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In-service Teachers' Attitudes, Knowledge and Classroom Teaching of Global Climate Change

Abstract

This study explores in-service teachers' attitudes and knowledge about a pressing environmental issue, *global climate change* (GCC), and how these may relate to their classroom teaching. In this work, nineteen teachers from Native American communities attended a professional development workshop that focused on enhancing their scientific understanding and classroom teaching of GCC. Teachers' responses to surveys and interviews revealed that the majority of them considered GCC as mainly human-induced and shared similar concerns about potential consequences of GCC, but their specific ecological beliefs varied to different degrees. Throughout the workshop, teachers became more aware of the urgency of GCC and the importance of incorporating climate issues into their science teaching. However, teachers' attitudes and beliefs about GCC were not strong indicators of their level of knowledge, as misconceptions were sometimes found among teachers who were very concerned about climate issues. This work opens up further discussions on the relationship between individuals' attitudes and knowledge about environmental issues. More importantly, it provides important implications for future professional development programs on climate change education and proposes effective tools to evaluate teachers' perspectives about GCC.

Introduction

The primary goal of environmental education is to develop students' sense of the relationship between humans and the environment (Desjean-Perrotta, Moseley, & Cantu, 2008). K-12 science classes offer opportunities to enhance students' environmental literacy, which lays important foundations for fulfilling this goal (Littledyke, 2008). However, existing literature shows that an increase in scientific knowledge about environmental issues may not necessarily parallel with pro-environmental attitudes or behaviors (Guy, Kashima, Walker, & O'Neill, 2014; Hamilton, 2011; Kollmus & Agyeman, 2002). The present study aims to explore the relationship between in-service teachers' attitudes and knowledge in the context of global climate change (GCC). In particular, three research questions guided this work:

(1) What are teachers' attitudes and beliefs about GCC and how do they change through professional development?
(2) What is the nature of teachers' knowledge about GCC and how does it relate to their attitudes?
(3) How do teachers' attitudes and knowledge relate to their classroom teaching of GCC?

Keywords: global climate change, attitudes, knowledge, professional development, climate change education

Literature Review

GCC involves "any substantial change in measures of climate (such as temperature or precipitation) lasting for an extended period (decades or longer)" which "may result from natural factors and processes or from human activities" (U.S. Environmental Protection Agency, 2014, p.3). Issues related to GCC have been a pressing concern and one of the grand challenges for scientists and educators (Crowley, 2000). Despite increasing evidence for GCC (e.g., Good et al., 2011), a considerable percentage of the U.S. public still doubt its seriousness and urgency (Leiserowitz, Maibach, Roser-Renouf, & Smith, 2011). GCC thus constitutes an important topic for both science and environmental education, and developing a scientific understanding of GCC is a prominent component of the *Next Generation Science Standards* (Achieve, Inc., 2013).

Teachers play a critical role in educating future generations about GCC. Research has shown that teachers' beliefs about science have important impacts on students' perspectives toward corresponding topics, and teachers often align teaching strategies with their own knowledge and beliefs (Duschl, 1990; Waters-Adams, 2006). Thus, to provide efficient support for climate change education in the classrooms, it is critical to first examine the nature of teachers' attitudes and knowledge regarding GCC.

Attitudes and Beliefs about GCC

The term *attitude* is often used interchangeably with *belief* (e.g., Oliver & Koballa, 1992; Lumpe, Haney, & Czerniak, 2000), but there is a distinction between these two constructs. Beliefs are propositions individuals hold to be true: they can be non-evidential and based on personal judgment and evaluation (Koballa & Crawley, 1985; Pajares, 1992). In contrast, attitudes are an individual's general feelings about certain things or situations. Bord, O'Connor, and Fisher (2000) defined attitude as a set of beliefs "connected with pursuing a given line of behavior and the relative rewards and costs connected with those outcomes" (p.207). Indeed, connections among beliefs can lead to the generation of certain attitudes, which may ultimately influence or determine behavior (Ajzen, 1985; Pajares, 1992).

Attitudes and beliefs are both critical for understanding people's perspectives

and predicting their behaviors regarding environmental issues. A comparison study on Gallup polls found that during 1989 and 2003, the U.S. public were increasingly worried about consequences of GCC and became more supportive of pro-environmental policies throughout these years (Brechin, 2003). Similarly, the Yale Project on Climate Change Communication reported that from 2011 to 2014, there was an 8% increase in Americans who believed that GCC is happening and a 10% increase in Americans who reported having taken more pro-environmental actions (Leiserowitz, Maibach, Roser-Renouf, Feinberg, & Rosenthal, 2014).

While there is a growing body of research that explores the general public's attitudes toward GCC, studies that specifically investigate in-service science teachers' perspectives about GCC are sparse. Teachers' attitudes and beliefs play an important role in how they organize knowledge and plan their teaching (Richardson, 1996; Taylor & Caldarelli, 2004; Waters-Adams, 2006), and can greatly affect the climate literacy of future generations. Studying teachers' attitudes and beliefs thus constitutes an essential step in promoting science and environmental education (Cheng & Monroe, 2011; Robertson, 1993; Wals, 1992). Therefore, the primary goal of this study is to measure in-service teachers' attitudes and beliefs about GCC.

Conceptual Knowledge about GCC

Given the complexity of climate science and mixed messages from the public media, GCC is a particularly challenging topic in environmental education. Despite the ongoing endeavors, misconceptions are still widespread among students and even teachers. One of the most common views students hold is that "ozone depletion" is a cause of global warming. Many students confuse stratospheric ozone with the greenhouse effect and believe that the greenhouse effect is the trapping of solar rays by the ozone layer (Lambert, Lindgren, & Bleicher, 2011). Some students make no distinction between the greenhouse effect and global warming, and consider that simply planting more trees and using renewable energy would prevent or resolve issues resulting from GCC (Shepardson, Niyogi, Choi, & Charusombat, 2011).

Compared to the heavy emphasis on students' knowledge about GCC, research on teachers' understanding of GCC is relatively limited. The few studies in this regard have revealed that, like students, pre-service teachers also hold misconceptions about GCC, greenhouse effect, and ozone layer depletion. For example, they confuse weather with climate, and incorrectly relate GCC to air pollution and ozone layer depletion (Groves & Pugh, 1999; Fortner, 2001; Papadimitriou, 2004). Nonetheless, little is known about whether such misconceptions also persist among in-service teachers. Hence, the second goal of this study is to explore in-service teachers' understanding about GCC.

Relationship between Attitudes and Knowledge about GCC

There have been ongoing debates regarding the relationship between individuals' attitudes and knowledge about environmental issues. Many researchers adopt a knowledge-deficit model (Hansen, Holm, Frewer, Robinson, & Sandoe, 2003) and consider that attitudes and knowledge operate together to elicit pro-environmental behaviors. Individuals may be more susceptible to initiating an action if they are familiar with the cause of a problem and believe in their coping abilities to solve the problem (Hungerford & Volk, 1990; Kollmiss & Agyeman, 2002). For instance, Papadimitriou (2004) found that pre-service teachers' climate literacy was related to their beliefs about GCC, and their level of GCC knowledge was a predictor of their pro-environmental actions. From this perspective, exposing individuals to more information about climate science may positively impact their personal efficacy for protecting the environment and perceptions about risks of GCC.

However, some researchers have argued that the relationship between attitudes and knowledge is not linear and many influential factors should be taken into consideration (Kellstedt, Zahran, & Vedlitz, 2008). Hines, Hungerford, and Tomera (1986) proposed a model of predictors of environmental behavior and suggested that the relationship between attitudes and knowledge is weak as it is constrained by "situational factors" such as economics and social pressures. High levels of knowledge and concerns thus do not necessarily guarantee that an individual will adopt pro-environmental behaviors (Monroe, 1993; Hwang, Kim, & Jeng, 2000). Maibach, Roser-Renouf, and Leiserowitz (2008) expanded the scope of this model to the context of GCC and added that pre-existing values and ideological orientations may act as a perceptual screen for the knowledge individuals take in and impact their perspectives toward GCC.

Given the inconclusive discussions concerning how attitudes and knowledge interact, the present study aims to extend the existing literature by exploring this relationship among in-service teachers. More importantly, this work further investigates how in-service teachers' attitudes and knowledge may relate to their teaching of GCC. As this work was embedded in the context of a teacher professional development program on climate change education, it provides important implications for teacher educators.

Method

Context

This research was part of a three-year NASA Innovations in Climate Education project, *CYCLES: Teachers Discovering Climate Change from a Native Perspective*. CYCLES aimed to enhance climate literacy in Native American communities through culturally-sensitive approaches. Challenges related to GCC are faced by all Americans, but Native American communities are especially concerned due to the adverse influence GCC imposes on their cultural and economic ties to the land. Thus, there is an urgent need to enhance the climate literacy of Native Americans so that they can be actively involved in policy making as it relates to climate change in their communities (Roehrig, Campbell, Dalbotten, & Varma, 2012). To meet this need, CYCLES provided a weeklong summer workshop and five follow-up daily workshops each year to engage science

teachers from Native American communities in professional development activities. These activities were designed to help teachers better understand the causes, evidence, and ecological impacts of GCC on Native lands and facilitate their classroom teaching of GCC. Table 1 provides a summary of the main topics covered in the workshops. For more details of the content and pedagogical approach of the workshops see Roehrig, Campbell, Dalbotten, and Varma (2012) and Kern et al. (2012).

Participants

The data presented in this paper is from the first year of *CYCLES*, when a total of nineteen secondary science teachers participated in the weeklong summer workshop (eleven females and eight males). These teachers were all from schools with high enrollments of Native American students in suburban areas of the Midwestern U.S., with twelve teachers at schools where Native American students account for more than 50% of the student population.

Data Collection

Attitudes toward GCC.

Pre- and post-workshop surveys were composed of items from the *Six Americas Survey* developed by the Yale Project on Climate Change Communication (Leiserowitz, Maibach, Roser-Renouf, & Smith, 2011), which measures the public's attitudes about GCC and related policy making. This survey identifies six categories ("*Six Americas*") that describe a spectrum of people's concerns and actions related to GCC: *Alarmed, Concerned, Cautious, Disengaged, Doubtful,* and *Dismissive* (Maibach, Leiserowitz, Roser-Renouf, & Mertz, 2011). A description of these six groups is provided in Table 2.

Beliefs about GCC.

To assess teachers' beliefs about the relationship between humans and Earth, we administered the *New Ecological Paradigm* (*NEP*) *Scale* (Dunlap, Van Liere, Mertig, & Jones, 2000) after the workshop and received responses from thirteen participants. The *NEP Scale* includes 15 Likert-scale items and was designed to examine the degree to which people endorse an ecological worldview. It provides a comprehensive coverage of key aspects of specific environmental concerns in the modern society, with five interrelated facets that measure individuals' internalized primitive beliefs (Dunlap, 2008; Dunlap et al., 2000, see Table 3). Previous research has shown that the *NEP Scale* possesses a high validity and reliability and is closely related to a wide range of environmental attitudes and behaviors (Dunlap et al., 2000).

Conceptual knowledge and classroom teaching about GCC.

Teachers' knowledge and classroom teaching about GCC were measured at three time points-before, during and after the weeklong workshop-with three forms of assessment: pre- and post-workshop surveys, daily reflection journals, and photo elicitation interviews.

Table 1 Main topics covered in the CYCLES workshops throughout the three years

Timeline	Workshop Topics
Year 1	• Exploring abiotic/biotic factors in different local biomes and discussing local climate change • Constructing past climate trends using local proxy data • Developing lesson plans for incorporating global and local climate change into classroom teaching
Year 2	• Discussing indigenous perspectives on climate change and impacts on wild rice • Analyzing local lake water sample and understanding lake ecology. • Developing lesson plans for incorporating global and local climate change into classroom teaching
Year 3	• Discussing the impacts of GCC on invasive species • Exploring effective tools and activities for teaching GCC in classrooms • Developing lesson plans for incorporating argumentation, concept mapping and video projects into the teaching of climate issues

Pre- and post-workshop surveys.

In the pre-and post-workshop surveys, two open-ended questions were used to evaluate teachers' understandings about greenhouse effect and the scientific process of GCC. In addition, four multiple choice questions were included to obtain baseline information about teachers' perceptions about teaching GCC in their classrooms and their previous experience in climate change education.

Daily reflection journals.

During the week-long workshop, participant teachers were asked to reflect on the information they learned through the professional development activities. Each day, three questions were designed to assess teachers' knowledge about climate issues discussed in the workshop and how they would incorporate the workshop materials into their classroom teaching.

Photo elicitation interviews.

In addition to the surveys and reflection journals, a photo elicitation interview (PEI) was developed to provide a more in-depth understanding of teachers' knowledge about climate issues. Usually, in a PEI, interviewees are presented with images to provoke comments and discussions on topics of interests (Banks, 2001). In the form of semi-structured interviews, PEIs create a more comfortable environment for longer and more comprehensive discussions and may impose less influence from interviewers compared to completely verbal interviews (Clarke- Ibañez, 2004). The PEI in this study included eight questions that closely aligned with principles in the *Climate Literacy: The Essential Principles of Climate Science* (NOAA, 2009) (see Table 4). Each question was paired with corresponding images from the NASA image collection and local climatology websites. The PEI was administrated both before and after the workshop and ten teachers consented to participate.

Data Analysis

Data from the pre-and post-workshop surveys, *NEP Scale,* and reflection journals were entered into a spreadsheet for

Table 2 Description of the six categories (*Six Americas*) of views on GCC (Maibach, Leiserowitz, Roser-Renouf, & Mertz, 2011)

Category	Description
Alarmed	Most engaged group in the issue of global warming. Very convinced climate change is happening, human-caused, and a serious and urgent threat. The Alarmed are already making changes in their own lives and support an aggressive national response.
Concerned	This group is convinced that global warming is a serious problem, but while they support a vigorous national response, they are distinctly less involved in the issue, and less likely than the Alarmed to be taking personal action.
Cautious	This group believes that global warming is a problem, although they are less certain that it is happening than the Alarmed or the Concerned. They do not view it as a personal threat, and do not feel a sense of urgency to deal with it through personal or societal actions.
Disengaged	This group has not thought much about the issue of climate change. They are the group most likely to say that they could easily change their minds about global warming where "don't know" was presented as an option.
Doubtful	This group is evenly split among those who think global warming is happening, those who think it is not, and those who do not know. Many within this group believe that if global warming is happening, it is caused by natural changes in the environment, that it will not harm people for many decades into the future, if at all, and that America is already doing enough to respond to the threat.
Dismissive	This group, like the Alarmed, is actively engaged in the issue, but on the opposite end of the spectrum. The large majority of the people in this segment believe that global warming is not happening, is not a threat to either people or non-human nature, and is not a problem that warrants a personal or societal response.

descriptive analysis. Teachers' responses to the *Six America Survey* items were entered on the KQED Climate Survey website (http://uw.kqed.org/climatesurvey/index-kqed.php) where each teacher's *Six Americas* profile was provided. The PEIs were first transcribed verbatim and a rubric was developed based on climate literacy to code the transcripts. Teachers' responses to each interview question were scored on a 0-4 point scale based on both their correctness and completeness. The *inductive analysis* approach (Patton, 2002) was then employed to obtain a more in-depth understanding of teachers' knowledge about GCC and four researchers were involved to enhance the reliability and validity of the data analysis.

Results

Teachers' Attitudes and Beliefs about GCC

A summary of the participant teachers' "*Six Americas*" categories is shown in Figure 1 with a comparison to the general U.S. public. Overall, the teachers on the CYCLES project were on the concerned end of the spectrum in terms of their attitudes toward GCC, with the majority believing that human-induced GCC is underway and may impose significant environmental and social consequences. Specifically, prior to the workshop, fifteen teachers fell into the *Concerned* category and one teacher was categorized as *Alarmed*. Among the remaining three teachers, one was categorized as *Cautious*, one *Doubtful* and one *Dismissive*. Compared to *Concerned* and *Alarmed* teachers, these three teachers were much less certain about whether GCC is happening and whether humans or natural changes are the cause for it. After the workshop, the majority of *Alarmed* and *Concerned* teachers stayed in the same category, with only one *Concerned* teacher moving to the *Alarmed* category. In contrast, the *Cautious* teacher moved to the *Concerned* category, and the *Doubtful* teacher and the *Dismissive* teacher both moved to the *Cautious* category.

While the majority of the teachers held similar attitudes toward GCC, there were different degrees of variations when it came to specific facets of their ecological views (see Table 5). Teachers were close to consensus on the facets of "balance of nature" and "eco-crisis." Almost all teachers believed that the balance of nature is delicate and is easily subject to human interference. In addition, most teachers held that if the current environmental situation continues, there will be disastrous consequences. In contrast, teachers' responses to the facets of "anti-exemptionalism"

Table 3 Five facets of an "ecological" worldview (Dunlap et al., 2000; Dunlap, 2008)

Facets	Definitions	Sample Items
Balance of nature	Beliefs that human activities impact the balance of nature	e.g., When human interfere with nature, it often produces disastrous consequences
Limits to growth	Beliefs that the earth has limited resources	e.g., We are approaching the limit of the number of people the earth can support
Anti-anthropocentrism (Human domination)	Beliefs that human beings have the right to modify and control the natural environment	e.g., Humans have the right to modify the natural environment to suit their needs
Anti-exemptionalism	Beliefs that human beings are not exempt from the constraints of nature	e.g., Humans will eventually learn enough about how nature works to be able to control it.
Eco-crisis	Beliefs that humans are causing detrimental harm to the physical environment	e.g., If things continue on their present course, we will soon experience a major environmental catastrophe.

Table 4 PEI Question contents and alignment with Climate Literacy Principles (NOAA, 2009)

No.	Question Content	Climate Literacy Principle Aligned
1	General opinion about climate change	
2	Difference between weather and climate	4
3	Differences between climate change, greenhouse effect and ozone depletion	2, 3, 6
4	Understanding of the Keeling Curve	3, 6
5	The effect of CO_2 on global temperature	2, 3
6	The recent climate change trend	2, 6
7	Opinion about computer models and proxy data	4, 5
8	Prediction about precipitation and droughts	7

and "anti-anthropocentrism" were less uniform. Responses split on statements about the limits of natural resources. For example, five teachers agreed that "*The earth has plenty of natural resources if we just learn how to develop them,*" whereas five other teachers mildly disagreed and two teachers were unsure (one of the thirteen teachers did not respond to this item).

Teachers' Knowledge about GCC

The participant teachers' average scores on each question are presented in Table 6. Due to limited sample size, statistical analysis is not applicable here. However, these scores provide baseline information about teachers' knowledge level in alignment with climate literacy principles. In general, the participant teachers held better understandings regarding the relationship between life on Earth and climate as well as how human activities are affecting the climate system. Yet, the teachers provided relatively weak explanations about aspects such as the complex interactions among components of the Earth system and computer models of climate data. The following section provides more details of teachers' knowledge on three main GCC topics: *underlying scientific processes*, *evidence of human-induced changes*, and *ecological and social consequences*. Pseudonyms are used when teachers' specific opinions and quotes are included.

Underlying scientific processes of GCC.

Before the workshop, when describing the scientific processes involved in GCC, teachers tended to focus on the causes of GCC and were vague about details of the scientific processes involved. Four of the *Concerned* teachers explicitly claimed that humans are the main cause of GCC, whereas the other eleven *Concernd* teachers either did not provide an answer or explained the processes very briefly. Of note, David, although identified as *Concerned*, indicated that GCC is more of a natural process and explained that "*Climate change, to me, is the gradual adapting of the plant and animal species, over time, to live in a particular environment.*" In addition, teachers who were *Dismissive* or *Doubtful* did not answer this question and the one *Cautious* teacher, Brandon, considered GCC as "*a result of human sanctioned release of pollutants into the atmosphere.*"

After the workshop, most of the *Alarmed* and *Concerned* teachers' responses became more detailed about the scientific processes underpinning GCC. A similar pattern of change was found among the previously *Cautious, Doubtful, or Dismissive* teachers. For example, Ron, who moved from *Doubtful* to *Cautious*, explained the scientific process of GCC as follows:

> Primarily CO_2 accumulates in the atmosphere and slows down the sun's energy from returning to space. Because it takes longer to leave, it is allowed to energize more molecules. This results in temperature increase and changes to the global climates.

Of note, while Ron was able to provide the brief description above, further details were needed to clarify how increased greenhouse gases in the atmosphere may affect the global climate. Moreover, changes in attitudes were reflected in teachers' explanations of GCC processes. For example, before the workshop, David suggested that GCC was mostly a natural adaptation, but after the workshop, he incorporated scientific details to explain that GCC is more than just a natural change:

> By putting more of the elements into the atmosphere, that do not move through the atmosphere as fast, the atmosphere slowly builds up an

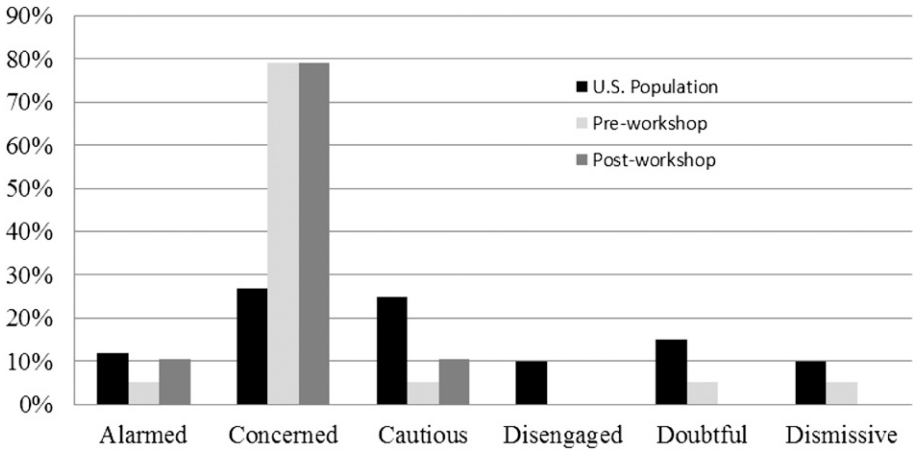

Figure 1. Proportion of the U.S. population (2011) and CYCLES teachers in the Six Americas

Table 5 Responses to the NEP scale from participant teachers*

NEP Items	Strongly Agree	Mildly Agree	Unsure	Mildly Disagree	Strongly Disagree
Balance of Nature					
When human interfere with nature, it often produces disastrous consequences	6	7	0	0	0
The balance of nature is strong enough to cope with the impacts of modern industrial nations	0	1	3	6	3
The Balance of nature is very delicate and easily upset	3	8	1	1	0
Limits to Growth					
We are approaching the limit of the number of people the earth can support	1	9	1	2	0
The earth has plenty of natural resources if we just learn how to develop them	1	4	2	5	0
The earth is like a spaceship with very limited room and resources	5	7	0	1	0
Anti-anthropocentrism					
Humans have the right to modify the natural environment to suit their needs	1	3	0	5	4
Plant and animals have as much right as humans to exist	9	4	0	0	0
Humans were meant to rule over the rest of nature	0	1	1	5	6
Anti-exemptionalism					
Human ingenuity will ensure that we do not make the earth unlivable	0	2	4	7	0
Despite our special abilities, humans are still subject to the laws of nature	10	3	0	0	0
Humans will eventually learn enough about how nature works to be able to control it	0	2	2	4	5
Eco-crisis					
Humans are severely abusing the earth	6	5	2	0	0
The so-called "ecological crisis" facing humankind has been greatly exaggerated	0	2	3	6	2
If things continue on their present course, we will soon experience a major environmental catastrophe	4	8	1	0	0

*The numbers show how many teachers chose a specific category under each item

> excess of greenhouse gasses. These warm the earth surface by trapping the CO_2, like a "pin ball", before releasing them to outer-space. This would in turn slowly melt the ice and puts additional moisture into the atmosphere, that changes plant life on the earth's surface until it locks up CO_2 to begin changing the atmosphere.

However, not all *Concerned* teachers were able to explain the scientific process in details. Leah, who was *Concerned* both before and after the workshop, only stated that the way greenhouse gases work is "*capturing heat-they trap the heat on the earth.*" But Brandon, who moved from *Cautious* to *Concerned*, gave more thorough explanations when answering the same question:

> [There are] more of those molecules getting trapped in the atmosphere. And they provide more of a chance for radiation from the sun to bounce off of it instead of getting, you know, [energy] usually may be bouncing off one molecule and it bounces its way back. When we were thinking about this, energy would maybe bounce once or twice off of a molecule and eventually it'd find its way out. Whereas now, there are more of the molecules to bounce off of, and it takes them longer to eventually make its way out, so more of the energy is trapped in the atmosphere.

Despite the improvement in teachers' understanding of climate change processes, the PEIs revealed some misconceptions teachers held. In particular, when asked if the ozone hole is related to GCC, six teachers (one *Alarmed* and five *Concerned*) believed that they were closely connected. Four teachers (one *Alarmed* and three *Concerned*) were able to differentiate ozone depletion and GCC. For instance, Ron, who moved from *Doubtful* to *Cautious*, indicated that ozone depletion and GCC were separate with a brief answer:

> I know back in the '80s or late '70s they were harping on the CFC's and stuff and that was causing the opening of the ozone. I think it had more to do with the ultraviolet radiation

Table 6 Teachers' average PEI scores by questions

No.	Question Content	Average Score
1	General opinion about climate change	2.5
2	Difference between weather and climate	2
3	Differences between climate change, greenhouse effect and ozone depletion	2.6
4	Understanding of the Keeling curve	2.7
5	The effect of CO_2 on global temperature	1.9
6	The recent climate change trend	2.6
7	Opinion about computer models and proxy data	1.8
8	Prediction about precipitation and droughts	1.9
	Total Average Score	2.25

more than anything else. So I think that's what that is.

Perspectives about evidence on GCC.

When discussing evidence for GCC, all teachers considered that computer models and proxy data are helpful tools to help us understand GCC, but only half of them gave specific reasons to support their opinions. For example, Molly, who moved from *Concerned* to *Alarmed*, said:

> I think it's an accurate picture... I think it's pretty cool that we actually see a correlation in the last 100 years that the temperature has risen a lot faster. And, in the past 100 years, I assume, would be more correct because you're getting it from thermometers as opposed to tree rings and ice cores and things like that. I do think we can trust the data. You know, it's sketchy because it's from tree rings and coral and ice cores, but that's an average of what they found from many samples. I think … you've got a lot of bases that are put together to make this graph, and they didn't get it from just one source.

However, while all teachers considered computer models helpful, Ron was the only teacher who raised the concern that using proxy data as evidence may not be sufficient for a comprehensive understanding of GCC:

> I think it's one of the things that you can use. I don't think you can go with just that. I mean, there are other departures in temperature. I think it's something that you have to use in conjunction with other things too, to help support it.

Consequences of GCC.

Regarding the possible consequences from GCC, many teachers referred to the local climate in their discussions. In particular, when answering the question of whether there be an increased risk of droughts and/or precipitation as a result of GCC, three *Concerned* teachers made very brief claims drawing on local climate or recent weather events. For example, Leah believed that "you're going to have more precipitation because that's how we're getting the flooding." The remaining teachers provided more detailed arguments stating that there is likely to be both more precipitation and droughts. For example, Tylor, who were *Alarmed* both before and after the workshop, first stated:

> It [precipitation] will increase, because warm air holds more moisture. So, if the atmosphere warms up, it will hold more moisture and the storms will be more intense because it also has more energy.

Then, Tylor continued to discuss the possibility of increasing droughts by comparing with the reasons for precipitation:

> I think due to the way that the global circulation patterns of winds and things are set up—so, areas now that are dry will get drier and areas now that are wet will get wetter. Because, if it's naturally a warm, dry area anyways, it's going to get hotter and hotter and hotter, and there's not going to be more moisture there. But, if it's normally an area with a more intermediate climate, where there's rainfall, the increased energy in the atmosphere and the increased temperature of the atmosphere is going to allow the air that's normally wet to hold even more water, which is going to give us more rain. So it's going to exacerbate or accentuate the cycles that are already there.

Classroom Teaching of GCC

Before the workshop, twelve *Concerned* teachers reported having taught about topics on climate issues in their classrooms but the remaining four *Concerned* teachers did not have such teaching experience due to job assignments at their schools. All teachers who were *Dismissive, Doubtful,* or *Cautious* reported that they had not taught about GCC but did not provide any reasons. Figure 2 presents a distribution of the topics the twelve teachers had taught. The results show that the three topics mostly taught were: *how human activities cause climate change*, *options for reducing or adapting to impacts of climate change*, and *causes and effects of rising temperatures on Earth*. Only one teacher reported having discussed local climate change issues with the students.

Before the workshop, when discussing the experienced challenges and potential barriers in teaching GCC, two teachers, one *Concerned* and one *Dismissive*, reported that the topic of GCC did not align well with their curricula. The teacher who was *Dismissive*, along with seven other *Concerned* teachers, suggested that a main challenge in teaching GCC was that they did not have sufficient scientific knowledge in this regard. In addition, two *Concerned* teachers indicated that topics related to GCC are too controversial and they were concerned about the potential conflicts with Native American students' own cultural perspectives.

Furthermore, there was a variation in teachers' perceptions of what to teach

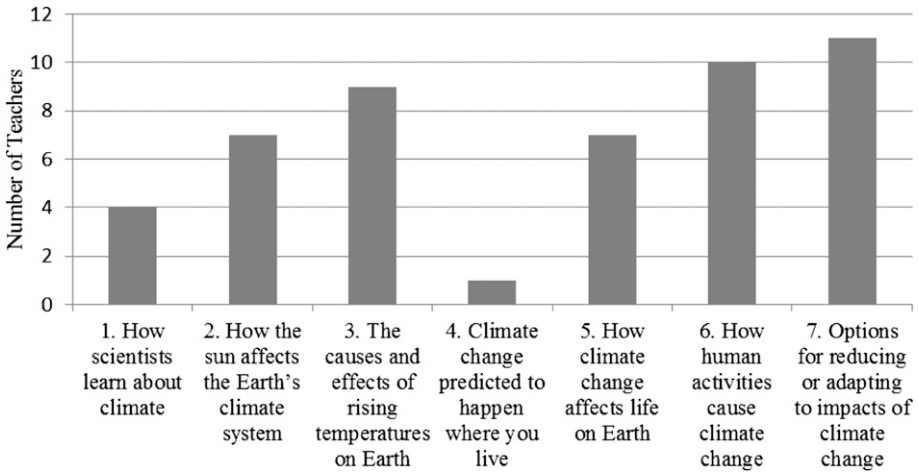

Figure 2 Topics of GCC that CYCLES teachers had taught

about GCC. Before the workshop, only two teachers (both *Concerned*) believed that basic scientific knowledge about GCC should be the priority in their teaching. At the same time, eleven *Concerned* teachers believed they should let students know what individuals could do to reduce GCC, with six of them considering it particularly important that their students are aware that humans are the cause for GCC and will be impacted by its effects. In comparison, the *Cautious, Doubtful* and *Dismissive* teachers did not respond to this question. However, after the workshop, these three teachers, together with the others, were more aware of the importance of teaching human impacts on GCC and helping students understand potential ways to reduce such impacts.

Discussion

The present study aimed to reveal the relationship between teachers' attitudes and beliefs concerning GCC, their developing knowledge about climate science, and classroom teaching of GCC. In the following section, we address the research questions that guided this study.

Research Question 1

Results from the *Six Americas Survey* items suggest that the majority of teachers fell into the *Concerned* category both before and after the workshop. They were convinced that human-induced GCC is underway and will bring tremendous consequences to the society. While most teachers' attitudes toward GCC stayed the same throughout the workshop, there were attitude changes among some teachers. In particular, teachers who were on the skeptical end of the spectrum became more aware of the significance of GCC and its potential threat to humans and shifted their attitudes about GCC. The current findings indicate that professional development may induce attitude changes on the topic of GCC.

As the *Six Americas Survey* tapped into teachers' general attitudes toward GCC, the *NEP Scale* revealed the ecological worldviews they held about the human-Earth relationship. We found that while teachers showed a similar degree of concerns about GCC, they did not necessarily share specific beliefs about humans' roles and responsibilities in relation to GCC. Their perspectives varied regarding human's rights to exploit natural resources and dominate the Earth, and especially when it came to whether human beings are exempt from the constraints of nature. These results provided more comprehensive information for us to understand teachers' perspectives toward GCC-related issues.

Research Question 2

Prior to the workshop, teachers' explanations of the scientific processes of GCC were non-existent or limited. Some teachers were able to describe causes of GCC but were unaware of the mechanisms or of the full-scale of the impacts of GCC. By the end of the workshop, the majority of the participant teachers possessed a basic understanding of climate science. Most of them were able to provide details about the causes and scientific processes of GCC, although misconceptions persisted for some teachers.

Attitudes were not strong indicators of teachers' levels of GCC knowledge. Some teachers on the *Concerned* end of the spectrum held misconceptions about topics such as the relationship between the ozone hole and GCC, whereas more skeptical teachers were able to differentiate these two scientific processes. On the other hand, when explaining the complex science underlying GCC, such as its influence on droughts and precipitation, the *Concerned* and *Alarmed* were more likely to give detailed responses. However, changes in GCC knowledge were more marked among teachers who experienced category changes in the *Six Americas* survey. Teachers with skeptical attitudes towards climate issues started the program with minimal knowledge but ultimately demonstrated strong growth in their understanding of climate change. It is possible that these skeptical attitudes stemmed from lack of knowledge about climate science and that the focus of the workshop on improving GCC knowledge promoted changes in attitudes based on access to scientific evidence. Conversely, increased awareness and concern about climate issues developed throughout the workshop may also have helped teachers to better integrate new and previous knowledge.

Similar to existing research in the literature (Kellstedt, Zahran, & Vedlitz, 2008), the current findings indicate an uncertain relationship between beliefs and knowledge on environmental issues. As changes in attitudes and knowledge related to a complex topic such as GCC may develop over time, we will continue to explore the relationship between teachers' attitudes and knowledge in our future professional development programs.

Research Question 3

While the majority of teachers in this study viewed GCC as an important

topic, their opinions varied about specific aspects that should be taught to their students. Teachers who were on the *Concerned* end of the spectrum generally considered it critical that students are aware that GCC is happening and know about its causes and effects. However, teachers who were more skeptical about GCC issues had not necessarily taught about them and tended to avoid discussing what they think students should know about GCC. As they became more aware of the significance of GCC after the workshop, these teachers started to stress that students should understand the influence human activities have on the climate. Consistent with previous studies which suggested that teachers' attitudes may play an important part in how they plan their teaching (e.g., Waters-Adams, 2006), the current results indicate that teachers' attitudes about GCC may influence their decision-making in teaching GCC.

On the other hand, we found that there was a lack of attention to teaching students the scientific evidence and processes related to GCC. Many teachers stressed that they did not have sufficient scientific background to teach GCC well. Even though data from surveys and interviews showed that, after the workshop, these teachers held basic scientific understanding about GCC, they still possessed certain misconceptions regarding this environmental issue. While it is uncertain what relationship there may be between knowledge and behaviors (Hwang, Kim, & Jeng, 2000), researchers have argued that a good understanding about certain issues may positively impact personal efficacy (Hansen et al., 2003). Therefore, future professional development should consider placing more emphasis on providing scientific information to teachers in order to enhance their capacity and confidence in implementing climate change education.

Conclusion

Humanity faces a number of environmental, economic, and social challenges related to GCC. Increasing attention has been given to climate change education due to its timeliness and importance. To better promote climate change education, it is important to understand teachers' perspectives toward GCC. This study explored the relationship between teachers' attitudes and knowledge about GCC. More importantly, considering that teachers' instructional decisions are closely related to their attitudes and knowledge, this work took a further step and looked into how attitudes and knowledge may relate to teachers' classroom teaching about GCC. The current findings will initiate more discussions on the nature of teachers' attitudes and beliefs about GCC and how their classroom practices may be influenced by attitudes and knowledge. In addition, this work will help inform teacher educators about how to cultivate positive environmental experiences and curricula in professional development programs (Moseley & Utley, 2008). Improving student learning is the ultimate goal of teacher professional development (Guskey, 2002; Supovitz & Turner, 2000). To fulfill this goal, it is important that professional development programs focus on initiating changes in the beliefs, attitudes, and perceptions of teachers (Borko, 2004). By exploring the relationship between teachers' attitudes, knowledge, and classroom teaching about GCC, this work provides helpful implications for the design of future professional development programs on climate change education.

References

Achieve, Inc. (2013). *Next Generation Science Standards*. http://www.nextgenscience.org/next-generation-science-standards

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In J. Kuhl & J. Beckman (Eds.), *Action control: From cognition to behavior* (pp. 11-39). New York: Springer-Verlag.

Banks, S. (2001). *Ethics and Values in Social Work.* Basingstoke, Palgrave.

Bord, R., O'Connor, R., & Fisher, A. (2000). In what sense does the public need to understand global climate change? *Public Understanding of Science*, *9*(3), 205-218.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher, 33*(8), 3-15.

Brechin, S.R. (2003). Comparative public opinion and knowledge on global climatic change and the Kyoto Protocol: The US versus the rest of the world? *International Journal of Sociology and Social Policy*, *23*(10), 106-134.

Cheng, J. C-H., & Monroe., M. C. (2010). Teachers' attitudes toward an environmental education program. *Applied Environmental Education and Communication, 9*(1*):* 28-37.

Clarke-Ibañez, M. (2004). Framing the social world with photo-elicitation interviews. *American Behavioral Scientist*, *47*(12), 1507–1524.

Crowley, T. (2000). Causes of climate change over the past 1000 years. *Science, 289*(5477*),* 270-277.

Desjean-Perrotta, B., Moseley, C., & Cantu, L. (2008). Preservice teachers' perceptions of the environment: Does ethnicity or dominant residential experience matter? *The Journal of Environmental Education, 39*(2), 21-32.

Dunlap, R. E. (2008). The new environmental paradigm scale: From marginality to worldwide use. *Journal of Environmental Education, 40*(1)*,* 3-18.

Dunlap, R. E., Van Liere, K. D., Mertig, A. G., & Jones, R. E. (2000). Measuring endorsement of the New Ecological Paradigm: A revised NEP Scale. *Journal of Social Issues*, *56*(3), 425-442.

Duschl, R. (1990). Restructuring Science Education: The Importance of Theories and Their Development. New York: Teacher's College Press.

Fortner, R. (2001). Climate change in school: Where does it fit and how ready are we? *Canadian Journal of Environmental Education, 6*(1)*,* 18-31.

Good, P., et al. (2011). A review of recent developments in climate change science. Part I: Understanding of future change in the large-scale climate system. *Progress in Physical Geography*, *35*(3), 281-296.

Grove, F., & Pugh, A. (1999). Elementary pre-service teacher perceptions of the greenhouse effect. *Journal of Science Education and Technology, 8*(1), 75-81.

Guskey, T. (2002). Does it make a difference? Evaluating professional development. *Educational Leadership, 59*(6), 45-51.

Guy, S., Kashima, Y., Walker, I., & O'Neill, S. (2014). Investigating the effects of knowledge and ideology on climate

change beliefs. *European Journal of Social Psychology, 44*(5)*,* 421-429.

Hamilton, L. (2011). Education, politics and opinions about climate change evidence for interaction effects. *Climate Change, 104*(2)*,* 231-242.

Hansen, J., Holm, L., Frewer, L., Robinson, P., & Sandoe, P. (2003). Beyond the knowledge deficit: recent research into lay and expert attitudes to food risks. *Appetite, 41*(2), 111-121.

Hines, J. M., Hungerford, H. R., & Tomera, A. N. (1986). Analysis and synthesis of research on responsible environmental behavior: A meta-analysis. *The Journal of Environmental Education, 18*(2), 1-8.

Hungerford, H., & Volk, T. (1990). Changing learner behavior through environmental education. *The Journal of Environmental Education, 21*(3), 8-21.

Hwang, Y. H., Kim, S. L., & Jeng, J. M. (2000). Examining the causal relationships among selected antecedents of responsible environmental behavior. *Journal of Environmental Education, 31*(4), 19-24.

Kellstedt, P., Zahran, S., & Vedlitz, A. (2008). Personal efficacy, the information environment, and attitudes toward global warming and climate change in the United States. *Risk Analysis, 28*(1), 113-126.

Kern, A., Roehrig, G., Reynolds, B., Bhattacharya, D., Varma, K., Hougham, R. , Finley, F., Miller, B., Liu, S., Nam, Y., & Karahan, E. (2012). Teacher Professional Development for Climate Change Education in Native Communities. Paper presented at the Conference of the Association of Science Teacher Education, Clearwater, FL.

Koballa, T. R., & Crawley, F. E. (1985). The influence of attitude on science teaching and learning. *School Science and Mathematics, 85,* 222-232.

Kollmus, A., & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to proenvironmental behavior? *Environmental Education Research, 8*(3)*,* 239-260.

Lambert, J., Lindgren, J., & Bleicher, R. (2011). Assessing elementary science methods students' understanding about global climate change. *International Journal of Science Education, 34*(8), 1167-1187.

Leiserowitz, A., Maibach, E., Roser-Renouf, C., Feinberg, G., & Rosenthal, S. (2014). *Climate change in the American mind: April, 2014.* Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change Communication.

Leiserowitz, A., Maibach, E., Roser-Renouf, C. & Smith, N. (2011). *Global Warming's Six Americas, May 2011*. Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change Communication.

Littledyke, M. (2008). Science education for environmental awareness: approaches to integrating cognitive and affective domains. *Environmental Education Research, 14*(1)*,* 1-17.

Lumpe, A., Haney, J., & Czerniak, C. (2000). Assessing teachers' beliefs about their science teaching context. *Journal of Research in Science Teaching, 37*(3)*,* 275-292.

Maibach, E., Leiserowitz, A., Roser-Rerouf, C., & Mertz, C.K. (2011). Identifying like-minded audiences for global warming public engagement campaigns: An audience segmentation analysis and tool development. PLoS one, *6*(3), e17571.

Maibach, E., Roser-Renouf, C., & Leiserowitz, A. (2008). Communication and marketing as climate change intervention assets: A public health perspective. *American Journal of Preventive Medicine, 35*(5)*,* 488-500.

Monroe, M. C. (1993). Changing environmental behavior. *Clearing, 77,* 28-30.

Moseley, C., & Utley, J. (2008). An exploratory study of preservice teachers' beliefs about the environment. *The Journal of Environmental Education, 39*(4)*,* 15-30.

National Oceanic and Atmospheric Administration (2009). *Climate Literacy: The Essential Principles and Fundamental Concepts (Second Edition)*. http://www.globalchange.gov

Oliver, J. S., & Koballa, T. (1992). Science educators' use of the concept of belief. *Paper presented at the annual meeting of the National Association of Research in Science Teaching.* Boston, Massachusetts.

Pajares, F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307-332.

Papadimitriou, V. (2004). Prospective primary teachers' understanding of climate change, greenhouse effect, and ozone layer depletion. *Journal of Science Education and Technology*, *13*(2), 299-307.

Patton, M. Q. (2002). *Qualitative research and evaluation methods*. Thousand Oaks, CA: Sage.

Richardson, V. (1996). The role of attitude and beliefs in learning to teach. In J. Sikula, T. Buttery, & E. Guyton (2nd eds), *Handbook of Research on Teacher Education* (pp. 102-119). New York: Macmillan.

Robertson, A. (1993). Eliciting students' understandings: Necessary steps in environmental education. *Australian Journal of Environmental Education, 9,* 95-114.

Roehrig, G., Campbell, K., Dalbotten, D., Varma, K. (2012). CYCLES: A Culturally-relevant Approach to Climate Change Education in Native Communities. *Journal of Curriculum and Instruction, 6*(1)*,* 73-89.

Shepardson, D., Niyogi, D., Choi, S., & Charusombat, U. (2011). Students' conceptions about the greenhouse effect, global warming, and climate change. *Climate Change, 104*(3-4)*,* 481-507.

Supovitz, J. A., & Turner, H.M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching, 37*(9)*,* 963-980.

Taylor, E., & Caldarelli, M. (2004). Teaching beliefs of non-formal environmental educators: A perspective from state and local parks in the United States. *Environmental Education Research, 10*(4)*,* 451-469.

U.S. Environmental Protection Agency (2014). Climate change indicators in the United States, 2014. Third edition. EPA 430-R-14-004. www.epa.gov/climatechange/indcators

Wals, A. E. J. (1992). Young adolescents' perceptions of environmental issues: Implications for environmental education in urban settings. *Australian Journal of Environmental Education, 8,* 45-58.

Waters-Adams, S. (2006). The relationship between understanding of the nature of science and practice: The influence of teachers' beliefs about education, teaching and learning. *International Journal of Science Education, 28*(8), 919-944.

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