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Argumentation as a Strategy for Increasing Preservice Teachers' Understanding of Climate Change, a Key Global Socioscientific Issue

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Argumentation as a Strategy for Increasing Preservice Teachers' Understanding of Climate Change, a Key Global Socioscientific Issue

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Abstract

Findings of this study suggest that scientific argumentation can play an effective role in addressing complex socioscientific issues (i.e. global climate change). This research examined changes in preservice teachers' knowledge and perceptions about climate change in an innovative undergraduate-level elementary science methods course. The preservice teachers' understanding of fundamental concepts (e.g., the difference between weather and climate, causes of recent global warming, etc.) increased significantly. Their perceptions about climate change became more aligned to those of climate scientists. A key assignment was to develop and present an evidence-based scientific argument based on an adaptation of Toulmin's argumentation model (1958). The participants were assigned a typical question and claim of climate skeptics and asked to conduct research on the scientific findings to prepare a counter-argument (rebuttal). The preservice teachers indicated that the integration of scientific argumentation was an effective strategy for increasing their understanding and perceptions about climate change as a socioscientfic issue.

Introduction

The relationship between global climate change and increasing need for energy is an important socioscientific issue facing our planet that is complex and difficult to understand without in-depth study and analysis (Lambert & Bleicher, 2014). Climate change has become an important planetary issue. In spite of this, climate change has been under-emphasized in school curricula (Bardsley & Bardsley, 2007). This is an important challenge for science educators, especially given the increasing public awareness of climate change impacts in their everyday lives.

One way to address this challenge is to begin with preservice teachers in science methods courses. The Framework for K-12 Science Education (National Research Council (NRC), 2012) and the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) highlight global climate change, energy, and human sustainability as important topics for science instruction. The Framework and NGSS further promote evidence-based scientific argumentation skills as a critical student learning outcome. This study examines whether the incorporation of argumentation in a science methods course increases preservice teachers' knowledge and/or perceptions of climate change. It is grounded in the climate science education and scientific argumentation research literature.

Climate Science Education and Scientific Argumentation

Climate change is a topic that facilitates teaching concepts spanning several fields of science (Washington & Cook, 2011). Research demonstrates that studying the science underlying climate change can enhance students' ability to evaluate resources and develop critical thinking skills (Bardsley & Bardsley, 2007). Given that K-12 students have numerous alternative conceptions about climate change, it is critical that teachers have an understanding of its underlying science (Feldman et al., 2015). Teachers need to understand the natural and human-induced factors affecting climate, the potential impacts, and ways to mitigate and adapt to climate change. Many teachers, however, do not demonstrate adequate understanding of the concepts underlying climate change (Daskolia, Flogaitis, & Papageorgious, 2006; Papadimitriou, 2004). Lack of conceptual understanding in a particular science topic area has been shown to affect self-efficacy to teach it (Bleicher & Lindgren, 2005). The influence of perceptions about climate change can play a role in a teacher's willingness to gain this conceptual understanding (Bleicher & Lambert, 2013). Elements of a curriculum that might be utilized to achieve results in improving perceptions and increasing conceptual understanding about climate change bear closer examination.

Research with university students in introductory atmospheric science classes indicates reading-based instruction that addresses both the correct science and the associated misconceptions of the greenhouse effect and global warming can promote student understanding compared to traditional instruction (i.e. McCuin, Hayhoe, & Hayhoe, 2014). One instructional approach that is especially relevant to climate change is the use of refutational lessons (Tippett, 2010). A growing body of evidence indicates that refutational lessons are one of the most effective means of reducing misconceptions (Kowalski & Taylor, 2009; Muller, 2008). Refutational lessons have been shown to nurture long-term conceptual change across a wide range of grade levels (Cook, Bedford, & Mandia, 2014). Research has demonstrated that refutational texts can: 1) increase argumentative skills and raise awareness of the relevance of evidence to argument (Kuhn & Crowell, 2011); 2) foster critical thinking and encourage students to assess evidence and to draw valid conclusions (Berland & Reiser, 2011: Kuhn and Crowell, 2011); 3) provoke more interest compared to traditional textbooks (Manson, Gava, & Boldrin, 2008); and 4) resolve to some degree the issue that knowledge is often imparted as a set of unequivocal facts with a lack of argument in the classroom (Osborne, 2010).

Despite the scientific consensus about climate change (Anderegg, Prall, Harold, & Schneider, 2010) and its potential risks, the media often portrays the issue as controversial and subject to debate (Kellstedt, Zahran, & Vedlitz, 2008; Washington & Cook, 2011), leading to lingering public confusion as to the extent of consensus (Leiserowitz, Maibach, Roser-Renouf, Feinberg, & Rosenthal, 2014). Engaging learners in scientific argumentation can help them to become more analytical and able to differentiate scientific evidence from opinions (Bardsley & Bardsley, 2007). Corner (2012), however, outlines four challenges that can hinder the ability to craft and evaluate these arguments: insufficient knowledge about climate change; uncertainty about the climate science; denial of the consequences of climate change; and mistrust in science communicators. This current study addresses these challenges by involving preservice teachers in an innovative methods course curriculum developed by the researchers (described in more detail in the Methods section). The focus of the curriculum is to engage leaners in argumentation learning experiences that are associated with a more complex understanding of climate and energy concepts, more positive perceptions about science (Tytler, 2014), and more proficient argumentation and communication skills.

The concept of science as argument and the view that engaging in scientific argumentation should play a key role in science education have become widely endorsed (e.g., Driver, Newton, & Osborne, 2000; Duschl, 2007; Kuhn & Crowell, 2011; Tippett, 2009). Argumentation has been identified as a mechanism for conceptual change (Mercer, Dawes, Wegerif, & Sams, 2004; Nussbaum & Sinatra, 2003). Specifically, Holthuis, Lotan, Saltzman, Mastrandrea, and Wild (2014) found that argumentative discourse supported students' understanding of climate change. Clayton (2006) agrees, stressing the importance of teaching students to think critically, evaluate claims related to the global environment, and emphasizing the need for educators to help students distinguish between scientific knowledge and opinion. When students learn to construct a sound scientific argument, they demonstrate critical thinking skills and a mastery of the subject matter being taught (Hand, Norton-Meier, Staker, & Bintz, 2009; Sampson & Clark, 2011). Opportunities to engage in argumentation allow students to learn the epistemic frameworks that are used to develop and evaluate knowledge in science. Argumentation makes the social processes and context that shape how knowledge is communicated, represented, and debated in science a central aspect of the learning environment (Duschl, 2008). Despite several initiatives supporting the use of argumentation, teachers often struggle to implement argumentation in the classroom (McNeill, Lizotte, Krajcik, & Marx, 2006). They do not have the instructional resources, skills or time to implement instruction on argumentation (Simon, Erduran, & Osborne, 2006).

We have also conducted pilot research on scientific argumentation as an instructional approach in our elementary science methods courses (Lambert & Bleicher, 2015). Preservice teachers are taught to develop a scientific argument that refutes a climate skeptic's argument. Results indicate that knowledge and interest about climate change increased. However, the quality of their arguments could be improved. Similar to the struggles of K-12 teachers to implement argumentation activities in classrooms (Sampson & Blanchard, 2012), we also struggled with how best to structure the activities. We believe that engaging preservice teachers in scientific argumentation will help them become more analytical and able to differentiate scientific evidence from opinions. Ultimately, it will enable them to teach their students to engage in classroom argumentation exercises that can lead to gains in climate change knowledge and perceptions more akin to those held by scientists. This study examines the following research questions:

After participating in an innovative science methods course, do preservice teachers:

1. Demonstrate gains in climate change knowledge?
2. Indicate changes in their perceptions about climate change?

Method

Research Design

This study was conducted using an action research design. Action research designs are systematic procedures often used in educational settings to gather quantitative and qualitative data about a teacher's own curriculum and instruction (Mills, 2013). The aim is to revise instruction in real time using new insights gained from the data collected. Action research provides an opportunity for the researcher to focus on self-development and student learning with the goal of improving practice.

One of the authors was the science methods course instructor, who assumed the role of a participant observer. She kept field notes while being strategically positioned in the field in her natural role as course instructor. This provided the access required for firsthand field observations. The authors' biases included a desire to see evidence of changes in preservice teachers' climate change knowledge and perceptions.

Participants and Context of the Study

Participants

The 59 participants in this study were preservice teachers enrolled in an elementary science methods course at a large southeastern United States Hispanic-serving university. This course is usually taken one or two semesters prior to student teaching. All but three were females under the age of 22. Approximately 33% were not Caucasian. Approximately 75% had taken two or more science courses at the undergraduate level, mostly in the biological sciences (i.e., marine biology) or one field of the earth sciences (i.e., astronomy). Most participants had a weak foundational knowledge of overall earth systems and less than 50% had taken an earth science course in middle or high school. Relevant to this study, very few had taken a weather and climate (meteorology) course. The participant pool included all students enrolled in the methods course. For the entire 15-week course, an innovative content and instructional approach was implemented

Course Content and Instructional Approach

Climate change was framed as a socioscientific issue that would prepare the preservice teachers to teach concepts spanning the earth, life, and physical sciences. Curriculum and instructional materials were incorporated throughout the elementary science methods course to promote climate literacy. Standards-based inquiry lessons, readings, videos and animations from Climate Science Investigations (CSI) (http://www.ces.fau.edu/nasa/)_were integrated into the course to support student learning. CSI is an online, interactive series of coherent modules and teaching resources funded by the National Aeronautics and Space Administration (NASA)'s Innovations in Climate Education (NICE) program. The curriculum was initially designed to enable high school and undergraduate students to analyze NASA, National Oceanic and Atmospheric Administration (NOAA), and other real data to address the public's questions and commonly held alternative ideas about climate change. However, the curriculum is also very informative and practical for teacher preparation courses.

Refutational lessons were developed as the instructional approach to reading resources. The course content was sequenced as a coherent "story" (Duschl, Maeng, & Sezen, 2011) that built on the basics of atmospheric science (e.g., difference between weather and climate, heat transfer, the electromagnetic spectrum, Earth's energy budget). 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 participants to the issue of climate change. Preservice teachers 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. The CSI modules are sequenced in a way that supports this coherent storyline. Table

1 shows the guiding questions, science concepts, and NGSS (2013) disciplinary core ideas taught in the course using components of CSI.

Table 1. CSI's module, skeptics questions, and NGSS disciplinary core ideas

CSI Module	Skeptics' Questions	NGSS Disciplinary Core Ideas
1. Nature of Science	What practices do scientists engage in to reach consensus about climate change?	Nature of scientific inquiry, experimental design, evidence-based argumentation, role of skepticism in science, scientific consensus and certainty
2.Weather and Climate	How do the methods used to study weather and climate differ?	Weather, climate, extreme weather events
3. Energy The Driver of Climate	How does the balance of incoming and outgoing energy affect Earth's climate?	Composition of the atmosphere, electromagnetic radiation, temperature, heat transfer, earth's energy balance, greenhouse effect
4.Temperature Over Time	Are recent trends in the Earth's temperature unusual compared to past trends?	Factors that affect temperature (latitude, angle of solar radiation, ocean currents, elevation), temperature over geologic time
5. Causes of Climate Change	Are humans mostly responsible for recent changes in climate?	Radiative forcing, carbon cycle, natural causes, anthropogenic causes, climate feedbacks
6. Impacts of Climate Change	What are the projected impacts on the planet and humans?	Global mean temperature increase, land and sea ice melt, sea level rise, human health
7. What Can We Do	What can we do to lessen and adapt to the impacts of climate change?	Mitigation, adaptation, energy consumption, renewable energy, environmental policy

Preservice teachers were first introduced to the evidence-based argument supporting anthropogenic (human-caused) climate change through the film, "An Inconvenient Truth." The film presents the scientific evidence for climate change. After viewing the film, we established classroom discourse that modelled evidence-based discourse similar to that valued in the scientific community.

The culminating course assignment was to respond to a skeptic's question (see Table 1) utilizing the CSI modules and scientific articles. Course participants developed, shared, critiqued, and refined an evidence-based argument that supported one explanation and provided a refutation to the alternative.

We followed the refutational scientific argumentation framework (Figure 1), adapted from Sampson and Schleigh (2012). Participants were asked to investigate the skeptics' claim based on one of the questions shown in Table 1 by reviewing of the skeptics' evidence and reasoning. Examples of skeptics' claims were the following:

- Earth's global average temperature has changed in the past—recent changes are NOT unusual.
- The sun's variability in energy output is the greatest cause of recent climate change.
- Humans can not lessen and adapt to the impacts of climate change.

<table>
<tr><td colspan="3">Skeptics' Question</td></tr>
<tr><td colspan="3">Contrarians' Argument
(Claim, Evidence, & Reasoning)</td></tr>
<tr><td colspan="2">Scientists' Counter-Argument/Refutation</td><td rowspan="4"><u>Evaluation</u>
Provides appropriate evidence.
Justifies the evidence using scientific explanations.
Refutes the contrarians' argument with valid, evidence, reasoning, and explanations.
References trustworthy scientific resources.</td></tr>
<tr><td colspan="2">Scientists' Claim</td></tr>
<tr><td><u>Evidence</u>
The data that supports the scientific claim.</td><td><u>Reasoning</u>
The rationale or explanation for why each type of evidence warrants the scientific claim.</td></tr>
<tr><td colspan="2"><u>Rebuttal to Skeptics' Argument</u>
The explanation that provides scientific evidence and reasoning for why the contrarians' argument is flawed.</td></tr>
</table>

Figure 1. Framework for refutational argumentation (Adapted from Sampson & Schleigh, 2012)

Based on research from trustworthy resources, participants then developed the scientists' counter-argument, which included the evidence and reasoning of why the evidence supports the scientific explanation. They also explained why the skeptics' argument is flawed (i.e., cherry-picking data). They, first, worked individually to develop and write the refutational argument. Each preservice teacher was then assigned to a team to share their argument and collaboratively develop a team presentation.

Each team presented their argument to the class. Peers and the instructor used a rubric, developed specifically for the assignment, to critique the arguments. The rubric asked observers to score the evidence, justification, and rebuttal of the skeptic's claim. More specific instruction on each of these components was provided throughout the course to help participants develop and evaluate arguments.

Data Collection and Analysis

The Climate Science Inventory of Knowledge (CSIK) and Perceptions on Climate Change (IPCC) instruments were employed to measure changes in knowledge and perceptions of climate change. Fieldnotes were kept by the course instructor (one of the researchers) and analyzed in collaboration with the other researcher to measure the effectiveness of argumentation activities. A one-group pre-post design was employed involving pre and post administrations of the CSIK and IPCC. Participants also responded to a post-questionnaire about specific curriculum, instructional, and assessment approaches implemented in the course. Authorization from the university's Institutional Review Board was obtained to conduct the study.

Instruments to Measure Knowledge and Perceptions

Climate Science Knowledge Inventory (CSIK)

We employed the CSIK to help answer the first research question of whether preservice teachers made gains in their climate change knowledge. The CSIK is the product of over three years of development resulting in a valid and reliable instrument for assessing basic climate science concepts (Lambert, Lindgren, & Bleicher, 2012; Lambert & Bleicher, 2013). The CSIK consists of 20 multiple-choice items. It provides an overall measure of climate change knowledge, including items about weather and climate, energy, causes (including the greenhouse effect and the carbon cycle), and impacts of the climate change.

The reliability of the CSIK, in this current study, was 0.788 as determined using the Cronbach alpha (α) statistical test. The Cronbach alpha provides a good measure of the internal consistency of a dataset. The higher the Cronbach alpha value, the more confidence one has that the sum of all the items on the test is measuring the variable of interest (Lance, Butts, & Michels, 2006). In our study, the value of 0.788 is considered to be a moderately high value for educational research. It provides a measure of confidence that the 20 items on the CSIK, taken together, provide a reliable measure of a respondent's overall knowledge about climate change.

Inventory of Perceptions about Climate Change (IPCC)

We employed the IPCC to help answer the second research question of whether preservice teachers indicated any changes in their perceptions of climate change. The IPCC was designed to measure participants' perceptions about four constructs: concern, causes and impacts, skepticism, and actions involved in climate change (Lambert & Bleicher, 2013). It consists of 12 Likert-scale items and six multiple-choice items. The IPCC, for this current study, had a reliability of 0.845 using the Cronbach a statistical test. In addition, quantitative survey data were collected to measure participants' interest about climate change, how important they felt it was, and their trust of information sources about it. We also asked participants to indicate which Six America's category they identified with both before and after the course to gain a second measure of their concern about the impacts of climate change.

End-of-Course Questionnaire

At the end of the course, participants were asked to reflect on the following questions:

- Which assignments/projects contributed the most to your learning about climate change?

- Is there anything else you learned about climate change that this survey does not reflect?
- Has studying the issue of climate change caused you to be more interested in climate change or science, in general?
- Is there anything else that you want me to know about your experience learning about climate change?
- If you have changed your mind about some aspect of climate change (ex. Cause, impacts, solutions, etc.)?
- Do you feel more confident now to teach climate change to your future K-12 students?

These questions were asked to obtain additional insight into the instructional approach and preservice teachers' understandings not captured by the CSIK and IPCC, nor the instructor's fieldnotes.

Results and Discussion

CSIK: Knowledge about Climate Change

Participants' knowledge of climate change increased significantly after completing the course. The descriptive statistics and results of the paired-sample t-test are summarized in Table 2.

Table 2. CSIK: Paired sample t-test (two-tailed) for climate change knowledge

		Mean	SD	SEM	t	p*
Climate Change Knowledge	Pre	7.58	3.137	0.408	4.634	0.001
	Post	9.49	2.811	0.366		

*Level of significance, $p \leq 0.001$; n =59

While there was a significant increase in the climate change science content knowledge, an item frequency analysis revealed specific concepts that participants had difficulty with even after instruction. They were most familiar with the consequences of climate change at the beginning of the course and instructional intervention. This is not surprising in the southeast U.S. where the news often reports on flooded streets due to sea level rise and king tides. Preservice teachers, however, were initially not as knowledgeable about the distinction between weather and climate or the effects of latitude on temperature. By the end of the course, though, over 66% of participants understood these concepts.

Energy concepts were the most difficult to understand even after instruction. Only 50% of the preservice teachers understood that Earth emits infrared radiation and the processes involved in Earth's energy budget. They had difficulty understanding the processes involved in the greenhouse effect—they confused the process of greenhouse gases absorbing infrared radiation and then re-emitting infrared radiation toward Earth. Over 20% still thought that infrared radiation absorbs greenhouse gases. This is in agreement with other research on teachers' conceptions of the greenhouse effect (Shepardson, Niyogi, Choi, & Charusombat, 2009).

Participants did develop some understanding of the causes of the recent increase in global average temperature. Over 75% came to the class knowing that, the burning of fossil fuels was the main cause of recent change in global climate. However, less than 30% of these preservice teachers knew that the increase in the concentration of atmospheric greenhouse gases is the cause for the recent rise in global mean temperature. By the end of the course, approximately 75% did understood this cause and effect concept.

Participants' understanding of the carbon cycle was incomplete. They did not develop an understanding of the processes that remove carbon dioxide (i.e., depositions in sediments, dissolution in ocean water, and photosynthesis). Even after instruction, 75% thought that fossil fuels, instead of carbon dioxide, are released directly into the atmosphere. This indicates that participants still had a limited understanding of the carbon cycle and its connection to energy consumption and climate change.

IPCC Results: Perceptions about Climate Change

Responses to the IPCC survey indicated that participants became significantly more concerned about climate change and developed perceptions more aligned to climate scientists about its causes and impacts. Table 3 shows the descriptive statistics and results of the paired-sample t-test for the first three IPCC constructs (i.e., concern, causes and impacts, and skepticism). The fourth concept, actions, does not lend itself to the t-test statistic and is discussed after the first three in its own section.

Table 3. IPCC: t-test results

		Mean	SD	SEM	t	p*
Concern About Climate Change	Pre	8.07	1.35	0.176	4.959	0.001
	Post	9.24	1.50	0.195		
Causes and Impacts of Climate Change	Pre	14.86	2.36	0.307	1.339	0.186
	Post	15.31	1.60	0.208		
Skepticism About Climate Change	Pre	11.98	1.71	0.222	3.604	0.001
	Post	13.19	2.45	0.318		

*Level of significance, $p \leq .05$; $n = 59$

IPCC: Concern about Climate Change

Preservice teachers were significantly more concerned about climate change after the methods course. A paired-samples t-test was conducted to determine if there was a significant difference between the pre and post categories. The result was $t = 2.966$, sig (two-tailed) = 0.006. At the beginning of the course, 60% were concerned or alarmed while, at the end, 95% were concerned or alarmed. Also, upon course completion, all participants were engaged in the issue.

Table 4 presents the pre and post results on an IPCC item that described the six-America's concern categories and asked participants to identify which category they felt best described their level of concern about the impacts of climate change at that point in time. The post results show a trend of participants moving up in their identification with the six-America's level of concern. None identified with any category lower than Cautious. Overall, 95% had moved into the top two concern categories after completing the course compared to 60% before.

Table 4. IPCC: Pre and Post Identification with 6 America's concern categories (percentage)

Category	**Pre**	**Post**
Alarmed	14	51
Concerned	46	44
Cautious	31	5
Disengaged	10	0
Doubtful	0	0
Dismissive	0	0

IPCC: Causes and Impacts of Climate Change

Perceptions about the causes and impacts of climate change changed significantly as a result of the instruction. This finding correlates with changes in their knowledge about the causes and impacts captured on the pre and post CSIK results. When asked what they thought was the main cause of recent climate change, 51% compared to 85% responded human activity on the pre-IPCC and post-IPCC, respectively. Results indicate that participants left the course taking the impacts of climate change more seriously. At the beginning of the course, 64% of the preservice teachers thought that a few degrees (3-4°C) of warming would be harmful to life on Earth, and, at course completion, this increased to 92%. After course completion, most preservice teachers thought that there was a very good chance of extreme weather events, people having to move away from their cities, and water and food shortages occurring over the next three decades.

IPCC: Skepticism about Climate Change

At the beginning of instruction, 94% of the preservice teachers thought that there was widespread disagreement among scientists on the anthropogenic cause of recent climate change. Course instruction included the fact that approximately 98% of climate researchers actively publishing in the field agree that climate change is occurring and that it is due to human activity. (Anderegg, Prall, Harold & Schneider, 2010). Despite this, after course completion, 30% still held onto the perception that there was widespread disagreement among scientists. This highlights that some perceptions have deep-rooted origins and are not easily shifted. One potential reason for this finding is that the media often portrays this point from different viewpoints which are heavily influenced by politics (Somerville and Hassol, 2011). The influence of daily exposure to media sources competes with the information being presented in the course. Initially, approximately 65% "agreed" that the media leads people to question the science of climate change, and even more, 74%, agreed by the end of the course. More participants (an increase of 23% to 46%) "strongly agreed" that oil and coal companies try to influence politicians to be skeptical of climate change. Also by the end of the course, more preservice teachers, 61% compared to 28%, thought that scientists were not making climate change sound more serious to receive grant funding.

When asked what caused them to question the science underlying climate change, participants' responses varied. Approximately 3% said that they do not question the science of climate change on the pre-IPCC compared to 49% on the post-IPCC. Reasons varied for questioning the science at the beginning of instruction, but the main reason was a lack of science knowledge. On the pre-IPCC, 41% of participants reported that they had a lack of scientific knowledge on the topic, compared to 17% on the post-IPCC.) Most (over 95%) of the preservice teachers indicated that they trusted scientists both at the beginning and end of instruction.

IPCC: Actions to Mitigate the Impacts of Climate Change

This IPCC item does not lend itself to a t-test statistic because it asked participants to rank order a list of possible actions. Participants were asked to rank order a list of possible actions the U.S. should take to mitigate climate change and what actions they were taking. Table 5 shows the top three choices at the beginning and end of the course.

Table 5. IPCC: Actions to mitigate climate change consequences

	Pre	Post
Ranked Actions for U.S. to take	Encourage Americans to eat fewer meat products Invest more in renewable energies Invest more in nuclear	Put a tax on carbon Invest in technology to remove greenhouse gases in the air Invest more in clean coal, natural gas, tar sands oil
Ranked Actions you are taking to reduce climate change	Teaching others about climate change Investing in green companies Trying to cut back on electrical use at home	Teaching others about climate change Riding a bike or walking to work or other places Driving a car with excellent gas mileage

Responses about what the U.S. should do varied on the pre and post-IPCC. After completing the course, more participants chose putting a tax on carbon and removing greenhouse gases. However, they also chose investing in clean coal, natural gas, and tar sands oil. They were asked why they were not taking more action to mitigate climate change. Only one said that climate change was not an urgent enough issue to take action on. Responses for the other reasons were evenly divided (i.e., individual actions not making a difference, too late, and too expensive).

Fieldnote Analysis: Scientific Argumentation

For this section, data from the instructor's (researcher) fieldnotes were analyzed collaboratively with the other researcher. The analysis was intended to be descriptive in order to reveal any patterns about the quality and effectiveness of argumentation activities. Many participants were able to differentiate between a common argument and a scientific argument. An example of a beginning quote is, "when scientists argue, they are fighting to prove they are right." Examples of ending quotes include the following:

> Arguments between scientists are about helping each other come to a consensus and it is professional and does not involve insults.

> It [a scientific argument] is based on research and uses evidence. The point is not necessarily to win. It is to have the most accurate claim that is back up by empirical research and not based on personal feelings.

The course also helped increase epistemological understanding of scientific argumentation. The following are common post responses to the question about the role of argumentation in the field of science.

> Argumentation helps scientists eventually come to a consensus.
>
> [Scientific argumentation] allows science to expand. Science is always changing and without argumentation there would be no challenging of ideas, changes, or advancements.
>
> [Scientific argumentation] allows scientists to check and understand new research with others.
>
> I think it [scientific argumentation] helps others see others see the data given to move and form their own opinions on the matter. I also think it helps change theories that may be now proven wrong.
>
> It [Scientific argumentation] plays a very large role because every time someone poses an argument, that topic is re-studied and re-evaluated in order to get a different correct outcome or get a stronger outcome.

Finally, preservice teachers understood the criteria that make a scientific argument convincing or resilient. Examples of criteria listed by participants included: empirical research, an accurate claim, justification of empirical evidence, having results that represent and support their claims, reliable evidence, evidence over time, and a large sample size.

Participants were asked to differentiate between skepticism and denial. These concepts are especially relevant to the issue of climate change and to the argumentation assignment. Most indicated that they had a very good understanding of difference between being skeptical and in denial at the beginning of instruction. They were also asked whether they thought skepticism and/or denial about climate change had increased over the past few years. At the beginning of instruction, the majority provided many examples about why they thought the public had grown more skeptical. Most of the responses included some blame on the media presenting "playing both sides of the argument, causing people to become confused." A few thought that the public had moved from being in denial to being skeptical. Some felt that the public was just "uninformed or chose to make a judgment knowing little about the data." At the end of the course, the majority also reported that they thought public skepticism or denialism had grown. A few participants disagreed because they thought that more research and information was available and easier to find. This could be a reflection of their own experience in the class developing their scientific arguments. A few also said that "the public just does not care or does not want to feel blame or change lifestyles".

End-of-Course Questionnaire Reflections

Approximately 75% stated that the argumentation assignment contributed most to their increased understanding of climate change. We followed up on this question and discovered that all the participants felt that the argumentation activity was both engaging and valuable and that they would use them in their own teaching practice. The 25% who had indicated that it was not the most important to increasing to their own climate change understanding felt that they already had a good understanding and so it did not appreciably increase that understanding in their opinion. Participants were asked whether they were skeptical about the socioscientific issue of climate change at the end of the course. More than 80% indicated that they, far from being skeptical, were keenly more aware and concerned about the consequences of climate change. They attributed this to the course and their increased understanding and skills in engaging in scientific argumentation. All participants indicated that they felt much more confident to teach students about climate change at the end of the methods course than they had felt at the beginning.

Conclusion and Recommendations

Scientific thinking is defined as "knowledge seeking" according to Kuhn (2010). It is something people do, not something they have (referred to as scientific understanding by Kuhn). In a world where there is an oversupply of information, the ability to make sense of information is now the scarce resource (Gilbert, 2005). Prior to the course, preservice teachers reported getting their most trusted information about climate change from Google or the Weather Channel. After completing the course, they reported that NASA information websites, *Skeptical*

Science, scientific reports and journals were their trusted sources. As science educators, we felt that this held promise that the knowledge they were seeking might come from more reliable sources in the future.

Preservice teachers need to understand the difference between skepticism, as a characteristic of the nature of science, and denial of climate change. The influence of perceptions about climate change can play a role in participants' willingness to learn the science needed to understand this complex issue (Skamp, Boyes, & Stanisstreet, 2013). It was encouraging that participants in this study developed perceptions more aligned to those of climate scientists and that this correlated with an increased knowledge base about the science underlying climate change. 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. Our findings in this current study concur with this. After completing the course, there was an increase in the number of preservice teachers who perceived that global warming is caused by human activity and this correlated with increased concern about the impacts of climate change on the environment and humans. It also galvanized their interest in supporting national and personal actions aimed at mitigating the impacts of climate change.

There is a broader impact on society as the gap grows between the science and the public's understanding of science (Sterman, 2011). The knowledge necessary to interpret science falls in six types (i.e., content knowledge, knowledge of methods of collecting data, how data is interpreted, the role of modeling in science, role of uncertainty in science, and how science is communicated in the public domain) (Ryder, 2001). Baram-Tsabari and Osborne (2015) challenge science educators to teach students to be able to make informed choices. This study presents a design-based research curricular innovation as one example of how to address this challenge posed to the science education community (Berry, Loughran, Smith, & Lindsay, 2009).

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