. The results are reported in Table 5b. There are four interesting results.

First, although many climate scientists might have endorsed this, very few teachers were willing to cut off discussion because climate skepticism is not grounded in solid science — only 8% reported having done this and only 14% said they would consider it.

Second, outright avoidance of controversy was also very rare — only 2% have done this — and only 6% of teachers have allowed students to opt out of the climate change portions of the class.

Third, a larger number of educators reported taking steps to remove the conflict from the classroom. For example, 33% of teachers have offered to meet students outside of class. This allows students to have their say without the risk of discussion derailing a carefully planned lesson and escalating as other students might join in.

In addition, though only 3% of teachers said they had sent an explanatory letter to parents, 41% told us that they might consider it.

Some teachers defuse controversy by emphasizing the nature of science

The most common approach — one also mentioned by many teachers in the 2007 evolution survey — is to place the political controversy concerning climate change in the context of the nature of science. In answering an open-ended question, one teacher from Michigan suggested that teachers must:

... learn to balance “validating” students’ right to speak their mind with need to teach evidence[-]based reasoning. Understand that we are opening students’ minds to consider [that] what they hear in media or at home may be only partly accurate.

There are indications that this approach can be successful.²²

Many teachers allow students to debate

However, the second most common answer was for the teacher to play a neutral role — to “allow students to discuss the controversy without me taking a position.” More than eight in ten teachers either have done this in class (47%) or would consider doing so (38%).

Table 5a. Teacher approaches to debate and inquiry in global warming education

	“When I do teach about climate change...”					
	Strongly Agree	Agree	Disagree	Strongly Disagree	Not Applicable	Total
... I encourage students to debate the likely causes of global warming.	19.1	38.9	10.1	2.9	28.9	100%
... I encourage students to come to their own conclusions about the causes of global warming.	21.5	38.6	12.2	2.6	25.1	100%

In addition, 27% reported that they had given “equal time to perspectives that raise doubt that humans are causing climate change.” While student debate might raise these issues, giving “equal time” might confer considerable legitimacy on positions that are widely rejected by major scientific organizations such as the National Research Council.²⁴

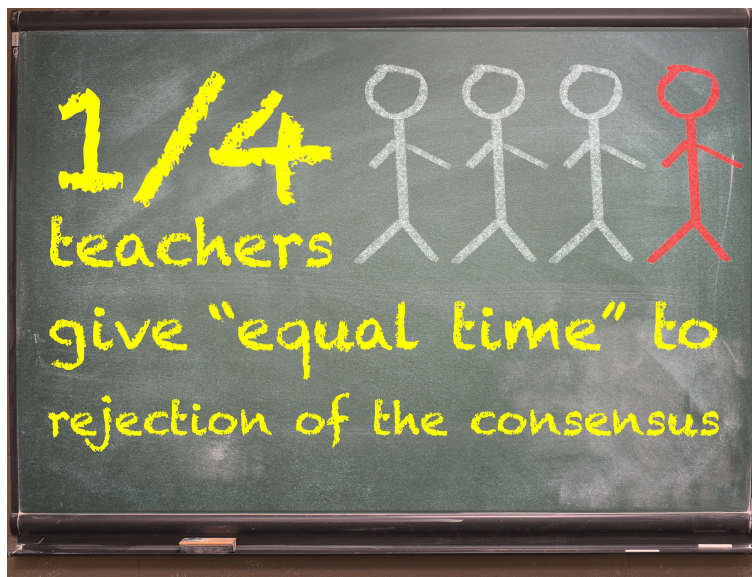


Table 5b. Teacher reports on their use of strategies used to address the controversial nature of climate change

“Some teachers tell us that they acknowledge that human-caused climate change is controversial and adopt particular strategies to do so. Tell us about your approach to each of the following”

	I have done this	I have not done this, but might	I would not do this	Did not answer
Discuss the controversy in the context of the nature of science.	55%	36%	6%	4%
Allow students to discuss the controversy without me taking a position.	47	38	11	3
Offer to meet with students after class.	33	43	21	4
Give equal time to perspectives that raise doubt that humans are causing climate change.	27	48	22	4
Adhere strictly to standards and not allow discussion that might become controversial.	8	18	70	4
Discourage debate because I believe most climate skepticism is not based on sound science.	8	14	75	4
Allow students to opt out of portions of the class.	6	27	64	3
Send an explanatory letter to parents.	3	41	53	4
Avoid all discussion of climate change.	2	6	88	3

PART 2: EXPLAINING WHAT TEACHERS DO IN THEIR CLASSROOMS

The first part of this report summarized data that led to five key findings about climate science education in the United States today. The pattern was one of considerable diversity. Most middle school, high school biology, and high school earth science classes spend at least one class on climate change, covering some of the underlying science and many of the consequences. As for the primary causes of climate change, a large majority of teachers tell us they emphasize the role of greenhouse gases, but a very sizable minority — more than a third who teach the topic — emphasize natural processes as causes of recent global warming.

How can we account for such wide variation in emphasis?

In the next sections of this report, we detail survey results that provide some preliminary

insights into possible causes. First, we examine the possibility that teachers are responding to pressures from their community. Second, we examine teachers' own scientific knowledge and expertise. And third, we examine teachers' personal values and political commitments.

Finding 6: By their own account, many teachers are more knowledgeable about other science topics

Assessing teacher knowledge and expertise is tricky, and especially difficult in a survey being completed voluntarily. In the 2007 survey of high school biology teachers, Berkman and Plutzer asked teachers to rate their own expertise. This proved to be very useful in understanding their teaching practices — those rating their own knowledge as low were less likely to teach evolution and less likely to teach it in accordance with the consensus recommendations of major scientific organizations. Berkman and Plutzer also found, however, a rather substantial “Lake Wobegon” effect, in which a large majority of teachers rated themselves as being above average.

We adapted their approach, but with two modifications intended to reduce the Lake Wobegon effect. First, rather than only being

Table 6. Teacher self-ratings of their content knowledge

“How would you rate your knowledge on each of the following topics:”

	Ecology	Modern genetics	Weather forecasting models	Health and nutrition	Climate change models
Exceptional: On par with many college-level instructors	9%	8%	3%	11%	3%
Very good compared to most high school teachers	36	36	21	37	25
Typical of most high school teachers	45	39	44	44	56
I know less about this topic than many other high school teachers	10	16	31	9	17
Total	100%	100%	100%	100%	100%

asked about climate change, teachers were asked to rate themselves on four other common science topics. Second, we asked about “climate change models” rather than “climate change” to raise the bar. The results of this experiment are reported in table 6.

The results show that the experiment worked insofar as large numbers of teachers were willing to rate themselves as average or below average. The data also reveal fairly wide differences across subjects. Three times as many teachers ranked their knowledge of ecology, genetics, and health “exceptional” than did so for climate models. Indeed, roughly a sixth of teachers rated their climate model knowledge as below average.

We want to emphasize that these measures cannot be used in any absolute sense. For any given topic, it permits comparisons among teachers even though the descriptors may not be realistic. But these give some sense that teachers know that their knowledge is not as extensive as it could be, and these self-ratings are predictive of teaching practice.

Finding 7: Many teachers’ understanding of greenhouse effects may be shaky

The previous tables summarize teachers’ self-reports of what they did in their own classrooms during the previous year. These patterns reflect choices made by the teachers themselves, but often within a highly structured and constrained environment. They are constrained by state curricular standards, the content of tests their students are expected to pass, the textbooks ordered by their school district, and so on.

To get an idea of teachers’ own preferences and perspective on climate change education, we posed a hypothetical question to them.

Imagine that you were asked to teach a 2–3 day unit on greenhouse gases and recent global warming. What priority would you give to including each of the following possible topics?

We deliberately did not ask about mathematical models that are fit to data from the distant past or those designed to forecast the future. These models are complex, require historical data, and are in a constant state of refinement, which can lead to legitimate scientific debate.

Rather, we focused this question tightly on greenhouse gases, since the basic science on how these gases trap heat is more than a century old and not controversial. This is also apt because the greenhouse effect was reported as taught by 85% of middle school teachers, and 93% of biology and 97% of earth science teachers (Table 3).

We listed a series of subtopics: some that are essential to a scientific understanding of the causes of the greenhouse effect, and some, more incidental, that address consequences.

We also included four “foils” — topics that are largely irrelevant to greenhouse processes (or whose connection is marginal and tenuous) or that are relevant to other environmental challenges. These “foils” included the impacts of launching rockets into space, the use of aerosol spray cans, and the use of pesticides.

For each topic we suggested, teachers could say that a topic was a high priority, a medium priority, not necessary, or a topic that “*should not be covered*” (emphasis in the original questionnaire). We assumed that the most scientifically prepared teachers would identify rockets, aerosols, and pesticides as inappropriate topics for a short module on greenhouse gases and recent global warming.

The data reveal that a discussion of CO₂ as an important heat-trapping gas is considered essential. However, it is notable that the underlying mechanism — that CO₂ and other gases trap heat because radiated heat has a longer wavelength than incoming solar energy — was considered a priority by only about a quarter of all teachers, and by especially few biology and middle school science teachers. Indeed, nearly one in five teachers declined even to rate the priority of this topic.

In contrast, three of the four foils elicited considerable support as high-priority topics. Specifically, pesticides, depletion of ozone,

and aerosol spray cans were regarded as a high priority for a unit on greenhouse gases by 23%, 42%, and 14%, respectively, of teachers. These are each important contributors to environmental pollution, but none are directly relevant to a unit on greenhouse gases or recent global warming.

While it is possible that some teachers read the survey question quickly, the large number of “incorrect” answers raises questions about the depth of scientific understanding of the typical science teacher. Indeed, the results are very similar to those of a survey of Australian pre-service teachers, 23% of whom also “confused

Table 7. Priority given to potential topics in a teaching unit on the greenhouse effect.

“Imagine that you were asked to teach a 2-3 day unit on greenhouse gases and recent global warming. What priority would you give to including each of the following possible topics?”

	A high priority	A medium priority	It is not necessary to cover this topic	This topic <i>should not</i> be covered	I do not have an opinion
Carbon dioxide trapping heat in the atmosphere	74%	22%	1%	0%	3%
Use of coal and oil by utility and electric companies	59	40	2	0	3
Emissions from industry	56	38	2	0	4
Destruction of forests	55	39	2	1	3
Depletion of ozone in the upper atmosphere (<i>foil</i>)	42	41	11	3	3
Incoming shortwave and outgoing longwave energy	24	39	15	1	20
Use of chemicals to destroy insect pests (<i>foil</i>)	23	42	23	5	8
People heating and cooling their homes	21	62	10	1	6
Use of aerosol spray cans (<i>foil</i>)	14	56	20	4	7
The impact of launching rockets into space (<i>foil</i>)	4	27	41	7	22

the role of the ozone layer with the greenhouse effect.”²⁴ Combined with the relatively low priority given to the underlying mechanism — rooted in the difference between longwave and shortwave energy — it seems possible that the scientific preparation of teachers accounts for some of the differences in how much time they devote to climate change and how they manage potential conflicts.

Finding 8: Most teachers are unaware of the scientific consensus on the causes of climate change

A recent survey conducted by the Pew Research Center reports that 87% of AAAS members attribute recent warming to human causes.²⁵ Extensive analyses of published scientific papers — including follow-up with the authors — estimate that 96% or more of active climate scientists also attribute climate change to human use of fossil fuels.^{26,27,28} In contrast, while strong majorities in the US accept that climate change is occurring, only about half of American adults believe that human activity is a predominant cause.²⁹

As a result, there are constant public controversies over climate change, and such controversies affect the classroom. There are four paths to such influence. On the one hand, teachers who accept the science may nevertheless regard it as a professional obligation or a pedagogical benefit to present “both sides.” Second, teachers may accept the science without being aware that it represents an overwhelming scientific consensus. Third, teachers who personally reject the scientific consensus and have well-developed personal opinions that reject anthropogenic climate change may teach their students accordingly. A final possibility is that teachers, whatever their personal opinion on the topic, are simply unaware that a consensus exists.

To assess this, we asked teachers directly, “To the best of your knowledge, what proportion of climate scientists think that global warming is caused mostly by human activities?” They were offered five broad categories, the last of which — 81% to 100% — encompasses both the high and low estimates of the scientific consensus. The results are reported below.

Table 8. Teachers’ estimates of the percentage of scientists who attribute global warming to human activities.

“To the best of your knowledge, what proportion of climate scientists think that global warming is caused mostly by human activities?”

	I don’t know	0 to 20%	21% to 40%	41% to 60%	61% to 80%	81% to 100%
Middle School	25%	2%	7%	13%	23%	30%
Earth science	14	2	6	12	22	44
Biology	20	2	4	13	16	44
Chemistry	18	2	7	12	16	45
Physics	19	1	7	9	19	46
All teachers	21	2	6	12	20	39

The data show that only 30% of middle school and only 45% of high school science teachers selected the correct option of “81–100%.” One in five checked “I don’t know.”

If most science teachers believe that there is substantial scientific disagreement, it is understandable that they would teach “both sides,” legitimizing those who dispute the overwhelming scientific evidence.

Finding 9: Prior training in climate science is limited

Although the broad principles of the greenhouse effect have been known since the pioneering work of nineteenth-century scientists such as John Tyndall and Svante Arrhenius, the study of global warming has not been a well-defined subfield for very long, and the opportunity to study the science of global warming has been limited for many teachers. To assess their formal education, we asked them a series of questions pertaining to college “courses entirely focused on climate change” and “courses that devoted one or more class sessions to climate change.” The answers provided by the teachers show considerable diversity, but the extent of formal education on

climate change through college and university education is extremely limited.

The reports of teachers show that only a minority of teachers (43%) had any formal instruction in climate change via a college- or university-level class. Only one in ten current science teachers completed a course largely devoted to climate change.

Even fewer teachers report professional development coursework on climate change, but as these are often short classes, it is not surprising that many of these are stand-alone courses on the topic. Of those who reported no formal instruction in climate change in college, only 18% reported that they had any professional development instruction in topic. Or, put another way, teachers who had some formal exposure to the topic in college were the most likely to report continuing education on climate change.

We can conclude that most teachers who devote time to climate change in their middle or high school courses have very limited formal education on the topic. This may help explain why so few judged the underlying radiation

Table 9. Teachers’ formal coursework and continuing education in climate change.

“Please tell us about your coursework and continuing education in the sciences.”

	Semester/quarter length college classes.	Continuing education classes.
No formal instruction on climate change	57.1%	71.1%
No stand-alone class, but one course that devoted one or more class sessions to climate change	17.3	8.9
No stand-alone class, but two or more courses that devoted one or more class sessions to climate change	14.6	3.9
One course entirely focused on climate change	7.7	9.2
Two or more classes entirely focused on climate change	3.8	7.2
	100.0%	100.0%

mechanisms as a high priority or were aware of the degree of scientific consensus.

Even among those with formal training, their scientific knowledge is likely to be outdated. The median US teacher is 41 years old,³⁰ meaning that half of teachers would have graduated from college before the mid-1990s. Indeed, the median teacher in our survey has been teaching for 15 years, meaning that half completed their formal science training in the '90s or earlier. That training may be actively misleading today. The climate change consensus has grown and solidified substantially since then, as can be seen by comparing IPCC statements from the early 1990s, which did not find a consensus that the role of humanity was greater than natural variation, with IPCC statements from the later 1990s and 2000s, which attribute climate change to human actions with ever-greater confidence. Even those teachers who took climate science courses in college would thus need continuing education if we expect

them to recognize and teach the current state of the consensus.

Finding 10: Many teachers are interested in professional development in climate science

The preceding sections suggest that there is a mismatch between the current desire to teach about climate change and the formal education that our respondents received as pre-service teachers. Only a small fraction of teachers report that they have been able to take advantage of professional development opportunities.

To see whether there is demand for more professional development opportunities to learn about climate science, we specifically asked teachers whether they “would take advantage of such an opportunity in the future.” More than two thirds, 67% of respondents, said that they would be interested in taking a continuing education course entirely focused on climate change.

Table 10. Teachers’ expressed interest in a “professional development course entirely focused on climate change”

	Percent agreeing “I would take advantage of such an opportunity in the future. “
No formal instruction in college and no prior continuing education course on climate change (<i>n</i> = 626)	47.1%
No formal instruction in college and one or more prior continuing education courses on climate change (<i>n</i> = 151)	72.4
Some formal instruction in college and no prior continuing education course on climate change (<i>n</i> = 356)	58.0
Some formal instruction in college and one or more prior continuing education courses on climate change (<i>n</i> = 301)	73.8
All teachers, combined (<i>n</i> = 1,434)	57.3

Many of these are teachers who have already taken coursework in climate change but want to take additional courses as professional development. Nevertheless, a clear majority — 57% — of those who report no formal training in college also expressed an interest in such classes.

Finding 11: When asked about their personal acceptance of scientific conclusions, only two thirds see human activities as the primary cause of recent global warming

In theory, the science a student learns should not depend on a teacher’s personal opinions. Broad learning goals, curricula, and textbook selection are typically outside the control of individual teachers. Even if they personally disagree, teachers are expected to teach according to the scientific consensus and state standards, or may do so to ensure that their students do well on exams.

Nevertheless, prior research on evolution suggests that personal opinions matter and can have an important influence on classroom decisions. Thus it is important to understand teachers’ personal opinions. Answers to the question we posed are reported in the table below.

The results place teachers somewhere in between scientists as surveyed by the Pew Research Center and the general public.³¹ While 12% of the general public deny that the planet is getting warmer, according to the most recent survey,³² that position was taken by only 2% of science teachers. In contrast, two thirds of teachers believe that recent global warming is caused “mostly” by human activities; this is nearly identical to the proportion of the general public expressing the same view.

It is important to also note that those who reject the scientific consensus fall into two groups. The first, about 17% of all teachers, believe that warming is due “mostly” to natural fluctuations. An additional 11% percent selected “other” and most of this group wrote “both” or “both equally.” A small proportion of this group told us that the planet was warming slowly due to natural causes, but that human activities “accelerated” this natural trend. All of these individuals are included in the “both” category for purpose of classification and reporting.

The 2.9% that remain in the “other” category include a wide range of responses that did not fit neatly into the “both” category.



Table 11. Teachers’ personal acceptance of the existence and causes of global warming.

“Which of the following comes closest to your view?”

Global warming is caused mostly by human activities	67.7%
Both (volunteered)	11.5
Global warming is caused mostly by natural changes in the environment	16.0
Global warming is not happening	2.2
Other (excluding “both”)	2.6
	100.0%

PART 3: POLITICAL AND CULTURAL FORCES FIND THEIR WAY INTO THE CLASSROOM

There is no denying the fact that many aspects of the scientific enterprise reflect the values and interests of stakeholders. Scientific funding comes from political processes that simultaneously reflect lofty desires to improve the human condition (by, e.g., funding research on common diseases) or to advance human knowledge (by, e.g., funding the Hubble Space Telescope) and also baser interests (shown, e.g., in legislators' attempts to steer research funding to universities and companies within their constituencies).

At the individual level, too, scientists may be drawn to scientific challenges that are highly personal (eradicating a disease that runs in the scientist's family) or reflect particular interests (eradicating a pest that reduces agricultural profits).

Issues that hinge on the difficult task of assessing risk — such as the safety of nuclear power plants, vaccines, or genetically engineered organisms — seem to be the most polarizing, and climate change fits squarely in this category.

Research suggests that practicing scientists are not immune to potential biases stemming from their values and interests³³ and there is no reason to think that middle and high school science educators would be any less susceptible than scientists.

The critical questions concern whether and to what extent political pressures and teachers' personal beliefs and values affect their classroom choices. The survey results do not allow us to answer these questions unequivocally. But it is possible to take initial steps to look at the potential sources of politicized instruction.

Finding 12: Few teachers report explicit pressure from students, parents, or the community

One major concern of teachers and organizations that support teachers is the extent to which the politicization of the curriculum can place pressure on teachers. In extreme cases, teachers may be tempted to bow to pressure or self-censor by avoiding or watering down a topic. In other cases, teachers seek to teach the topic forthrightly but need to marshal diplomatic skills to ensure that the focus remains on science even as students may hold values and ideologies that color their reactions and interpretations.

As an initial exploration of this complex topic, we asked teachers a series of questions that began, "Some topics can be controversial enough that teachers get pressured or lobbied to either emphasize or de-emphasize it. For

Only 4.4% of teachers report experiencing overt pressure not to teach about climate change.

In a previous survey, 22% reported experiencing such pressure not to teach evolution.

Table 12. Teacher reports of pressure to teach or not to teach global warming

	I have received pressure...	
	to teach about human causes of global warming from:	NOT to teach about human causes of global warming from:
School administrators	0.7%	0.6%
Local religious or community leaders	0.3	1.5
Parents	0.6	1.9
School board members	0.4	0.4
Fellow teachers	3.1	1.5
Other	2.5	1.0
<i>Mentioned any of the above</i>	5.9	4.5

each of the following, select all that apply.” The results, shown in Table 12, show that outside pressure is extremely rare.

The bottom row, reporting all potential sources, shows only 4.5% of teachers reported experiencing overt pressure not to teach about climate change. Although other surveys used different question wording, we should note that this is considerably less than the picture conveyed by several non-probability surveys. For example, 13% of the Colorado science teachers surveyed by Wise⁵ reported that parents, fellow teachers or administrators suggested that they *not* teach about global warming. Likewise, the report of the non-probability survey conducted by the National Earth Science Teachers Association (NESTA) suggests that 36% had been “influenced” to teach both sides of the climate change debate.²

This is not to say that teaching climate change is controversy-free, but these percentages

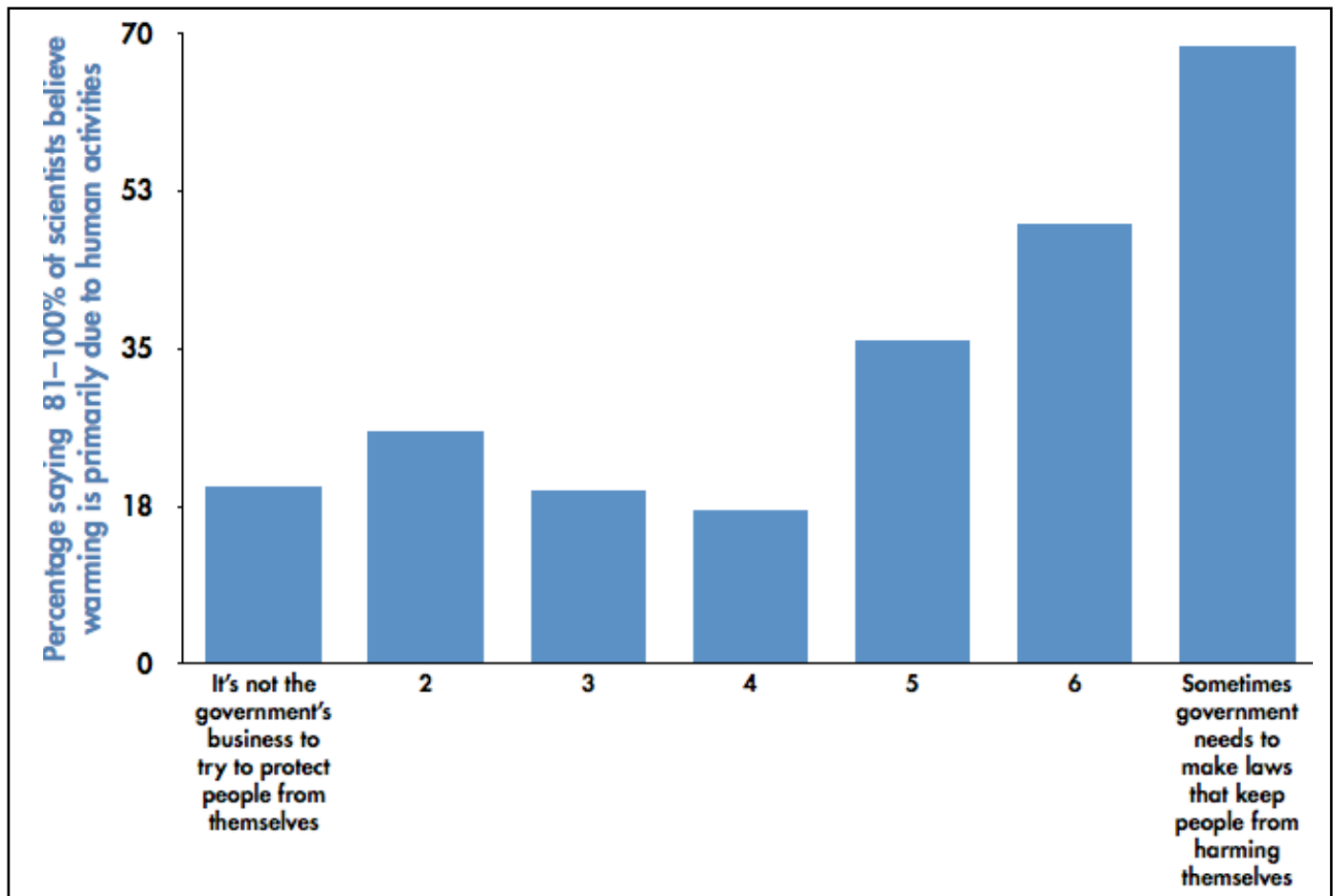
suggest considerably less pressure than biology teachers reported experiencing in a similar survey on teaching evolution. In that survey, 33% reported receiving pro- or anti-evolution pressures.³⁴

Finding 13: Teachers’ awareness of the scientific consensus is linked to their attitudes toward the role of government.

Climate change is a politically polarized topic in the United States. The sources of polarization are rooted in the many subcultures that comprise the United States, in conflicts of interest related to the energy industry and its regulation, and in the very different stances towards climate change taken by leaders of the country’s two major political parties.

As citizens, teachers are embedded in the web of social forces that contribute to polarization. Although science teachers may identify with the scientific profession, they are also members of

Figure 3. Percentage of teachers aware of scientific consensus, by political ideology concerning the role of the government



communities, churches, neighborhoods, and local economies. Our goal in this section is to explore to what degree political orientations affect teachers' personal acceptance of climate change and its anthropogenic causes.

Our initial investigation looks at teachers' orientations towards the role of government. We included in our survey a question that has been employed frequently in the study of risk assessment. Teachers were given two statements at opposite ends of a seven-point scale and asked to locate themselves. The question elicits the values that citizens bring to discussions about the role of government. Figure 3, above, plots the percentages of teachers who correctly answered "81–100%"

when asked how many scientists attribute warming to human activities.

The data show that teachers' understanding of what climate scientists believe is strongly correlated with their political ideology. Among teachers who are even slightly sympathetic to the idea that "it's not the government's business," only a very small fraction gave the 81–100% answer.

This is our first indication that increasing formal climate science training — whether through more extensive coursework in college or expanded professional development opportunities — will not be sufficient. And efforts to improve secondary climate science education — as in the case of evolution — are likely to be complex.

Finding 14: Perception of the scientific consensus is strongly, but inconsistently, correlated with teachers' personal opinions concerning the causes of recent global warming

Earlier, in *Finding 11*, we saw that most teachers personally believe that human activities are the primary cause of recent global warming.

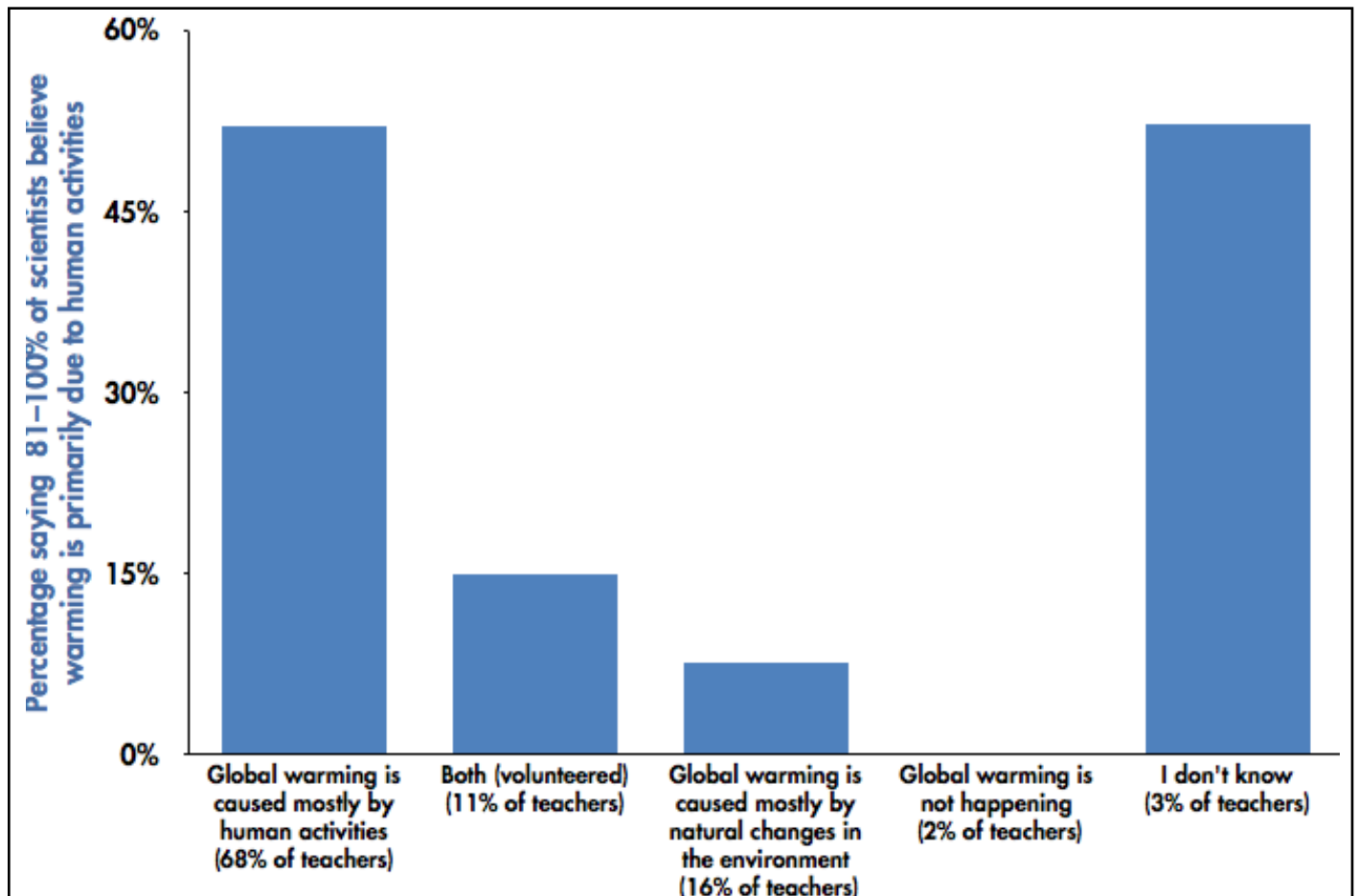
However, members of the public have shown they can often hold views at odds with science even while correctly characterizing the position taken by scientific experts.³⁵ But this is not at all true of science teachers. The figure below, adapted from Plutzer *et al.*,⁶ shows that zero percent of outright climate change deniers acknowledge that almost all

scientists attribute warming to human activities.

It should be noted that 48% of respondents who personally believe warming is the result of human activity are nonetheless unaware that the vast majority of scientists share this opinion. Presumably this reflects a willingness to believe in human-caused global warming because of cultural affinity with the political or ideological groups that accept it, instead of personal awareness of the degree of the scientific consensus.



Figure 4. Percentage of teachers aware of scientific consensus, by personal opinions on causes of global warming



PART 4: IMPLICATIONS FOR POLICY MAKERS AND OTHER STAKEHOLDERS

We undertook this survey to answer four broad questions. By conducting the first survey to examine comprehensively how middle and high school science teachers are handling the challenge of teaching about climate change, we hoped to obtain information that would not only provide a baseline understanding of what is going on in U.S. classrooms, but also suggest policies and programs that would address any shortcomings or challenges identified by the survey.

Indeed, the results of the survey suggest that the situation in classrooms is complex. There is a

great deal of room for improvement, but no magic bullet will address all the challenges revealed by the survey. Many stakeholders have an interest in improving climate change education, and we hope that the survey results will help guide their efforts. Here we summarize what we see as the main implications of the survey results for those whose aim is to ensure that all students leave high school with a sound understanding of the mechanisms, consequences, and possible responses to anthropogenic climate change.

Question 1: How many students are receiving instruction about recent global warming?

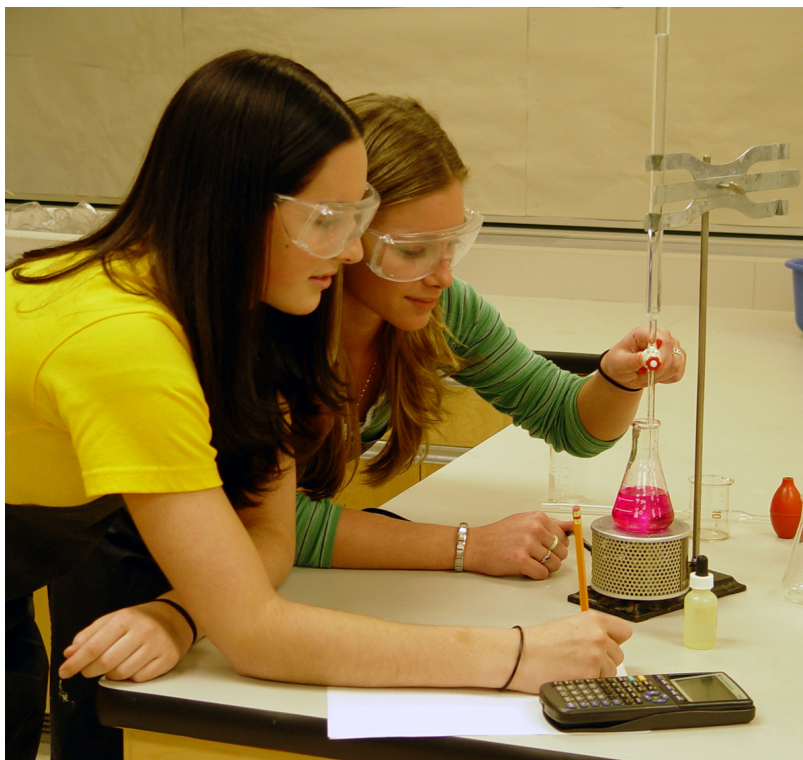
and

Question 2: What topics and scientific principles are they being taught?

Findings: We found that most secondary students are receiving some instruction and that virtually all students encounter climate science at some point in middle and high schools.

However, the patchwork of exposure does not appear to be in any way cumulative. Some students are likely to encounter little more than discussion of climate change consequences, such as rising sea levels. Others will learn about greenhouse gases, but without the scientific foundations that explain the greenhouse effect. Overall, the evidence suggests that few will encounter sophisticated and reinforcing instruction in multiple classes taught by different teachers.

In addition to the instruction in basic science, many students are being introduced to ideas and concrete steps aimed at slowing or mitigating the impacts of global warming. Yet



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here, too, the amount and quality of such discussions vary widely. Adding to the heterogeneity of the classroom experience, students arriving at a high school from different middle schools are likely to bring differing levels of exposure and understanding.

Implication 1: *Cumulative, coordinated climate change curricula are needed.*

Ideally, climate change should be taught in a cumulative, cross-disciplinary, and structured way, beginning in middle schools and junior high schools, and continuing through high school. It is unrealistic to expect individual teachers to cover the topic comprehensively in every course, and the current lack of coordination is contributing to a situation where students are probably encountering some important topics repeatedly and others not at all. Whether it occurs at the level of a single science department, an individual school or, better, at the level of school districts or states, an agreed-upon curriculum is critically important.

The learning objectives described in the Next Generation Science Standards (NGSS) provide a useful framework for developing a coordinated curriculum. Schools or districts may decide to supplement, re-order, or otherwise adapt the NGSS guidance on climate change education; the important thing is that science teachers must have clear expectations of what topics they are expected to cover, and when.

Question 3. Are teachers well equipped to teach effectively today and in the future when enhanced attention to climate change is required by new state content standards?

Findings: We found that few teachers have extensive formal education in climate science,

and the survey results suggest substantial limitations in the content knowledge of current teachers. Their selection of topics in an idealized 2–3 day unit on the greenhouse effect may reflect the limited opportunities teachers have to learn the science themselves or low expectations about what students can understand. It is a matter of considerable concern that so many current teachers are unaware of the scientific consensus. However, a strong majority of teachers expressed interest in learning more about climate change through access to high quality teaching materials and opportunities for professional development.

Implication 2: *Colleges that prepare students to be science teachers should provide more opportunities for them to gain a sound understanding of climate change, the evidence for anthropogenic causes, the approaches to forecasting its impact, and likely consequences for the natural and built environments.*

Ensuring that all future science teachers learn about climate change will require coordination across departments. College and university science faculty should assess the exposure to climate science of their pre-service science teachers, and set realistic goals for expanding learning opportunities in consistent and coordinated ways across their curriculum. One obvious approach would be to offer — or require — inter-disciplinary, stand-alone courses on climate change. Alternatively, pre-service teacher training programs might work to integrate units on climate change into core courses that all science majors, or at least all pre-service science teachers, are expected to complete, such as general chemistry or biology.

Implication 3: *Teachers who are already in the classroom need, and want, help to remain up to date with the current science via effective teaching materials and opportunities for professional development.*

The active dissemination of educational materials that document why anthropogenic climate change is now scientifically well-established is essential. (High quality, vetted online instructional resources include resources distributed by NASA,³⁶ NOAA,³⁷ and the NSF-funded CLEAN collection.³⁸ Directly relevant to our findings, Michael Ranney and his colleagues at the University of California at Berkeley have found that understanding the greenhouse effect is integral to understanding the nature and risks of climate change. They have developed a website with videos describing these often misunderstood basics.³⁹

Implication 4: *Authors of curricula, lesson plans, and online teaching resources should not assume that teachers adopting their materials have fully mastered the underlying science.*

Refresher material and tutorials for teachers should accompany lesson plans and textual material. This is critical because many teachers hone and update their scientific understanding by carefully reading educational materials such as textbooks, web sites, and lesson plans.

While there are numerous high-quality online resources available, such as CLEAN, there is no substitute for teachers working directly with other educators to increase their individual and collective capacity to teach complex, cross-disciplinary topics, which climate change surely is.

Many teachers told us that they would be interested in professional development related to climate change — including a majority of teachers who do not personally accept anthropogenic causes. This is a positive sign, but to make this happen, administrators should prioritize increased professional development opportunities for this emerging and rapidly-developing topic, professional teacher societies should include more climate change workshops at their national and regional meetings, and parents and elected officials should advocate for professional development for the teachers in their local schools.

Because the survey revealed that so many teachers are unaware of the scientific consensus around climate change, it is essential that professional development courses emphasize the areas of relative certainty (rising levels of carbon in the atmosphere, rising global temperatures, rising sea levels, and the unprecedented speed of these changes), the areas of relative uncertainty (exactly how high and how quickly sea levels might rise in the coming decades), and how climate scientists integrate many sources of data to build confidence in their conclusions. These topics connect to the broader nature of science, and ensuring teachers have a solid foundation in the nature of science will help them overcome resistance and convey the compelling evidence for climate change and other socially contentious scientific topics.

Question 4. How much do non-scientific ideas and ideologically motivated reasoning find their way into public school classrooms?

Findings: The survey found very little evidence of teachers feeling explicit political pressures, but did show that teachers are just as susceptible to ideological bias as ordinary citizens. A substantial percentage of teachers

are ideologically inclined toward distrusting the scientific establishment. Others may wish to bend over backward to avoid controversy. And it is not only conservatives who are affected; our data suggest that ideological liberals may also give short shrift to climate science by diluting their lessons with discussion of other, unrelated, environmental pollutants such as insecticides.

Limiting the intrusion of politics into climate science education is a particularly difficult goal, but it is essential if public schools are to help prepare all children to be conscientious citizens.

Implication 5: *Teacher education programs should anticipate, and equip future teachers to deal with, the politicization of science in general.*

We recommend that required courses on the methods of science teaching explicitly address the ways that science can become politicized. Some teachers will have encountered such discussions in their evolution training, but the science/religion framing of such discussion may not prepare them for the differently polarized ideological resistance to climate change (or conflicts over vaccines, genetic engineering, nuclear energy, and new topics that will emerge over the course of their careers). Training that exposes future teachers to the wide range of politicized sciences will help teachers anticipate issues and prepare scientifically sound responses to questions or complaints from students, parents or members of the community, and guide their students and communities toward productive ways of discussing those sciences.

Education faculty should pay particular attention to explaining the difference between a scientific controversy and a political one,

with both reflective exercises and practical suggestions for how science teachers can be respectful of differing political values but also teach the science with integrity.

Implication 6: *Teachers, administrators, and community members must remain vigilant against efforts to introduce denial into classrooms.*

While teachers can shape their communities, they are undoubtedly shaped by their communities as well. Teachers from communities that reject the scientific consensus are more likely to bring false balance into their classrooms, regardless of how personally knowledgeable and confident those teachers are about the science. Advocates for climate education and science education in general can help teachers by expressing support for climate education in classrooms and school board meetings. Teachers who know that they have support for a forthright presentation of the science will feel less fearful and be less tempted to undercut the science.

Owing to organized efforts by climate change deniers, there is a wealth of well-presented misinformation available online and in some cases mailed directly to teachers. Whether teachers are unfamiliar with the current state of the science, are seeking artificial balance, or simply are in agreement with the message of those materials, these resources can easily slip into classrooms. Districts should ensure that their policies for use of supplemental materials ensure that such materials are aligned with standards, curricula across all district classrooms, and the current scientific consensus. It is far easier to block inappropriate material before it enters the classroom than to undo the damage it causes once the lesson is over.

Implication 7: *At all levels of instruction, effective climate change education will require recognizing the ideological diversity of educators and tailoring instruction to be inclusive.*

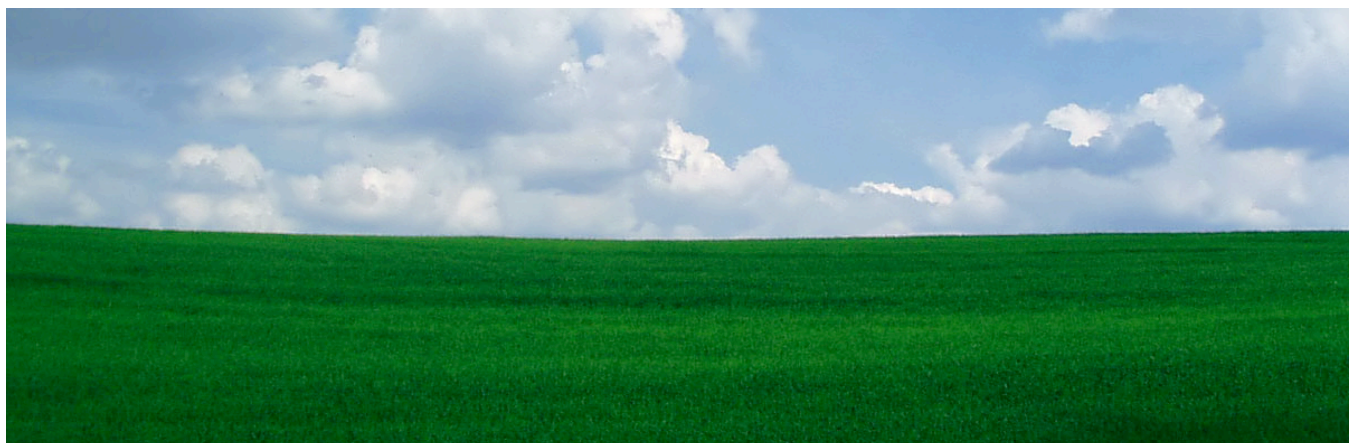
Especially for political or cultural conservatives, our data suggest that simply more traditional science education will not necessarily lead to better outcomes in the classroom — we need better education for teachers. To reach those in the teaching profession who are culturally motivated to reject climate change, education efforts will need to acknowledge their beliefs,⁴⁰ and use insights from the emerging science of science communication to avoid the boomerang effects that can occur when students perceive instructors to be biased or advocating for a particular partisan perspective.^{41,42,43}

This challenge applies not just to teachers, but all those who contribute to their pre-service development and education. In addition to professors of education, supervisors of student teaching, and more senior teachers who serve as mentors, college and university science professors have a critical role to play. Yet scientists who teach at the college level are unlikely ever to have received guidance on how to address topics that are socially, but not scientifically, controversial. Professors may be unaware that their straightforward presentation

of the scientific evidence may be discounted as value-laden, “preachy,” or simply foreign by audiences outside their academic bubbles. Training to help professors recognize and address the biases and misconceptions students bring to class would be helpful, and should be made available at universities and scientific society meetings. This would ensure that pre-service teachers appreciate the importance of climate change and the weight of evidence behind the scientific consensus as well as model the pedagogy that teachers will find most effective in their classroom.

Summary:

These results demonstrate that the landscape of climate change education is particularly complicated. No single policy or program will fundamentally change how climate change is taught in U.S. classrooms. But we hope that the results of the survey — the first to investigate in depth exactly what is being taught in the public schools about climate change, by whom, and how — will help guide those whose goal it is to ensure that today’s students and the next generation of citizens have the scientific foundation that will allow them to grapple with complex proposals to address the challenges of climate change.



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