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Emotions about Teaching about Human-Induced Climate Change

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Global climate change is receiving increasing attention as a classroom topic. At the same time, research has shown that individuals have strong emotions about the topic. Emotions about controversial topics and individuals' dispositions toward knowledge have been shown to influence judgments about these topics. This study examined the relationships among preservice elementary and in-service secondary science teachers' emotions about and plausibility perceptions of climate change, background knowledge of weather and climate distinctions (a principle related to understanding climate change), and dispositions toward knowledge. Teachers' topic emotions (anger and hopelessness) were significant predictors of plausibility perceptions, with more anger associated with lesser plausibility and greater hopelessness associated with higher plausibility. Decisiveness—an urgent desire to reach closure—was also significantly related to plausibility perceptions with greater decisiveness associated with reduced plausibility perceptions. In-service secondary teachers who do not currently teach about climate change exhibited greater anger and decisiveness than preservice elementary teachers and in-service secondary teachers who do teach about climate change. Implications for climate literacy education are discussed.

Keywords: *Teacher beliefs; Plausibility judgments and reasoning; Earth science education; Teacher emotions; Climate change*

Global climate change is receiving increasing attention as a classroom topic. Recently, the US National Oceanic and Atmospheric Administration and the American Association for the Advancement of Science developed a guide to promote greater understanding of the science behind climate change and, also, to assist teachers in aligning climate change lessons to science content standards (U.S. Global Change

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Research Program, 2009). The guide provides a focused and succinct overview of the complex science underlying global warming. Such a resource can be beneficial to classroom teachers because of the topic's complexity. However, in addition to the complexities of climate change science, the teacher may have other concerns when covering this topic. Climate change is associated with strong emotions, particularly when discussing the potential relationship between human activities and global warming (i.e. human-induced climate change; Broughton, Pekrun, & Sinatra, 2012). Both students and teachers may feel a wide range of negative emotions about the topic, including anger, hopelessness, fear, and anxiety (Moser, 2007) which could impact their instruction.

Our purpose in conducting this study was to examine teachers' emotions about climate change and teaching about climate change. Because the issue of climate change involves the understanding of fundamental scientific principles, we chose science teachers as participants, including elementary preservice teachers who are preparing to teach science. The new framework for K-12 science education also has an increased emphasis on teaching about climate science at all grade levels (National Research Council, 2012). Furthermore, we investigated relationships between teachers' topic emotions and their background knowledge, need for cognition, need for closure, and plausibility perceptions about climate change. We discuss the theoretical background and importance behind these relationships in more detail below.

Emotions and Learning

Recent work by Pekrun and his colleagues has contributed greatly to our understanding of associations between emotions and learning. In developing his control-value theory of emotions associated with academic achievement, Pekrun (2006) integrated the antecedents and effects of emotions experienced in academic environments (e.g. positive emotions such as enjoyment, which are associated with increased academic achievement, and negative emotions such as anxiety, which are associated with decreased academic achievement). Central to the theory is Pekrun's perspective that emotions integrate several psychological processes, including motivation and development of cognitive mental representations. Therefore, emotions can strongly influence learning.

In addition to Pekrun's (2006) work, other researchers have also developed theories to describe the relationship between emotions and learning (see, for example, Linnenbrink, 2007; Eynde & Turner, 2006); however, empirical results do not always show a clear connection. For example, a recent study by Kim and Hodges (2012) showed that individuals subjected to a treatment promoting emotional self-control experienced a greater degree of positive academic emotions (i.e. enjoyment and pride) and interest in mathematics. However, there was no significant difference between treatment and control group participants in mathematics learning. Linnenbrink (2007) also reports that she and colleagues found that 'pleasant affect [was] consistently unrelated to ... [mathematics and science] learning ... across [a series of] four studies' (p. 117). On the other hand, 'unpleasant affect was negatively related' to mathematics and science learning in these same four studies (Linnenbrink, 2007, p. 117). One reason for this inconsistent link between emotions and learning may be the highly dynamic nature of simultaneous emotional, motivational, cognitive, and behavioral processes that are present in typical instructional settings (Eynde & Turner, 2006).

Topic Emotions

Classroom emotions emerge from teacher and student interactions (Schutz, Cross, Hong, & Obson, 2007), achievement-related activities and outcomes (Linnenbrink-Garcia, Rogat, & Koskey, 2011; Pekrun, Frenzel, Goetz, & Perry, 2007), and the topic of instruction (Broughton, Sinatra, & Nussbaum, 2011, Broughton et al., 2012). Emotions connected directly to the topic of instruction are the focus of the present study and distinct from other achievement emotions (e.g. test anxiety). For example, teachers and students may have generally good feelings about the domain of science, but adverse emotions about controversial topics such as stem cell research, evolution, or human-induced climate change (for a review of topic emotions see, Sinatra, Broughton, & Lombardi, forthcoming).

There is a paucity of research on teachers' emotions about climate change. However, there is research on affect and teaching about other controversial science topics: specifically biological evolution. Griffith and Brem (2003) found that teachers often experience an appreciable amount of anxiety when teaching about evolution. In particular, teachers they called 'selective' tended to cope with their high level of anxiety by avoiding sensitive aspects of evolutionary theory and maintaining strong control of the classroom by using a 'highly structured teaching style' (Griffith & Brem, 2003, p. 805). This prevailing affect may also discourage teachers from promoting mastery learning in their students (Linnenbrink, 2007). Furthermore, with such high levels of control, teachers may not encourage metacognitive strategies that would result in their students achieving a high level of engagement, and subsequently decrease the possibility of achieving deep understanding (Reeve, 2009).

Another look at teacher emotions comes from Gregoire (2003) who found that challenges to teachers' beliefs about mathematics reforms 'promoted greater negative affect compared with a control group whose beliefs were not challenged' (p. 173). Such negative affect may lead to teachers feeling threatened by messages related to reforming their educational practice, and subsequently, resulting in lower degree of adoption of these reform strategies. In a professional development setting, in-service teachers who are learning about climate change may resist both the content and pedagogical message because of adverse emotions. Similarly, preservice teachers enrolled in a science methods course may have negative emotions about climate change, which subsequently could limit their development as science teachers.

Emotions based specifically on the topic of instruction could interfere with motivation and cognition in a similar way to emotions experienced in the learning environment (Pekrun et al., 2007). Recent research showed that emotions dynamically interacted with other cognitive processes during learning (Linnenbrink, 2007). These emotions might often affect learning implicitly and could occur automatically before the student or teacher seriously considers the instructional message (Gregoire, 2003).

Automatic processing based on emotional responses may be particularly problematic for controversial and complex topics, such as climate change, where both teachers and students may have appreciable misconceptions that are unlikely to be overcome without reflection (see, for example, Boyes & Stanisstreet, 1993; Choi, Niyogi, Shepardson, & Charusombat, 2010; Gowda, Fox, & Magelky, 1997; Lombardi & Sinatra, 2012; Moxnes & Saysel, 2009; Papadimitriou, 2004). Misconceptions are notoriously robust to change and can act as a barrier to learning scientifically accurate ideas (Chi, 2005). To reconstruct knowledge structures into scientifically correct conceptions, Dole and Sinatra (1998) have theorized a complex interaction among (a) students' existing mental representations, (b) their motivation to change, and (c) the incoming, scientifically accurate message that teachers present to students. The judgment about a message's plausibility is a characteristic that may particularly sensitive to students' and teachers' emotions about a particular topic.

Plausibility Judgments

Plausibility judgments may be an important way in which teachers and students evaluate an incoming message. In situations of cognitive dissonance, plausibility judgments comparing the incoming information to the existing conception could influence the degree to which individuals engage in conceptual change (Dole & Sinatra, 1998; Pintrich, Marx, & Boyle, 1993; Posner, Strike, Hewson, & Gertzog, 1982). Specifically, plausibility perceptions result in a judgment on the *relative potential* truthfulness of incoming information compared to our existing mental representations (Rescher, 1976). Pintrich et al. (1993) proposed that when students seek plausibility in a new mental representation they may undergo a deeper level of cognitive processing through elaboration and organization, which 'facilitate encoding and learning' (p. 174). Although plausibility has long been theorized as an important component in conceptual change, empirical studies concerning plausibility judgments in knowledge reconstruction have been lacking. Recently, however, Lombardi and Sinatra (2012) found that plausibility perceptions about climate change accounted for statistically significant changes in undergraduate students' knowledge over semester-long instruction, above and beyond their initial background knowledge. Authors specifically examined knowledge change about weather and climate distinctions, a common source of misconceptions (e.g. using short-term weather events to predict long-term climate trends; Papadimitriou, 2004).

Emotions that individuals have about particular topics may directly influence their plausibility judgments. Broughton et al. (2012) examined emotions that graduate students had about three controversial topics, including climate change. Greater emotional intensity (measured using a Likert scale ranging from not experiencing an emotional at all to experience a very strong emotion about a topic) was associated with holding a larger number of misconceptions about a topic. Broughton et al.

(2012) did not measure plausibility judgments associated with these controversial topics, however, based on Lombardi, Sinatra, and Nussbaum (2012), evidence suggests that misconceptions influence the degree of evaluation made between incoming information and background knowledge, with lesser critical evaluation related to a greater number of misconceptions. When teaching about controversial topics, the teacher would need to be an active agent in encouraging students to weigh the plausibility of the incoming information with the background knowledge in a way that is not adversely affected by students' emotions. However, the potential for the teacher to facilitate such critical reappraisal could be impacted if they too exhibit adverse emotions about the topic.

Epistemic Motives and Dispositions

Emotions about a topic may relate to individuals' disposition toward knowledge, such as need for cognition (Cacioppo, Petty, Feinstein, & Jarvis, 1996). Individuals who express a greater need for cognition enjoy effortful thinking and thus may enjoy learning about a complex topic such as climate change. Conversely, individuals who do not enjoy thinking about complex topics may avoid learning about climate change. Epistemic motives—an individual's inclination toward a particular view of knowledge—may also interact with topic emotions. One such motive is the need for closure, which is the degree to which an individual desires 'a definite answer on some topic. . .as opposed to confusion and ambiguity' (Kruglanski, 1989, p. 14). For example, Sinatra, Kardash, Taasoobshirazi, and Lombardi (2012) found that one aspect of need for closure (i.e. closed-mindedness) was significantly associated with less willingness to take actions to reduce global warming. Based on the results of these studies, we speculate that individuals who are more open-minded may also be less angry about the topic of climate change, may have more motivation to engage with the topic, and may find climate change to be more plausible.

Misconceptions about Climate Change

Individuals' background knowledge may be inconsistent with scientific understanding and this can have a significant bearing on their plausibility judgments about human-induced climate change (Lombardi & Sinatra, 2012). Common misconceptions relate to the causes of current climate change (e.g. thinking that stratospheric ozone depletion is a significant contributor to recent climate change; see, for example, Boyes & Stanisstreet, 1994; Österlind, 2005). Misunderstandings may also be expressed about the evidence supporting current climate change. For example, individuals sometimes use weather events, which are localized and short term, to make conclusions about the potential for climate change, which would occur regionally over much longer periods (Choi et al., 2010). Knowledge of weather and climate distinctions directly represents a core idea in the development of students' understanding about Earth's atmospheric systems (National Research Council, 2012), and is therefore particularly relevant to teachers. However, teachers can be as confused about weather and climate distinctions as their students (Gowda et al., 1997; Lombardi & Sinatra, 2012; Papadimitriou, 2004).

Teachers' misconceptions about climate change are problematic not only because scientifically inaccurate ideas may be transferred to their students, but also because their misunderstandings could be related to adverse emotions about the topic. Negative emotions—along with certain dispositions toward knowledge (e.g. decisiveness, which is an urgent desire to reach closure)—may also reduce the opportunities to engage in critical evaluation of the connections between evidence and alternatives. Critical evaluation is a necessary component to develop scientific reasoning skills (Kuhn & Pearsall, 2000) and may enable teachers and students to generate plausibility perceptions consistent with those developed by scientists. Whereas the research literature suggests linkages among teachers' background knowledge, dispositions toward knowledge, topic emotions, and plausibility perceptions about the controversial topic of climate change, the nature of these connections are heretofore speculative. The potential to explore this connection empirically, and thus provide greater understanding of the connection among these variables provided the motivation for the present study.

The Present Study

Research Questions

The present study examined the relationship between background knowledge, need for cognition, need for closure, topic emotions, and plausibility perceptions in three groups of teachers: (a) in-service teachers who do teach about climate change, (b) in-service teachers who do not teach about climate change, and (c) preservice teachers (who by definition, also do not currently teach about climate change). We asked the following two research questions.

1. Do background knowledge about weather and climate distinctions (an important conception related to climate change), topic emotions, and epistemic motives and dispositions (i.e. needs for cognition and closure) predict plausibility perceptions of climate change in teachers?
2. Do background knowledge, plausibility perceptions, topic emotions, need for cognition, and need for closure differentiate these three teacher groups (i.e. preservice teachers, in-service science teachers currently teaching about climate change, and in-service science teachers not teaching about climate change)?

Hypotheses

With regard to the first research question, we hypothesized that teachers with a greater understanding of weather and climate distinctions would rate the plausibility of climate change as more plausible than those with a lower understanding of these distinctions. We based this hypothesis on our earlier work connecting plausibility perceptions to knowledge change about weather and climate distinctions (Lombardi &

Sinatra, 2012) and a recently developed model of plausibility judgments (Lombardi, Nussbaum, & Sinatra, 2012). We also hypothesized that teachers' emotions about human-induced climate change would predict their plausibility perceptions. The earlier work of Broughton et al. (2012) showed significant associations between emotional intensity level and number of misconceptions. Climate change is also an inherently complex issue that requires critical thinking and open-mindedness during consideration. We therefore hypothesized that need for cognition and need for closure would also predict plausibility perceptions (Lombardi et al., 2012).

For the second research question, we hypothesized that in-service teachers would have greater knowledge of weather and climate distinctions than preservice teachers. Several studies show that preservice teachers have many misconceptions about climate change (see, for example, Papadimitriou, 2004) and also that in-service teachers have greater content knowledge than preservice teachers have about Earth science topics (see, for example, Barba & Rubba, 1992). Based on our previous study showing the relationship between plausibility perceptions of climate change and knowledge (Lombardi & Sinatra, 2012), we hypothesized that in-service teachers would have greater plausibility perceptions than preservice teachers. We also hypothesized those teachers who do not currently teach about climate change would express a greater intensity of negative emotions (e.g. anger, boredom, hopelessness, and fear) compared to those that currently do. We based this final hypothesis on research showing that increasing levels of knowledge about a topic tend to dampen adverse feelings (Broughton et al., 2011).

Method

Participants

Eighty-five teachers participated in the study. Forty were in-service secondary science teachers from a school district in the southwestern USA, who had self-enrolled in four-day professional development workshop. The workshop theme was air quality and included a 1-h discussion of global climate change on the workshop's third day. Sixteen of these in-service teachers reported that they had previously taught about climate change in their classrooms and 24 reported that they had not. The remaining 45 teachers were preservice elementary teachers enrolled in an urban university's science methods course. Participants ranged in age from 20 to 60 ($M = 33.0$, SD = 11.7), with 0 to 35 years of teaching experience. The participants were predominantly female (84%) and white (76%), with the remainder of the participants being Hispanic (7%), African American (7%), Native American (6%), and Asian/Pacific Islander (4%).

Measures

We used five measures in the study: (a) emotions about human-induced climate change and teaching about climate change, (b) knowledge of weather and climate distinctions, (c) plausibility perceptions of climate change, (d) need for cognition, and

(e) need for closure. Participants who were in-service teachers completed the measures using an online survey tool just prior to starting the four-day workshop. Pre-service teacher participants completed the measures in the first two weeks of their elementary science methods course, also using the online survey tool. Table 1 shows reliability and covariation between scores for each of the instruments, which we discuss in more detail below.

Emotions about climate change and teaching about climate change. We created the Emotions about Teaching Human-Induced Climate Change (ETCC) questionnaire for this study (Appendix 1). This Likert-scale survey contains five statements about human-induced climate change (the first three statements) and teaching about this topic (the last two statements). For example, one statement said, 'When I hear people say that human activities are causing climate to change, I feel ...' This statement rates emotions that participants may have about climate change. Another statement reflecting emotions about teaching climate change read, 'When I teach about [think about teaching about] climate change, I feel ...' After reading each statement, participants rated how well 10 different emotions reflected their intensity of feelings about the statement using a 5-point scale (1 = strongly disagree to 5 = strongly agree). The 10 emotions are anger, anxiety, boredom, curiosity, fear, frustration, happiness, hopelessness, shame, and surprise. These emotions were taken from Pekrun et al.'s (2007) control-value theory of achievement emotions and a previous study on topic emotions conducted by Broughton et al. (2011). With five statements and 10 emotions measured per statement, there were 50 total items in this questionnaire.

As shown in Appendix 1, we used two different forms of the ETCC for the study. Participants who were currently teaching about climate change completed one form, while those who were not currently teaching about climate change completed the other. The last three items differed slightly to reflect the participants' status. For example, participants who were currently teaching about climate change responded to the statement, 'When I teach my students about the impacts of climate change, I feel ...' The corresponding statement on the second form (for participants not currently teaching about climate change) read, 'When I think about teaching in the future about the impacts of climate change, I feel ...' We attempted to word the ETCC items as unambiguous declarative statements in the form of short simple statements without jargon (DeVellis, 2003). Furthermore, three science education experts reviewed the ETCC to ensure content validity.

Weather and climate distinctions. We used the Distinctions between Weather and Climate Measure (DWCM; Lombardi & Sinatra, 2012) to measure participants' understanding about this topic fundamental to understanding global climate change. Individuals sometimes use weather events, which are localized and short term, to make conclusions about the potential for climate change, which would occur regionally over much longer time periods—30 years or greater (National Climatic Data Center, 2008). The DWCM contains 13 single-sentence statements

Table 1. Bivariate correlations, descriptive statistics, and coefficient α values for some study variables ($n = 85$)

Variable	1	2	3	4	5	6	7	8	9	10
1. Age	–									
2. DWCM	0.492**	–								
3. PPM	−0.056	−0.069	–							
4. Need for cognition	0.138	0.274*	0.028	–						
5. Decisiveness	0.207	0.314*	−0.254*	0.482**	–					
6. Anger about CC	−0.088	−0.065	−0.251*	−0.053	0.009	–				
7. Bored about CC	0.095	0.094	−0.231*	0.000	0.199	0.241*	–			
8. Fear about CC	−0.212	−0.235*	0.281*	−0.083	−0.171	0.404**	−0.015	–		
9. Hopeless about CC	−0.216*	−0.230*	0.336**	−0.083	−0.216*	0.227*	0.214*	0.588**	–	
10. Angry about teaching about CC	0.161	0.226*	0.237*	−0.135	−0.001	0.281**	0.362**	−0.002	0.172	–
M	33.0	6.29	6.90	63.8	26.8	7.52	5.33	7.81	6.78	3.45
SD	11.8	2.66	1.60	8.06	5.49	2.62	2.23	3.03	3.08	1.54
Skewness	0.965	0.036	−0.466	−0.237	−0.221	0.170	0.770	0.084	0.490	0.674
Kurtosis	−0.199	−1.01	0.195	−0.005	−0.366	−0.183	−0.013	−0.821	−0.610	−0.683
Coefficient α	–	0.711	0.903	0.839	0.762	0.621	0.831	0.709	0.810	0.731

Notes: DWCM, distinctions between weather and climate measure; PPM, plausibility perceptions measure; CC, climate change. The possible score range was 0–11 for DWCM, 1–10 for PPM, 18–90 for need for cognition, 7–42 for decisiveness, 8–48 for closed-mindedness, 3–15 for the emotion about CC variables, and 2–10 for the angry about teaching about CC variable.

*$p < 0.05$.

**$p < 0.01$.

that specifically probe for this misunderstanding. Study participants classified each statement as being either weather or climate (Lombardi & Sinatra, 2012). The statements included in the DWCM reflect the results of research on individuals' confusion about weather and climate (Gowda et al., 1997; Papadimitriou, 2004). For example, the first statement says, 'There was a heat wave last summer.' This statement is about a memorable weather event that may confuse individuals about being a predictor of future climate changes. Like the emotions questionnaire, we wrote the DWCM items as short and simple declarative statements without jargon (DeVellis, 2003).

Plausibility perceptions of climate change. To measure participants' plausibility perceptions of climate change, we used the plausibility perceptions measure (PPM) (Lombardi & Sinatra, 2012). The PPM has eight statements about climate change that have been extracted from the latest summative report produced by a United Nations' expert panel (Intergovernmental Panel on Climate Change, 2008). Most of the PPM's statements are verbatim from major conclusions presented in the report, including, for example, the following: 'Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level' (Intergovernmental Panel on Climate Change, 2008, p. 2). Lombardi and Sinatra (2012) altered other statements slightly to improve clarity, including removing acronyms such as TAR (standing for Third Assessment Report). Participants rated each statement on a 1–10 Likert scale (1 = greatly implausible or even impossible and 10 = highly plausible). Lombardi and Sinatra (2012) report that 'that the PPM's readability [is] at the college level' (p. 7), which is typically a greater reading level than used on many educational research instruments. However, all of the participants were either attending college or had graduated from college, and we wanted to maintain fidelity to the climate report in order to gage plausibility perceptions of scientific statements more precisely.

Needs for cognition and closure. Cacioppo et al. (1996) developed the Need for Cognition Scale, which includes 18 items measuring the extent to which people engage in and enjoy effortful cognitive activities. Participants rated each item on a 5-point Likert scale, from 1 (strongly disagree) to 5 (strongly agree).

Webster and Kruglanski (1994) created the Need for Closure Scale to examine individuals' 'motivation with respect to information processing and judgment' (p. 1049). This instrument has 42 items that ask participants to rate their need for—or desire to avoid—cognitive closure using a 6-point Likert scale, from 1 (strongly disagree) to 6 (strongly agree). The scale comprises five subscales measuring how need for closure is manifested: (a) preference for order and structure, (b) discomfort with ambiguity, (c) decisiveness in judgment and choices, (d) affording predictability to future contexts, and (e) closed-mindedness.

Qualitative Research Approach

To explore research questions 1 and 2 more fully, we conducted a systematic qualitative inquiry. In studies such as the present study, qualitative analyses can provide a richer description of the relationship between topic emotions, epistemic motives and dispositions, and plausibility perceptions. Furthermore, qualitative analyses can provide deeper understanding of participant perspectives. The design of this analysis was sequential, where the lead author first conducted field observations of the study participants, then using information from the observations, the lead author conducted detailed interviews of two participants. Details of our qualitative methods are discussed below.

Observations. The lead author conducted observations of the in-service teacher participants as they engaged in the four-day summer workshop. He had an official role in the workshop as a member of the planning team, and therefore was a moderate participant observer because he maintained a 'balance between being an insider and an outsider, between participation and observation' (Spradley, 1980, p. 60). Specifically, the lead author conducted observations only when activities were led by other individuals and when the teachers were working in small groups, but did not conduct observations when he was leading any activities.

The lead author attempted to overcome any potential researcher bias by focusing on adopting a learner's stance during the observation processes. The following were some important guiding questions he had. *How were the teachers speaking and acting differently than expected? Is what I am inferring shaded by my prior experience and knowledge?* With proper application of these questions, the lead author attempted to make the 'familiar strange' because he 'continually question[ed my] assumptions and perceptions' (Glesne, 2003, p. 51). The lead author's intent was to allow the participants to teach him. In the many months he spent preparing for the workshop, the lead author had come to visualize how the professional development would transpire and tried to anticipate different scenarios for planning purposes. Such teacher workshops rarely happen as previously visualized.

The lead author transcribed both handwritten and typewritten notes during the field observations. These field observations included both a description of the teacher interactions and the lead author's interpretation of these actions.

The lead author observed all workshop participants to inform his observations; however, he focused on the two teachers whom he later interviewed based on discussions with the most senior workshop leader who has 20 years of professional development leadership experience in the local school district. This workshop leader recommended that the lead author's observations focus on these two teachers because they generally display a large degree of emotionality in workshop settings and range in their understandings, attitudes, and beliefs about global climate change (i.e. from anger and skepticism to acceptance and commitment). Descriptions of these two teachers are discussed below (Note that we have used pseudonyms).

Claudia Roberts. Claudia is a white female and had just turned 60 at the time of the study. Claudia had been teaching high school for over 35 years. She was previously retired, but returned to teaching because of a high need for science teachers in the district. Claudia had taught many subjects in science, including biology and chemistry, but was currently teaching marine science, which covers oceanography and earth science.

Millie Shire. At the time of the study, Millie had been teaching for about 15 years and was in her early 40s. Millie is also a white female. She had been currently teaching physics at a science and mathematics magnet high school, where students are typically high achieving (i.e. as measured on state criterion referenced tests).

Interviews. The lead author conducted interviews of Claudia and Millie one week after the workshop. The interviews were semi-structured, with prepared questions providing the framework for the interview. He based the interview questions on stems from the questionnaires used in the quantitative analysis (see Appendix 2 for the interview protocol) and was specifically looking for connections between their emotions about climate change and teaching about climate change, plausibility perceptions, dispositions toward knowledge, and understanding about climate change. For example, a question that probed emotions about teaching climate change asked, 'what kind of emotions do you feel about climate change and how does this affect your teaching about climate change?'

Results

Quantitative Data Analysis

Data screening, descriptive statistics, and associations. Table 1 shows the means, standard deviations, skewness, kurtosis, and bivariate correlations for the measured variables: (a) emotions about climate change (i.e. the first three items in the ETCC), (b) emotions about teaching about climate change (i.e. the last two items in the ETCC), (c) knowledge of weather and climate distinctions, (d) plausibility perceptions of climate change, and needs for (e) cognition and (f) closure. For ETCC, Table 1 includes only those emotions that were significantly correlated to the other non-emotion variables and had coefficient alpha values greater than 0.6 (i.e. greater than the questionable reliability threshold; George & Mallery, 2003). Likewise, decisiveness is listed in Table 1 because it is the only need for closure subscale that was significantly correlated to the other variables and had a coefficient alpha value greater than 0.6. All skewness and kurtosis values were less than or equal to an absolute value of 1, indicating that we could assume normality in the remainder of our analyses. Furthermore, we found no outliers in any of the data (i.e. zs ≤ 3).

We conducted a screening analysis to determine comparability of the three teacher groups: preservice teachers, in-service science teachers who do not currently teach about climate change, and in-service science teachers who do currently teach about climate change. We found no significant differences between groups for categories of gender, $\chi^2(2) = 4.52$, $p = 0.11$, or ethnicity, $\chi^2(10) = 12.2$, $p = 0.275$. Not surprisingly, we did find a significant difference in age, $F(2,82) = 25.0$, $p < 0.001$, $\eta^2 = 0.379$, with the average preservice teacher being younger ($M = 26.2$, SD = 6.35) than both groups of in-service teachers currently teaching about climate change, ($M = 40.3$, SD = 12.9); not currently teaching about climate change ($M = 40.8$, SD = 11.3). We discuss further analyses for age and other outcome variables that passed these data screenings in more detail below.

Research question 1: overall predictors of plausibility perceptions. We conducted two multiple regression analyses to examine the relationship among the predictor variables (DWCM, needs for cognition and need for closure, and topic emotions) to the criterion variable (PPM). For these regression analyses, we combined all teacher participants into a single group. The first regression (Model 1) includes only topic emotions that individuals have about climate change and met the screening criteria discussed above (see Table 2). There was a significant relationship between the predictors and the plausibility perceptions measure, $F(8,76) = 5.09$, $p < 0.001$, with $R^2 = 0.349$. Anger and hopelessness about human-induced climate change were significant predictors of plausibility perceptions. A greater intensity of anger resulted in lower ratings of plausibility. Alternatively, more hopelessness was associated with higher ratings of plausibility. In Model 1, fear, boredom, age, background knowledge, need for cognition, and decisiveness did not significantly contribute to the prediction of plausibility perceptions.

Model 2 includes only emotions about teaching about climate change and met the screening criteria discussed above (i.e. anger about teaching about climate

Table 2. Results from the multiple regression analysis predicting plausibility perceptions about climate change

Predictor variable	*B*	*β*	*p*
Model 1: emotions about climate change			
Age	0.066	0.041	0.706
Knowledge of weather and climate distinctions	0.035	0.059	0.603
Need for cognition	0.025	0.128	0.242
Decisiveness	−0.058	−0.197	0.087
Anger about climate change	−0.220	−0.361	0.001
Bored about climate change	−0.125	−0.174	0.101
Fear about climate change	0.131	0.247	0.056
Hopeless about climate change	0.156	0.300	0.018
Model 2: emotions about teaching about climate change			
Age	0.001	0.009	0.941
Knowledge of weather and climate distinctions	0.027	0.046	0.722
Need for cognition	0.029	0.148	0.231
Decisiveness	−0.100	−0.342	0.006
Angry about teaching about climate change	−0.238	−0.229	0.040

change; see Table 2). There was a significant relationship between the predictor variables and the measure of plausibility perceptions, $F(5,79) = 2.61$, $p = 0.031$, with $R^2 = 0.142$. Anger about teaching climate change and decisiveness were significant predictors, with greater anger and decisiveness resulting in lower plausibility perceptions. In Model 2, age, background knowledge, and need for cognition did not significantly contribute to prediction of plausibility perceptions.

Research question 2: analyzing group differences using discriminant function analysis. We conducted a discriminant function analysis to assess loadings of the predictor variables (age, DWCM, PPM, needs for cognition and closure; as well as the topic emotions of anger, boredom, fear, and hopelessness about climate change and anger about teaching about climate change) on group membership (i.e. preservice teachers, in-service teachers who currently teach about climate change, and in-service teachers who do not currently teach about climate change). We did not identify any cases as multivariate outliers, and assumptions of linearity, normality, multicollinearity, and homogeneity of the variance–covariance matrices were met. We calculated two discriminant functions with a combined $\chi^2(20) = 108$, $p < 0.001$. After removal of the first function, associations between predictor and group variables were not significant, $p = 0.220$. The two discriminant functions accounted for 93.7% and 6.3% of the variance between group variability, respectively.

The first discriminant function maximally separated preservice teachers from both groups of in-service teachers. The loadings of predictors into the discriminant functions (Table 3) suggest that knowledge of weather and climate distinctions and age are significant predictors of differences between preservice and in-service teachers. Preservice teachers exhibited much less knowledge of weather and climate distinctions ($M = 4.31$, SD = 1.61) than both teachers who currently teach about climate change ($M = 8.69$, SD = 1.74) and those who do not ($M = 8.42$, SD = 1.61).

The second discriminant function maximally separated those teachers who currently teach about climate change from those that do not (i.e. including both in-service science teachers who do not currently teach about climate change and preservice teachers). The loadings of predictors into the discriminant functions (Table 3) suggest that anger about climate change is the greatest significant predictor of differences, with in-service teachers who do not currently teach about climate change expressing greater anger ($M = 8.17$, SD = 2.78) than both preservice teachers ($M = 7.67$, SD = 2.48) and in-service teachers who currently teach about climate change ($M = 6.13$, SD = 2.42). Decisiveness, a need for closure subscale, is the other significant predictor of differences in this second discriminant function. We recorded a greater level of decisiveness in in-service teachers who do not currently teach about climate change ($M = 29.9$, SD = 5.46) than those currently teaching about climate change ($M = 26.4$, SD = 5.55) and preservice teachers ($M = 25.2$, SD = 4.86).

Table 3. Results of the discriminant analysis of variables related to teacher group

Predictor variable	Function 1[a] structure coefficient	Function 2[b] structure coefficient	Wilks' λ	$F(2,82)$
DWCM	0.956	−0.059	0.368	70.6**
Age	0.499	0.062	0.621	25.0**
PPM	−0.192	0.019	0.975	1.04
Need for cognition	−0.174	0.139	0.933	2.94
Decisiveness	−0.051	0.670	0.866	6.34*
Anger about CC	0.227	0.591	0.927	3.23*
Bored about CC	0.148	0.430	0.949	2.21
Fear about CC	0.123	0.394	0.943	2.47
Hopeless about CC	−0.085	−0.268	0.935	2.86
Angry about teaching about CC	0.161	0.234	0.945	2.38

Note: DWCM, distinctions between weather and climate measure; PPM, plausibility perceptions measure; CC, climate change.

[a]Function 1 discriminates preservice teachers from in-service teachers.

[b]Function 2 discriminates in-service teachers who are not currently teaching about climate change from in-service teachers who do and preservice teachers.

*$p < 0.05$.

**$p < 0.01$.

The classification results in the discriminant function analysis reveal that cross-validated grouped cases were correctly classified 93.3% of the time for preservice teachers, 37.5% of the time for in-service teachers who currently teach about climate change, and 62.5% of the time for in-service teachers who do not currently teach about climate change. Overall, 74.1% of the cases were correctly classified, which is significantly greater than chance (33.3%) ($z = 8.00$, $p < 0.001$), which indicates that the two functions reveal reasonable discriminations between the groups.

The size of the overall sample ($N = 85$) and smallest group ($N = 16$), as well as the number of dependent variables that we included in the discriminant function analysis could make the group predictors potentially unstable (Stevens, 1992). Although our analysis meets the guideline stated by Tabachnick and Fidell (2007), where '*the sample size of the smallest group should exceed the number of predictor variables*' (p. 381, emphasis theirs), we conducted a nonparametric analysis to confirm group differences in knowledge of weather and climate distinctions, decisiveness, and anger about climate change (i.e. the significant predictors that emerged from the discriminant function analysis). We specifically used Kruskal–Wallis (K–W) tests for multiple independent groups, which robustly allows for small group sizes (i.e. minimum group sizes of 5). The K–W tests confirmed the results of the discriminant function analysis showing that there were significant differences between the groups in knowledge, $\chi^2(2) = 53.8$, $p < 0.0001$; decisiveness, $\chi^2(2) = 12.6$, $p = 0.002$; and anger, $\chi^2(2) = 6.23$, $p < 0.045$.

Qualitative Findings

Observations and interviews. The lead author conducted observations during two periods of the workshop when he was not leading activities. The first observation occurred on the workshop's first day during a presentation led by a local official who directs the county's air quality monitoring program. The second observation occurred on day three of the workshop, which occurred at a local nature center. Both Claudia and Millie exhibited a range of emotionality (both positive and negative) during both of these periods, particularly when the topic focused on climate change and teaching about climate change. For example, when a workshop facilitator posed a discussion question—how can widespread use of fuel cells change the atmosphere?—many of the teachers responded that fuel cells do not change the atmosphere because they would only emit water vapor. The facilitator then asked if emitting water vapor would change the atmosphere. One teacher responded saying that water vapor is a greenhouse gas. Millie immediately exclaimed, 'A huge greenhouse gas!' She was very focused on the teachers and seemed somewhat agitated. Millie turned to another teacher and said, 'they won't talk about it, water is never mentioned. It's negligible.' Millie began to nod when the other teachers joined her skeptical argument about climate change and smiled when a teacher says that maybe water vapor would be a pollutant. Millie then exclaimed, 'The *Inconvenient Truth* is the worst movie ever made! It does not talk about *the why*! It is missing the context!' Based on observations such as these, the lead author selected Claudia and Millie for follow-up, in-depth interviews.

The two interviews focused on plausibility perceptions and topic emotions related to human-induced climate change, as well as emotions about teaching climate change. Each interview lasted about 45 min. The lead author created detailed transcriptions of these interviews. Interestingly, both the interviewees expressed high degrees of emotionality and plausibility perceptions during their interviews. The following examples highlight the relationships between topic emotions related to climate change and teaching about climate change, plausibility perceptions about climate change, and need for closure.

Claudia discussed her knowledge of the distinctions between weather and climate, the emotions she has observed from her students when teaching about climate change, and her emotions about climate change. Claudia had a strong focus on water during the interview, which is no surprise given that she is one of the few high school teachers in her large urban district who teaches marine science. In discussing weather and climate distinctions, she related information about a current 10-year drought, which had resulted in a local reservoir's low water level. While she suspected that the drought might be related to climate change, she was uncertain and said,

> Well, unfortunately you have a lot of factors here. I have lived here since 1977. I've seen how they have not had adequate planning . . . .I think . . . of how we needed to use our resources and yes . . . yes there is a point at which, even if we are saving our resources, there are only so many people who can live here based on the amount of water that was allocated.

Claudia seemed to think that that the low reservoir level is a complex problem that may be more plausibly related to regional overpopulation (a misconception) than to climate change (an answer that many regional climate scientists think is accurate; Overpeck & Udall, 2010). Toward the end of the interview, Claudia expressed angry emotions about what she referred to as 'lax' environmental regulations, and how this neglect had led to the recent oil spill in the Gulf of Mexico. She said that such things made her angry and frustrated because,

> ... they don't get it! They are looking at what it is going to cost them ... it's all about money! It's all about money!

In this statement, Claudia was clearly attributing the cause of the spill on industry and may have been referring to environmental impacts in general, including climate change.

Millie focused almost exclusively on plausibility perceptions of scientific statements in general, and human-induced climate change specifically. About her understanding of scientific knowledge, Millie said,

> I have a network of people that I can go to and I am not afraid to pick up a phone and say, 'I don't understand this.' So, I will call people. I will ask questions. I am not afraid to go to the experts. You know I enjoy reading the primary source, the primary references.

Just after this comment, Millie related how she heard that many of the world's glaciers are actually advancing (a misconception) and not receding as reported by scientific statements. When the lead author asked her about the source of this information, Millie said,

> I read it online ... I haven't found the primary source for that yet. I am still looking for those primary sources. I was told that there was this think-tank in DC where a lot of this information is coming out of, but my first question is: who are they being funded by ... who's paying their salary?

Millie also seemed extremely agitated by a recent mistake in a scientific climate change report. Her reaction to apologies made by scientists when they discovered their mistake was,

> Oh yeah, [the scientists] lied about it ... Well, you just discredited yourselves! Well, now how am I supposed to believe you when you then come out with another statement ... are you lying again? My question then becomes: what is your agenda?

Millie directed her anger directly at scientists and their claims about climate change.

Both interviewees discussed student emotions when teaching about climate change, and interestingly, neither seemed anxious about adverse feelings that their students may have. In fact, both Claudia and Mille indicated that strong emotions from their students might be beneficial to the learning environment. Claudia specifically implied that she tries to elicit strong emotional reactions from her students in order to promote action (e.g. willingness to act to mitigate environmental impacts). For example, when discussing issues related to drought, Claudia shows her students a video of how the Colorado River dries up before reaching the ocean.

> I... want [the students] to see that the Colorado River doesn't make it to the ocean... and they are somewhat shocked. You have to build [their emotions] up so they talk about the problem.

Claudia therefore uses shocking visual images to promote productive dialog among her students.

Discussion

Our results provide support for our research hypotheses in that they show a predictive relationship among topic emotions, knowledge dispositions (specifically decisiveness), and plausibility perceptions. Our findings reveal that certain topic emotions about climate change and teaching about climate change predict plausibility perceptions of climate change. Negative emotions such as hopelessness and anger were related to plausibility perceptions about climate change, with hopelessness positively related to plausibility and anger negatively related. Decisiveness (a need for closure subscale) also negatively related to plausibility perceptions teaching about climate change. We interpret this finding to suggest that negative emotions such as anger may reduce the evaluative judgment needed to weigh the evidence and decide whether climate change is indeed occurring. Our results show that greater anger results in lower plausibility, thereby suggesting the potential for less engagement with the topic. Hopelessness could also result in teachers failing to engage because they may have a perceived inadequacy to influence future outcomes. Decisiveness may also be an indicator that engagement is reduced in the learning and teaching situation. In this study, greater decisiveness resulted in lower plausibility, thereby potentially indicating that individuals with an urgent desire to decide may tend to evaluate information heuristically (i.e. as theorized by Dole & Sinatra, 1998, p. 117). The teacher observations and interviews also show a connection between emotionality, decisiveness, and plausibility judgments. For example, one teacher's anger about a mistake in a major report on climate change was associated with feelings that climate scientists were not being truthful and, therefore, she perceived that statements in the report were implausible.

Counter to our hypothesis, knowledge of weather and climate distinctions did not predict plausibility perceptions of climate change. We based this particular hypothesis on our prior research showing the relationship between plausibility and knowledge change (Lombardi & Sinatra, 2012). Therefore, general knowledge alone may not be sufficient to promote plausibility judgments; perhaps a situation of cognitive dissonance where incoming information is compared to the existing mental representation is needed. We did not measure conceptual change in the present study (i.e. we only measured variables prior to any instructional intervention or professional development), but prior research has indicated a relationship between plausibility perceptions and conceptual change (Lombardi & Sinatra, 2012).

Both our quantitative and qualitative analyses did not reveal any relationship between need for cognition and plausibility perceptions, which was counter to our hypotheses. Cacioppo et al. (1996) said, 'individuals high in need for cognition are more likely to engage in the cognitive effort necessary to correct their judgments' when personal biases are detected (p. 238). Because we examined our variables before any possible situation of dissonance, participants may not have had the opportunity to think reflectively about their plausibility judgments.

Finally, the results also support our second research question showing that topic emotions, dispositions about knowledge, and knowledge of weather and climate distinctions differed among the three teacher groups. Levels of anger and decisiveness were discriminating factors between in-service science teachers who do not currently teach about climate change to those who do currently teach about climate change and preservice teachers, with greater anger and decisiveness in those who do not currently teach about climate change. This result may emerge from an increased potential for critical evaluation as teachers who currently teach about climate change prepare lessons about the topic, and thus have likely had more opportunity to reflect on the evidence. On the other hand, preservice teachers and in-service teachers who do not currently teach about climate change may have had less opportunity for critical evaluation of climate change evidence because they are not preparing lessons on the topic.

Knowledge of weather and climate distinctions was also a significant discriminator between preservice teachers and in-service science teachers, with preservice teachers exhibiting a less knowledge. This result supports the idea that teachers hold many of the same misconceptions that their students do (see, for example, Papadimitriou, 2004; Trundle, Atwood, & Christopher, 2007) and that preservice teachers may lack some knowledge (i.e. understanding of weather and climate distinctions) necessary to promote students' understanding of climate change (Barba & Rubba, 1992, p. 1031).

Implications for Instruction and Future Research

Earlier studies have shown a relationship between anxiety and teaching about biological evolution (Griffith & Brem, 2003). The present study reveals a relationship between anger and hopelessness to the controversial topic of climate change, providing additional evidence that topic emotions are present in teachers and that these emotions may influence instruction. As Broughton et al. (2011) state, individuals can 'exhibit overall enjoyment of science learning, [whereas] a specific topic may unexpectedly trigger negative emotions' (p. 18). Furthermore, establishing a relationship between topic emotions and plausibility perceptions may provide insight into how teachers provide instruction on controversial topics. That is, teachers may bring these negative emotions to the classroom when they teach about climate change. The epistemic motive of decisiveness in judgment and choices may also have a strong impact on climate change instruction, as suggested by the results of this study and earlier studies conducted by Sinatra et al. (2012). Teachers who do not currently teach about climate change may express a greater level of anger and decisiveness as indicated by both the qualitative and quantitative data which could negatively impact their instructional decisions. Science methods courses and professional development of science teachers may need to address topic emotions specifically, particularly when the topic is controversial. Teachers should be encouraged to reflect on how their topic emotions and epistemic motives influence their understanding of the scientific principles underlying these controversial topics as well as their instructional practices. We speculate that greater content knowledge, and opportunity to reflect on scientific evidence, would likely also lead to improved emotional stances and understandings which teachers can then convey to their students.

Climate change and other controversial topics provide opportunities for teachers to facilitate the development of emotions that allow students to engage with the topic (in other words, emotions that would be more productive from a science learning perspective). Griffith and Brem (2003) documented that some science teachers purposefully avoid controversy to reduce the influence of emotionality on learning. However, teachers who limit the amount of controversial content may actually allow students' negative emotions about a topic to remain in place, and thereby limit their instructional engagement. In addition, scientific inquiries that are most current and relevant are conducted at the frontier of what is known and unknown (Chalmers, 1999). Therefore if students are to be exposed to the most cutting-edge science, controversy cannot be avoided. Science teachers—as recommended by Sadler (2009)—should therefore develop a community of practice around controversial and meaningful issues (also, known as socio-scientific issues) to potentially increase deep learning about topic important to our society.

As teachers think about how topic emotions and epistemic motives influence their own knowledge and instructional practice, they may become more critically evaluative, which in turn may facilitate reappraisals of the plausibility judgments about controversial topics. This plausibility reappraisal may then facilitate conceptual change about the topic. We have conducted a recent study to ascertain the influence of critical evaluation on plausibility reappraisal. Results from this study reveal that an activity promoting critical evaluation and plausibility reappraisal promoted significant change in perceptions of plausibility and correctness toward the scientific model of human-induced climate change, an important first step toward conceptual change (Lombardi, Sinatra, & Nussbaum, 2012).

This study did not measure conceptual change, and therefore we cannot speculate on the impact of topic emotions on teachers' reconstruction of knowledge from these data. However, this study has suggested an opportunity for further research and a potential contribution to increase not only conceptual understanding of teachers, but also the potential to increase the understanding of epistemic cognitive processes that may influence their instruction. For example, studies could examine the potential influence of instruction on critical evaluation and development of topic emotions that lead to deeper engagement about a topic. Ultimately, such research may benefit students through more effective instructional practices that promote scientific reasoning about controversial topics, such as climate change.

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References

Barba, R., & Rubba, P.A. (1992). A comparison of preservice and in-service earth and space science teachers' general mental abilities, content knowledge, and problem-solving skills. *Journal of Research in Science Teaching*, *29,* 1021–1035.

Boyes, E., & Stanisstreet, M. (1993). The greenhouse effect—children's perception of causes, consequences and cures. *International Journal of Science Education*, *15,* 531–552.

Boyes, E., & Stanisstreet, M. (1994). The idea of secondary school children concerning ozone layer damage. *Global Environmental Change*, *4,* 311–324.

Broughton, S.H., Pekrun, R., & Sinatra, G.M. (2012). Climate change, genetically modified foods, airport body scanners: Investigating students' emotions related to science topics, *Proceedings of the American Educational Research Association Conference-April 2012*, Vancouver, BC: American Educational Research Association.

Broughton, S.H., Sinatra, G.M., & Nussbaum, E.M. (2011). "Pluto has been a planet my whole life!" Emotions, attitudes, and conceptual change in elementary students learning about Pluto's reclassification. *Research in Science Education*, doi: 10.1007/s11165-011-9274-x.

Cacioppo, J.T., Petty, R.E., Feinstein, J., & Jarvis, W. (1996). Dispositional differences in cognitive motivation: The life and times of individuals varying in need for cognition. *Psychological Bulletin*, *119,* 197–253.

Chalmers, A.F. (1999). *What is this thing called science?* (3rd ed.). St. Lucia, Australia: University of Queensland Press.

Chi, M.T.H. (2005). Commonsense conceptions of emergent processes: Why some misconceptions are robust. *The Journal of Learning Sciences*, *14,* 161–199.

Choi, S., Niyogi, D., Shepardson, D.P., & Charusombat, U. (2010). Do earth and environmental science textbooks promote middle and high school students' conceptual development about climate change?: Textbooks' consideration of students' misconceptions. *Bulletin of the American Meteorological Society*, *91,* 889–898.

DeVellis, R.F. (2003). *Scale development: Theory and applications* (2nd ed.). Newbury Park, CA: Sage.

Dole, J.A., & Sinatra, G.M. (1998). Reconceptualizing change in the cognitive construction of knowledge. *Educational Psychologist*, *33*(2/3), 109–128.

Eynde, P.O.T., & Turner, J.E. (2006). Focusing on the complexity of emotion issues in academic learning: A dynamical component systems approach. *Educational Psychology* Review, *18*(4), 361–376.

George, D., & Mallery, P. (2003). *SPSS for Windows step by step: A simple guide and reference* (11.0 update, 4th ed.). Boston, MA: Allyn & Bacon.

Glesne, C. (2006). *Becoming qualitative researchers: An introduction*. Boston, MA: Pearson Education, Inc.

Gowda, M.V.R., Fox, J.C., & Magelky, R.D. (1997). Students' understanding of climate change: Insights for scientists and educators. *Bulletin of the American Meteorological Society, 78,* 2232–2240.

Gregoire, M. (2003). Is it a challenge or a threat? A dual-process model of teachers' cognition and appraisal processes during conceptual change. *Educational Psychology Review, 15,* 147–179.

Griffith, J.A., & Brem, S.K. (2003). Teaching evolutionary biology: Pressures, stress, and coping. *Journal of Research in Science Teaching, 41,* 791–809.

Intergovernmental Panel on Climate Change. (2008). *Climate change 2007: Synthesis report*. Geneva: World Meteorological Organization.

Kim, C., & Hodges, C.B. (2012). Effects of an emotion control treatment on academic emotions, motivation and achievement in an online mathematics course. *Instructional Science, 40*(1), 173–192.

Kruglanski, A.W. (1989). *Lay epistemics and human knowledge: Cognitive and motivational bases*. New York, NY: Plenum.

Kuhn, D., & Pearsall, S. (2000). Developmental origins of scientific thinking. *Journal of Cognition and Development, 1,* 113–129.

Linnenbrink, E.A. (2007). The role of affect in student learning: A multi-dimensional approach to considering the interaction of affect, motivation, and engagement. In P.A. Schutz & R. Pekrun (Eds.), *Emotion in education* (pp. 107–122). San Diego, CA: Academic Press.

Linnenbrink-Garcia, L., Rogat, T.K., & Koskey, K.L.K. (2011). Affect and engagement during small group instruction. *Contemporary Educational Psychology, 36,* 13–24.

Lombardi, D., Nussbaum, E.M., & Sinatra, G.M. (2012). *Plausibility judgments in conceptual change and epistemic cognition*, Manuscript in review.

Lombardi, D., & Sinatra, G.M. (2012). College students' perceptions about the plausibility of human-induced climate change. *Research in Science Education, 42,* 201–217.

Lombardi, D., Sinatra, G.M., & Nussbaum, E.M. (2012). *The influence of critical evaluation and plausibility reappraisals on middle school students' conceptions of climate change*, Manuscript in review.

Moser, S.C. (2007). More bad news: The risk of neglecting emotional responses to climate change information. Chapter 3. In S.C. Moser & L. Dilling (Eds.), *Creating a climate for change: Communicating climate change and facilitating social change* (pp. 64–80). New York, NY: Cambridge University Press.

Moxnes, E., & Saysel, A.K. (2009). Misperceptions of global climate change: Information policies. *Climatic Change, 93*(1), 15–37.

National Climatic Data Center. (2008). *Weather/climate events*. Retrieved April 21, 2008, from http://www.ncdc.noaa.gov/oa/climateresearch.html

National Research Council (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

Overpeck, J., & Udall, B. (2010). Dry times ahead. *Science, 328,* 1642–1643.

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

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review, 18,* 315–341.

Pekrun, R., Frenzel, A.C., Goetz, T., & Perry, R.P. (2007). The control-value theory of achievement emotions: An integrative approach to emotions in education. In P.A. Schutz & R. Pekrun (Eds.), *Emotion in education* (pp. 107–122). San Diego, CA: Academic Press.

Pintrich, P.R., Marx, R.W., & Boyle, R.B. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63,* 167–199.

Posner, G.J., Strike, K.A., Hewson, P.W., & Gertzog, W.A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66,* 211–227.

Reeve, J. (2009). Why teachers adopt a controlling motivating style toward students and how they can become more autonomy supportive. *Educational Psychologist*, *44,* 159–175.

Rescher, N. (1976). *Plausible reasoning: An introduction to the theory and practice of plausibilistic inference*. Amsterdam: Van Gorcum.

Sadler, T.D. (2009). Situated learning in science education: Socio-scientific issues as contexts for practice. *Studies in Science Education*, *45,* 1–42.

Schutz, P.A., Cross, D.J., Hong, J.Y., & Obson, J.N. (2007). Teacher identities, beliefs, and goals related to emotions in the classroom. In P.A. Schutz & R. Pekrun (Eds.), *Emotion in education* (pp. 223–242). San Diego, CA: Academic Press.

Sinatra, G.M., Broughton, S.H., & Lombardi, D. (forthcoming). Emotions in science education. In R. Pekrun & E.A. Linnenbrink (Eds.), *Handbook of Emotions and Education*. New York: Taylor & Francis/Routledge.

Sinatra, G.M., Kardash, C.M., Taasoobshirazi, G., & Lombardi, D. (2012). Promoting attitude change and expressed willingness to take action toward climate change in college students. *Instructional Science*, *40*(1), 1–17.

Spradley, J.P. (1980). *Participant observation*. Belmont, CA: Wadsworth, Cengage Learning.

Stevens, J. (1992). *Applied multivariate statistics for social sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Tabachnick, B.G., & Fidell, L.S. (2007). *Using multivariate statistics* (5th ed.). Boston, MA: Pearson Education.

Trundle, K.C., Atwood, R.K., & Christopher, J.E. (2007). A longitudinal study of conceptual change: Preservice elementary teachers' conceptions of moon phases. *Journal of Research in Science Teaching*, *44*(2), 303–326.

U.S. Global Change Research Program. (2009). *Climate literacy: The essential principles of climate sciences, a guide for individuals and communities* (2nd ed.). Washington, DC: U.S. Global Change Research Program.

Webster, D.M., & Kruglanski, A.W. (1994). Individual differences in need for cognitive closure. *Journal of Personality & Social Psychology*, *67*(6), 1049–1062.

Appendix 1. ETCC

Below are several emotions that you may feel about climate change. Please read the following statement. Then, for each emotion, circle the number that best describes the degree to which you feel that emotion.

1. *When I hear people say that the climate is changing, I feel . . .*

	strongly disagree	disagree	moderate	agree	strongly agree
Angry	1	2	2	4	5
Anxious	1	2	2	4	5
Ashamed	1	2	2	4	5
Bored	1	2	2	4	5
Curious	1	2	2	4	5
Fear	1	2	2	4	5
Frustrated	1	2	2	4	5
Happy	1	2	2	4	5
Hopeless	1	2	2	4	5
Surprise	1	2	2	4	5

2. *When I hear people say that human activities are causing climate to change, I feel . . .*

2. *When I hear people say that the government is considering regulatory steps to mitigate climate change, I feel . . .*

4a. (Form A only: Teachers who currently teach about climate change). *When I teach about climate change, I feel . . .*

4b. (Form B only: Teachers who do not currently teach about climate change). *When I think about teaching climate change in the future, I feel . . .*

5a. (Form A only: Teachers who currently teach about climate change). *When I teach my students about the impacts of climate change, I feel . . .*

5b. (Form B only: Teachers who do not currently teach about climate change). *When I think about teaching in the future about the impacts of climate change, I feel . . .*

Note: All questions contain the list of emotions as presented in item 1, but the emotions are omitted here for brevity.

Appendix 2. Emotions when teaching about human-induced climate change interview script

This is a semi-structured interview. The questions below will be used as the guiding framework for the interview. However, the interview may choose to ask additional questions to follow up on the subject's responses as needed. The estimated interview time is 60 minutes.

1. What subjects do you teach? What other subjects have you taught in the past?
2. Do you currently teach students about climate change? Have you taught students about climate change in the past?
3. [Asking only if Question 2 is affirmative] What content do [did] you cover related to climate change?
4. Do you think the climate is changing? Why (or why not)?

5. [Asking only if Question 4 is affirmative] Do you have any personal experiences that have led you to believe the climate is changing?
6. [Asking only if Question 4 is negative] Do you have any personal experience that has led you to believe that climate is not changing?
7. Which do you think is more plausible, that the climate is changing naturally or that humans are causing the climate to change? Why?
8. Do you think there is anything that humans do (or can do) that would influence climate? If yes, what do you think humans do (or can do) that would influence climate?
9. Do you think we are past the "point of no return" in climate change, or you think that humans can do something about climate change? Why? If you think we have some time, how long do you think we have before we need to take major actions?
10. What are the differences between weather and climate?
11. Do you think that the 10-year drought that has caused Lake Mead's level to drop so drastically is evidence of human-induced climate change? Why or why not?
12. What kind of emotions might your students have when teaching about climate change? How would this affect you teaching about climate change?
13. What kind of emotions do you feel about climate change? How might these emotions affect how and what you teach about climate change?
14. Are there certain ideas related to climate change that you would not teach? If there are certain ideas that you would not teach, what are these ideas? Why or why not?