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Teacher perceptions of state standards and climate change pedagogy: opportunities and barriers for implementing consensus-informed instruction on climate change

A. Lee Hannah[1] · Danielle Christine Rhubart[2]

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Abstract

The public education system can play a pivotal role in creating an electorate that is well informed of the consensus around climate change and its anthropogenic causes. In particular, more states have education standards that specifically address climate change today than ever before. However, previous research raises concerns about the discretion teachers have in if and how particular types of content are presented. The effectiveness of new state standards and the extent to which such state-level standards are coopted by teacher discretion has received minimal attention. Therefore, using a nationally representative sample of 1500 middle school and high school science teachers, this research examines the effectiveness of such state-level standards and the extent to which teacher ideology and knowledge mediate the relationship between standards and actual use of a consensus-informed approach to teaching climate science. Results show that teachers in states with any type of standards around climate change spend significantly more time on the topic in the classroom. However, teachers in states that have standards that require teachers to present "both sides" of climate change are significantly less likely to use a consensus-informed approach. While teacher characteristics (knowledge and ideology) can weaken their effect, standards continue to be important predictors of the time spent on climate change in the classroom and how content is presented. The paper concludes with a discussion of the policy implications of climate science standards.

Keywords Climate change · Global warming · Pedagogy · State standards

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✉ A. Lee Hannah
lee.hannah@wright.edu

[1] Wright State University, Dayton, OH, USA

[2] University of Dayton, Dayton, OH, USA

1 Introduction

Acknowledgement by policy makers and the broader public of the scientific consensus on the anthropogenic nature of climate change (Oreskes 2004; Cook et al. 2016; IPCC 2018) is strongly influenced by partisan politics. Such partisan divides are particularly prominent in American politics. For example, in 2016, only approximately a quarter of Republicans acknowledged human activity as the primary cause of global warming. And among Democrats, only 70% acknowledged this (Funk and Kennedy 2016). This is supported by other research that shows the highly politicized nature of trust in climate science (Myers et al. 2016; Leiserowitz et al. 2018). In this paper, we argue that effectively mitigating climate change requires a well-informed electorate, which in turn requires that quality climate science education be provided by schools. Government action to mitigate the causes and address the effects of climate change will largely be contingent on public opinion, which in turn is contingent on the quality of information that the populace has. Therefore, educational standards on climate change instruction play a critical role in ensuring that the future electorate is informed not on a politicized topic, but on the science behind fundamental changes to the earth's climate.

Unfortunately, the classroom can also be a place of misinformation. Previous research has highlighted the challenges associated with relying on teachers to transfer knowledge of climate science to students, including the great deal of discretion teachers have in if and how content is presented to students (e.g., Plutzer and Hannah 2018; Kunkle and Monroe 2018; Foran 2014). Teaching standards may be a mechanism for streamlining climate science instruction. However, few empirical efforts have been made to measure and assess the effects of state standards on climate science pedagogy and to what extent that teacher discretion minimizes the effect of state standards. Using a nationally representative sample of 1500 middle school and high school science teachers, this paper examines the effectiveness of such state-level standards in shaping the number of hours spent on climate change in the classroom and the extent to which teachers use a consensus-informed disposition to climate change instruction—as opposed to reinforcing the public debate. In addition, we examine the extent to which teacher knowledge and ideology mediates those relationships.

1.1 Conceptual framework

Figure 1 illustrates the conceptual framework we use to examine the effects of teachers' perceptions of state-level standards to explain variation in the amount of time spent on climate change and the extent to which the teacher uses a consensus-informed disposition to instruction as well as whether teacher characteristics mediate those relationships. In this section, we review the literature on each aspect of this conceptual framework.

1.1.1 State standards

In this paper, we are interested in how state-level standards for climate science instruction might influence the amount of time spent on the topic in the classroom and whether a teacher uses a consensus-informed disposition. Less attention has been given to this topic, in part because state-level standards for inclusion of climate science into K-12 curricula have been a rather recent phenomenon. For example, by the early 2000s only 11 states had curriculum standards that included the "historical mechanisms, recent human causes, and impacts of

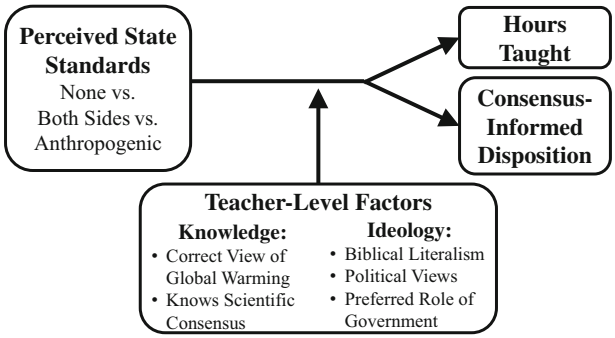

Fig. 1 Conceptual model for climate change instruction and pedagogy

climate change science" (Kastens and Turrin 2008). Research conducted in Colorado during those early years of climate standards did indeed find that teachers who believed their states had standards that included climate change content were more likely to include it in their instruction (Wise 2010). By the end of 2014, which is when data collection for this study began, 12 states and the District of Columbia had signed[1] on to the Next Generation Science Standards (NGSS). NGSS standards are K-12 science content standards that include climate change content (NGSS 2019). A number of other states have developed their own standards—separate from the NGSS—based on the National Research Council's Framework for K-12 Education, which has led to very disparate approaches across non-NGSS expanding states. This includes some state legislatures and state boards of education that have chosen to include climate science content and others that have chosen to exclude such content (e.g., West Virginia and Oklahoma) (Loewus 2015; Colston and Ivey 2015; Stark 2018).

While the NGSS standards include explicit and proximal climate science content, they also de-emphasize the memorization of specific content, which has been the focus of previous standards, and instead focus more on students' ability to apply, analyze, and interpret content and ideas (Loewus 2016). With the focus of instruction being more applied, organizations such as the National Science Teachers Association (NSTA) actually argue that climate-based science concepts should not be de-emphasized in the classroom as this takes attention away from important information that is needed to understand scientific facts (NSTA 2018). In addition, climate change is only included in one domain of the NGSS (i.e., the Earth and Space Science Domain)—a domain that is typically aligned with earth science courses for which many high school students are not required to take (Wise 2010; Schaffer 2012). Therefore, this segment of the student population would likely receive substantially less exposure to climate change content in the classroom.

Regardless of these criticisms, the position of the NSTA is that K-12 science curricula utilize evidence-based science to include the scientific consensus on the anthropogenic causes of climate change as well as mitigation, intervention, and adaptation strategies (NSTA 2018). Very few studies have examined the effectiveness of climate change content included in the NGSS standards or other more rigorous state-developed standards being pursued in place of NGSS (e.g., in Massachusetts) and the extent to which they shape the amount of time spent on climate change in the classroom and the approach that is used by teachers in presenting the material. Prescriptive research articles around the NGSS have suggested the need for research-

[1] By August 2019, 19 states and the District of Columbia had adopted the NGSS and another 24 states had chosen to develop their own standards based on the NRC Framework for K-12 Education.

based professional development around climate change–related NGSS standards, including curricular and instructional resources and regional case studies to provide relevance to students (Hestness et al. 2014). More broadly, Monroe et al. (2017) found in a systematic review of 49 research articles on the efficacy of climate change education that using strategies that are engaging (e.g., inquiry-based learning) and that lessons incorporating personal relevance of climate change were most effective. The authors note, though, the problematic nature of utilizing traditional debate and discussion methods in the classroom to engage students, especially if students are not required to explore how their viewpoints are culturally informed and contextualized as well as the science of how we know what we know (Monroe et al. 2017). Most recently, Gehlbach et al. (2019) found that initiating discussions about climate science is more effective when preceded by a discussion of the acceptance of science as a tool for understanding the world. This brief review of the literature shows the disparate nature of state-level approaches to climate change instruction.

1.1.2 Climate change instruction and consensus-informed dispositions

There is wide variation in the way and extent to which climate science is taught in middle schools and high schools across the USA. Some science teachers do not cover climate change while others spend substantial time on the topic (Plutzer et al. 2016a). The way content is presented also varies substantially, with some teachers emphasizing the anthropogenic nature of climate change and other teachers encouraging in-class debate and/or allowing students to develop their own conclusions (Wise 2010), thus reinforcing a false narrative. A consensus-informed disposition refers to the extent that teachers use pedagogical methods that affirm the consensus around climate change and its anthropological causes rather than reinforcing public debates through their teaching. The anthropogenic nature of climate change is a closed empirical question—one that should not be open for debate in the classroom (Oreskes 2004; Cook et al. 2016; IPCC 2018). This is in line with work from McAvoy and Hess (2013) who argue that empirical questions, for which we have sufficient evidence and consensus, should not be open for debate in the classroom. However, research suggests that many teachers, unwittingly or not, are treating climate change as an open empirical question and reinforcing the public debate around science (Plutzer et al. 2016a; Plutzer et al. 2016b).

Based on this previous research, we acknowledge that pedagogical disposition around climate change is likely best exemplified as a spectrum. At one end of the spectrum, teachers may approach climate science instruction using a consensus-informed approach in teaching about the anthropogenic nature of global warming and discourage arguments or approaches that validate "both sides" perspectives. On the other end of the spectrum, they may approach such instruction using an approach that accommodates alternative perspectives or simply avoids teaching about climate change altogether. In this paper, we are interested not only in the amount of class time spent on climate change, but also the extent to which teachers use a consensus-informed approach rather than a deferential approach.[2]

[2] We use language that is consistent with the survey instrument's wording of specific concepts. The survey asks teachers to record how many hours they spend on "recent global warming (last 150 years)" as a specific manifestation of climate change and the one aspect tied to a specific finding: average global temperatures have risen. In latter questions, the survey addresses additional findings related to climate change (drought, extreme weather, etc.). In addition to this survey question, the authors use a question that asks teachers about their approaches to teaching "human-caused climate change."

It is important to note that the variation in climate science instruction and pedagogical disposition is exacerbated by wide variation in how the topic is covered in text books (Meehan et al. 2018), a lack of earth science requirements in some high schools and states (Schaffer 2012), as well as by concerted efforts to restrict or obscure consensus-informed instruction on climate change (Dunlap and Jacques 2013; Dunlap and McCright 2011). For example, efforts by partisan groups such as the Heartland Institute have actively worked to undermine the consensus on climate change, including by sending misinformation materials directly to high school teachers (Gillis and Kaufman 2012; Goldenberg 2012).

1.1.3 Teachers as street-level bureaucrats: teacher ideology and knowledge

While on first glance the idea of teachers being responsible for implementing state-level policies appears to be a straightforward task, a teacher's instruction and pedagogy are influenced by their own values, beliefs, and worldviews (Plutzer and Hannah 2018; Kunkle and Monroe 2018). While states have standards in place for curriculum, teachers often have discretion in how that curriculum is taught and if and how they insert their own opinions and beliefs (Berkman and Plutzer 2010). Previous research has drawn on the concept of "street-level bureaucrats" to describe how top-down federal and state policies can be implemented in disparate and unequal ways based on the characteristics of the individuals actually implementing those policies (e.g., Berkman and Plutzer 2010; Weatherley and Lipsky 1977; May and Winter 2007). Teachers are one example of street-level bureaucrats who are able to exhibit bottom-up control on if and how particular content is presented to students (e.g., Berkman and Plutzer 2011). For example, research has shown teachers who have liberal ideologies spend significantly more time on climate change instruction and are more likely to teach on the consensus of climate change and its anthropogenic causes than their more conservative peers (Plutzer and Hannah 2018). Therefore, personal ideology does appear to be a significant predictor of teachers' decisions around what content is covered (i.e., class time) and how that content is covered (i.e., pedagogy). It is also important to consider the role of teacher knowledge in explaining instruction and pedagogy. Previous research has shown that prior course work has a small effect on teacher pedagogy. A measure for quality that yields higher internal validity is that of actual measured knowledge of the teacher. In the case of climate science, teachers' performance on questions related to climate science can be used to test the quality of their knowledge (Plutzer and Hannah 2018).

In this paper, we utilize a nationally representative sample of middle school and high school teachers to answer two research questions: (1) Is the amount of time spent on recent global warming in the classroom or the use of a consensus-informed approach to human-caused climate change instruction dependent on state-level curriculum standards around climate change? (2) And is the relationship between time spent on recent global warming in the classroom or the use of a consensus-informed approach to human-caused climate change instruction with state-level curriculum standards around climate change affected by street-level bureaucracy (i.e., teacher characteristics)?

2 Data and methods

To explore the factors influencing the amount of time teachers spend on climate change and the extent to which they use a consensus-informed disposition, we utilized secondary data from

the National Survey of Science Educators conducted in 2014 and 2015 by Plutzer et al. (2016b). The data come from The National Survey of American Science Teachers that was sent to a stratified probability sample of 5000 middle and high school teachers between November of 2014 and February of 2015. The survey was the first nationally representative survey of science educators to focus on climate change. The 12-page survey was sent to a sample of middle school science teachers and high school science teachers, specifically those teaching biology, earth science, chemistry, and physics. The survey included questions about the topics that teachers prioritize in their classes, approaches they take when teaching climate change, perceptions of state standards, materials they used, personal views on global warming, and demographic questions. A total of 1500 teachers completed a paper or online survey.[3]

A descriptive report of the study was published in *Science* (Plutzer et al. 2016b) and by the National Center for Science Education (Plutzer et al. 2016a). We utilize the replication data set that the original investigators archived at the Harvard Dataverse (Hannah and Rhubart 2019). Observations with missing data were excluded from the analyses. At the time of data collection, 26.5% of the teachers in this sample were in states that had adopted the NGSS. Teachers who lived in states that had adopted NGSS standards were no more likely to report that they had climate change standards (46.9%) than their counterparts in non-adopting states (45.1%).

2.1 Dependent variables

To measure *time spent on global warming instruction* in the classroom, participants were asked to indicate how many class hours (40–50 min) they typically spend on "recent global warming (last 150 years)." Response options included not covered, 1–2 h, 3–5 h, 6–10 h, 11–15 h, 16–20 h, and 20 or more hours. Averages for each category were used for analysis (e.g., 1–2 h was coded as 1.5 h) with an overall mean of 3.4 h and a standard deviation of 4.8 h (see section 3.1a of Supplementary Materials). The number of hours taught varied by teachers' subject area. Earth science teachers spent 5.8 h of instruction on recent global warming on average, compared to 3.5 h of instruction by biology teachers and 3.1 h of instruction by middle school teachers. Meanwhile, physics and chemistry teachers spent less than 2 h of classroom instruction on average (physics = 1.95 h and chemistry = 1.75 h).

A consensus-informed approach refers to the extent teachers treat recent global warming as a closed question in their classroom. More specifically, do teachers use consensus-informed pedagogy in teaching about the role of humans in recent global warming as opposed to reinforcing the public debate or simply avoiding teaching about climate change? To measure this, the authors created a Pedagogical Disposition Index of teachers' responses to whether they have adopted or might intend to adopt various strategies in teaching climate science. Teachers had the option to respond to the following statements with "I have done this," "I have not done this, but might if the situation were to arise," and "I would not do this."

1. Give equal time to perspectives that raise doubt that humans are causing climate change
2. Allow student to discuss the controversy without me taking a position
3. Discourage debate because you believe most climate skepticism is not based on sound science

[3] The majority of teachers completed the paper survey ($N = 1299$) A postcard with a link to the online survey was only sent to the teachers that did not return a paper survey and a replacement survey.

4. Allow students to opt out of portions of the class
5. Avoid all discussion of climate change

Teachers who indicated "I would not do this" to all of the statements except for Statement 3 were given a value of 1, indicating consensus-informed disposition. Teachers who indicated "I have done this" or "I have not done this, but might if the situation were to arise" to all of the statements except for Statement 3 were given a value of 0 indicating that they did not use a consensus-informed pedagogy. Statement 3 was reverse coded so that those who had or would consider discouraging debate were coded as 1 (i.e., using a consensus-informed pedagogy). The authors then created a Pedagogical Disposition Index that is an additive measure of teachers' responses to these five questions. The scores range from 0 to 5 with a mean of 2.15 and a standard deviation of 1.04 (see section 3.1b of Supplementary Materials).

2.2 Independent and control variables

The primary independent variable in our models is *whether and what type of standards teachers perceived their states to have around climate change instruction*. Teachers were asked "So far as you know, do your state's science standards include climate change?" The response options were recoded into the following categories: (1) had standards for climate change that emphasized the anthropogenic nature of climate change, (2) had standards for climate change that emphasize natural causes or a "both sides" approach, or (3) have no standards. Those who indicated "I am not sure" were coded as having no standards (see sections 3.2a and 5 in Supplementary Materials).

To measure *teacher awareness of consensus* on climate change, we rely on two measures. First, we use teacher knowledge of scientific consensus and whether they attribute recent global warming to human causes. To measure whether teachers had a correct perception of the scientific consensus around global warming, they were asked "to the best of your knowledge, what proportion of climate scientists think that global warming is caused mostly by human activities." Response options included 0–20%, 21–40%, 41–60%, 61–80%, and 81–100%, and "I don't know." Teachers who answered "81 to 100%" were coded as 1 (39.7%), and all other answers coded as 0. Given the consensus on the anthropogenic nature of climate change within the climate science community of experts (Cook et al. 2016), if a teacher believes that 79% or fewer climate scientists hold this view, then, they likely view the causes of global warming as an open question.

To measure *correct view of global warming*, we use a question from the survey that asks teachers "Which of the following comes closes to your view? (1) Global warming is caused mostly by human activities, (2) Global warming is caused mostly by natural changes in the environment, (3) Global warming is not happening, and (4) Other. Teachers who correctly attributed global warming to human activities were coded as 1 (68.0%), and all other answers were coded as 0. This variable is dichotomized because teachers are not likely to use a consensus approach to global warming—let alone affirm its anthropogenic causes—if they think global warming is not happening or that it is mostly caused by natural changes in the environment.

To measure *teacher ideology*, we rely on three measures: biblical literalism, preferred role of government, and party identification. Biblical literalism was measured by asking teachers to identify which statement came closest to describing their

feelings about the Bible. Response options included "the Bible is the actual word of God and is to be taken literally, word-for-word" (scored 1), "the Bible is the inspired word of God, but not everything should be taken literally, word-for-word" (scored 0.5), and "the Bible is an ancient book of fables, legends, history, and moral precepts recorded by man" (scored 0). Research has shown that global warming skepticism is greater among those who value the ideas of a free market economy and small government (Hornsey et al. 2016). To measure views on the role of government, teachers were asked to designate their preferences along a 7-point scale where "1" indicates "It's not the government's business to try to protect people from themselves" and "7" indicates "Sometimes government needs to make laws that keep people from harming themselves." The measure was rescaled to run from − 1 (small government) to + 1 (big government). To measure political views, respondents were asked to identify themselves politically. Response options were recoded into the following categories: Democratic and Green Party, Libertarian & Tea Party, Republican, and Independent. Those who indicated "other" were removed from the analysis.[4]

Finally, given that recent global warming should be more central to some subject areas than others, we control for the teacher's primary teaching *subject area*. Response options included middle school, high school earth science, high school biology, high school chemistry, and high school physics.

We use ordinary least squares regression to estimate the effects of the independent variables on both hours spent on climate change instruction and extent to which the teacher uses a consensus-informed pedagogy. The standard errors and 95% confidence intervals account for survey design and post-stratification weights. The weights are two-stage inverse probability weights with a first stage design weight to account for the five subject-content strata and a second weight to account for differential response rates. The second weight can only account for characteristics related to the school rather than individual characteristics of the teachers since those data are unavailable. The supplementary materials include descriptive statistics and descriptions of each control variable and more information about the survey.

3 Key findings

Table 1 presents three models for each dependent variable. Models 1a and 1b report the main effects of state-level standards on hours spent on climate change instruction and on the extent to which the teacher uses a consensus-informed pedagogy (i.e., the Pedagogical Disposition Index). Models 2a and 2b add teacher's knowledge and ideology to examine whether these individual-level characteristics change the relationship between state-level standards and the

[4] The original survey allowed for respondents that selected "other" to fill in an open-ended answer ($n = 92$). The authors did not have access to the information and therefore could not include the teachers in the analysis. The results were robust even if all "others" were coded as independent. There are only 7 respondents that identified as Green Party (hence, they were lumped in with Democrats—but the results are overwhelmingly driven by the 571 Democrats in the sample). There are only 32 respondents that identified as Libertarian and only 8 respondents who selected Tea Party as their party identification. Following Plutzer and Hannah (2018), we placed Libertarian ($N = 32$) and Tea Party ($N = 8$) identifiers in a separate category. We also combined Libertarians and Tea Party with Republicans ($N = 376$) in an alternate OLS model. Regardless of the measurement approach, the results do not change in substantive ways.

Table 1 Ordinary least squares regression results predicting class hours spent on recent global warming and consensus-informed pedagogy by standards, teacher characteristics, and control variables

	Model 1—Standards		Model 2—Standards and teacher characteristics		Model 3—Standards, characteristics, and subject taught	
	(a) Hours taught	(b) Pedagogy	(a) Hours taught	(b) Pedagogy	(a) Hours taught	(b) Pedagogy
GW standards (ref = none)						
Both sides	2.32**	− 0.30**	2.47**	− 0.17*	2.21**	− 0.16 **
	(0.43)	(0.08)	(0.42)	(0.07)	(0.43)	(0.07)
Anthropogenic	1.94**	0.18	1.79**	0.07	1.50**	0.08
	(0.30)	(0.08)	(0.31)	(0.08)	(0.31)	(0.08)
Teacher characteristics						
Aware of consensus			0.59	0.55**	0.60	0.53**
			(0.34)	(0.08)	(0.34)	(0.08)
Correct view of GW			0.61	0.23**	0.63	0.24**
			(0.34)	(0.07)	(0.35)	(0.07)
Biblical literalism			− 0.11	− 0.28**	0.01	− 0.27**
			(0.56)	(0.10)	(0.56)	(0.11)
Role of government (small to big government)			0.58	0.13	0.63	0.11
			(0.34)	(0.07)	(0.35)	(0.07)
Party ID (ref = Democratic and Green)						
Libertarian & Tea Party			− 0.89	− 0.12	− 0.61	− 0.18
			(0.49)	(0.18)	(0.49)	(0.18)
Republican			0.83	− 0.14	0.78	− 0.16
			(0.47)	(0.08)	(0.46)	(0.08)
Independent			− 0.14	− 0.24**	− 0.12	− 0.26*
			(0.33)	(0.09)	(0.33)	(0.09)
Subject (ref = middle school)						
HS Biology					0.32	0.09
					(0.38)	(0.08)
HS Earth Science					2.04**	0.04
					(0.43)	(0.07)
HS Physics					− 0.60	0.18
					(0.52)	(0.11)
HS Chemistry					− 1.08**	0.12
					(0.37)	(0.10)
Constant	1.92**	2.17**	0.98*	1.97*	1.05*	− 1.90**
	(0.19)	(0.06)	(0.44)	(0.09)	(0.55)	(0.09)
N	1,192	1,172	1,192	1,172	1,192	1,172
R^2	0.04	0.03	0.07	0.19	0.09	0.19

Unstandardized regression slopes with design-corrected standard errors in parentheses

**$p < 0.01$; *$p < 0.05$

dependent variables. Finally, Models 3a and 3b add primary subject area for each teacher as a control variable.

The main effects models (Models 1a and 1b) show that, on average, a teacher that perceives their state to have standards is significantly likely to spend time (1.9 more hours for those with anthropogenic standards and 2.3 more hours for those with both sides standards) on climate change compared to a teacher that perceives their state not to have standards. Given that the average teacher spends 3.4 h on recent global warming, the average teacher increases their time spent on global warming by

61.8% (about half a standard deviation, or 2 class hours) if they believe their state has standards. However, those who indicated that their state had standards that emphasized "both sides" were less likely to use a consensus-informed approach to instruction compared to teachers that did not report having standards. Meanwhile, teachers who perceived that their standards emphasized anthropogenic climate change were no more likely to use a consensus-informed approach than teachers who reported not having standards. The R^2 statistics for both models indicate that teacher's identification of state standards explains less than 5% of variation in the model.

Models 2a and 2b add teacher characteristics (awareness of consensus and ideology) to the main effects model. Most important is that the R^2 increases from Model 1b to 2b for the Pedagogical Disposition Index. The predictive power of the model increased from 3 to 19%. That is, teachers' personal characteristics (i.e., awareness of consensus and correct view of global warming) explain much of the variation as to whether or not they emphasize the consensus. Those teachers who know the consensus around climate change and who had the correct view of the anthropogenic causes of global warming were significantly more likely to use a consensus-informed approach to instruction than teachers who did not know the consensus and who did not have the correct view of the anthropogenic causes of global warming. And those teachers who held a literalist view of the Bible were significantly less likely to use a consensus-informed approach. The results for Model 2a show that teacher characteristics have less of an effect on the number of classroom hours teachers spend on climate change. Finally, the original findings of the effects of standards on hours spent and Pedagogical Disposition Index remain consistent.

Models 3a and 3b add teacher subject area as a control. Compared to middle school teachers, high school earth science teachers are significantly likely to spend more time on climate change content and high school chemistry teachers spend significantly less time on climate change content. And again, the original findings of the effects of standards on hours spent and Pedagogical Disposition Index remains consistent. After controlling for teachers' characteristics and the subject taught, those who think their state has anthropogenic or "both sides" standards are significantly likely to spend more time (1.5 and 2.2 more hours, respectively), on climate change in the classroom. In addition, the effects of teacher characteristics remain important predictor variables for the Pedagogical Disposition Index (i.e., consensus-informed pedagogy).

The coefficient estimates for Models 1 and 3 are plotted in Fig. 2 for hours taught and in Fig. 3 for Pedagogical Disposition Index. These coefficient plots correspond to the OLS results in Models 1 and 3 of Table 1. The graph plots the regression coefficients for each variable along with the 95% confidence intervals. The vertical red line indicates 0, or no significant effect; thus, confidence intervals or coefficient estimates that touch the red line are not significant at $p < 0.05$ (Jann 2014).

Most notable, the effect of standards holds in each of the models. Teachers who reported that their state standards include recent global warming were significantly likely to spend more time to the topic. Teachers who reported their states have "both sides" standards are significantly less likely to use a consensus-informed pedagogy, even after controlling for the teachers' characteristics and subject. However, teachers who reported that their states have anthropogenic standards are no more likely to use a consensus-informed approach compared to teachers who reported that their states have no standards. Compared to hours taught, the effects of standards on a teachers'

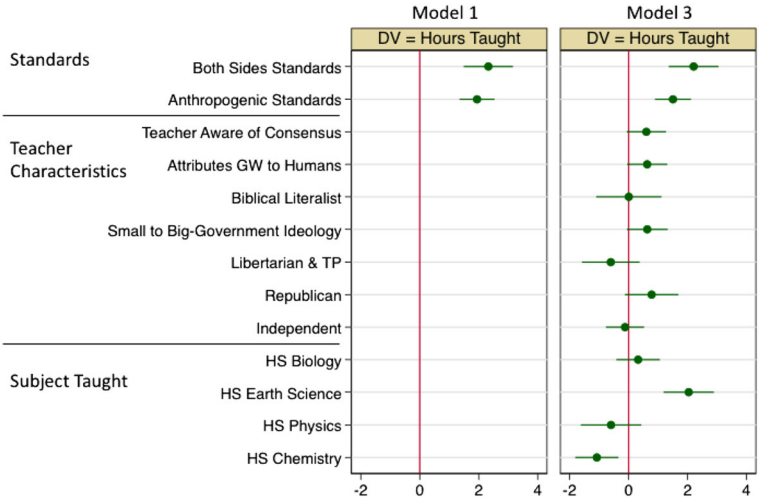

Fig. 2 Effects of standards and teachers characteristics on class hours spent on recent global warming. Note: Coefficient plots correspond with Models 1a and 3a in Table 1. The *x*-axis depicts hours taught and range from − 2 to + 4 h. The dots represent the coefficient estimates, and the horizontal line depicts 95% confidence intervals. Coefficient estimates indicate negative effects if left of the red zero line and positive effects if to the right of the zero line. Variables are not statistically significant if the confidence intervals touch the red line

use of a consensus-informed pedagogy are modest. The independent effects of a teachers' awareness of the scientific consensus and a correct view of the causes of global warming on pedagogy are greater than the effect of standards.

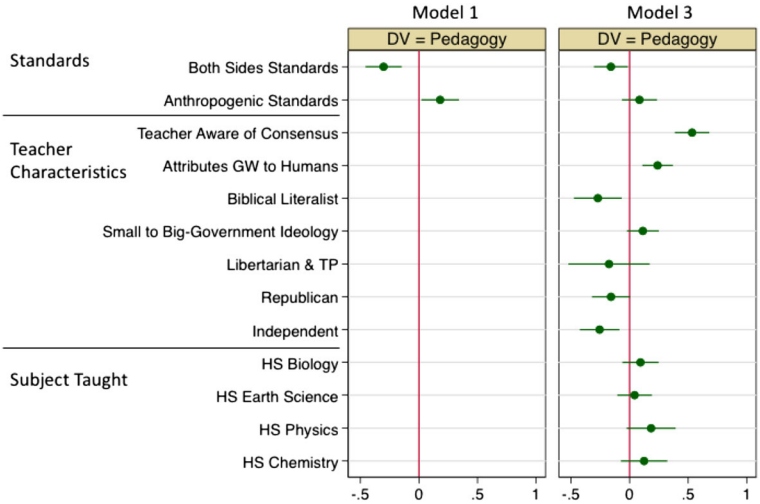

Fig. 3 Effects of standards and teachers characteristics on consensus-informed pedagogy. Note: Coefficient plots correspond with Models 1b and 3b in Table 1. The *x*-axis is based off of an additive index that ranges from 0 to 5 and is scaled to capture effects sizes ranging from − 0.5 to 1. The dots represent the coefficient estimates, and the horizontal line depicts 95% confidence intervals. Coefficient estimates indicate negative effects if left of the red zero line and positive effects if to the right of the zero line. Variables are not statistically significant if the confidence intervals touch the red line

4 Discussion

4.1 Findings and contributions

The scientific consensus on climate change and its anthropogenic causes is certain (Oreskes 2004). And yet, large shares of policy makers and the American electorate fail or choose not to understand that consensus (Funk and Kennedy 2016). Climate change is not unlike previous scientific issues (e.g., CFCs, Ozone, and smoking) which went through similar cycles where scientific warnings with little scientific controversy were followed by concerted efforts by particular interest groups to cast doubt on that science. What followed was typically a period of debate and then finally the consensus winning the argument and effective policies being passed (Oreskes and Conway 2011). However, this process for climate change is unique in its post-truth era context. This post-truth world is driven by a distrust in science and the breeding of disinformation and misinformation campaigns prevalent across all media, and especially the Internet (Iyengar and Massey 2018; Peters 2017). We are left with important questions about how to create a more scientifically informed electorate. Without support from constituencies, legislation in the USA to mitigate and address climate change will be minimal.

In this paper, we have argued that standards can play a role in creating a more informed electorate. More specifically, we have shown that state-level instructional standards around climate change are essential for increasing student exposure to climate science. This finding aligns with previous research that has shown how standards increase in-class hours of exposure to specific content (Cohen and Ball 1990; Mead and Mates 2009). However, state-level instructional standards that provide a "both sides" perspective or allow students to come to their own conclusions reduce the use of a consensus-informed approach and risk reinforcing a narrative of doubt about a closed-empirical question, even more so than those with no state standards around climate change. Moreover, while standards increase the amount of hours devoted to recent global warming in the classroom, differences in the extent to which a consensus-informed pedagogy is used is largely driven by their personal views and ideological commitments.

Building on previous research that has examined the role of teachers as street-level bureaucrats who are able to exert their own influence on if and how content is presented (Berkman and Plutzer 2010; Weatherley and Lipsky 1977), we have shown that while teacher characteristics (i.e., awareness of consensus and ideology) do not fundamentally change the effects of state standards, they do have a significant impact on the extent to which a consensus-informed approach is utilized. Previous work has shown how teacher political ideology can influence pedagogy (Plutzer and Hannah 2018). Here, we are showing that the power of teachers as street-level bureaucrats is not evident in the amount of time spent on climate change content, but is evident in the way that content is presented. This should raise important conversations about the need for state standards to outline that climate change content should be presented from a consensus-informed approach.

Ensuring that teachers have the correct knowledge about the consensus around climate change and the anthropogenic causes of global warming also has a significant effect on teachers use of a consensus-informed approach to instruction. This finding aligns with previous work that has shown a modest effect of teacher knowledge on instruction of climate change (Plutzer and Hannah 2018). Also consistent with previous work is that teachers who subscribe to Biblical literalism are significantly less likely to use a consensus-informed approach to teaching about climate change. Previous research has warned about the barriers

for effective pedagogy in settings where teachers and/or students subscribe to Creationist beliefs (Long 2012). This work reaffirms the important role of teachers as street-level bureaucrats to influence climate change instruction.

4.2 Limitations

While this paper makes several important contributions to the literature, there are two important limitations to acknowledge. First, in this paper, we have examined the role of state-level standards in understanding climate change instruction and pedagogy. There are, however, school districts that have made more rigorous efforts than their state governments to expand content and curricula around climate science (Heitin 2015). Such district-level decisions are not able to be reflected in this analysis. In addition, we have assumed teachers have accurate knowledge about their state's standards. We justify the use of teachers' knowledge of standards, though, because regardless of what the standards are, teachers' perceptions of their state's standards is a better measure of what expectations they think they need to meet. Moreover, to the best of the authors' knowledge, no comprehensive state-by-state comparison on climate science curriculum exists. Given that only 12 states and the District of Columbia had adopted the NGSS by the time of data collection, each of which had likely not fully implemented the new standards at that point in time, teachers' perceptions of standards must act as a proxy. Future research should conduct state-by-state comparisons of climate science curriculum.

A second limitation is that the survey captures teachers at one moment in time. Since this survey was implemented in late 2014 and early 2015, a number of changes have occurred including the wider acceptance of the anthropogenic causes of climate change by some conservative leaders (e.g., Adragna and Savage 2019; Campo-Flores 2019) and the adoption of new science-based standards and in particular the expanded adoption of the NGSS standards by a total of 20 states and the District of Columbia (NSTA 2019). Meanwhile, since the administration of this survey, teachers have had more opportunities to be directly affected by a polarizing environment spear-headed by a post-truth environment following the 2016 election campaign (Iyengar and Massey 2018; Peters 2017) as well as concerted misinformation efforts by organizations like the Heartland Institute (Dunlap and Jacques 2013; Dunlap and McCright 2011; Gillis and Kaufman 2012; Goldenberg 2012; Worth 2017). Therefore, these findings should be interpreted within a changing context of expectations for science teachers and an increasingly polarized country, the latter of which may discourage teachers from using a consensus-informed disposition or compel them to double-down on the science of climate change.

5 Conclusion

There are three primary policy implications from this research. First, this research shows that if states are interested in increasing student exposure to the scientific consensus behind climate change—as opposed to partisan or polarizing debates—then a potential pathway is through the implementation of state-level standards that do not rely on pedagogical strategies that present a "both sides" debate or allows students to "make up their own mind" about something that is in fact a closed empirical question. Therefore, standards should include not only what content is to be covered, but should also provide resources for pedagogical strategies such as the use of

regional case studies to provide relevancy to students as well as inquiry-based learning strategies (Hestness et al. 2014; Monroe et al. 2017). Second, teacher education assessment (e.g., via Praxis exams) could include measures of teacher's knowledge of the consensus around climate change and the anthropogenic nature of its causes. Given that these are significant predictors of use of a more consensus-informed disposition toward climate change instruction, ensuring that teachers have this knowledge is essential. Finally, as mentioned earlier, the NGSS standards on climate change content are largely restricted to the Earth and Space Science domain, which would likely be restricted to earth science courses. Climate science should be integrated into other domains (e.g., the physical sciences domain and the engineering, technology and applications of science domain) given the interdisciplinary nature of our need to respond and adapt to a changing climate. Moreover, research has demonstrated that teachers of earth science courses have been historically underqualified and that earth science courses are not required for all students across states (Schaffer et al. 2012; Wise 2010). Coupled with our findings that high school earth science teachers spend significantly more time on climate change content, states should require earth science courses and that teachers for those courses have appropriate qualifications. This should also include pedagogical guides that help teams of science teachers coordinate their content on climate science to prevent over repetition and ensure scaffolding. Otherwise, students in those states will be left with significantly less exposure and/or misinformation on climate change content.

Combating the effects of climate change requires public policy that is informed by scientific prescriptions. However, such action is dependent on an informed electorate that recognizes that human-generated emissions of greenhouse gases are the leading cause of global warming. This gives public schools a tremendous opportunity to affect change. In fact, education may accelerate societal and policy change. For example, a recent study of middle school students showed that middle school children who are correctly educated about the perils of climate change can increase their parents concern about climate change (Lawson et al. 2019). This research shows that states can play a pivotal role in creating standards that increase class time spent on climate change and that use a consensus-informed approach, rather than using the "both sides" approach that simply furthers a polarizing narrative. Scientifically informed state standards paired with ensuring teachers have accurate knowledge about climate change and its anthropogenic causes is essential in creating an informed future electorate on a topic that is paramount to our existence.

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References

Adragna A, Savage L (2019) A new tone from some Republicans on climate change – mostly behind closed doors. Politico. https://www.politico.com/story/2019/08/22/climate-change-global-translations-1675710 Accessed 4 September 2019

Berkman M, Plutzer E (2010) Evolution, creationism, and the battle to control America's classrooms. Cambridge University Press, New York

Berkman M, Plutzer E (2011) Local autonomy versus state constraints: balancing evolution and creationism in U.S. high schools. Publius J Federalism 41(4):610–635. https://doi.org/10.1093/publius/pjr008

Campo-Flores A (2019) Some Republican lawmakers break with party on climate change. The Wall Street Journal. https://www.wsj.com/articles/some-republican-lawmakers-break-with-party-on-climate-change-11560337010 Accessed 4 September 2019

Cohen D, Ball DL (1990) Relations between policy and practice: a commentary. Educ Eval Policy Anal 12(3): 331–338. https://doi.org/10.3102/01623737012003331

Colston NM, Ivey TA (2015) (un)Doing the next generation science standards: climate change education actor-networks in Oklahoma. J Educ Policy 30(6):773–795. https://doi.org/10.1080/02680939.2015.1011711

Cook J, Oreskes N, Doran P, Anderegg W, Berheggen B, Maibach E, Carlton JS, Lewandowski S, Skuce A, Green S, Nuccitelli D, Jacobs P, Richardson M, Winkler B, Painting R, Rice K (2016) Consensus on consensus: a synthesis of consensus estimates on human-caused warming. Environ Res Lett 11(4). https://doi.org/10.1088/1748-9326/11/4/048002

Dunlap RE, Jacques PJ (2013) Climate change denial books and conservative think tanks: exploring the connection. Am Behav Sci 57(6):699–731. https://doi.org/10.1177/0002764213477096

Dunlap RE, McCright AM (2011) Organized climate change denial. The Oxford Handbook of Climate Change and Society 1:144–160. https://doi.org/10.1093/oxfordhb/9780199566600.003.0010

Foran C (2014) What are kids learning about global warming. The Atlantic. https://www.theatlantic.com/education/archive/2014/06/what-are-kids-learning-about-global-warming/373532/ Accessed on 7 March 2019

Funk C, Kennedy B (2016) The politics of climate. The Pew Research Center. https://www.pewresearch.org/science/2016/10/04/the-politics-of-climate/. Accessed 5 March 2019

Gehlbach H, Robinson C, Vriesema C (2019) Leveraging cognitive consistency to nudge conservative climate change beliefs. J Environ Psychol 61:134–137. https://doi.org/10.1016/j.jenvp.2018.12.004

Gillis J, Kaufman L (2012) Leak offers glimpse of campaign against climate science. The New York Times. https://www.nytimes.com/2012/02/16/science/earth/in-heartland-institute-leak-a-plan-to-discredit-climate-teaching.html. Accessed 5 March 2019.

Goldenberg S (2012) Lead exposes how Heartland Institute works to undermine climate science. The Guardian. https://www.theguardian.com/environment/2012/feb/15/leak-exposes-heartland-institute-climate. Accessed 5 March 2019

Hannah, AL Rhubart DC (2019) Replication data for perceptions of state standards and climate change pedagogy: opportunities and barriers for implementing consensus-informed instruction on climate change. Harvard Dataverse V1. https://doi.org/10.7910/DVN/N89RD2

Heitin L (2015) Districts out ahead of states in adopting science standards. Education Week. https://www.edweek.org/ew/articles/2015/05/06/districts-out-ahead-of-states-in-adopting.html. Accessed 5 March 2019

Hestness E, McDonald RC, Breslyn W, McGinnis R, Mouza C (2014) Science teacher professional development in climate change education informed by the Next Generation Science Standards. J Geosci Educ 62(3):319–329. https://doi.org/10.5408/13-049.1

Hornsey MJ, Harris EA, Bain PG, Fielding KS (2016) Meta-analyses of the determinants and outcomes of belief in climate change. Nat Clim Chang 6(6):622–626

International Panel on Climate Change (2018) Global Warming of 1.5 °C. https://www.ipcc.ch/sr15/ Accessed 4 September 2019

Iyengar S, Massey D (2018) Scientific communication in a post-truth society. Proc Nal Acad Sci https://doi.org/10.1073/pnas.1805868115

Jann B (2014) Plotting regression coefficients and other estimates. Stata J 14(4):708–737

Kastens K, Turrin M (2008) What are children being taught in school about anthropogenic change? In: Ward B (ed) Communicating on climate change: an essential resource for journalists, scientists, and educators. Metcalf Institute for Marine and Environmental Reporting, Narragansett 86 p

Kunkle KA, Monroe MC (2018) Cultural cognition and climate change education in the US: why consensus is not enough. Environ Educ Res 1–23. https://doi.org/10.1080/13504622.2018.1465893

Lawson DF, Stevenson KT, Peterson MN, Carrier SJ, Strnad RL, Seekamp E (2019) Children can foster climate change concern among their parents. Nat Clim Chang 9:458–462. https://doi.org/10.1038/s41558-019-0463-3

Leiserowitz A, Maibach E, Roser-Renouf C, Rosenthal S, Cutler M, Kotcher J (2018) Climate change in the American mind: March 2018. Climate Change Communication. http://climatecommunication.yale.edu/publications/climate-change-american-mind-march-2018/3/

Loewus LH (2015) West Virginia amends science standards again, to reflect doubt on climate change. Curriculum Matters. https://blogs.edweek.org/edweek/curriculum/2015/04/west_virginia_amends_science_s.html Accessed 5 March 2019

Loewus LH (2016) Eight things to know about the Next Generation Science Standards. Curriculum Matters. http://blogs.edweek.org/edweek/curriculum/2016/02/next_generation_science_standards_8_things_to_know.html. Accessed 5 March 2019

Long D (2012) The politics of teaching evolution, science education standards and being a creationist. J Res Sci Teach 49(1):122–139. https://doi.org/10.1002/tea.20445
May PJ, Winter SC (2007) Politicians, managers, and street-level bureaucrats: Influences on policy implementation. J Public Adm Res Theory 19(3):453–476. https://doi.org/10.1093/jopart/mum030
McAvoy P, Hess D (2013) Classroom deliberation in an era of political polarization. Curric Inq 43(1):14–47. https://doi.org/10.1111/curi.12000
Mead L, Mates A (2009) Why science standards are important to a strong science curriculum and how states measure up. Evol Educ Outreach 2(151):359–371. https://doi.org/10.1007/s12052-009-0155-y
Meehan CR, Levy BL, Collet-Gildard L (2018) Global climate change in US high school curricula: portrayals of the causes, consequences, and potential responses. Sci Educ 102:498–528. https://doi.org/10.1002/sce.21338
Monroe M, Plate R, Oxarar A, Bowers A, Chaves W (2017) Identifying effective climate change education strategies: a systematic review of the research. Environ Educ Res. https://doi.org/10.1080/13504622.2017.1360842
Myers T, Kotcher J, Stenhouse N, Anderson A, Maibach E, Beall L, Leiserowitz A (2016) Predictors of trust in the general science and climate science research of US federal agencies. Public Underst Sci 26(7):843–860. https://doi.org/10.1177/0963662516636040
National Science Teachers Association (2018) NSTA position statement: the teaching of climate change. https://www.nsta.org/about/positions/climatescience.aspx. Accessed 5 March 2019
Next Generation Science Standards (2019) About the Next Generation Science Standards. https://ngss.nsta.org/About.aspx. Accessed 5 March 2019
Oreskes N (2004) Scientific consensus on climate change. Science 306(5702):1686. https://doi.org/10.1126/science.1103618
Oreskes N, Conway E (2011) Merchants of doubt: how a handful of scientists obscured the truth on issues from tobacco smoke to global warming. Bloomsbury Press, New York
Peters M (2017) Education in a post-truth world. Educ Philos Theory 49(6):563–566. https://doi.org/10.1080/00131857.2016.1264114
Plutzer E, Hannah AL (2018) Teaching climate change in middle schools and high schools: investigating STEM education's deficit model. Clim Chang. https://doi.org/10.1007/s10584-018-2253-8
Plutzer E, Hannah AL, Rosenau J, McCaffrey M, Berbeco M, Reid A (2016a) Mixed messages: how climate is taught in America's schools. Oakland, CA: National Center for Science Education. http://ncse.com/files/MixedMessages.pdf. Accessed 5 March 2019
Plutzer E, McCaffrey M, Hannah AL, Rosenau J, Berbeco M, Reid AH (2016b) Climate confusion among US teachers. Science 351(6274):664–665. https://doi.org/10.1126/science.aab3907
Schaffer D (2012) It's time to stand up for earth science. J Geosci Educ 60:291–294. https://doi.org/10.5408/11-264.1
Stark L (2018) Some states are trying to downplay teaching of climate change. Teachers see 'educational malpractice'. PBS News Hour. https://www.pbs.org/newshour/show/some-states-are-trying-to-downplay-teaching-of-climate-change-teachers-see-educational-malpractice Accessed 5 March 2019
Weatherley R, Lipsky M (1977) Street-level bureaucrats and institutional innovation: Implementing special-education reform. Harv Educ Rev 47(2):171–197. https://doi.org/10.17763/haer.47.2.v870r1v16786270x
Wise SB (2010) Climate change in the classroom: patterns, motivations, and barriers to instruction among Colorado science teachers. J Geosci Educ 58(5):297–309. https://doi.org/10.5408/1.3559695
Worth K (2017) Climate change skeptic group seeks to influence 200,000 teachers. PBS Frontline. https://www.pbs.org/wgbh/frontline/article/climate-change-skeptic-group-seeks-to-influence-200000-teachers/ Accessed 7 March 2019