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Climate Change in the Preservice Teacher's Mind

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Abstract Given the recent media attention on the public's shift in opinion toward being more skeptical about climate change, 154 preservice teachers' participated in an intervention in an elementary science methods course. Findings indicated that students developed a deeper level of concern about climate change. Their perceptions on the evidence for climate change, consensus of scientists, impacts of climate change, and influence of politics also changed significantly. The curriculum and instruction appear to be an important factor in increasing understanding of climate change and developing perceptions more aligned to those of climate scientists. More broadly, this study provides preliminary support for the value of providing a careful framing of the topic of climate change within the context of science methods courses.

Keywords Climate change · Perceptions · Preservice teacher education · Framing

Introduction

Global climate change has become an important planetary issue. Despite the scientific consensus about climate change and the potential risk, the media often portrays the science as controversial and subject to debate (Kellstedt et al. 2008; Washington and Cook 2011). In response, we have been integrating climate science

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content into elementary science methods courses (Lambert et al. 2011). Climate change is also an issue that is useful for teaching concepts spanning several fields of science, as well illustrating the nature of scientific inquiry (Washington and Cook 2011). For the past few years, we have been assessing our students' knowledge of climate science concepts (Lambert et al. 2012). However, given the recent media attention and reports on the public's shift in opinion toward being more skeptical, we began to question our students' overall concern and perceptions about climate change.

Climate Change as a Frame in Preservice Teacher Education

One common way to interest someone in a topic is to use frames. Frames are interpretive storylines that help organize central ideas or define a controversy to resonate with core values and assumptions (Nisbet and Mooney 2007). Framing, a concept originating in sociolinguistics and anthropology (Goffman 1974; Tannen 1993), has more recently emerged as an active area of research in the science education literature (e.g., Berland and Hammer 2011; Russ et al. 2012). Framing describes the way people make sense of a situation or something they read or hear on the news. People's expectations and beliefs, based on past experiences, come into play in framing. Over recent decades, framing is often applied to the way that news, ideas, and issues are reported in the media (Hulme 2009). Frames help citizens rapidly identify why an issue may be a problem, who or what might be responsible for it, and what should be done about it. The most successful communicators are adept at framing, whether using frames intentionally or intuitively (Nisbet 2011). Scientists use frames to motivate greater interest and concern or to shape preferences for policies informed by, or supportive of science (Nisbet 2010).

Framing of climate change has changed from the 1980s to the present by emphasizing certain aspects of the issue (i.e., as an environmental issue, a development issue, or a national or global security issue) while de-emphasizing others (Hulme 2009). Much of the media coverage has offered audiences more ideologically focused frames (Nisbet 2010). For example, in the 1990s, climate change was framed as a scientific debate, requiring further research before United States government action is taken or this action would result in an economic burden on the country. In 2006, "An Inconvenient Truth" was released and climate change was framed as a looming crisis, as an attempt by Al Gore, many environmentalists, and some scientists to counter the uncertainty and economic development frames from the previous decade (Nisbet 2010). E.O. Wilson also frames climate change as not just a scientific matter, but also a moral and ethical matter (Nisbet 2010). An "Inconvenient Truth" also frames climate change as a moral and ethical issue. Since the release of the film, there appears to be a shift toward framing climate change as an energy challenge. Nordhaus and Schellenberger (2007) claim that refocusing messages and building coalitions to support innovative energy technology and sustainable economic prosperity is the way to achieve meaningful action on climate change. This focus on energy is evident in the United States Department of Energy's publication, *Energy Literacy: Essential Principles and Fundamental Concepts for*

Energy Education (DOE 2012). Climate change as a public health issue is also emerging as an interpretative frame.

We have applied the idea of framing to our thematic approach within our elementary science methods course curriculum. We presume that organizing science content around a theme with a real-world context, such as climate change, will increase students' interest and motivation to learn. According to a NRC (2000) report, *How People Learn,* "learners of all ages are more motivated when they can see the usefulness of what they are learning and when they can use that information to do something that has an impact on others" (NRC 2000, p. 61). Another NRC (2002) report, *Learning and Understanding,* contends that, if a goal of education is to teach students so that they can transfer new knowledge, it is important that learning involve "applications and take place in the context of authentic activities" (National Research Council 2002, p. 128). Reiser, Krajcik, Moje, and Marx (2008) have argued that connecting learning experiences to students' own lives, *contextualization*, provides motivation, a need to know. If students see the importance of what they are learning about to their own lives, they will tend to develop a deeper understanding of the science concepts.

Research Questions. This study examines changes in preservice elementary teachers' concern and perceptions about climate change after participation in an intervention situated in an elementary science methods course. The following research questions guided the study:

1. What changes are evident in overall concern about climate change?
2. What changes are there in perceptions about knowledge of climate change?
3. Is there a relationship between level of concern and perception about knowledge of climate change?
4. What changes are there in perceptions about constructs of climate change (e.g., causes, evidence and impacts, solutions, scientific consensus, influence of politics, and trust of information sources)?

Research on teacher beliefs, interest in science, scientific literacy, and the public's perception of climate change provides the theoretical framework for this study.

Theoretical Framework

Teacher Beliefs

Teacher beliefs is a concept related to attitudes and values (Pajares 1992; Richardson 1996). In our study, we focus on preservice teachers' beliefs about teaching and learning and epistemology in specific discipline areas (i.e., climate change). Beliefs are based on prior experience and personality traits (Stooksberry et al. 2009). Beliefs affect how we are inclined to think and act in a particular context (e.g., during classroom instruction interacting with students) (Rimm-Kaufman et al. 2006). Assumptions arise from these beliefs. It is these assumptions that will either allow or disallow a preservice teacher to embrace new ideas (Bryan 2003). We agree with Decker and Rimm-Kaufman (2008) that, while preservice teachers' beliefs cannot be assumed to be equivalent to teaching practice, they are important to consider in preservice teacher education. We recognize that this one experience will probably not fundamentally change belief structures that have been established over many years. However, we are optimistic, based on the findings of several studies (e.g., Brownlee et al. 2001; So and Watkins 2005) that preservice teacher's beliefs can be modified during even one or two semester preservice teacher education programs. We embrace the advice of Seung et al. (2011) that the first step is identifying current beliefs at the beginning of the preservice program in order to plan for activities that can lead to changes in their beliefs about teaching and learning and eventually in teaching practice in their beginning years as classroom teachers. Therefore, we presume that providing an opportunity for preservice teachers to learn more about climate change in a science methods course will have some effect on their knowledge and beliefs and that this is an important first step in their development as teachers. One approach to modifying beliefs is to increase preservice teachers' interest in science and teaching science.

Interest in Science

Climate change is an issue facing our planet that is complex, abstract, and difficult to understand without in-depth study and analysis. Yet, the public increasingly desires information that is in the form of easily expressed and digested snippets. Saylan and Blumstein (2011) stress that climate change is one issue that cannot be learned through this approach. They further propose that the public must be informed about environmental issues and stimulated to act and that the primary responsibility for making this happen falls on education.

The construct of interest has a deep literature base in psychology (Ainley 2006; Schraw and Lehman 2001; Smith et al. 2007). There is general agreement in motivational psychology that there are two aspects to interest. One, personal science interest, resides in the individual (Deci 1992; Hidi 1990; Schraw et al. 1995) and is recognized as having a profound effect on motivation. The other is usually referred to as situational interest, or what has been termed "interestingness" (Mitchel and Gilson 1997; Pintrich and Schunk 1996), which tries to account for the interaction of environmental variables with an individual's cognitive interest. Both aspects come into play in creating one's interest in a discipline such as science. This study argues that having strong interest in science enhances one's confidence in teaching it. We teach what we know more convincingly (Bleicher 2007).

We think that engaging preservice teachers in studying a current environmental science issue, such as climate change, will increase their awareness and interest in the topic and in science. Today's public has wider access to science information than any other time in history. Yet the public's knowledge about climate change remains modest (National Science Board 2008). According to Nisbet (2010), a major reason for this knowledge gap is due to choice and the public's preference or lack of interest in public affairs and science-related information (Prior 2005). This creates the paradox of a small population of citizens who are interested in becoming more informed, while the broader American public remains disengaged (Nisbet 2010).

Scientific Literacy

FrameWorks Institute is an organization dedicated to translating and modeling relevant scholarly research on framing public debate about social problems (FrameWorks Institute 2006). This organization believes that the lack of understanding of basic issues is the root cause of public misunderstandings about climate change. It claims that Americans do not need further convincing that climate change is real and that there are severe negative consequences. What they need, instead, is deeper understanding (Bales 2009). Due to a lack of foundational knowledge about climate change, Americans can easily become skeptical of what they view as political posturing, scientific overstatement, or environmentalist exaggeration, leading them to either disengage from trying to understand the topic, or to embrace solutions that are ineffective (Bales 2009). Somerville and Hassol (2011) argue that one of the major factors for the large-scale public confusion about climate change is scientific illiteracy. They list additional factors such as follows: a well-funded disinformation campaign; the media's handling of the topic as if it is a debate with equally credible sides; and the way that scientists communicate about the topic.

Recently, the National Research Council (NRC) established the Committee on Conceptual Framework of New K-12 Science Education Standards. Their task was to develop a framework to guide the writing of new science standards for science education that would ensure that by the end of 12th grade, all students would have sufficient knowledge of scientific and engineering principles to engage in public discussion on science-related issues (NRC 2012). The rationale for developing new standards is based on the accumulation of new scientific knowledge and research on the teaching and learning of science over the past 15 years. The Next Generation Science Standards will include three dimensions: practices that scientists engage into investigate and build models and theories about the natural world; crosscutting concepts that have application across all domains of science; and disciplinary core ideas in the physical, life, earth and space sciences, and engineering, technology, and applications of science.

Global climate change is one of the core ideas in the earth and space sciences domain of the Next Generation Science Standards. By grade 5, the framework calls for students to understand the basic concepts of climate change and the impact to humans and other organisms; by grade 8, to understand the role of human activities on global climate change; and by grade 12, to not only understand the concepts listed previously but to understand the science, engineering, and technology concepts of possible solutions to slow its rate and consequences. (NRC 2012).

It is therefore imperative to educate future teachers on the issue of climate change. It is common knowledge among elementary science methods' instructors that students come to their courses with limited science knowledge, especially about climate change (Lambert and DeBoer 2007; Lambert et al. 2010). Many preservice teachers hold some of the same alternative conceptions about climate change as those of middle- and high-school students (Lambert et al. 2012). As these teachers prepare to go out into our schools, they must be appropriately prepared.

The Public's Perceptions About Climate Change

The need for a more thorough understanding of the concepts of climate change is highlighted by several recent studies on the public perceptions and attitudes on the subject. The most comprehensive and significant are the following. Climate Change in the American Mind is a series of reports on national surveys of Americans' climate change and energy beliefs, attitudes, policy support, and behavior. The Yale Project on Climate Change Communication and the George Mason University Center for Climate Change Communication have released four reports that are relevant to our study, titled American's Global Warming Beliefs and Attitudes, over the past few years (January 2011; May 2011; Leiserowitz et al. 2011c; and November 2011; and March 2012).

Global Warming's Six Americas (2009, January 2010; June 2010, May 2011) is a progression of reports in the Climate Change in the American Mind series. In the first report (Maibach et al. 2009), six distinct groups of Americans were identified and profiled based on a large, nationally representative survey of the public's beliefs, attitudes, risk perceptions, policy preferences, behaviors, barriers to action, motivations, and values. These groups form a continuum beginning with the "alarmed" group, who are convinced of the reality and seriousness of global warming and are taking personal and political action to address it, followed by the "concerned" group, who are also convinced that global warming is happening and a serious problem, but are not yet taking action to address it; the "cautious" group, who believe global warming is a problem but not urgent, and who are unsure whether it is human-caused; the "disengaged" group, who do not know much about global warming or whether it is happening and have not thought much about it; the "doubtful" group, who are not sure whether global warming is happening and believe that if it is, it is natural and a distance threat; and finally, at the other end of the continuum, the "dismissive" group, who are very sure global warming is not happening and are actively involved as opponents of a national effort to reduce greenhouse gas emissions.

The National Survey of American Public Opinion on Global Warming (Krosnick and MacInnis 2011), American Teens' Knowledge of Climate Change (Leiserowitz et al. 2011a, b), and a Gallup Poll study (March 2011) are other recent surveys on the public's opinions on climate change. The results of our study will be compared to these national surveys throughout the body of this paper.

Based on this rationale and results of these recent studies that indicate a skeptic public, we framed climate change to the preservice teachers as a crosscutting theme, as well as a core idea in the Next Generation Science Standards. We propose that studying the issue of climate change will help preservice teachers not only become more interested in the topic, but also be more prepared to teach core science concepts spanning several disciplines (physical, life, and earth sciences). Framing climate science as an interdisciplinary science can also highlight the "practice of scientific inquiry" and help the preservice teachers become more analytical and able to differentiate scientific evidence from opinions.

Methods

The 154 participants in this study were preservice teacher candidates enrolled in an undergraduate elementary (Kindergarten–8th grade level) science methods course taught by the authors at a large southeastern Hispanic-serving university. This methods course is usually taken one or two semesters prior to a student teaching internship. All but three of the students were female, and approximately 80 % were under the age of 27. Approximately 50 % were not from underrepresented minority populations. Most students had completed two science courses at the undergraduate level in the biological and earth sciences prior to enrolling in the methods course.

Context of the Study: The Science Methods Course

Curriculum and instructional materials were developed and integrated into the elementary science methods course as a specific intervention for enhancing awareness and knowledge about climate change. Framing was used as a guiding principle for the curriculum development. Students were first introduced to the "story" of climate change through the film, "An Inconvenient Truth." The film presented the evidence for climate change. We framed the classroom discussion after the film to establish classroom discourse in which scientific evidence was set as an expectation by students. Thus, early in the course, we modeled the same kind of evidence-based discourse valued in the scientific community as the basis for discussions.

Students were provided a 30-page study guide, developed by one of the authors, based on a careful framing of the core science concepts underlying weather and climate change. The guide was sequenced in a "storyline" that builds on the basics for understanding the atmospheric composition and factors that affect weather and climate (e.g., latitude and the seasons, heat transfer, the electromagnetic spectrum, Earth's energy budget, water cycle, air pressure and winds, and ocean currents). An explanation of the greenhouse effect—and how an amplified greenhouse effect changes the energy balance and causes a rise in global mean temperature—followed and transitioned the students to the issue of climate change. Students were then introduced to the methods used to study past climates, the natural and human-induced causes, the observed and projected impacts, and finally suggestions for mitigating and adapting to climate change. Classroom instruction correlated with the study guide content framing sequence. Concepts were taught using simple controlled investigations and Bybee's (1997) 5-E (i.e., engage, explore, explain, extend, evaluate) version of the Learning Cycle (Karplus and Thier 1967). Table 1 summarizes the sequence of course/study guide topics and the alignment of inquiry-based lessons and investigations integrated in class instruction. Students were also assigned questions to guide their reading and reflections on the lessons and investigations. The fidelity of the framing was constantly discussed by the authors throughout the intervention, and adjustments made when necessary, to ensure consistency of the instructional approach.

Table 1 Global climate change as a theme to teach science concepts to preservice elementary science teachers

Global climate change storyline	Examples of 5-E learning cycle lesson topics (LC) and controlled investigations (CI)
The atmosphere	
The composition of the atmosphere	
The ancient atmosphere	
Ozone and the Ozone Hole	
Factors that affect climate	
Weather versus climate	Does the area of earth's surface receiving sunlight vary at different latitudes? (CI)
Latitude and climate—the seasons	
Heat and earth's energy budget	The reasons for the seasons (LC)
Heat transfer (conduction, convection, and radiation)	Heat capacity: does land or water absorb and lose heat faster? (CI)
Electromagnetic spectrum	
Heat properties of water—heat capacity	The hydrologic cycle (LC)
Water cycle	
Air pressure and winds	
Local winds	
Global wind patterns	
Ocean currents	Ocean currents (LC)
Surface currents	The effect of temperature and salinity on the density of water (CI)
Deep density-driven currents	
El Niño-southern oscillation	
Climate change	
The natural and amplified greenhouse effect	The effect of carbon dioxide on earth's temperature (CI)
Methods for studying climate change	
Causes of climate change	
Natural causes of climate change	

Table 1 continued

Global climate change storyline	Examples of 5-E learning cycle lesson topics (LC) and controlled investigations (CI)
Volcanic eruptions, sunspot cycles, plate tectonics, and orbital changes	Photosynthesis & respiration (LC)
Carbon cycle and natural cycles of carbon dioxide exchange	The rock cycle and coal formation (LC)
Human activities and climate change	
Burning of fossil fuels	
Rainforest destruction	
Potential impacts of climate change	The impact of type of ice melt (Glaciers versus floating ice) on sea level rise (CI)
Global warming	Albedo: Does the color on an object affect the amount of light (Heat) absorbed? (CI)
Melting of glaciers and ice caps	The effect of the pH of the oceans on dissolution of calcium carbonate shells (CI)
Sea level rise	
Lower pH of oceans	
Changes related to water cycle	
Precipitation and droughts, forest fires	
Feedbacks	
Cultural and geographic impact	
Ecosystem Impact (Polar Bears, Coral Reefs)	
Increased intensity of storms	
Solutions	
Alternative energy sources	Tragedy of the Commons (LC)
Reduction of greenhouse gas emissions	Calculating Your Carbon Footprint (LC)
Reducing your carbon footprint	

Views on Climate Change (VCC) Instrument

The instrument, Views on Climate Change (VCC), was constructed to assess students' perspectives on global climate change at the beginning and end of the semester-long course. A few items were adapted from the Global Warming's Six Americas instrument (Leiserowitz et al. 2011b). Other items were constructed over the past 3 years as we studied the growth of climate science content knowledge of preservice teachers. These items were developed based on preservice teachers' written and oral discussions about climate change.

The 43-item VCC instrument was developed to specifically measure students' perspectives on (1) their self-reported knowledge of climate change, (2) evidence (or indicators) of climate change, (3) causes of climate change, (4) scientific consensus, (5) impacts of climate change, (6) actions or solutions, (7) influence of politics on the issue of climate change, and (8) trust of sources of information. Table 2 shows the item probes used to measure each construct. The reliability of the VCC was $\alpha = 0.811$ as determined using the Cronbach alpha statistical test.

Findings

The following discussion examines the preservice teachers' changes in views for each construct on the VCC as well as an examination of their overall concern about climate change in general. We also compare our students' pre- and post-views with those published in national survey results.

Knowledge and Concern

Preservice Teachers' Knowledge and Concern

The first five Likert-scale VCC items measure self-reported knowledge—how informed students felt about global climate change, causes, consequences, solutions, and competence to evaluate scientific information about it. Self-reported knowledge scores could range from a low of 5 to a high of 25 points. A paired sample t test was conducted to compare changes in students' self-reported knowledge and levels of concern before and after the methods course. The students' self-reported knowledge of climate change increased significantly, from 13.19 points (52 %) to 21.38 points (84 %) out of a possible 25 points after participation in the methods course (see Table 3). The students' self-reported data results are validated by the significant increase in their climate change knowledge about the greenhouse effect, carbon cycle, and global climate change causes and consequences on another climate change content assessment measure. See Lambert et al. (2012) for more details.

To indicate overall concern about climate change, items 6–18, Likert-scale items, and items 25, 28, and 29, compatible multiple-choice items, were added together. Although in multiple-choice format, some of these additional items were written in ordinal sequence indicating a steady gradation of perspective that matched the Likert-scale items and could be combined without violating statistical model

Table 2 Views on climate change instrument constructs and item probes

Construct	Item number and probe
Self-reported knowledge of climate change	Items 1–5 (e.g., How informed do you feel about the causes of global warming)
Evidence (Indicators) of climate change	6. Convinced that global warming is happening***
	8. Weather extremes as normal variability
	9. Rate of current warming trend
	26. a–d Confidence in global temperature record, ice caps and glaciers melting, sea level rising, reliable climate models.
Causes of climate change	7. Influence of human activity on global warming
	24. Cause of recent climate change*** (MC*: 5 choices)
Scientific consensus	12. Whether global warming is a hoax perpetrated on Americans
	13. Whether most scientists agree that global warming is happening***
	16. Whether scientists agree on human activity causing global warming***
	25. Whether most scientists agree that global warming is happening and that it is very likely due to human activity (MC: Continuum of 5 choices**)
Impacts of climate change	14. Global warming potential impact as a urgent issue
	15. Fifty years before global warming impacts will harm
	20. Personal experience of effects of global warming***
	21. When climate change will impact people in Florida
	22. When climate change will impact people of U.S. ***
	23. When climate change will impact people of world***
Actions/solutions	10. Humans ability to reduce global warming***
	17. Whether new technology can solve global warming***
	18. Whether U.S. should reduce greenhouse emissions***
	28. Views on humans' ability to reduce the effects of global warming*** (MC: Continuum of 5 choices)
	29. Why United States should make efforts to reduce global warming (MC: Continuum of 5 choices)
	30. Personal steps to reduce carbon footprint (MC: 5 choices)
	31. Personal actions to reduce global warming (MC: 10 items—can choose multiple items)
Influence of politics	11. Views on whether global warming should be a political argument
	19. Views on whether Republicans and Democrats agree about global warming
Trust of Sources	27 a–i. Trust in scientists, Obama, Al Gore, newspapers, news, radio, etc.***
Identification with 6 America's group	32. Choice of one of the 6 Six America's levels of concern***

MC* Multiple choice; ** Continuum of choices is a scaled series of choices that is equivalent to a fully anchored Likert-scale; *** Items were adapted from Leiserowitz et al. (2011b, c and Leiserowitz et al. (2012)

Table 3 Paired sample *t* test (Two-Tailed) for items 1–5 on self-reported knowledge of and concern about climate change

	Mean	SD	SEM	*t*	*p**
Knowledge of climate change					
Pre	13.19	3.62	0.294	24.56	.000
Post	21.38	2.85	0.232		
Concern about climate change					
Pre	58.000	7.150	0.611	10.015	.000
Post	64.329	7.350	0.628		

*Level of significance, $p \leq .05$; $n = 154$

constraints. These overall concern scores could range from 15 to 75, the higher score indicating more concern about climate change. The results indicated that, after completing the methods course, students had developed a level of concern about climate change that was significantly closer, from 58.00 (77 %) to 64.33 (86 %), to that held by the majority of climate scientists (Table 3).

The overall measure of concern measured by the VCC can be deconstructed into the specific categories listed in Table 2. These are analyzed in more detail in the following sections. This overall measure was constructed here in order to get a global picture of our students' concern about climate change. It was also used to test the correlation to a single VCC item (item 32) that asked students to identify with one of the Six America's study categories, ranging from alarmed to dismissive (Leiserowitz et al. 2010). The correlation was strong and positive ($r = 0.482$) which allows us to use this single-item response as a valid measure of identification with one of the Six America's categories.

Of the 154 preservice teachers, 54 % were either concerned or alarmed about global warming at the beginning of the course, compared to 76 % were at the end. And while the percentage of students who were doubtful did not significantly decrease, no students were disengaged in the issue of climate change by the end of the course.

A Comparison of Preservice Teachers' to the Public's Level of Knowledge and Concern

Within the public, there is a disparity in the amount of understanding of the basic concepts, as well as a debate on the existence and seriousness of climate change. Leiserowitz et al. (2010) found that 61 % of the respondents reported that they were either "very well informed" or "fairly well informed" about global warming; yet in a related study (Leiserowitz et al. 2010), only 46 % of adults and 54 % of teens received a passing grade on basic climate change knowledge. This corresponds reasonably well to our study's findings of 52 % at the beginning of the methods course. It is reassuring that 84 % of our students' reported feeling well informed about climate change by the end of the course.

Regarding concern about climate change, a March 2011 Gallup Poll reported that Americans were split on their concern about global warming, with 51 % reported worrying a "great deal" or a "fair amount", while 48 % worrying "not much" or "not at all" (Gallup 2011). This is in contrast to the public opinion study that found that only 39 % of Americans could be classified as "alarmed" or "concerned", while 25 % were classified as "doubtful" or "dismissive" (Leiserowitz et al. 2011a, d). Table 4 shows a comparison of the preservice teachers' concern about global warming to the Generation X groups (Miller 2012). We do not presume that the respondents in the Generation X and our study are equivalent groups, but see value in the comparison as providing a larger context in which to understand the results in this present study.

Leiserowitz et al. 2011a, d also found that self-reported knowledge is related to the level of concern, with 85 % of the "alarmed" group reporting that they were well informed and 68 % of the "concerned" group reporting that they "well informed" or "fairly well informed". However, the report also found that 91 % of the "dismissive" group thought that they were "well informed" or "fairly well informed." Overall, the study reported that 61 % of Americans felt confident in their knowledge, whereas 38 % felt that they were either "not at all" or "not very well informed."

Pre-overall identification with a Six America's category showed a moderate positive correlation to self-reported climate change knowledge ($r = 0.330$) and likewise, for the post-correlations, ($r = 0.331$). This is empirical evidence that knowledge and concern are related and that the relationship predicts that a person with high self-reported knowledge is likely to be highly concerned about climate change. There were significant ANOVA results for the pre-measure taken before students began the methods course. Table 5 shows the significant ANOVA results for pre-self-reported knowledge of climate change for the six categories.

The ANOVA results indicate that there were differences among the six possible groups (Alarmed, Concerned, Cautious, Disengaged, Doubtful, and Dismissive). Fisher's Least Significant Differences (LSD) post hoc comparisons were run to determine which specific groups showed these differences.

Table 4 Concern about global warming of preservice teachers compared to generation X

Item	Frequency (%)			
	Concern level	Our study Pre	Our study Post	Generation X
Overall, how would your characterize your feelings about global warming? (Item 32)	Alarmed	11	29	5
	Concerned	58	60	18
	Cautious	18	9	25
	Disengaged	10	0	41
	Doubtful	3	2	6
	Dismissive	0	0	4

$n = 154$, preservice teachers; $n = 2{,}924$, Generation X

Table 5 ANOVA: pre-self-reported climate change knowledge across the six Americas' groups

Variable	Sum of squares	Mean squares	*F*	Sig.
Pre-self-reported GCC knowledge				
Between groups	180.80	45.20	3.62	.008
Within groups	1560.28	12.48		

* Level of significance, $p \leq .01$; $n = 154$

Table 6 Pre-knowledge LSD post hoc comparisons, effect size, and cohen category

Group	Mean	SD	Group	Mean	SD	Effect size**	Cohen category*
Concerned (89***)	13.88	3.17	Doubtful (5)	9.40	5.59	0.44	Medium
Concerned (89)	13.88	3.17	Disengaged (15)	11.33	3.46	0.36	Medium
Alarmed (17)	14.29	3.10	Doubtful (5)	9.40	5.59	0.36	Medium
Alarmed (17)	14.29	3.10	Disengaged (15)	11.33	3.46	0.41	Medium

*** Number of preservice teachers in this category out of a total of 154)

** Effect Size = Difference of Means/Pooled Standard Deviation

* Cohen Category Small < .20 Med = 0.50 Large > .80

Table 7 ANOVA: post-self-reported climate change knowledge across the six Americas' groups

Variable	Sum of squares	Mean squares	*F*	Sig.
Post-self-reported CC knowledge				
Between groups	87.03	29.01	3.85	.011
Within groups	971.70	7.53		

LSD Post Hoc Comparisons

LSD post hoc comparisons are presented in Table 6 below. They revealed that the "alarmed" and "concerned" students indicated significantly higher self-reported knowledge of climate change than either the "doubtful" or "disengaged" students. The effect sizes were determined to be medium by Cohen category evaluation (Cohen 1992).

Post-ANOVA of Mean Differences by Six America's Category

ANOVA for the post-self-reported knowledge of GCC yielded significant results (Table 7). We interpret this as indicating that after completing the methods course, students shifted significantly toward the "concerned" and "alarmed" groups and also felt that they had more knowledge of climate change. This resulted in significant group differences on this measure.

LSD Post Hoc Comparisons

LSD post hoc comparisons are presented in Table 8 below. They revealed that the "alarmed" and "concerned" students indicated significantly higher self-reported

Table 8 Post-knowledge LSD post hoc comparisons, effect size, and Cohen category

Group	Mean	SD	Group	Mean	SD	Effect size**	Cohen category*
Alarmed (45***)	22.32	2.46	Concerned (92)	21.06	2.82	0.23	Small
Alarmed (45)	22.32	2.46	Cautious (14)	19.86	3.28	0.39	Medium

*** Number of preservice teachers in this category out of a total of 154

** Effect Size = Difference of Means/Pooled Standard Deviation

* Cohen Category Small < .20 Med = 0.50 Large > .80

knowledge of climate change than either the "doubtful" or "disengaged" students. The effect sizes were determined to be small and medium by Cohen category evaluation.

This empirical evidence seems to support the commonsense notion that the more knowledgeable we are the more concern we may have for the topic at hand. In fact, we can say, with some justification, that the more we are concerned, the more likely that we might take action about the concern. Our students demonstrated that they thought they were more knowledgeable about climate change after completing the methods course. Our own assessment of their knowledge supports the fact that they did gain in their knowledge (Lambert et al. 2012). We can be confident that the gain in knowledge is related to the increase in their concern about climate change. Specifically, the highest concern category, "alarmed," felt that they had gained more information about climate knowledge from the course than either the "concerned" or "cautious" students. These results give us great hope as instructors that our preservice teachers will be prepared to overcome the misinformation about climate change that is prevalent in the public today.

Perceptions on the Causes of and Consensus About Climate Change

The students' views on the causes of climate change were more reflective of scientists' views at the end of the course; however, the change was not significant. At the beginning of instruction, 68 % of the students were convinced that human activity played a role in global warming compared to 88 % at the end. On a related item, students were asked to choose the main cause of climate change over the last 100 years. On the pre-assessment, 52 % chose human activity, and the remainder of the students were not sure whether it was due to changes in the sun's energy output, natural variability, or the cyclical changes in Earth's tilt and orbit. On the post-assessment, 74 % chose human activity as the main cause of climate change over the past 100 years.

The students' responses indicate that they do believe that there is more scientific consensus on the cause of climate change by the end of the course (paired sample t test result: $t = 6.830$, $p < 0.01$). Although 97 % of climate researchers actively publishing in the field agree that climate change is occurring (Somerville and Hassol 2011, Anderegg et al. 2010), the May 2011 Yale study showed that only 64 % of American adults and 54 % of teens think that the world is warming, and 50 % of adults and 57 % of teens believe that, if global warming indeed exists, it is caused by human activities (Leiserowitz et al. 2011a, d).

Perceptions on the Evidence (or Indicators) and Impacts of Climate Change

The students' views about the evidence (or indicators) of climate change significantly changed to be more reflective of climate scientists (paired sample *t* test result: $t = 13.222$, $p < 0.01$). On the post-survey, 63 % of the students were convinced that global warming is happening. Reassuringly to us, as teacher educators, 87 % of the students thought that the warming trend was occurring much faster since the industrial revolution. Students' confidence in the reliability of the worldwide temperature record, melting ice caps and glaciers, rising sea level, and reliability of climate models increased significantly.

After participation in the methods course, students felt that climate change was a more urgent issue for Florida, as well as the United States and world (paired sample *t* test result: $t = 4.241$, $p < 0.01$). Our students are more worried about the impact of climate change than the general public. When they were asked when they believed people in the United States would be harmed, 32 % reported that they are being harmed now, while 12 % believed that it will occur in the next 10 years; 13 %, in the next 20 years, and 11 %, in 100 years. When asked when global warming will start to harm people around the world, 34 % reported that "they are being harmed now," while 12 % reported within 10 years; 12 %, within 50 years, and 11 %, within 100 years.

Perceptions on Actions to Mitigate Climate Change

All percentages in this section are for the post-VCC results after completion of the methods course. The students (80 %) were optimistic that humans could do something to reduce global warming; yet when asked if they would do so successfully in item number 28, they were not as optimistic. Approximately 50 % of the students thought that humans could reduce global warming, but are not willing to change their behavior or lifestyle. Most (88 %) of the students disagreed that the United States should reduce its emissions only if other countries do so, and about two-thirds thought that the United States should make the effort even if there are great economic costs. The number of students, who are already taking steps to reduce their carbon footprints, nearly doubled by the end of the course. Students reported carpooling, buying more efficient cars, reducing electric use, and recycling as the main actions that they are taking.

Influence of Politics

The students' responses indicated that they saw climate change as more politicized at the end of the course (paired sample *t* test result: $t = 2.181$, $p < 0.05$). More students, a change from 56 to 62 %, thought that Republicans and Democrats generally disagreed about global warming. In a survey conducted by Krosnick and

MacInnis (2011), 66 % of Republicans and 91 % of Democrats believe that global warming has been happening.

Trust of Sources

The students' responses indicated that they had more trust in scientists by the end of the course—a change from 64 to 79 %. The students indicated that they had more trust (from 16 to 25 %) in President Obama, but even more trust (from 17 to 54 %) in former vice president Gore. Students reported that viewing the film, "An Inconvenient Truth," influenced their trust in Gore. Students also seemed to gain trust in professors—a change from 40 to 59 %. Students had little trust (less than 20 %) in the television news media. They did have more trust (almost 30 %) trust in National Public Radio news.

Regarding whom the public trusts, Leiserowitz et al. (2012) reported that 71 % reported trusting scientists and 62 % said they trusted the EPA as a source of information. Compared to the preservice teachers, the public (46 %) had more trust in President Obama. Also, the public (38 %) seemed more trusting of the general news media than the students in our study were.

Discussion

This study of our students' (preservice teachers) perceptions about climate change provides preliminary support for the value of providing a careful framing of the topic of climate change within the context of the science methods course. Our findings indicate that this approach was successful in promoting more scientific perceptions about climate change for several reasons.

First, we integrated disciplinary core ideas, as described in *A Framework for K-12 Science Education* (NRC 2012). We focused on the relevant physical, life, and earth and space sciences; and the engineering, technology, and applications of science ideas so that the students could see how they would be able to integrate climate change into K-8th grade science curriculum. A science methods course also incorporates instructional strategies. Hence, we modeled an inquiry-based approach in lessons. For example, in a lesson on the hydrologic cycle, which is a commonly taught at several grade levels, students constructed a physical model of the hydrologic cycle. This lesson also reviewed the phases of matter and properties of water. We then demonstrated how to apply this concept to climate change. Students had not considered how a warmer atmosphere causes more evaporation in certain locations and then is capable of holding more water vapor. An atmosphere with more water vapor results in more intense rainfall in another location. Students could then see the connections between the hydrologic cycle and events covered in the media from extreme weather events, such as floods or droughts, to fires or impacts on agriculture.

Second, we used the practices of scientific inquiry, as described in *A Framework for K-12 Science Education* (NRC 2012), as an underlying frame or storyline throughout the course. Hulme (2009) suggests that originators of stories may frame according to their specific worldview or according to their understanding of the worldviews of the audience(s) they are trying to reach. In the context of a science methods course, it was appropriate to provide opportunities for students to follow practices of scientific inquiry. This nurtured their analytical skills and enabled them to differentiate scientific evidence from opinions. One of their first assignments was to evaluate the evidence and explanations presented in the film, "An Inconvenient Truth." Nisbet (2011) proposed that the film used "impending disaster" as a frame. Our students were impacted by this "disaster" frame, especially living along the coast in southeast Florida. They also became more engaged in the issue by learning about the practices of scientific inquiry. Engaging students in the practices of science helps them understand how scientific knowledge develops over time (NRC 2012). Students planned and conducted simple investigations on a variety of topics related to climate change. They were able to see how simple investigations could be applied to real-world phenomena as they viewed the film. For example, one investigation was to explore the question of whether the location of the melting ice causes a difference in sea level rise. The film illustrated ice and water displacement and why the partial melting of Greenland or Antarctica would raise sea level and the melting of the Arctic ice would not. In another investigation, students studied albedo and heat absorption. This investigation allowed them to come to the conclusion that, while the melting of the Arctic ice would not raise sea level, it would allow a darker Arctic Ocean to absorb more heat, causing more global warming.

Finally, climate change is an issue that is constantly in the media. Hence, students came to the methods course with some familiarity of the topic. Yet, this did not necessarily make them interested or concerned about climate change. By the end of the methods course, no students were "disengaged." This finding was encouraging when compared to the 41 % of Generation X (Miller 2012) who are "disengaged." Most of the students reported becoming more interested in learning about climate change and science, in general. Many reported that this was due to becoming more aware of the issue and the urgency of finding solutions. In summary, the careful framing of climate change seems to have been effective in changing perceptions about it and promoting interest in the issue. The following responses are representative student reflections on the course.

> Studying this issue has led me to see that science has an impact on my everyday life. I can see how the scientific process is important and is an integral part of everything I do. I am much more interested in climate change than I was previously. I can see the importance of it and how rapidly it is occurring. I not only want to be as educated on it as I can, but I also want to take a proactive role in preventing as much global warming as possible. (Student RB).
>
> Studying this issue has caused me to be more interested in climate change and I feel as though I had a change of heart because before I came into this class I didn't really care about global warming and climate change because I didn't know hardly anything about it. Now I feel as though I am obligated to do something about it. (Student PB)

It is encouraging that students developed views more aligned to those of climate scientists. For most constructs, when compared to the public's views, students' views were more aligned to scientists' views and overall more concerned. Krosnick and MacInnis (2011) found that the primary factor driving a person's overall level of concern about global warming was the belief that global warming is caused by human activity. Secondary factors were the public's trust in scientists, the belief that scientists are in agreement, and the overall level of attention being paid to the issue (i.e., media coverage).

Climate change science has unfortunately been highly politicized and misrepresented in the media. Future and practicing teachers need to understand the difference between appropriate scientific skepticism and denial of climate change. This study seems to indicate that the influence of perceptions about climate change can play a role in students' motivation to learn the science needed to understand this complex issue.

Implications for Science Teacher Education

Framing, the setting of an issue within an appropriate context to achieve a desired interpretation or perspective, can make climate science more accessible to the public (Center for Research on Environmental Decisions 2009). Based on our study, we think that framing can make climate science (and science in general) more accessible to preservice teachers. A frame is a conceptual term for an interpretive storyline that selectively emphasizes specific dimensions of a complex issue over others, while setting a train of thought in motion for audiences about who or what might be the cause of a problem, the relevance or importance of the issue, and what should be done in terms of policy or personal actions (Gamson and Modigliani 1989). *A Framework for K-12 Science Education* (NRC 2012) incorporates this notion of framing by selectively emphasizing scientific practices, crosscutting concepts, and core ideas.

In this study, we found that framing provided a platform for curriculum development that could support "interestingness" (Mitchel and Gilson 1997), that aspect of interest that can be affected most easily by educational experiences. Our hope is that increases in this aspect of interest would result in increases in preservice teachers' personal science interest. Our assumption is that increased personal science interest might lead to more likelihood that our preservice teachers would teach more science in elementary school settings. More empirical studies linking these two, science interest and science teaching, are an important area of future science education research.

Knowing the Preservice Teacher Audience

Climate science has the potential to integrate ideas from multiple disciplines using climate change as the organizing framework. It is a complex issue for most of our preservice teachers and therefore must be coherently framed in a way that is understandable and personally relevant. Cullen (2010) stresses the importance of knowing your audience. Audiences rely on framing to make sense of an issue. The public is faced with a daily barrage of competing or conflicting news stories and often must use their own framing of issues as a way of filtering or selecting stories that accord with these frames (Somerville 2012).

Effective framing depends on knowing the expectations, beliefs, and content knowledge of an audience. Our audience, students in our science methods course, was generally not confident in their science knowledge. Many students reported that they had not written a laboratory-type report on a scientific experiment. Yet, these students expected the methods course to help prepare them to teach many of the state science standards. Our students, as a group, expressed a range of perceptions about climate change. These perceptions were based on a number of variables, including beliefs that had developed from prior educational and life experiences (Stooksberry et al. 2009). Our careful framing of climate change was successful in gaining students' attention, establishing relevancy, and providing a coherent connection for several core science concepts. The framing was crucial to challenging prior beliefs and expectations that students brought with them to the methods course.

Framing climate change within the course curriculum with careful consideration can help preservice teachers learn to evaluate information in ways akin to scientists. For example, if climate change is framed as a result of an imbalance of incoming energy from the sun and outgoing energy from Earth, preservice teachers should develop a deep understanding of this one physical science concept and be more able to evaluate claims made in various sources of information. Cullen (2010) claims that the primary goal for the scientific community should be to help the general public understand the connection between fossil fuel burning, heat-trapping carbon dioxide pollution, and climate change impacts. She thinks that once the public connects the dots, their level of concern is raised.

The Importance of Coherence

The growing national consensus for greater coherence in K-12 science education was one motivation for developing A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC 2012). Standards are often long lists of detailed and disconnected facts. This approach may be alienating to young people and may also leave them with fragments of knowledge, little sense of the creative achievements of science, its inherent logic and consistency, and its universality (NRC 2012, p. 10). To move science education toward a more coherent vision, the framework proposes the concept of learning as a developmental progression, a limited number of core ideas in science and engineering, and an emphasis on integration of scientific explanations (i.e., content knowledge) and the practices needed to engage in scientific inquiry and engineering design.

Coherence refers to the relationships or connectedness between a larger conceptual whole and its component parts. One way to achieve coherence (besides fixing the problems that exist in disciplinary-based courses) is to contextualize the content around some non-disciplinary but still overarching concept or theme. Themes having to do with environmental issues, such as climate change, provide a way of addressing a wide range of concepts from the perspective of different disciplines. The approach to curricular organization that our study investigated is one in which fundamental ideas from a variety of science disciplines are integrated within a single real-world context, namely, climate science.

Framing helps provide an interpretative lens or filter for choosing resources to continue to develop their understanding of the science of climate change. Framing can help preservice teachers understand that the media often portrays a "false balance" even when over 97 % of scientists have reached consensus about human-caused climate change. With the multitude of ways to frame the issue of climate change, introducing preservice teachers to how framing has been used the field of communication can help them choose the most valid and reliable sources of information. Because of the changing nature of climate science knowledge and its relevance to societal issues, teachers must be able to understand the basic concepts and remain up-to-date on scientific issues (NRC 2012).

As science teacher educators, we need to be constantly questioning our own approaches to teaching science and science pedagogy. Considering our own use of framing in the way we present new science topics and science pedagogical approaches can be a useful strategy to challenge and/or build upon the science content knowledge, expectations, beliefs, and science interest that our preservice teachers bring with them.

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