

## Epistemological and Pedagogical Beliefs of Preservice Secondary Science Teachers on Global Climate Change

*Aris Reynold V. Cajigal\* and Deborah J. Tippins*

### Abstract

Global climate change is a socioscientific issue that is popular in socio-political, economic, and educational contexts. This study explored the epistemological and pedagogical beliefs of preservice secondary science teachers on global climate change. Specifically, it examined the experiences of preservice teachers that informed their perspectives on the issue, and the negotiations they anticipate when developing this topic in their classrooms. Employing an interpretive research methodology, data were collected from four preservice secondary science teachers through case study methods, in-depth interviews, and written products.

The analysis of data revealed that the preservice science teachers' epistemological and pedagogical beliefs on global climate change were in a dynamic relationship and bound by two significant points: a) Global climate change is a seemingly inevitable topic and b) Global climate change has a rightful place in the science curriculum. Perspectives on global climate change were mediated by the preservice teachers' experiences with people, places, and events. More specifically, themes that emerged from the four case narratives through within-case and cross-case analyses were identified. Among these include: a) natural versus anthropogenic causes; b) information audit; c) relevance of the topic of global climate change to the individual lives of students; d) influence from family and friends; e) controversy surrounding global climate change transcends the scientific, political, and economic aspects of society; and f) classroom debate as a microcosm of the larger scientific community. Recognizing the controversial nature of global climate change, the preservice teachers plan to negotiate the teaching of this concept in terms of content, context, process, and outcomes vis-à-vis the implications of the findings.

**Keywords:** *epistemological belief, pedagogical belief, climate change*

### Introduction

Numerous changes in the world have occurred throughout the history of humankind. In particular, the environment has undergone many changes due to natural processes and human activities. The problem of global climate change has gripped the global scene and stimulated governments throughout the world to find ways that mitigate the potential impact of this environmental crisis. The political and social affairs of many nations have served as an impetus to design programs that limit the anthropogenic contributions to global climate change. Nations convened in Copenhagen, Denmark in December 2009 to discuss global climate change together with measures to curb its impact. At the conclusion of this conference, nations

---

\*Corresponding Author: Current Address: College of Teacher Education, Mariano Marcos State University, Laoag City, Ilocos Norte; email: arvcajigal@yahoo.com

expressed their desire to mitigate global climate change through an agreement known as the Copenhagen Accord [United Nations Framework Convention on Climate Change (UNFCCC), 2009], which stressed the need to combat climate change by stabilizing “greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.”

Global climate change refers to significant changes in temperature, precipitation, wind, and other measures of climate lasting through an extended period of time and can be caused by natural processes and human activities [Environmental Protection Agency (EPA), 2010]. Scientists contend that global climate change could result in an inevitable crisis if continued greenhouse gases are emitted to the atmosphere. However, skeptics dismiss present findings about increasing global temperatures and argue that this is just a part of the earth’s normal cycle of warming and cooling.

The call for action to reduce the impact of global climate change and the promotion of environmentalism usually involves children of school age. Most adults believe that it is their responsibility to ensure a world that is safe and sustainable for their children and for future generations to come. Relative to this, schools are considered as one of the primary learning avenues for promoting environmental awareness and developing a sense of protection among students. Current reforms in science education focus on the development of scientific literacy among all students. Anderson (2007) posits that scientific literacy refers to the science-related knowledge, practices, and values that students acquire as they learn science. Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity [National Research Council (NRC), 1996]. Scientifically-literate students can read with understanding scientific articles; engage in social conversation about the validity of the conclusions; identify scientific issues underlying national and local decisions; express positions that are scientifically and technologically informed; and evaluate the quality of scientific information.

Science teacher education has its role in preparing mentors who can increase students’ awareness of global climate change. Some teachers may believe that employing a crisis approach to encourage environmentalism would be a desirable approach. However, Mueller (2009) argues that an ecological crisis approach to environmentalism may evoke fear, anxiety, and hopelessness among the youth. Alternatively, he recommends that rather than crisis thinking, teachers and students should: a) view environmentalism as an opportunity to assume individual responsibilities; b) be comfortable in dealing with uncertainties in ecological education; and c) be guided by projects that integrate local knowledge and skills. Simply put, a crisis can be turned into an opportunity for meaningful actions. It is vital, therefore, to examine preservice teachers’ beliefs about this global environmental concern from a personal level – the nature and development of such beliefs, in order to understand the

influence of these beliefs to their decisions about pedagogy, curriculum, and their visions for teaching global climate change in their own science classes.

Meanwhile, the conceptual understanding of students was the primary emphasis of the majority of related studies. Specifically, they were concerned with the cognitive (conceptions and knowledge) and affective (willingness for some action) domains of learning. Accompanied by the desire to measure K-12 and college students' conceptions about global climate change was the extensive use of questionnaires. Alternative conceptions surrounding the topics of global warming, greenhouse effect, and ozone layer persisted in most of the studies reviewed. There was an apparent gap in the literature in terms of studies that allowed participants to elaborate on their beliefs about global climate change in a holistic sense, that is, in view of their personal and social experiences. For example, Dove (1996) studied the knowledge and understanding of 60 secondary science student-teachers about greenhouse effect, ozone layer depletion, and acid rain. Most of the student-teachers believed that the greenhouse effect was caused by solar radiation passing through ozone layer holes thereby warming the earth. Groves and Pugh (1999) examined preservice elementary teachers' views about global warming and the greenhouse effect, and the impact of their views on elementary student performance. Results showed that preservice elementary teachers hold many alternative conceptions about the given environmental issues, which can affect their teaching of the specified topics in elementary classes.

Preservice science teachers are often prepared to teach in schools through their experiences in the natural sciences. Summers, Kruger, Childs, and Mant (2001) found that practicing primary teachers and preservice teachers displayed a good grasp of concepts related to the loss of diversity of species, length of time needed for fossil fuel formation, role of chemicals in ozone depletion, and the increase of carbon dioxide as a cause of global warming but showed uncertainty or lack of understanding about the concepts of variation in individuals, role of carbon in decay, awareness of the effects of increased ground-level ozone, and non-scientific ideas about global warming. Likewise, Khalid (2003) identified and described the alternative conceptions held by preservice secondary science teachers regarding the greenhouse effect, ozone depletion, and acid rain. In another study, Demirkaya (2008) found that Turkish preservice teachers' conceptions about global warming ranged from least sophisticated to the most inclusive and expansive. Papadimitriou (2004) revealed that the prospective teachers believed climatic changes were happening based on their personal experiences.

Students' thinking can lack structure and children as young as four years are observed to have various ideas and alternative conceptions of environmental issues (Rickinson, 2001). According to the study of Kiliñç, Stanisstreet, and Boyes (2008), many students believed that radioactivity is causally linked to global warming. In another study, Lee, Lester, Ma, Lambert, and Jean-Baptiste (2007) found that fifth

grade students tended to define greenhouse effect as a rise in temperature due to trapped heat and related its cause to burning of fossil fuels.

From another perspective, Jakobsson, Mäkitalo, and Säljö (2009) called into question the poor results often reported in studies about students' conceptions of global warming and greenhouse effect. In their study, the authors argued that substituting questionnaires with other research methods may pave the way for understanding better students' thinking about concepts related to global climate change. The authors further argued that studying reasoning as part of an extended project allows for a clearer understanding of how students can meaningfully talk about complex phenomena, develop their understanding, and identify gaps in their own understandings.

Socioscientific issues (SSI) are social dilemmas with conceptual and technological ties to science (Sadler, 2004). Global climate change is one of these issues included in the science curriculum. Preservice teachers' experiences with socioscientific issues have been examined in recent years. For example, Kolstø, Bungum, Arnesen, Isnes, Kristensen, and Mathiassen *et al* (2006) analyzed teachers' texts about the different evaluative criteria used by the students regarding global climate change. In their investigation, Forbes and Davis (2010) found that preservice teachers navigated multiple learning goals, subject matter knowledge, informal reasoning about SSI and role identity in their critique and adaptation of the curriculum and recognized the important role of their own values and beliefs in negotiating issues in the classroom.

Barrett and Nieswandt (2010) found that beliefs about teaching physics and chemistry using SSI were derived from a complex web of fundamental beliefs exemplified by four specific identities of the teacher candidates—Model Scientist/Engineer, Model Individual, Model Teacher, and Model Citizen. Nuangchalem (2009) found that most of the preservice teachers in Thailand expressed their beliefs for socioscientific issues-based teaching in terms of ways to promote nature of science, awareness of science and society, scientific values, personal experiences, morals and ethics in science, and social judgment.

The beliefs of preservice teachers are the focus of this study. Teacher beliefs, as defined by Kagan (1992), refer to the preservice or inservice teachers' implicit assumptions about students, learning, classrooms, and the subject matter to be taught. Kagan adds that teacher beliefs are at the heart of teaching. While there was a preponderance of studies on science teachers' beliefs these were limited to the examination of their relationships to the teachers' actual classroom practices and curriculum implementation.

Focusing on teachers' beliefs, Pajares (1992) posits that teachers possess beliefs about educational matters such as students, course contents, and their roles and responsibilities in the school, and hence these should become an important focus

of educational inquiry. He noted that 'teacher beliefs' is an 'elusive construct' that is difficult to clarify due to definitional problems and poor contextualizations. These terms are represented as "attitudes, values, judgments, axioms, opinions, ideology, perceptions, conceptions, conceptual systems, preconceptions, dispositions, implicit theories, explicit theories, personal theories, internal mental processes, action strategies, rules of practice, practical principles, perspectives, repertoires of understanding, and social strategy" (Pajares, 1992).

Epistemological beliefs form part of the central focus of this study. In Hofer and Pintrich's (1997) scholarly work, they proposed a model to integrate the various theoretical notions of epistemological beliefs by previous scholars. Hofer (2005) posits that "personal epistemology is an identifiable set of dimensions of beliefs about knowledge and knowing, organized as theories, progressing in reasonably predictable directions, activated in context, operating both cognitively and metacognitively". Hofer (2006) further claims that one's personal epistemology is strongly influenced by context but not isolated to context; thus, individuals hold beliefs about knowledge and knowing that are coherent and congruent, and are influenced by and enacted within particular contexts.

Hofer and Pintrich (1997) contends that epistemological beliefs should be limited to the individual's beliefs about knowledge, reasoning and justifications, and they referred to this as an individual's epistemological theories. They posited that the dimensions of an individual's epistemological theories seemed to cluster around two core areas: nature of knowledge and nature of knowing. There are four dimensions in their model of epistemological theories. Under the nature of knowledge, the dimensions, certainty of knowledge and simplicity of knowledge are included. Under the nature of knowing, the dimensions, source of knowledge and justification for knowing are included. These four dimensions comprise an integrated, relatively coherent structuring of related beliefs.

Louca, Elby, Hammer, and Kagey (2004) provide an alternative view to personal epistemology. They claimed that epistemological resources made of beliefs compiled in a rich network are activated by differing contexts. In the classroom, Louca *et al* (2004) likewise claimed that teachers extend help to students to locate and apply resources in varying contexts instead of providing support and practice in order for students to reach their developmental stages.

As such, this study explored the epistemological and pedagogical beliefs of preservice secondary science teachers around the issue of global climate change. Epistemological beliefs pertain to those that are related to the nature of knowledge and knowing and how knowledge is constructed and evaluated. Meanwhile, pedagogical beliefs are beliefs of teachers about the teaching-learning process. The study is significant as it will provide a better understanding of the experiences that shape these beliefs and how these may influence preservice teachers' decisions regarding science

teaching and learning. Richardson (2003) posits that preservice teachers tend to bring with them strong beliefs that oftentimes become stumbling blocks in the reform of classroom instruction.

Preservice teachers' epistemological and pedagogical constructs of global climate change do not occur in a vacuum. They are influenced by deeply embedded beliefs. Cobern (2000) argues that "people simply do not hold beliefs for no reason". Cobern (2000) adds that ignoring or denying the reasoned basis of beliefs in the context of science teaching could result in prejudging students' belief systems and assuming that they will accept results based on authority. Snider and Roehl (2007) posit that teacher beliefs influence classroom practice.

There is also a need to clearly discern the extent to which preservice teachers' beliefs influence how they value global climate change as a genuine issue, which has a central place in schools and informal learning contexts. It is important to understand how preservice teachers translate their conceptual understanding into practice. Richardson (2003) feels that the beliefs of preservice teachers are challenged through classroom readings, dialogues, or experimentation; she emphasizes that it is vital to understand their thinking as they engage in learning to teach, planning, actual teaching, reflecting, or assessing. Likewise, a close examination of preservice teachers' beliefs can provide educators with guidance in structuring curricula, provide program direction, and allow them to better understand the role they may play in future perspectives and practices (Pajares, 1992).

The study focused on the epistemological and pedagogical beliefs of preservice secondary science teachers regarding global climate change. More specifically, it attempted to:

1. explore the epistemological and pedagogical beliefs of preservice secondary science teachers about global climate change;
2. elaborate the experiences that influence the development of preservice science teachers' beliefs regarding global climate change; and
3. examine how preservice teachers negotiate and integrate these beliefs in designing learning experiences about global climate change.

## **Methodology**

The qualitative research approach was employed in exploring the beliefs of preservice science teachers on global climate change. Tobin (2000) asserts that interpretive research provides a locus for understanding individuals or a community in terms of actions and interactions, based on the participants' own perspectives. Tobin further maintains that the advantage of employing an interpretive study is its flexibility

and emergent nature.

The study employed the case study methodology to look closely into the belief systems of teachers regarding the teaching of global climate change. Yin (2009) contends that a case study “investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.” The study was conducted during the Fall 2009 semester in the course, Science Curriculum and Learning at a university in the southeastern United States. The course emphasized science curriculum models for students in grades 6 through 12 in relation to goals for science education and classroom practice. Four preservice science teachers (with pseudonyms Cherry, Eddie, Summer, and Vince to protect their identities) participated in this study.

Other methods of data collection include semi-structured interview, observation, and collection of students’ written products. Four semi-structured interview sessions lasting from 45 to 60 minutes each were conducted. The interviews were audio recorded and transcribed. After engaging the preservice teachers in informal conversations and obtaining consent, four preservice teachers were chosen as the primary participants. They were individually interviewed from 45 to 60 minutes, (Interview 1), to understand their general thoughts and beliefs about global climate change.

The second interview session was aided by two YouTube clips by WWF (2008) and Mortensen (2007) and a published cartoon by Lane (2002). Two journal articles (Rosenzweig, Karoly, Vicarelli, Neofotis, Wu, Casassa *et al*, 2008; Lindzen, 2006) were used in the third interview session. A final interview was conducted toward the end of the semester.

Inductive analysis was employed in this study. The inductive analysis started with line by line coding, then in-vivo coding (by using the words in the transcript or document), and focused coding. Coding was done to allow the subsequent synthesis of vital information gleaned from the interview transcripts, written products, and observation notes. Initial codes were provisional since they remained open to other analytic possibilities (Charmaz, 2006).

The individual cases were written in the form of narratives. Riessman (2008) claims that sequences of action characterize narrative analysis and narrative analysts tend to “interrogate intention and language” to know how and why events happened the way they did. After an analysis of the individual cases (within-case analysis), emerging themes were identified which helped the researcher to make valid interpretations. A cross-case analysis of the four cases followed.

## Results and Discussion

The following section presents excerpts from two of the four narratives about the preservice science teachers and their beliefs about climate change and global warming. Themes emerging from each case (within-case analysis) were embedded in the discussion and were italicized for emphasis. In addition, themes from the cross-case analysis are also presented. The following table summarizes the main themes discussed in this section.

### The Case of Cherry

Cherry, a mother and a wife, is enrolled in the Master of Arts in Teaching (MAT) program at a university in the Southeastern United States. Her rich academic preparation and work experiences boosted her desire to be a high school chemistry teacher. Her work as a laboratory manager in a university-based research institution offered her rich experiences in conducting empirical studies about parasites and tropical and emerging diseases. As part of her scientific research work, she co-authored peer-reviewed articles in a number of journals in her discipline. Cherry comes from a family that taught her to respect the land and to be personally connected with the environment. To illustrate, as a child Cherry experienced raising poultry and keeping a garden with her family who at that time lived in a rural area in her home state. Her academic preparation and experiences in scientific research often made her the authority in her family circle as regards to issues related to science. In her own words, she said: “They’re gonna take my opinion as fact because a lot of times they don’t do the research and I don’t want to lead them astray. I don’t want to give them facts that I know are more emotionally based. I feel the responsibility to do that, too.”

Movies that depict doomsday for humans, apocalyptic scenes that result in the

Table 1. Themes emerging from the participants’ meanings of global climate change.

PARTICIPANT	COMMON THEME ACROSS CASES & THEME FROM THE INDIVIDUAL CASES		
	Characterizing Global Climate Change	Credibility of Information	Science Classroom & Global Climate Change
<b>Cherry</b>	Distinction between the “what” and the “why”	Source/s	Establishing a climate for learning
<b>Eddie</b>	Intersection between life with change	Choice/s	Serving as teacher-mediator
<b>Summer</b>	Reduction of personal carbon footprint	Authority	Being persuasive and persuaded
<b>Vince</b>	Attention to uncertainties surrounding climate change	Scientific processes	Examining controversial issues



extinction of the human race, invasion of aliens, judgment day events, and other related catastrophe-plagued themes are often watched with excitement, thrill, and disbelief. But Cherry had some thoughts to share about the depiction of such catastrophic events; not only limited to what was portrayed in the movies. She said, "I get very frustrated with the whole doomsday scenario." Cherry was not reacting to a Hollywood movie, but rather to the prevailing talk about global climate change.

When asked about how she defined global climate change, she responded by characterizing it as "changes in the temperature and in the weather patterns of the entire planet and probably over time periods that we've been keeping up with temperature and climate, which I know has not been that long period of time." Elaborating on this, Cherry emphasized the point that changes vary from place to place, such that change in one location may involve a rise in temperature while others may involve a drop in temperature. Time period of record keeping was considered by Cherry when she defined global climate change. She said, "So to be able to say we have a certain amount of change in weather patterns or in temperature patterns, we have to look, I think we have to be very careful about comparing hundredths of a degree today to something that might have been recorded 200 years ago because of accuracy and scientific data that we had." Cherry hates "to be on the fence" with respect to the issue of global climate change. But her position is accompanied by a feeling that there are certainly changes in climate and weather patterns. The only thing that puts her "on the fence" is the belief that the world doesn't know yet the exact causes of global climate change with certainty.

Cherry's distinction between the "what" and the "why" is significant in light of the present differences in claims made by climate scientists. The uncertainty that prevails allowed her to believe that climate change is indeed happening but the reason for this phenomenon is not yet thoroughly explained, studied, and understood. Cherry's position is associated with the dimensionality of personal epistemology. In Hofer and Pintrich's (1997) model of personal epistemology, Cherry's "certainty of knowledge" could be considered as the dimension that treats knowledge as tentative and evolving. With this, Cherry assumes that in due time, an explanation for global climate change will be well understood by everyone.

The credibility of the source of information is of paramount importance to Cherry, as shown by her elaboration in the following lines: "I just think that you have to be careful. Like I've said earlier, people can bias their data. And you've got to be careful that the person that you're getting the information from is not biased." She looks for the expert as a genuine source of accurate information. On the issue of global climate change, Cherry explained: "I want to look for someone who is an expert on that field and to me scientists are the experts in global climate change."

Though Cherry considers climate scientists as the experts, she feels that not all may qualify for her standard of credible information. She feels less skeptical about

scientists working in the academe. She explained her reasoning, noting: “Well, scientists who work in academia have probably less to lose for whatever data they collect...They’re not out there trying to make money...They’re out there trying to learn and most of their endeavors are to publish and to get that next grant so that they can continue to do their work and not to try to further the company or the institution that they work for. You don’t want to take the word of a scientist that works for the oil company because they’re biased. I’m not saying they are always biased. But you don’t always say. You don’t always take the word of a scientist who works for the drug companies.”

The stress placed by Cherry on the importance of credibility of scientists suggested that her academic background strongly influenced her thinking of claims and evidence from a scientific standpoint. It was evident that Cherry was very concerned with the answer to the question: *Who is the source?* As the preceding discussion suggests, it appears that Cherry refused to accept claims blindly. Her rich experiences in the laboratory allowed her to be a critical reader, listener, audience, and consumer. The dimension, justification for knowing, in Hofer and Pintrich’s (1997) model is closely related to Cherry’s notion of scientific authority. Cherry tended to justify claims of others based on her view of authority and expertise and her evaluation of these experts (Hofer, 2008).

Elements that influence a teacher’s desire for *establishing a climate for learning* were revealed in Cherry’s explanation of the inclusion of global climate change as an emphasis in the science curriculum. These elements included: a) seamless and continuity of science topics; b) time; c) neutrality of the teacher; d) development of critical thinking; and e) emphasis on process. According to Cherry, seamless and continuity are essential because “chemistry builds upon itself”. Time allows the teacher to keep focused on the standards in light of the time schedule that is being observed in most schools. Neutrality requires not explicitly telling students one’s personal beliefs and convictions. In line with her desire to foster critical thinking, she came up with the idea of starting a journal club in her future classroom to examine articles that could trigger further investigations. An emphasis on process requires the teacher to present global climate change as well-balanced as possible, and encourages students to learn how to look for good sources of information. Studying should be an opportunity for exploration to students “instead of just being spoon fed information from their instructor”. It can be inferred from Cherry’s statements that her desire to establish a climate for learning is consistent with the proposition of Louca *et al* (2004) that epistemological resources of students are activated through various learning experiences designed by the teacher.

### **The Case of Eddie**

Eddie is a naturalist, a person who has the heart and affection toward plants, animals and other living organisms. Eddie’s warmth and caring attitude for plants and animals did not diminish as he matured.

Eddie characterized global climate change as follows: “Climate is always changing but I would assume that the way they speak of it as like the overall change of the climate due to unnatural reasons. And by “they” I mean politicians and activists and what not. The way I, I mean global climate change is happening for millions of years or what not. I mean it’s not something new. It’s just something maybe change at faster rate.” Aside from recognizing natural causes of global climate change, Eddie also attributed this phenomenon to human activities. He explained: “I feel like as humans are causing the climate to or like causing climate change to be more rapid. I feel like it would kind of happen. What we’re doing to the earth now is happening faster than what it would do naturally.”

Eddie’s *life with change* can be narrated here in terms of the various experiences that influenced, in one way or another, his ideas about evidence of global climate change. Eddie shared these mini-stories through his recollection of personal experiences, both personal and academic. Eddie’s parents, especially his mother, nurtured him with a positive attitude toward living organisms. Teachers in the elementary grades can be very influential in the way they foster students’ views about life and the environment. This happened to Eddie. Even in the early grades, Eddie was already introduced into a form of activism that promotes environmental protection.

*Making choices* has become a significant part of Eddie’s personal and academic experiences. But beyond his experiences comes choices that all humans have to make. To Eddie, these choices have far-reaching effects because they impact on the environment and individual way of living. Stressing his future role as a science teacher, Eddie opined that he should present factual information about global climate change to his students. Though he personally supports environmental protection, “being forced to do something” is unacceptable, as shown by his remarks: “I have this thought process that it’s, they want me to do something that I don’t really like doing forced things that’s just not in my nature. I don’t like being forced to do anything.”

In the light of Eddie’s conversations with the researcher about global climate change, he believes that teaching involves a person who assumes the role of a mediator. The notion, *teacher as mediator*, was consistently emphasized by Eddie. To Eddie, being a teacher and mediator goes beyond the role of a classroom arbiter of student issues and concerns. From his perspective, the primary rationale for this role is to make sure teachers present both sides of the topic on global climate change or any relevant socioscientific issue. Eddie added: “As a middle school student, they probably have their parents to, you know, believe one way or the other, for many different reasons. And they’ve probably been influenced like that. I believe it’s our duty to at least give the students, try to give the students unbiased information so they could process their own opinion about the matter instead of just maybe having their parents tell them that it’s happening or just natural.”

According to Eddie, a mediator presents information without pushing students to

a specific position. When asked about a specific way of being a mediator, Eddie replied: “I would like to have I guess assignments for maybe both sides of the story. I’d like to be the mediator and I would kind-of want to find more articles sort of like the one that we read last week and be able to maybe read both sides of the global warming story.” Eddie also believes that a mediator creates and fosters a neutral ground for debate and argumentation.

Case-based issues, a thematic area in Zeidler, *et al* (2005) model framework for socioscientific issues instruction, provide an explanation for Eddie’s notion of a teacher as a mediator. In case-based issues, students are engaged in experiences about socioscientific issues that develop both their intellect and character. Zeidler *et al* (2005) assert that these experiences focusing on multiple perspectives might confront students’ entrenched beliefs, and hence, stimulate analysis and consideration of the evidence surrounding a socioscientific issue that requires the teacher to mediate learning.

### **The Case of Summer**

Summer comes from a family that allowed her to grow up experiencing the outdoors. Her family had gardens which at a young age molded her understanding of the environment and the functioning of its systems. Summer is expecting to obtain her certification to teach secondary science (earth science, chemistry or physical science). A short visit to a foreign country provides an individual with a different perspective on life. Such a trip brings to an individual a rich cultural experience. Summer, through her university’s Study Abroad Program, had an opportunity to experience an academic-related interaction with the French people. This travel actually provided her a foreign perspective of sustainability and environmentalism. Also related to her observation of the French people’s environmental consciousness were the seemingly sustainable communities that flourished in France’s rural areas as evidenced by neighborhood gardens, local products sold in markets, and community-based industries. In her own words, Summer said: “You’re not necessarily having to go to the big box grocery store. You’re more of the small community industry of just the simple products.”

Summer shared her general thoughts about global climate change and the various experiences that influenced her way of thinking about the issue. To her, global climate change refers to “a general progression of temperatures and environmental conditions that have changed throughout earth’s history.” Summer elaborated more on her thoughts about global climate change by recognizing the contribution of human activities to this phenomenon. She stated: “I know that obviously there’s a lot to do with human, contribution to this global change.” Summer further explained that humans tend to contribute to an imbalance of nature through industrialization.

In her recollection, she remembered that at a very young age, she used to reason out that global climate change was part of earth’s natural cycles and that there

was nothing to be anxious about. In her college years, she remembered doing small-scale research studies in ecology, weather map interpretations in atmospheric science, and class discussion on coffee production and rainforest destruction. She also had professors who showed passion and conviction about global climate change.

Media also played a role in influencing Summer's way of thinking about global climate change. Television programs and commercials often present the topic in a casual mode, which "makes the general public more convinced of global climate change because it's easier to watch television than it is to read a magazine on global climate change." One of the books she read that influenced her way of thinking was *An Inconvenient Truth*. In addition to reading the book, she watched the movie of the same title, where Al Gore (former US Vice President) discussed global climate change and its impact on humanity. In a more detailed description, Summer explained: "I thought it was a nice read. It was entertaining. But he was so shallow for me."

Summer attributed global climate change with natural and anthropogenic processes. To Summer, it was necessary then to exert efforts in *reducing personal carbon footprint*. In her encounters with individuals, events, and materials about global climate change, she believed that these allowed her to be aware and more conscious of her impact on the environment. She said: "I guess, your consumption, use of your, reducing your carbon foot print, reducing your pollutants you consume/emit and I suppose trying to reduce the demand for the product of the corporation, the demands for things like gas emissions and all the pollutants. So definitely, it's the same idea that some vegetarians take. You do not necessarily hate the idea of eating meat. You just don't create the demand for the meat through large scale; so just reducing the demands."

To Summer, *authority matters* when considering sources of information about global climate change. In elaborating what she considered as an authority on the subject matter, she explained: "I think that it being in televisions certainly persuades me and the general public towards believing in global warming but it doesn't necessarily discuss why global warming has taken place. It (referring to the movie, *An Inconvenient Truth*) was almost like he deleted some data." The deficiency is rooted not in the lack of information but from the seemingly edited version of a bigger picture of the whole global climate change story. Still reflecting on the importance of authority as a source of information, Summer recalled that she had the opportunity to listen to a visiting professor who talked about global climate change. She found this professor persuasive and convincing because he worked with NASA. She likewise believed that "they (referring to the students) just have to understand the difference between a peer reviewed article and *The New Yorker*."

Summer considered persuasion as an important dimension when discussing global climate change, whether in formal or informal contexts. Summer mentioned that she might be willing to engage in academic discussion on this subject and *to be*

*persuaded but not to be persuasive* depending on the availability of credible information about global climate change. Although Summer felt she enjoyed engaging in discussions that persuaded her, she refused to be persuasive as a science teacher. This claim is supported by the contention that teachers should not be “filling students’ minds with opinions.” Summer added: “First of all, you have to be careful about the opinions of the parents and not being too persuasive. I mean there are two sides to the issue. You definitely want to be careful about just giving them the information and just telling them to believe it.” It is then evident that she desires to display: a) respect for parental authority over their own children; b) tact in dealing with controversial issues; and c) high regard to the possible legal implications of her actions in the classroom.

Summer pointed out the relevance of future citizenship roles of the students. She elaborated: “Just starting at an early age you know how they can do little things environmentally and things like that can progress through their ages. So even they can see the value in doing little things or unplugging their television because old televisions use 40% of the power when they’re off so you know just little things like that, that they see the value and can build upon as they grow up and have their own homes and make their own decisions.”

Summer placed importance on the dimension, source of knowledge, as a key criterion for filtering vast sources of information. Summer specifically mentioned that media tend not to be credible sources of information. For Summer, the source of knowledge rests within those who have experience and education in regards to global climate change. Summer’s source of knowledge appeared to be residing outside of ‘self’. But Hofer (2008) claimed that the notion of ‘self as knower’ allows an individual to construct knowledge as a result of his or her interactions. In the case of Summer, she remained as a ‘knower’ and maintained her interaction with other people, resources, and evolving ideas.

### **The Case of Vince**

Vince is preparing to teach high school biology. He grew up in a suburban community near his home state’s capital city. In his recollection, Vince shared that he was nurtured by a family that helped him develop critical thinking about societal issues.

Green technology is a familiar term for product manufacturers who claim to be environment-friendly. These green products that companies produce range from small gadgets to big appliances. Vince, on his part, enjoys having a green toy – his motorcycle. Vince’s personal decision to drive a motorcycle instead of a car was driven by the: a) desire to pay less for fuel; b) joy of having a toy for fun; and c) feeling of satisfaction in helping the environment. Vince considers owning a motorcycle to be personally and environmentally helpful. In connection with whether or not global climate change is happening, Vince said: “The cost of being wrong really isn’t that great. But if it’s (referring to global climate change) true and I’m doing this, well then I guess I’m sort

of helping.”

Vince defined global climate change as “a change in what would normally be expected or what could be predicted based on historical data, basically a deviation from a natural cycle of heating and cooling on earth.” Elaborating on his definition, Vince emphasized that the limitations of recorded data on global temperatures pose a problem and open a “window for debate”. Vince’s perspectives on global climate change were influenced by his personal experiences and by the people around him. For example, he explained that seeing the movie, *An Inconvenient Truth*, opened his eyes to the subject matter. Vince further explained: “But I think I just wasn’t totally aware of that topic at all. So the presentation of the new information was something that just made me think or like, sort of open the window or cause me to start thinking about something I hadn’t really thought about before, at least not in a scientific way.” The other factors influencing his perspective on global climate change included his reading materials about habitat loss of certain insects and his personal experience with drought in his home state. Talking more about the drought in his state, Vince shared: “I don’t necessarily think that because there is drought in one place that means that global climate change is happening.”

The theme, *uncertainties surrounding the issue*, emerged from the data as revealed by Vince’s belief that global climate change has not been fully understood yet by the scientific community. To him, the continuing debate on the evidence of global climate change obscures the public’s understanding of the issue. Vince claimed: “My guess would be that just because there’s a debate amongst everything, which is good probably. And getting to the point I guess what you asked. People have different research methods or things that they think should be done to determine those things. And so a lot of times people may reject the validity of other people’s experiments or disagree with their methods.”

The second emerging theme, *reliance on the processes of science*, revealed that Vince highly regarded scientific investigations as a basis for explaining various phenomena. Vince felt that he should take a scientist’s word since he himself was not involved in experimental work. He believed, however, that scientists might also have personal limitations. The resulting inaccuracies in the scientists’ experiments, Vince opined, do not necessarily come out of data manipulation.

In explaining the role of the topic global climate change in the science classroom, Vince said: “I think it’s a good issue. What I mean by that is there’s a standard that talks about issues and I think it’s a perfect place for it, basically having students able to present their findings and present their viewpoints.” Vince added that engaging students in experiments would relate classroom science to the real world and make science “more authentic.” When asked to explain more about this point, Vince said: “It (referring to nature of science activities) will paint a more accurate picture of science as just not facts to be memorized and people in lab coats.”

The third emerging theme, *examining controversial issues in the classroom*, provides insight into what approaches Vince planned to use when teaching the topic of global climate change. Vince specifically mentioned inquiry, use of classroom debates, exploration of various resources, and data collection tasks as some of the approaches he would employ. Inquiry activities and exploration, as Vince described, would require students to filter information from different sources. To him, it is essential to prepare students to be critical and skeptical about the sources of information about controversial issues. To him, debates should not be construed as opportunities to “preach” a particular viewpoint; he stressed the importance of recognizing that some students might have highly entrenched beliefs or positions on controversial issues.

The uncertainties that Vince held were a function of the dimension, certainty of knowledge, which Hofer and Pintrich (1997) proposed in their model of epistemological theories. With this dimension, Vince views knowledge of global climate change as fluid and evolving. The uncertainties therefore stemmed from the lack of standard procedures among climate scientists who study this environmental phenomenon. Human beings tend to be skeptical of matters that do not have strong or concrete epistemological certainty.

The next section presents the cross-case analysis that provides a detailed discussion of the themes emerging across the four individual cases. This section also elaborates on the commonalities and relationships of the four cases. Merriam (1998) argues that a cross-case analysis is necessary to build abstractions across cases. She adds that this level of analysis provides a unified description across cases. It can also lead to the identification of emerging themes, categories, or typologies that synthesize the data from all the cases. In the present study, the researcher was guided and informed by the principles of cross-case analysis proposed by Stake (2006). Stake contends that a researcher has the obligation to provide cross-case analysis to arrive at a binding concept, whether a theme, issue, phenomenon, or functional relationship. The cross-case analysis was based on the research questions posed at the beginning of the study.

### **Beliefs of Preservice Secondary Science Teachers on Global Climate Change**

Based on an analysis of the four cases, beliefs of preservice science teachers on global climate change were elaborated through characterizations and shared binding concepts. The preservice science teachers’ epistemological beliefs on global climate change were manifested by how they defined and characterized this phenomenon and by a detailed elaboration of their perspective on the evidence for it. Their definition encompasses the characteristics of global climate change, the apparent causes, and the present danger it poses. The analysis of the four cases suggests that these preservice science teachers tended to emphasize uncertainties associated with global climate change. To them, there is a prevailing doubt on the causes of global



climate change. Natural versus anthropogenic causes, as a theme can be seen across all four cases. For all four participants, the uncertainty of whether natural processes or man-made activities contribute to global climate change stemmed from what they perceived as the continuing differences of research findings and interpretation by scientists. Another source of this apparent uncertainty was the increased media publicity and promotion of a politicized discussion about the subject. To the four preservice science teachers, a unified perspective on global climate change remains elusive.

As the four preservice science teachers elaborated on their beliefs about global climate change, it was noted that an emerging theme, information audit, was evident. In this analysis, an information audit was necessary to filter the information taken from the internet. In addition, the four teachers stressed the need to filter, assess, and test the credibility of the sources of information.

Pedagogical beliefs refer to the teachers' thoughts and notions of how instructions should occur, the role of the teacher, students, and the learning environment, and how knowledge should be cultivated in schools (Pajares, 1992). The four preservice science teachers believed that there is a need to teach global climate change using *process-oriented and constructivist approaches*. The constructivist nature of these activities can be attributed to the preservice teachers' intention to have students explore ideas on their own, synthesize obtained information, construct knowledge, and build upon their existing perspectives, through their interaction with other members of the class. Process-oriented activities are essential in order to walk students through a scientific way of investigating phenomena. Processes require students to perform laboratory experiments, obtain information from the internet, and assess the relevance and authenticity of internet resources. The teachers' beliefs were grounded on the notion of relevance of the topic global climate change to the individual lives of students. Likewise, the preservice teachers believed that socioscientific issues, in general, are important components of the science curriculum in the middle and high school levels. All four preservice science teachers contended that socioscientific issues offer an opportunity for students in a science classroom to construct an understanding of the relationship between science and society. In particular, they emphasized the relevance of global climate change to students' lives because of the urgency of the matter.

Hofer and Pintrich's (1997) model of personal epistemology is closely associated with the preservice teachers' position. The certainty of knowledge as a dimension shows that teachers view the topic of global climate change based on of tentative and constantly evolving ideas and notions. Likewise, the preservice teachers' source of knowledge, as a dimension, relied primarily on external sources, that is, mostly from the scientific community. The teachers' justification for their knowledge of the evidence of global climate change stemmed from their educational background and personal experiences. Louca *et al* (2004) posit that individuals possess epistemological

resources, which are activated by varied contexts. Relative to this, the preservice science teachers in the study certainly invoked and used their epistemological resources when elaborating their beliefs, writing their unit skeleton assignments, and constructing their concept maps. To Louca *et al* (2004), these epistemological resources come in the form of rich cognitive networks that can always be activated by differing contexts.

### **Experiences that Shaped Preservice Science Teachers' Beliefs on Global Climate Change**

It was interesting to note that all the four preservice teachers belong to biocentric families. This means that as growing children and adolescents, they were given the opportunity to establish an attachment with nature and the environment. They also identified friends who were environmentally-conscious and who engaged them in educational discussions. The theme, influence from family and friends, highlights the way in which preservice science teachers' beliefs were partly influenced by their involvement in environment-related activities while growing up.

The last category that could be considered sources of influence for the preservice science teachers is academic context. Their experiences in the academic setting influenced the way how they think about life and the environment that surrounds them. Experiences in the academic setting involved interactions with teachers, peers, and administrators.

After a close examination of the experiences of the four preservice science teachers as analyzed in this study, it is evident that their thoughts and perspectives on global climate change were mediated by three important forces: people, places, and events. The preservice teachers tended to draw their thoughts from various sources. The unit skeleton assignment prepared them to examine the extent of their roles as teachers when incorporating a controversial topic such as global climate change. As Richardson (2003) claims, preservice teachers tend to bring with them their own beliefs, which may at times, hinder their understanding of the basic tenets of educational practice. The importance of examining one's beliefs is reflected in the instructional decisions that have to be made inside or outside of the classroom.

### **Negotiating Classroom Teaching of Global Climate Change**

Global climate change is a socioscientific issue that the preservice science teachers believe to have a rightful place in the science classroom. But this place in the classroom, they all agree, could sometimes pose challenges because of the nature of the subject matter. Based on the analysis of the four cases, it appears that the tension arising from integrating global climate change in science instruction surrounds what they perceive to be the controversial nature of the topic. The preservice science teachers emphasized that creative approaches are needed to help both themselves

and their students negotiate science instruction and the nature of this socioscientific issue. It must be noted that for these future teachers, the controversy surrounding global climate change transcends the scientific, political, and economic aspects of society. In view of this, science teacher preparation should provide preservice teachers with interdisciplinary examples of how to approach the teaching of controversial issues such as global climate change in ways that include economic, political, and social dimensions.

### **Conclusions and Recommendations**

From the four cases, it was apparent that teacher neutrality is of paramount importance. To these preservice science teachers, being neutral involves avoidance of any activity that persuades students to believe in one position relative to the global climate change issue. The four preservice science teachers further emphasize an alternative to the tendency of persuading, that is, *emphasizing on student-centered activities*. To them, student-centered activities allow students to explore the topic on their own, with the guidance of a teacher, and look for information that they themselves assess as relevant. For these preservice teachers, the use of student-centered activities on global climate change does not mean avoidance of responsibility for facilitating learning. Rather, they emphasized that student-centered activities promote critical thinking and personal accountability of students.

Global climate change remains a topic of debate in scientific, political, and economic fora, as discussed earlier. With this in mind, there is a contradiction regarding the position of the preservice science teachers in negotiating controversy surrounding the topic. This contradiction is manifested in the preservice teachers' reference to the use of debate and argumentation in the science classroom. In effect, it is apparent that classroom debate is a microcosm of the scientific community, because students are allowed to mimic the scientists' way of presenting the results of their studies through logical arguments. In like manner, having students debate on global climate change seems to be counterintuitive to the desire to avoid controversy. A closer examination of the four cases reveals that there is something more than the teacher's desire to have students debate and argue with one another. The intention of debate in the classroom, as pointed out by the preservice science teachers, is to develop scientific processes, attitudes, and logical arguments. The preservice teachers contend that through debate, students are able to support or refute a position based on evidence. In the same manner, scientists deliberate their positions within the scientific community and their explanations of phenomena transcend the arena of public opinion. The pre-service science teachers elaborated on using varied activities for students when engaged in a debate about global climate change. To them, it would extend the usual manner of debate that requires designation of sides to take, research of information, and then the debate proper. The different activities that students engaged in were thought of by the preservice science teachers as a way to bring out and justify the issues related to

global climate change through scaffolding.

The analysis then showed that the four preservice science teachers thought of a confluence of the meaning of persuasion with other terms related to debate and argumentation. Koballa (1992) posited that persuasion is a “conscious attempt to bring about a jointly developed product common to both source and receiver through the use of symbolic cues”. Freely and Steinberg (2005) add that persuasion is a form of communication that intends to influence the actions, beliefs, attitudes, and values of others. Koballa (1992) noted that the common alternative conception about persuasion involves equating it with the terms coercion, indoctrination, propaganda, and brainwashing. Koballa then shed light on this by distinguishing persuasion from the other terms. In persuasion, a person is free to accept or reject a position while in coercion, an individual feels compelled to comply as the messages are presented with threat. Koballa claimed that both persuasion and indoctrination are concerned with the change and formation of beliefs. Indoctrination, however, tends to present a biased statement and involves “inculcating the right answer, but not for the right reasons or even for good reasons” (Koballa, 1992). In view of the tension, preservice science teachers expressed the role of persuasion in teaching, a deeper analysis of the structure, design, content, and process of argumentation in diverse classroom contexts may be warranted.

As it appeared from the earlier discussion, negotiation of teaching global climate change comes in four significant ways. These are negotiations of: a) content; b) context; c) process; and d) outcomes. The negotiation of content pertains to the place of the topic of global climate change in the curriculum. The negotiation comes in the form of an integration of the topic in any of the science subjects, instead of teaching the concept as a stand-alone lesson. ‘Negotiation of context’ refers to the type of venue where the topic of global climate change is developed as part of class activities. ‘Negotiation of process’ refers to the teacher’s creative ways of fostering students’ understanding of the topic. As noted by the participants in this study, filters of information should be emphasized when planning activities that utilize the internet. ‘Negotiation of outcomes’ pertains to the teacher’s goals for the class relative to the topic of global climate change or any relevant socioscientific issue.

Socioscientific issues (SSI) are social dilemmas with conceptual and technological ties to science (Sadler, 2004). These issues are controversial in nature because they require an individual to draw on personal content knowledge and moral reasoning to choose a position with an unclear outcome (Sadler, 2004). Kolstø (2006) corroborated this by claiming that two issues are involved when considering SSI: a) the ethical, personal, or social question related to what scenario to prefer or what actions to take; and b) the decision made on the scientific question involved. In this study, the four preservice science teachers characterized their creative ways of designing learning experiences for their students. Due to the controversial nature of the topic global climate change, it can be gleaned from the cases that they appear to be very careful

inside their classroom. In effect, the findings suggest the need to re-examine ethical considerations when developing lessons involving controversial topics in science. These ethical considerations could be briefly stated as follows: a) argumentation is not indoctrination; b) respect for diversity; and c) recognition of an individual's freedom of choice.

*Argumentation is not indoctrination.* While argumentation is an essential component of science teaching, teachers should examine their practices so as not to employ this strategy as a form of indoctrination of one's beliefs and knowledge of a specific subject. Indoctrination involves a change of beliefs as a result of providing biased statements to the students. This should not be the focus of argumentation. Rather, argumentation in the science classroom should be as productive as possible. Sadler and Donnelly (2006) posit that argumentation should be a way of preparing students to be critical in assessing scientific claims by scrutinizing claim, logic, and empirical support. They further noted that it is imperative for science teachers to provide students with the fundamental knowledge about argument structure, status of evidence, fallacious reasoning, and consistency of claims.

*Respect for diversity.* As noted by the four preservice science teachers, students come from various racial and cultural backgrounds. Hence, teachers are urged to be sensitive with this reality in the science classroom. Respect for diverse backgrounds calls for teachers to suspend their personal beliefs and judgment in order to avoid offending students with different perspectives on a topic. The science classroom should never be a context to criticize an individual's or a group's perspectives on an issue. Reis and Galvao (2009) noted that controversial topics in science should promote learning through the exploration and expression of ideas in a context that is not seen as a verbal combat between opposing sides.

*Recognition of an individual's freedom of choice.* The science classroom should respect individuality in terms of beliefs. Highly-entrenched beliefs and knowledge about a particular subject may be difficult to change but it should always be a personal decision. The presentation of scientific facts and claims supported by empirical evidence will eventually result to students choosing their own side. What science instruction should aim for is that science be presented in such a way that students become informed citizens capable of making informed decisions.

The above findings suggest that preservice science teachers should have opportunities to design lessons that enable them to reflect on how they will teach a socioscientific issue such as global climate change. Moreover, future inquiries should consider studying the: a) overall process of using SSI-based lessons from planning through implementation; b) specific ways preservice science teachers assess information about controversial issues as credible and appropriate for classroom instruction; and c) relationship between belief and action in teaching about socioscientific issues, particularly in the context of standards-based environment.

## **Acknowledgement**

The authors wish to thank the research participants, the participants' course professor, faculty and students of the Department of Mathematics and Science Education of the University of Georgia (Athens, Georgia, U.S.A.), members of their respective families, and their friends for their assistance and support to the study.

## **Literature Cited**

- Anderson, C.W.** (2007). Perspectives on science learning. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 3-30). Mahwah, NJ: Erlbaum.
- Barrett, S.E., and Nieswandt, M.** (2010). Teaching about ethics through socioscientific issues in physics and chemistry: Teacher candidates' beliefs. *Journal of Research in Science Teaching*, 47(4), 380-401.
- Charmaz, K.** (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. Thousand Oaks, CA: Sage Publications.
- Cobern, W.W.** (2000). The nature of science and the role of knowledge and belief. *Science and Education*, 9, 219-246.
- Demirkaya, H.** (2008). The understanding of global warming and learning styles: A phenomenographic analysis of prospective primary school teachers. *Educational Sciences: Theory and Practice*, 8(1), 51-58.
- Dove, J.** (1996). Student teacher understanding of the greenhouse effect, ozone layer depletion and acid rain. *Environmental Education Research*, 2(1), 89-100.
- ENVIRONMENTAL PROTECTION AGENCY (EPA).** (2010). Climate change. Retrieved from <http://www.epa.gov/climatechange/basicinfo.html>, 14 February 2010.
- Forbes, C.T., and Davis, E.A.** (2010). Beginning elementary teachers' beliefs about the use of anchoring questions in science: A longitudinal study. *Science Education*, 94, 365-387.
- Freeley, A.J., and Steinberg, D.L.** (2005). *Argumentation and debate*. Belmont, CA: Thomson Wadsworth.
- Groves, F.H., and Pugh, A.F.** (1999). Elementary pre-service teacher perceptions of the greenhouse effect. *Journal of Science Education and Technology*, 8(1), 75-81.

- Hofer, B.K.** (2008). Personal epistemology and culture. In M.S. Khine (Ed.), *Knowing, knowledge and beliefs: Epistemological studies across diverse cultures* (pp. 3-22). Dordrecht, Netherlands: Springer.
- \_\_\_\_\_ (2006). Domain specificity of personal epistemology: Resolved questions, persistent issues, new models. *International Journal of Educational Research*, 45, 85-95.
- \_\_\_\_\_ (2005). The legacy and the challenges: Paul Pintrich's contributions to personal epistemology research. *Educational Psychologist*, 40(2), 95-105.
- Hofer, B.K., and Pintrich, P.R.** (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research*, 67(1), 88-140.
- Jakobsson, A., Mäkitalo, A., and Säljö, R.** (2009). Conceptions of knowledge in research on students' understanding of the greenhouse effect: Methodological positions and their consequences for representations of knowing. *Science Education*, 93, 978-995.
- Kagan, D.M.** (1992). Implications of research on teacher belief. *Educational Psychologist*, 27(1), 65-90.
- Khalid, T.** (2003). Pre-service high school teachers' perceptions of three environmental phenomena. *Environmental Education Research*, 9(1), 35-50.
- Kilinc, A., Stanisstreet, M., and Boyes, E.** (2008). Turkish students' ideas about global warming. *International Journal of Environmental and Science Education*, 3(2), 89-98.
- Koballa, T.R.** (1992). Persuasion and attitude change in science education. *Journal of Research in Science Teaching*, 29(1), 63-80.
- Kolstø, S.D.** (2006). Patterns in students' argumentation confronted with a risk-focused socio-scientific issue. *International Journal of Science Education*, 28 (14), 1689-1716.
- Kolstø, S.D., et al.** (2006). Science students' critical examination of scientific information related to socioscientific issues. *Science Education*, 90(4), 632-655.
- Lane, M.** (2002). *Global warming non-believer*. Retrieved from [http://www.sitnews.us/DaveKiffer/061106\\_lane.jpg](http://www.sitnews.us/DaveKiffer/061106_lane.jpg), 30 July 2009.
- Lee, O., Lester, B.T., Ma, L., Lambert, J., and Jean-Baptiste, M.** (2007). Conceptions of the greenhouse effect and global warming among elementary students from diverse languages and cultures. *Journal of Geoscience Education*, 55(2), 117-125.

- Lindzen, R.S.** (2006). Understanding common climate claims. In A. Zichichi & R. Ragaini (Eds.), *International seminar on nuclear and planetary emergencies – 34<sup>th</sup> session* (pp. 189-210). Singapore: World Scientific Publishing Co. Pte. Ltd.
- Louca, L., Elby, A., Hammer, D., and Kagey, T.** (2004). Epistemological resources: Applying a new epistemological framework to science instruction. *Educational Psychologist*, 39(1), 57–68.
- Merriam, S.B.** (1998). *Qualitative research and case study applications in education* (2<sup>nd</sup> Ed.) San Francisco, CA: Jossey-Bass.
- Mortensen, L.O.** (2007, March 21). Global warming – Doomsday called off (Part 5 of 5) [Video file]. Retrieved from <http://www.youtube.com/watch?v=v2XALmrq3ro>.
- Mueller, M.P.** (2009). Educational reflections on the “ecological crisis”: EcoJustice, environmentalism, and sustainability. *Science and Education*, 18, 1031-1056.
- NATIONAL RESEARCH COUNCIL (NRC).** (1996). *National science education standards*. Washington, DC: Academy Press.
- Nuangchalerm, P.** (2009). Development of socioscientific issues-based teaching for preservice science teachers. *Journal of Social Sciences*, 5(3), 239-243.
- Pajares, M.F.** (1992). Teachers’ beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, 62(3), 307-332.
- Papadimitriou, V.** (2004). Prospective primary teachers’ understanding of climate change, greenhouse effect, and ozone layer depletion. *Journal of Science Education and Technology*, 13(2), 299-307.
- Reis, P., and Galvao, C.** (2009). Teaching controversial socio-scientific issues in biology and geology classes: A case study. *Electronic Journal of Science Education*, 13(1), 1-24. Retrieved from <http://ejse.southwestern.edu>.
- Richardson, V.** (2003). Preservice teachers’ beliefs. In J. Raths & A.C. McAninch (Eds.), *Teacher beliefs and classroom performance: The impact of teacher education* (pp. 1-22). Greenwich, CT: Information Age Publishers.
- Rickinson, M.** (2001). Learners and learning in environmental education: A critical review of the evidence. *Environmental Education Research*, 7(3), 207-320.
- Riessman, C.K.** (2008). *Narrative methods for the human sciences*. Thousand Oaks, CA: Sage Publications.
- Rosenzweig, C., et al.** (2008). Attributing physical and biological impacts to anthropogenic climate change. *Nature*, 453, 353-358.



- Sadler, T.D.** (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching*, 41(5), 513-536.
- Sadler, T.D., and Donnelly, L.** (2006). Socioscientific argumentation: The effects of content knowledge and morality. *International Journal of Science Education*, 28(12), 1463-1488.
- Snider, V.E., and Roehl, R.** (2007). Teachers' beliefs about pedagogy and related issues. *Psychology in the Schools*, 44(8), 873-886.
- Stake, R.E.** (2006). *Multiple case study analysis*. New York, NY: The Guilford Press.
- Summers, M., Kruger, C., Childs, A., and Mant, J.** (2001). Understanding the science of environmental issues: Development of a subject knowledge guide for primary teacher education. *International Journal of Science Education*, 23(1), 33-53.
- Tobin, K.** (2000). Interpretive research in science education. In A.E. Kelly & R.A. Leash (Eds.), *Handbook of research design in mathematics and science education* (pp. 487-512). Mahwah, NJ: Lawrence Erlbaum Associates.
- UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE.** (2009). Copenhagen accord. Retrieved from [http://unfccc.int/files/meetings/cop\\_15/application/pdf/cop15\\_cph\\_auv.pdf](http://unfccc.int/files/meetings/cop_15/application/pdf/cop15_cph_auv.pdf), 14 February 14, 2010.
- WORLD WILDLIFE FUND (WWF-US).** Observations on climate change in the Arctic – WWF [Video file]. Retrieved from <http://www.youtube.com/watch?v=Jak1pExql0U>, 02 September 2008.
- Yin, R.K.** (2009). *Case study research: Design and methods* (4<sup>th</sup> ed.). Thousand Oaks, CA: Sage Publications.
- Zeidler, D.L., Sadler, T.D., Simmons, M.L., and Howes, H.V.** (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science Education*, 89, 357-377.