EXPLORING THE EPISTEMOLOGICAL, PEDAGOGICAL, AND CURRICULAR BELIEFS

OF PRESERVICE SECONDARY SCIENCE TEACHERS

ON GLOBAL CLIMATE CHANGE

by

ARIS REYNOLD VERTIDO CAJIGAL

(Under the Direction of 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, pedagogical, and curricular beliefs of preservice secondary science teachers on global climate change. It examined the experiences of preservice teachers that influenced their perspectives on the issue, and the negotiations they anticipate in the future 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, pedagogical, and curricular beliefs on global climate change were in a dynamic relationship and bound by two significant points: (1) Global climate change is a seemingly inevitable topic. (2) Global climate change has a rightful place in the science curriculum. Perspectives on global climate change tended to be mediated by the preservice teachers' experiences with people, places, and events. More specifically, themes that emerged within the four cases include: (1) distinction between the "what" and the "why"; (2) Who is the source?; (3) establishing a climate of learning; (4) life with global climate change; (5) making choices; (6) teacher as mediator; (7)

reducing personal carbon footprint; (8) authority matters; (9) to be persuaded but not to be persuasive; (10) uncertainties surrounding the issue; (11) reliance on the processes of science; and (12) examining controversial issues in the classroom. The themes emerging from cross-analysis include: (1) natural versus anthropogenic causes; (2) information audit; (3) relevance of the topic of global climate change to the individual lives of students; (4) influence from family and friends; (5) dealing with *An Inconvenient Truth*; (6) academic context; (7) controversy surrounding global climate change transcends the scientific, political, and economic aspects of society; and (8) classroom debate as a microcosm of the larger scientific community. Recognizing the controversial nature of the topic of global climate change, the preservice teachers plan to negotiate the teaching of this concept in terms of content, context, process, and outcomes. Theoretical, methodological, and practical implications of the study are also elaborated in this report.

INDEX WORDS: Teacher beliefs, Global climate change, Socioscientific issues, Preservice secondary science teachers, Negotiating belief

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ARIS REYNOLD VERTIDO CAJIGAL

B.S.Ed., Mariano Marcos State University, Philippines, 2001

M.A.Ed., Mariano Marcos State University, Philippines, 2006

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ARIS REYNOLD VERTIDO CAJIGAL

Major Professor: Deborah J. Tippins

Committee: Norman F. Thomson
Thomas R. Koballa, Jr.
Shawn M. Glynn

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
August 2010

DEDICATION

To my loving parents,

siblings,

nieces and nephews,

relatives, friends,

and all stewards of the earth,

I dedicate this piece of work.

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"Gratitude is not only the greatest of virtues,
but the parent of all the others."
– Cicero

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BACKGROUND OF THE STUDY

Introduction

Numerous changes in the world have occurred throughout the history of humankind. The changes that happened have shaped world history and influenced the present-day social, political, economic and environmental conditions. In particular, the environment has undergone many changes that have resulted from natural processes and human activities. The environment in which we live has offered humankind the conditions that allow our very existence. Along with changes in our surroundings are changes in human societal affairs – personal, social, economic, and political endeavors. Focusing on the environment, global changes are continuously monitored by scientists and environmental activists because of the impending threat of global climate change driven by unprecedented global warming.

The problem of global climate change has gripped the global scene and stimulated governments throughout the world to find ways to mitigate the potential impacts 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 last December 2009 to discuss global climate change and measures of mitigation to curb its impact. At the conclusion of this conference, nations 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). Recognizing the urgency of the issue, the accord stressed the Nations' political will 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" (UNFCCC, 2009, p. 2).

Defining Global Climate Change

Global climate change refers to significant changes in temperature, precipitation, wind and other measures of climate lasting through an extended period of time (Environmental Protection Agency [EPA], 2010). EPA adds that global climate change can be caused by natural processes and human activities. Global warming, the term many people often use to denote climate change, refers to an increase in average temperature in the atmosphere near the surface of the earth thereby influencing global climate patterns. According to many scientists (Carpenter et al., 2008; Francis & Hengeveld, 1998; Garrett, Dendy, Frank, Rouse, & Tracers, 2006; IPCC, 2002; Zell, 2004), global climate change could result in an inevitable crisis if continued greenhouse gases are emitted to our atmosphere. According to the Pew Research Center for the People and the Press (2009), 84% of scientists believe that global warming is caused by human activity. 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. Guterl (2009) admits that empirical evidence is worrying, but not enlightening and not telling us about natural variability. Lindzen (2007) refutes the popular claim by most climate scientists that global climate change is a result of anthropogenic activities. To him, the prevailing publicity of a crisis is a baseless alarm. To refute the claims of anthropogenic global climate change, Lindzen (2007) argues that climate models pose uncertainty since the properties of natural and human-induced mechanisms for warming and cooling are poorly understood. He further claims that the IPCC predictions of global temperature rise is a huge overestimate because climate models cannot account for other significant mechanisms that influence global warming and cooling.

Global Climate Change, Environmental Systems, and Humans

The Intergovernmental Panel on Climate Change (IPCC) (2002) projects that the globally averaged surface temperature will increase by 1.4 to 5.8 ^{o}C from 1990 to 2100, with land areas warming more rapidly than the global average. Francis and Hengeveld (1998) posit that greenhouse warming causes increase in extreme weather conditions, such as tropical storms and hurricanes, as these result from changes in the distribution of heat and flow of energy. Global climate change may also have the potential for increasing the emergence of diseases. Increased frequencies of heavy rainfall and increased temperature could pose the risk of infection due to contaminated water sources; emergence of vector-borne diseases (Hunter, 2003); and increased exposure of man to vector- and water-borne diseases (Zell, 2004). For example, dengue fever, a dreaded disease in tropical countries, is carried by the vector mosquito, *Aedes aegypti*. Increased rainfall could produce more breeding grounds for the dengue-carrying mosquitoes while prolonged drought could make people store water for their consumption thereby attracting these vectors to breed on uncovered and stagnant water (Anyamba, Chretien, Small, Tucker, & Linthicum, 2006; Patz & Reisen, 2001).

Food security is also at risk with global climate change by potentially affecting plant growth, plant susceptibility to diseases and crop yield. Chakraborty, Tiedemann, and Teng (2000) claim that weather influences all stages of host and pathogen life cycles. Garrett, Dendy, Frank, Rouse and Tracers (2006) contend that elevated carbon dioxide levels result in changed plant structure and that elevated temperature induces stress resulting in wilting, leaf burn, leaf folding, and changes in metabolism. In our oceans, global climate change threatens coral reefs, the sanctuary of aquatic organisms. Increased ocean temperatures as a result of global warming have the potential of inducing coral bleaching and ocean acidification. Coral bleaching is characterized by reduced/no skeletal growth and reproductive activity, and a lowered ability to shed sediments and disease resistance (Glynn, 1996). Ocean acidification reduces ocean carbonate ion concentrations and the ability of corals to build skeletons (Carpenter et al., 2008). Another threat of global climate change is sea level rise which will certainly affect coastal communities. Sea level rise is attributed to thermal expansion of water and melting of polar icecaps which are both caused by increasing global temperatures. In the IPCC (2002) predictions, the Earth's mean temperature is expected to rise from 1.4 to 5.8 ^{o}C by the end of the 21st century and sea level rise is predicted to be 0.09 to 0.88 m. Mimura (2006) and Perez, Amadore, and Feir (1999) note that if the sea level rise becomes large, the greatest threats will be the inundation of low-lying plains and wetlands, flooding related to storm surges and overflowing rivers, accelerated coastal erosion and saltwater intrusion into freshwater systems and aquifers. The potential impacts from global climate change presented above are not intended to sow chaos and panic, nor cause despair and hopelessness. Rather, this discussion is intended to present a realistic scenario and suggest that collective action has the potential of reducing the impacts of global climate change.

Global Climate Change and Public Perception

In the past few years, the issue of global climate change has shaped the consciousness of every citizen such that increased public awareness was inevitable. The media is considered a powerful force in providing information or misinformation about global climate change to a large population, depending on how the news reports are framed and presented. Likewise, media portrayal of this issue has influenced the public's perception and thinking about possible environmental actions that could reduce the impacts of global climate change. Fortner et al. (2000) examined media portrayal of global warming and the certainty of the media's information, and assessed public knowledge about key topics in global climate change. They found that media reports were scarce and more than half of the references made were hedged. With regard to their public survey, they found that people were fairly knowledgeable and certain about the existence of the global climate change phenomena. In addition, Antilla (2005) found that a lot of news articles framed global climate change as a debate, controversy, or uncertainty.

In 2009, The Pew Research Center for the People & the Press released the result of a survey of the general public (sample of 2,001 adults) and the scientific community (sample of 2,553 scientists) about their opinions on the state of science, and issues concerning the impact of global climate change on society. One of the issues included in the survey was global climate change. The survey results showed that majority (85%) of Americans say that the earth is warming. About half (49%) of them believe that the earth is getting warmer as a result of human activity; 36% believe that warming is caused by natural changes in the atmosphere and 11% say that there is no solid evidence of warming. When asked about whether or not a scientific consensus exists, 76% of the people who believe that human activity is causing global climate change think that most scientists agree on this point; 41% of those who believe that atmospheric changes contribute to warming think there is a scientific consensus on the issue; and 22% of those who believe that there is no solid evidence of global climate change think that there is scientific consensus on the issue. The topic global climate change transcends human awareness and societal consciousness. Slimak and Dietz (2006) found that population growth and global warming are issues that are more of a concern to the experienced public and the risk professionals than for the lay public. Awareness may potentially be influenced by a public understanding of the issues surrounding global climate change. Longino (1990) argues that scientific claims have an influence on governmental policies, social values, informal policies, and cultural ideals. Relative to this, individual decision making is given primordial importance when calls for urgent action to mitigate the negative consequences of global climate change are stressed. Longino (1990) adds that personal autonomy in decision making rests on one's own values, beliefs and social context; and personal responsibility refers to actions that are attributed to an individual's intentions. Hess (1997) further notes that citizens' participation is frequently observed in environmental issues.

Global Climate Change and Schooling

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. The science curriculum, for example, is typically designed to include topics about the earth and the functioning of its various systems. To this end, educational reforms stress not only the learning of academic content and preparation of students for responsible citizenship but also how students should interact with and sustain a healthy environment.

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. In the *National Science Education Standards* (National Research Council [NRC], 1996), scientific literacy is defined as the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. In addition, these standards stress the development of scientifically literate students who 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 be able to evaluate the quality of scientific information. The issue of global climate change has been a subject of debate for various groups of people. Scientific literacy then operates among students by way of using critical thinking in distinguishing facts from fallacies about global climate change. Since scientific literacy entails being informed on societal issues, environmental literacy may be closely associated with it. Disinger (2005) defines environmental literacy as behavior in an environmentally responsive manner that includes skills (human interactions with environment), affect (emotional traits) and behavior (activities that improve the quality of the environment). Jenkins (1999) claims that school science education, citizenship and public understanding of science are interrelated. He believes that schools are responsible for developing an informed citizenry who can later contribute to decision making. But the school science curricula may not be the end-all of developing scientific literacy. The context of schooling must also be taken into consideration.

Science teacher education has its role in preparing science teachers 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 cause the marginalization of women, children, and aboriginal people. Likewise, Mueller (2009) believes that crisis thinking may evoke fear, anxiety, and hopelessness among our youth. Alternatively, he recommends that rather than crisis thinking, teachers and students should: (1) view environmentalism as an opportunity to assume individual responsibilities; (2) be comfortable in dealing with uncertainties in ecological education; and (3) be guided by projects that integrate local knowledge and skills. Simply put, a crisis can be turned into an opportunity for meaningful actions. The *Standards for Science Teacher Preparation* (National Science Teachers Association [NSTA], 2003) emphasize the fundamental role of students' informed decisions about contemporary societal issues in developing scientific literacy and citizenship in a democratic society. The standards likewise stress that making meaningful decisions on global issues requires knowledge of related science content, the nature of science and technology, and the ways science communicates with the society. Gautier and Solomon (2005) emphasize that global climate change is an issue that transcends the social and political spheres and is situated in scientific practice as a source of arguments and negotiations. 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 or relationship, if any, of these beliefs to their decisions about pedagogy, curriculum, and their visions for teaching global climate change in their own science classes.

Rationale for the Study

This study was conceptualized to explore the epistemological, pedagogical, and curricular beliefs of preservice secondary science teachers around the issue of global climate change. The study is significant as it will provide us 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. In addition, it must be noted that most studies done about global climate change in an educational context have focused on preservice science teachers' conceptual understandings of global climate change processes and their conceptions and alternative conceptions (Boyes, Stanisstreet, & Papantoniou, 1999; Dove, 1996; Groves & Pugh, 1999; Jeffries, Stanisstreet, & Boyes, 2001; Khalid, 2003; Kilinç, Stanisstreet, & Boyes, 2008; Kirkeby Hansen, 2010; Lee, Lester, Ma, Lambert, & Jean-Baptiste, 2007; Papadimitriou, 2004; Rye, Rubba, & Wiesenmayer, 1997; Taber & Taylor, 2009).

Preservice teachers' conceptual and pedagogical understandings 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" (p. 234). 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. Preservice teachers' conceptual understanding of global climate change may not be enough to explain their beliefs and how these influence whether or not global climate change becomes a viable part of the science curriculum. In addition, it is imperative to understand how their pedagogical decisions on the teaching of global climate change are influenced by epistemological beliefs and moral values. Snider and Roehl (2007) posit that teacher beliefs influence classroom practice. They further claim that beliefs that are guided by knowledge which could potentially enhance expertise, but may evolve into an ideology, dogma, or myth if not substantiated by evidence.

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, reflection, or assessment. A close examination of preservice teachers' beliefs can also provide teacher educators guidance in structuring curricula, provide program direction, and allow us to better understand the role they may play in teachers' future perspectives and practices (Pajares, 1992).

Purpose of the Study and Research Questions

This study aimed to explore the epistemological, pedagogical, and curricular beliefs of preservice secondary science teachers regarding global climate change. Specifically, this study attempted to answer the following questions:

1. What are the epistemological, pedagogical, and curricular beliefs of preservice secondary science teachers about global climate change?
2. What experiences influence the development of preservice science teachers' beliefs regarding global climate change?
3. How do preservice teachers negotiate and integrate these beliefs in the design of learning experiences about global climate change?

Overview of Theoretical Framework

The theoretical framework for this study is comprised of assumptions regarding teacher beliefs, Hofer and Pintrich's (1997) model of epistemological theories, the notion of epistemological resources (Louca, Elby, Hammer, & Kagey, 2004; Elby, 2009), Gee's (1996) notion of cultural models, a synthesis of theoretical ideas concerning socioscientific issues in the school context, espoused theory of action (Argyris & Schön, 1974) and constructionism. The theoretical framework as discussed below and in a separate chapter provides a discussion of the theoretical underpinnings that inform this study.

Hofer and Pintrich (1997) noted in their comprehensive review of literature that the term ‘beliefs’ lacks conceptual clarity and that the majority of studies about the nature of students’ thinking and beliefs resulted in varying definitions and characterizations of epistemological tenants. As a response to the common developmental approaches to epistemological beliefs, they proposed a model to integrate various theoretical notions of epistemological beliefs limited to the individual’s beliefs about knowledge, reasoning and justifications, and what they called an individual’s “epistemological theories”. The model is made up of four dimensions. Under the nature of knowledge, the dimensions, certainty of knowledge and simplicity of knowledge are included. Under the nature of knowing component of the model, source of knowledge and justification for knowing are the key features. The four dimensions of this model comprise an integrated, relatively coherent structuring of related beliefs, activated in context, operating both cognitively and metacognitively (Hofer, 2005). The model theoretically informs this study with its focus on the individual’s belief systems and how these are influenced by personal and external factors. The model does not intend to provide a clear cut delineation of the construct of epistemological beliefs from other constructs but rather as a starting point for the examination of individual beliefs. In this study, a clear understanding of belief systems will enable us to better understand the teaching and learning processes in the classroom (Hofer & Pintrich, 1997).

Louca, Elby, Hammer, and Kagey (2004) provided an additional perspective on personal epistemology. These scholars posit that personal epistemologies consist of cognitive resources for understanding knowledge. They further claim that epistemological resources made of beliefs compiled in a rich network are activated by differing contexts. This view of epistemological beliefs informs the present study by augmenting the model of epistemological theories with the notion of resources being used by an individual depending on the context. Hence, preservice teachers' beliefs about global climate change can be examined using the framework of epistemological resources invoked by teachers as they explicate their beliefs about a topic.

Beliefs about global climate change can be communicated by invoking personal knowledge and experiences and attributing meaning to every aspect of human affairs. Gee (1996) posits that cultural models include assumptions about models of simplified worlds and make our choices and meanings to these worlds. The meanings humans attribute are based on their beliefs and values. Cultural models, Gee (1996) adds, can be learned by acculturation and having personal experiences and interactions with the social group. In this study, preservice teachers are part of a group that has potentially established cultural models that they tend to invoke when openly discussing their views and beliefs.

The topic global climate change is a socioscientific issue that has generated different views and actions worldwide. Socioscientific issues are social problems or dilemmas that are often complex, open-ended and contentious, posed to students that have ties to science (Sadler, 2004). Infusion of socioscientific issues in teaching traces its roots from the STS (Science, Technology and Society) movement geared to make science classrooms reflective of the society. The scholarship on socioscientific issues as used in the school context has been focused on students' conceptual and moral reasoning on social issues (Sadler & Donnelly, 2006). Zeidler, Sadler, Simmons, and Howes (2005) provided a framework to guide socioscientific issues education. The framework is composed of the elements: nature of science, classroom discourse, cultural issues, and case-based issues. The present study is informed by this framework in the sense that understanding beliefs of preservice science teachers requires an examination of how their thinking on global climate change is framed on the basis of their prior beliefs, commitments, moral, and ethical stance and constructed reasoning.

In this study, preservice science teachers were asked to communicate their beliefs on global climate change through their talk and written plans for teaching about it in the science classroom but they did not have an opportunity to carry out their plans through actual classroom teaching. Interestingly, they have elaborated on the different elements that make their teaching of global climate change meaningful to their students as well as the specific intentions they have for the class. Argyris and Schon (1974) proposed a theory of action in explaining organizational learning. Through their scholarship, they organized their ideas into a coherent theory of action which puts primary importance to theories put into practice that help human beings to understand, explain, anticipate, know, and act in the world. In effect, they contend that deliberate human behavior is the consequence of theories of action held by humans. In organizational learning, Argyris (2003) posits that humans use the same theories of action regardless of their position in the hierarchy, gender, race and type of organization. Part of the theory of action is theories-in-use and espoused theory of action. Theories-in-use describes how an individual actually behaves (Raelin, 1997). An espoused theory of action, on the other hand, is the theory of action to which a person communicates to others as to what he or she will perform (Argyris & Schon, 1974; Raelin, 1997). The espoused theory of action potentially informs this study as the beliefs of preservice science teachers are communicated through the conversations surrounding their plans for teaching about global climate change.

Finally, constructionism is the broader perspective that theoretically informs this study. Constructionism views that "all knowledge, and therefore, all meaningful reality as such, is contingent upon human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context" (Crotty, 2003, p. 42). This characterization suggests that humans are active participants in the construction of knowledge. Longino (1990) adds that scientific knowledge is constructed through interactions among individuals. Constructionism theoretically informs this study by providing a framework to explain the nature of preservice teachers' mental construction of their beliefs about global climate change and by allowing us to examine these from their own perspectives.

Overview of Methodology

Interpretive research methodology guided this study in exploring the beliefs of preservice science teachers regarding global climate change. Tobin (2000) asserts that interpretive research is a good way of understanding a community and individuals in terms of actions and interactions. It is known for its flexibility, emergent nature, emphasis on the participants' own perspectives, and the formation of "multifaceted images of human behavior as varied as the situations and contexts supporting them" (Cohen, Manion, & Morrison, 2007, p. 22).

An interpretivist perspective further informed this study in its attempts to "look for culturally derived and historically situated interpretations of the social life-world" (Crotty, 2003, p. 67). Willis (2007) adds that the core belief of interpretive research is that reality is socially constructed and its goal is to understand a particular situation or context. The individual is the focus of interpretive research. Cohen, Manion and Morrison (2007) assert that an interpretive study begins with individuals, sets out to understand how they interpret the world, and ascertains the intentions of the actors and how these actors make sense of their experiences.

This study was conducted in the course, Science Curriculum and Learning at a university in the southeastern United States. The course presents science curriculum models for students in Grades 6 through 12 in relation to the goals for science education and classroom practice. Students in this course (preservice science teachers) were either in traditional or alternative certification programs. Four preservice science teachers enrolled in the Science Curriculum and

Learning course during the Fall 2009 semester were primary participants in this study. Two of the participants were biology majors, one was a chemistry major, and one was an earth science major.

Multiple sources of data were collected for this study. These sources of data included interview transcripts, concept maps, learning experiences assignment and its related documents and observation notes. The interview transcripts were important sources of information for the case studies developed to represent the beliefs of the four participants.

The researcher employed an inductive analysis (Charmaz, 2006) of the data obtained in this study. The inductive analysis started with open coding, line by line coding, then in-vivo coding (by using the words in the transcript or document), and focused coding. Coding is an important step in identifying information about the data and interpretive constructs (Merriam, 1998). The data were organized into four cases. The cases resulted from compressing and linking together the data in a narrative that conveys meaning of the phenomenon being studied (Merriam, 1998). Then, the researcher analyzed the individual cases and organized abstractions from data into categories (within-case analysis). Cross-case analysis followed to build a general explanation that fit individual cases (Merriam, 1998).

Definition of Salient Terms

The following terms used in this study have been defined for purposes of clarity:

Global climate change refers to significant changes in the measures of climate such as temperature, wind and precipitation (EPA, 2010). The global changes are attributed to both natural processes and human activities. Anthropogenic sources of greenhouse gases, primarily carbon dioxide are said to be the culprit of the changing climate. Global warming is related to global climate change. Global warming involves a significant increase in average global temperatures that influences the flow of heat and energy in the climate system.

Socioscientific issues are topics that are presented as social dilemmas with conceptual and technological ties with science (Sadler, 2004). In this study, global climate change is a socioscientific issue that was examined in light of the preservice teachers' beliefs. Socioscientific issues are generally controversial topics that allow individuals to consider an ethical, political or social question by drawing upon his/her personal knowledge and moral position (Sadler, 2004; Kolstø, 2006).

Teacher beliefs are generally regarded as teachers' predispositions and attitudes toward teaching, learning, and schooling. This study focused on the beliefs of preservice science teachers around a specific topic, that is, global climate change and how this topic transcends the teaching-learning process in the science classroom. The literature is replete with diverse and often overlapping conceptualizations of teacher beliefs. In view of this, teacher beliefs may be used as a collective term for "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, repertories of understanding, and social strategy" (Pajares, 1992, p. 309). Belief and knowledge are distinct but closely related constructs. Smith and Siegel (2004) claimed that most philosophers view belief as necessary but not sufficient condition for knowledge. They added that Plato's influence on the distinction between these two constructs persisted, that is, knowledge as justified true belief. In the literature, knowledge is characterized as more objective while beliefs as more subjective or value-laden (Smith & Siegel, 2004). Pajares (1992) opined that "belief is based on evaluation and judgment while knowledge is based on objective fact" (p. 313). In light of these theoretical notions, this study treated knowledge as an individual's repertoire of information, skills, and experiences gained from school and formal undertakings and beliefs as those that are more subjective and affective than knowledge (Southerland, Sinatra, & Matthews, 2001), developed through everyday experiences. This distinction does not discredit belief or place it in a lower epistemic status than knowledge but rather as an operationalized definition that guided the entire study. The researcher kept in mind that knowledge and belief are interrelated constructs that exert influence on the practices and actions of preservice science teachers.

YouTube clips refer to video clips downloaded from the YouTube website. YouTube is an internet-based technological innovation launched in 2005 by Hurley, Chen and Karim (Burgess & Green, 2009). The website provides a simple technological interface where users can upload, publish and view streaming videos about any desired topic (Burgess & Green, 2009). The clips used in this study were specifically focused on the topic of global climate change.

Subjectivity Statement

In this study, the researcher was positioned primarily as an outsider. The researcher recognized the impact of being a Filipino citizen conducting research with American undergraduate students and bringing his teaching and research experiences to the study. This cultural difference may have affected the responses that he obtained from the participants. In addition, the issue of cultural sensitivity may have influenced the participants in framing their responses so as to be consistent with their convictions that everyone should be respectful of other peoples' cultural and social backgrounds. The topic global climate change elicited different opinions based on personal knowledge and experiences as well as socio-political factors. Generally, global climate change is treated as a serious threat to human survival and hence causes, effects and possible solutions are often discussed openly regardless of one's religious or political affiliations.

The researcher's gender and ethnicity may have posed an influence on the result of the interviews with the participants. The researcher's nationality is wrought with a slightly different set of moral values. One of the core values taught during his academic preparation was environmental protection and respect for Mother Earth. His religious belief of humans being responsible in protecting the earth also forms part of his belief system.

The researcher's academic preparation and various experiences also shaped his belief systems on various issues. He was active in environment-related student activities during his high school and college education. He was prepared as a chemistry teacher in a teacher education program that values environmentally literate individuals. Likewise, the teacher education curriculum that he's been exposed to stressed both academic content and societal issues. The chemistry of greenhouse effect and other environmental concerns was included in the researcher's teacher education curriculum. He was also a part of various organizations that integrated environmentalism as part of the activities for each school year. Most recently, he attended a teachers' institute that focused on global climate change and how this topic is best taught in science classes and in informal contexts. As part of the institute requirements, he implemented a lesson plan with an elementary science teaching methods class and co-facilitated a six-hour professional development for teachers geared toward enhancing their understanding of global climate change and ways to integrate it in their own teaching.

In terms of the researcher's teaching experiences, he taught high school level and college level chemistry courses, environmental science for college students, and STS (Science, Technology and Society). In all these courses, environmental issues were often discussed in relation to the science concepts being considered. Global climate change was explicitly discussed in his teaching of an environmental science course. He developed lessons featuring classroom discussions and first-hand experiences for students with investigation of environmental concerns in their respective communities. The researcher is also very familiar with the environmental programs of the student organizations in his home university. He was an active adviser of a student organization that promotes academic, moral, social development and environmental awareness. Part of his teaching experience was his designation as teacher training instructor for chemistry student teachers. He was assigned to mentor student teachers to prepare them for their future career. Hence, his previous teaching experiences with preservice science teachers in his home country might have shaped his views of preservice teacher education in the United States. In addition, his personal experiences with student teachers in science might have influenced his dealings with the four participants in this study.

The researcher originally comes from a country that is highly at risk in terms of the impacts of global climate change. The researcher's local community lies along the coastline which may be threatened by sea level rises as a result of global climate change. Inundation of low-lying coastal areas in his home country could cause physical damage and a host of societal issues. The government in his home country has taken initiatives to mitigate global climate change after the disastrous flooding that happened recently in the country.

Preview of the Chapters

The dissertation is organized into five chapters. Chapter 1 is the introduction and a discussion of the questions and rationale of this study, an overview of the theoretical framework and methodology, definition of terms, and researcher subjectivities. Chapter 2 presents a review of literature and the theoretical framework of the study. Chapter 3 discusses the methodology employed in this study. This chapter also provides details about the participants, context, and the specific methods and procedures undertaken in this study. Chapter 4 includes the presentation, analysis and interpretation of findings with respect to the four individual case studies. Chapter 5 provides a cross-case analysis, elaborates on the conclusions relative to the research questions, and discusses implications of the research.

Chapter 2

REVIEW OF LITERATURE AND THEORETICAL FRAMEWORK

Introduction

Global climate change has become not only an environmental topic but also a socio-political, economic, and educational topic. It has been widely studied in the natural sciences. Since the focus of this study was on preservice science teachers' beliefs about global climate change, the researcher attempted to limit his search to relevant literature to those studies that pertain to educational contexts. This chapter, then, aims to present a synthesis of this literature in light of the research questions.

This chapter is composed of two parts. The first part is the review of literature which guided the researcher in framing the study. The review was organized into three important topics that informed the present study. The review centered on the topics of global climate change in educational contexts, socioscientific issues in school settings, and science teacher beliefs. The researcher's effort to locate relevant literature was guided by online library databases. The terms used in his search included "global climate change", "global warming", "preservice teachers' beliefs", "teacher beliefs", "science teacher beliefs", "beliefs about environment", "socioscientific issues", "beliefs on global climate change", "beliefs on global warming", and "global climate change education". The search was aided by databases that included Academic Search Complete, EBSCOHost, ERIC, Ecology Abstracts, Education Full Text, Educational Research Complete, Environment, Environmental Sciences and Pollution Management, JSTOR, Web of Science, and Web of Knowledge. The second part of this chapter explains the theoretical framework. This portion of the chapter discusses the different theoretical underpinnings that informed this study.

Review of Literature

The following discussion provides a review of literature that was relevant to the study. The review is a synthesis of studies on three areas of scholarly work: global climate change in educational settings, socioscientific issues, and teacher beliefs. The studies included in this review provided a basis for identifying a gap in the literature and helped frame the study. Toward the end of each main section of the review, a summary and discussion of the implications of the reviewed literature to the present study is provided. This brief discussion intended to identify the gaps in the literature that led to the design and conceptualization of the present study. The review of literature looked into the studies about global climate change involving university students, preservice science teachers, inservice science teachers, and K – 12 students. Though the primary focus of the present study involves preservice science teachers, examination of studies about K-12 students and inservice science teachers were also salient to the study. As beginning science teachers, there is potential that preservice teachers might draw from their past experiences as science students and reflect on their observations and experiences with inservice teachers with whom they might have worked. Likewise, looking closely at studies involving inservice teachers and K-12 students provided a frame of reference for possible comparisons and contrasts with the experiences and beliefs of preservice teachers.

Global Climate Change as a Topic in Educational Settings

Global climate change is an issue that constantly appears in media, political debates, economic forums, and school contexts. Science education, in particular, is closely associated with this global issue since schools are one of the main avenues for helping students gain a clear understanding of the scientific basis of global climate change. Likewise, the environment is a central concept in most of the sciences that are taught in schools. Littledyke (2008) admitted that one of the challenges in schools is how to encourage children to develop a sense of relationship with their environment. He further posited that such sense of relationship is a function of both the cognitive and affective dimensions of students' experiences. The following section is intended to provide a glimpse of what has been studied about students and preservice teachers' understanding, conceptions, and beliefs about global climate change.

Global climate change in teacher education and other university contexts. University students are engaged in a slightly different set of learning experiences than their K-12 counterparts. Since college students enroll in courses according to their fields of specialization, conceptions about the issue of global climate change may dramatically vary. In this section, studies about college students' conceptions and beliefs about global climate change are reviewed. The majority of these studies identified and addressed misconceptions of college students about the greenhouse effect, global warming, and ozone depletion. The students' conceptions and alternative conceptions were identified using various instruments such as questionnaires, interviews, and assessment tools.

College students may have gained an understanding of the greenhouse effect through their previous educational experiences. However, their alternative conceptions about specific mechanisms of these phenomena are carried over during their college education. For instance, 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 in his study believed that the greenhouse effect was caused by solar radiation passing through ozone layer holes thereby warming the earth. All of them believed that an intensified greenhouse effect could result in higher temperatures and that emission from cars are a major culprit for increased greenhouse effect, ozone layer depletion and acid rain. The majority of the student teachers understood that acid rain could be produced from burning coal but were unable to enumerate the gases responsible for its formation.

Groves and Pugh (1999) claimed that environmental issues are important topics in science education. Their study aimed to expand and build upon previous studies about preservice teachers' alternative conceptions related to global warming, ozone depletion, and acid rain. 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 from the questionnaire administered to these future teachers supported previous findings that preservice elementary teachers hold many alternative conceptions about the given environmental issues, and these can affect their teaching of the specified topics in elementary classes. The authors accounted for this finding in terms of the teachers' lack of formal encounters with these environmental issues. The authors suggested that preservice teachers' experiences with these issues were likely limited to what they had learned from the media.

Comparison of students' conceptions from various research periods may help researchers track significant changes and identify changes in conceptions over time. Jeffries, Stanisstreet, and Boyes (2001) conducted a study of the ideas of undergraduate biology students about the consequences, causes, and remedies for the greenhouse effect. A closed-form questionnaire was used and the results were compared to a parallel study conducted ten years earlier. Despite the popularity of the issue of greenhouse effect in media and in academic settings, the students' thinking was broadly similar to the students in the previous study. Most of the students held confusing explanations in regard to the greenhouse effect and ozone layer depletion, which was also seen in the older study.

Preservice science teachers are often prepared to teach in schools through their experiences in the natural sciences. In many cases, they are also prepared to integrate scientific and environmental issues in their teaching in ways deemed relevant to the curriculum. Regardless of how intense or deliberate the instruction they receive, alternative conceptions about the mechanisms of environmental phenomena may still be carried on through their college years. Summers, Kruger, Childs, and Mant (2001) explored the understanding of 170 practicing primary school teachers, 120 primary preservice teachers, and 88 secondary science preservice teachers about the issues of biodiversity, carbon cycle, ozone, and global warming. The questionnaire used in the study tested the teachers' knowledge of the component parts and explanations of the four environmental issues. 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. By contrast, these teachers 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. The secondary science preservice teachers' knowledge about ozone and global warming were better than the other two groups.

Likewise, Khalid (2003) identified and described the alternative conceptions held by preservice secondary science teachers regarding the greenhouse effect, ozone depletion, and acid rain. A 30-item questionnaire, consisting of qualitative and quantitative components, was administered to 27 preservice secondary teachers enrolled in a science teaching methods course.

The questionnaire items focused on the causes, effects and interactions of the three environmental issues and required the students to provide explanations for their responses. Findings indicated that many of the preservice science teachers held alternative conceptions about the greenhouse effect, ozone depletion and acid rain. Some of these alternative conceptions included: (1) Greenhouse gases break down ozone molecules; (2) Ozone depletion is the cause of greenhouse effect; (3) Greenhouse effect is solely caused by human activities; (4) Car emissions cause ozone depletion; and (5) Burning coal emits sulfur which will react with oxygen to form sulfuric acid. These findings revealed that the preservice science teachers tended to hold alternative conceptions due to an incorrect understanding of the relationships between issues.

In another study, Demirkaya (2008) studied the conceptions of prospective primary school teachers about global warming and the relationship to their learning styles. Demirkaya found that the Turkish preservice teachers' conceptions ranged from least sophisticated to the most inclusive and expansive and that these conceptions did not change with the teachers' learning style preferences. The teachers' conceptions of global warming included: "(1) Global warming is the gradual increase in the temperature of the earth; (2) Global warming is the gradual enhancement of the hole in the ozone layer; (3) Global warming is the deterioration of ecological balance; (4) Global warming is the change of climates and seasons; (5) Global warming is the deterioration of mutual relation between people and ecological balance; (6) The cause of global warming is the people and they are responsible for its prevention; and (7) Global warming is the portent of vanishing process of living things and people" (p. 55).

Based on a similar line of research conducted earlier in another country, Papadimitriou (2004) studied the conceptions of 172 prospective primary teachers in Greece about climate change, greenhouse effect and ozone layer depletion. An open-ended questionnaire was used to determine the understandings of the teachers about these three environmental concepts. The findings revealed that the prospective teachers believed climatic changes were happening. These prospective teachers based their belief on personal experiences. Two alternative conceptions surfaced with regard to the causes of climate change: (1) Ozone depletion results in climate change; and (2) Climate change is connected to pollution and environmental hazards such as chemicals, radioactive wastes, and acid rain. It was also evident that the students demonstrated a concern for the environment and recognized their roles in reducing the harm of climate change. Students, however, confused the greenhouse effect with ozone depletion and pollution.

Assessment tools may be helpful in monitoring the nature of students' conceptions about global climate change. This was illustrated by Gautier, Deutsch, and Rebich (2006) who explored the level of understanding and the nature of undergraduate students' alternative conceptions about climate change. These researchers administered pre- and post-test questions to the undergraduate students to help them become aware of the inconsistencies of their beliefs and the information provided by the teachers. Four questions about global climate change were asked and the students' responses were corrected using expert answers and based on completeness and accuracy of the responses. The findings showed that though students improved and deepened their understanding of the greenhouse effect, there were still alternative conceptions that they held after instruction. This finding also reminded the researchers that the undergraduate students may not realize that their mental models do not fit in an accepted framework.

Classroom intervention strategies are potential ways of addressing undergraduate students' alternative conceptions about global climate change. Meaningful diverse activities engage students in thinking more deeply and critically about the scientific concepts involved in the mechanism of environmental phenomena. To illustrate, Rebich and Gautier (2005) examined conceptual change among undergraduate students through a course that used diverse activities. The "Mock Environment Summit" (p. 357) was an undergraduate course designed to allow students to build upon their knowledge through research, role playing and argumentation. Analysis of pre- and post-course concept maps showed that the students' knowledge of global climate change was significantly improved after participating in these kinds of activities. However, students' alternative conceptions also emerged from the maps including ones such as: (1) Rise in global temperature due to increased solar input through the ozone holes; (2) Aerosol is used to describe a type of a greenhouse gas; and (3) Greenhouse gases are synonymous to pollution.

In a more recent study that involved an intervention, Kerr and Walz (2007) assessed the alternative conceptions held by general chemistry students about the greenhouse effect and ozone hole and engaged the students in computer-based activities to address the alternative conceptions. Assessment was conducted before and after the computer-based activities. Students completed four electronic data analysis tasks that required them to create and analyze graphs of data regarding greenhouse gas concentrations, and answer questions about chemical mechanisms based on web resources. The students showed moderate improvement in their performance after completing the tasks; however, many of them still held the idea that ozone depletion was the cause of global warming.

Dahlberg (2001) believed that global climate change as an issue could be used as a pedagogical tool for encouraging environmental awareness. For example, Matkins and Bell (2007) assessed the impact of situating explicit nature of science instruction within the issues of global climate change and global warming among preservice elementary science students. Data were obtained through the questionnaire, *Views of Nature of Science*, class assignments, journals and interviews. They found that preservice teachers' conceptions of the nature of science and global climate change and global warming improved during the semester and that the prospective teachers were able to apply these conceptions in decision making. There was a substantial change in the teachers' ideas about global climate change and nature of science. These conceptions included the idea that the greenhouse effect was natural and beneficial and not the same as global warming; scientists held different positions about whether global climate change was happening or not; and the needed support for the utilization of alternative energy sources.

Global climate change in K-12 settings. Studies about children's conceptions of the environment and various earth systems have increased since the call for environmentalism has intensified. These studies, however, were mostly focused on conceptions and alternative conceptions of K-12 students. Rickinson (2001) posited that students' thinking can lack structure and children as young as four years are observed to have various conceptions and alternative conceptions of environmental issues.

As mentioned above, most studies identified and focused on alternative conceptions of students. For example, Rye, Rubba, and Wiesenmayer (1997) investigated alternative conceptions about global warming held by 24 students in Grades 6 through 8. The students were interviewed after instruction centered around a global warming unit. The researchers found that students held the alternative conception that carbon dioxide causes ozone layer depletion that eventually leads to global warming. Relative to students' conceptions about the ozone layer, Boyes, Stanisstreet, and Papantoniou (1999) studied the perceptions of Greek high school students about the ozone layer. The ideas of 1161 students were examined through a questionnaire that asked what and where they think the ozone layer is, its function, how it may be damaged and its consequences. The findings showed that the Greek students had a good grasp of the location of the ozone layer in the atmosphere and the protection it gives to humans from harmful UV radiation. A small number of students believed that the ozone layer keeps the world warm, protects the earth from acids, and its depletion would intensify the greenhouse effect. Likewise, the students were aware that pollution poses danger to the ozone layer and that its damage may result in an increased risk of skin cancer and eye cataracts.

Also using a questionnaire, Kilinç, Stanisstreet, and Boyes (2008) explored ideas about global warming of Year 10 (age 15-16 years) students in Turkey. Results showed that many students believed that radioactivity is causally linked to global warming, believing that radioactive leakage from nuclear power stations exacerbates global warming, and that reduction of the global nuclear arsenal could minimize global warming. In addition, Turkish students: (1) appeared to confuse the causes and consequences of global warming with those of ozone layer depletion; (2) exhibited a conflation of ideas whereby many pro environmental actions that are not connected with global warming were seen as helping to reduce it; (3) accepted the scientific mechanism of global warming while simultaneously believing erroneous explanations; and (4) realized that saving electricity would contribute to a reduction in global warming.

In light of the use of questionnaires to access students' understanding of the greenhouse effect and ozone layer, Kirkeby Hansen (2010) reported on Norwegian compulsory schools that used four national curricula in which two prescribed explicitly the topics of greenhouse effect and ozone layer. Kirkeby Hansen (2010) was interested in analyzing the development of the students' knowledge since a questionnaire was used with students in 1989 to 2005, when this was the approach to accessing student learning. This analysis of student responses to the questionnaire was thought to guide policy making and curriculum development. In 1989 only one out of four 15-year-old students knew that the greenhouse effect is necessary for life on the earth. In 2005 a significant development was evident as shown by three out of four students who understood these concepts. The author attributed these improvements to formal learning in school and informal learning from media and public discourse.

Some scholars employed classroom interventions to explore students' conceptions of global climate change. Pruneau, Gravel, Borque, and Langis (2003) reported on how they used classroom experiences as part of climate change education in Eastern Canada. Informed by social constructivism, experiential learning, and conceptual change as theoretical perspectives, these researchers engaged 39 students aged 13 to 14 in activities designed to improve their conceptions about climate change: the nature of the phenomenon, signs, causes, consequences, and remedial action. The activities included local observation of a beach area, simulation of group responsibilities (e.g. chemist, ecologist, urban planner, etc.), and identification of possible signs of climate change in the area. Results of the initial and final interviews revealed that there was a significant improvement in the students' conceptions of climate change and its diverse dimensions.

In another study, Lee, Lester, Ma, Lambert, and Jean-Baptiste (2007) examined conceptions of the greenhouse effect and global warming among fifth grade students from diverse languages and cultural backgrounds in the United States. The researchers were interested in finding out the students' conceptions of greenhouse effect and global warming, changes in conceptions throughout an instructional intervention and the differences in conceptions based on demographics. The intervention was based on a unit titled, *Living Planet*, developed to make science relevant to students from diverse backgrounds. Teaching this unit to the 611 fifth grade students involved various activities that focused on climate and seasons, plate tectonics, solar system, global warming and greenhouse effect, and ecology. Students responded to a writing prompt about the greenhouse effect and global warming before and after the unit. The results showed that the students tended to define greenhouse effect as a rise in temperature due to trapped heat and related its cause to burning of fossil fuels. However, the students erroneously equated greenhouse effect of the earth with its literal definition and the ozone layer. Students from the demographic subgroups showed statistically significant improvement in their conceptions of the two topics after the intervention.

In a more recent study employing classroom activities, Taber and Taylor (2009) used a mixed-methods approach in examining the development of knowledge of global warming of Australian students. A hands-on science unit was used in teaching 29 primary school students in year 6 (the final year of primary) from two regional Australian schools. The science unit was specifically designed with global warming as the main topic. Data gathered were in the form of pre- and post-test scores, and post intervention interviews. The findings indicated that after the unit, students had a clearer understanding of the science of climate change, with the largest improvement in student knowledge resulting from hands on activities or effective visual aids. The data also revealed that an increase in knowledge was accompanied by an increase in levels of concern and students' belief that they could make a positive impact in relation to global warming and climate change.

Students often create mental models when engaged in various classroom activities. These models are believed to help students recall and connect relevant information. Some of these models, however, do not fit into an acceptable scientific framework due to incorrect connections of information coming from the school, the media, learning resources, or personal experiences. To illustrate, Koulaidis and Christidou (1999) studied the conceptions of primary school students about the greenhouse effect. Forty students in various Greek schools were interviewed with the aid of media information, photos, and activity cards about the greenhouse effect. After an analysis of the data collected, the researchers identified six models of the greenhouse effect based on students' thinking: "(1) Carbon dioxide and methane layer traps heat from the sun; (2) Carbon dioxide and methane layer traps UV radiation coming in from the ozone holes; (3) Carbon dioxide and methane, uniformly spread in the atmosphere, trap heat from the sun; (4) Ozone layer traps UV radiation coming in from the ozone holes; (5) Ozone layer traps solar radiation; and (6) Greenhouse effect as atmospheric pollution" (p. 568). Also interested in the mental models of students, Andersson and Wallin (2000) examined the conceptions and views of Swedish students in grades 9 and 12 regarding the greenhouse effect, reduction of carbon dioxide emission and ozone layer depletion. A national evaluation using multiple choice tests and open ended questions was conducted with students from twelve schools throughout the country. The students' written responses to open-ended questions became the basis for the development of five models of the greenhouse effect, which integrated the concepts of incoming radiation, outgoing radiation, and a barrier (greenhouse gases) as a system in the atmosphere. Students confused ozone layer depletion and greenhouse effect and recommended drastic reduction of carbon dioxide emissions from human activities.

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. A class of 14–15-year-old students was divided into small groups and each group was given a task in which they were confronted with two contradictory claims about the earth's future temperature and climate. The purpose of the study was to investigate how students made sense of, and how they were able to formulate arguments when talking about the greenhouse effect and global warming as part of doing a project in a science classroom. The focus was on students' use of scientific vocabulary, concepts, and arguments in the context of learning something about global warming and the greenhouse effect. Thematic patterns were identified through students' discussions. The authors argued then that studying reasoning as part of an extended project allows for a clearer understanding of how students can meaningfully talk about rather complex phenomena, develop their understanding, and identify gaps in their own understandings.

McNeill and Pimentel (2010) posited that argumentation is an essential goal of science education. Their study focused on discourse in urban high school science classrooms in which the teachers used the same global climate change curriculum. Through an analysis of transcripts from three teachers' classrooms, examining both the argument structure as well as the dialogic interactions between students, it was found that in the three classrooms, 19%, 21%, and 35% of the discourse focused on scientific argumentation in that students were using evidence and reasoning to justify claims. Only one teacher's classroom was characterized by student-to-student interactions and students explicitly supporting or refuting their classmates' ideas. The teacher's use of open-ended questions and explicit connections to students' comments encouraged them to construct and justify their claims using both their scientific and everyday knowledge, to consider multiple views, and to reflect on their own thinking and that of others.

Meaningful learning experiences have the potential for addressing alternative conceptions among students. According to Osterlind (2005), the use of scientific terminology may cause confusion if words have multiple meanings in different contexts. Osterlind (2005) conducted a case study to describe the work of three 8th grade Swedish students regarding intensified greenhouse effect and ozone layer depletion, and their understanding of such related concepts as photosynthesis, radiation and catalyst. An analysis of recorded conversations, observational notes and written products showed that students encountered difficulty understanding the concept of greenhouse effect and ozone layer depletion, as well as related ideas such as catalyst, radiation and photosynthesis. Their confusion was primarily due to difficulties interpreting meanings in English and Swedish. Osterlind (2005) explained that this specific finding suggests that "concepts do not have given meanings but get their meanings from a given context" (p. 905).

Environmental awareness and attitudes are stressed when discussing the negative impacts of human activities on the planet. Presentation of environmental topics may invoke among students feelings of altruism and a sense of environmental stewardship. For instance, Lester, Ma, Lee, and Lambert (2006) examined the science knowledge and awareness of social activism regarding greenhouse effect and global warming of 420 fifth grade students coming from diverse backgrounds. Data were collected using a writing prompt which students responded to before and after instruction. Students were engaged in inquiry-based activities about the greenhouse effect. In this particular study, social activism referred to a student's manner of identifying ways of stopping the production of greenhouse gases. The researchers found that the students gained content knowledge of an increased greenhouse effect and global warming after the instruction; more students expressed social activist ideas after the instruction; students with adequate content knowledge expressed activist ideas more frequently.

The affective domain of learning in relation to global climate change was also a topic of investigation for other researchers. Devine-Wright, Devine-Wright, and Fleming (2004) explored children's beliefs about global warming and energy sources from a psychological perspective. A comparative research design was employed with a sample of 198 UK children and adults, who belonged to Woodcraft Folk organization and a comparative educational organization, to explore the influence of cooperative learning on children's beliefs about global warming and energy source. Findings revealed that Woodcraft Folk children were more highly convinced about the existence of global warming than the other group of children. The adults working in the Woodcraft Folk organization were even more convinced about the existence of global warming and the reality of global climate change and concerned about the use of fossil fuel resources than the children. The results of the study suggested that children's exposure to cooperative learning outside of a formal school environment could have a positive impact on children's beliefs about environmental issues.

In another study about environmental attitudes and beliefs of students, Boyes, Skamp, and Stanisstreet (2009) conducted an investigation to determine the relationship between students' beliefs about specific actions to reduce global warming and their willingness to act. A validated questionnaire was used to obtain the responses of 500 students in New South Wales, Australia. The questionnaire was composed of 20 items probing students' beliefs about the usefulness of actions paired with 20 items probing the students' willingness to take such actions. Students believed that traveling by public rather than private transportation, using fuel-efficient cars, maximizing renewable energy sources, and tree planting were effective modes of reducing global warming. In terms of their willingness to act, the students considered conservation of energy and recycling as pro-environmental actions that would reduce global warming. The findings further revealed that the students were willing to undertake energy conservation, recycling and use of energy-efficient appliances, though they did not have a strong belief in their effectiveness for reducing global warming. By contrast, students believed that the use of public transport and renewable energy sources could reduce global warming but were unwilling to take such actions.

Global warming is an issue that children may be aware of and express concern about its consequences. Relative to this, Barraza (1999) analyzed the drawings of English and Mexican school children to evaluate their environmental perceptions and concerns. School children from ages seven to nine years old were asked to draw the planet earth based on different conditions. The drawings of the children revealed their deep concern for environmental problems such as pollution, war, global warming, acid rain and deforestation. The study also indicated that children of ages seven to nine years old have some fundamental information about environmental issues.

Students may also hold beliefs about global environmental issues based on experiences and personal concerns. Boyes and Stanisstreet (1998) quantified the beliefs of students about the possible links between skin cancer and global environmental effects. The researchers interviewed students to identify their various ideas about the environmental causes of skin cancer. Then, they developed a questionnaire and gave it to 647 students from ten high schools in the United Kingdom. Most of the students (85%) believed that holes in the ozone layer were more culpable than the greenhouse effect in allowing more UV rays to enter the earth. The students also came up with a model to explain why holes in the ozone layer could increase the risk of skin cancer in relation to increased temperature of the air.

Implications for the present study. No specific delineation between K-12 and undergraduate students' knowledge, beliefs and attitudes toward global climate change or related concepts could be ascertained in the previous studies. The conceptual understanding of students was the primary emphasis of the majority of the studies. Another point to be made here is that global climate change as an issue was treated in research studies using the term global warming and this phenomenon was associated with greenhouse effect, ozone layer destruction, other atmospheric changes and their consequences. The majority of the studies 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. It is interesting to note that Jakobsson, Mäkitalo, and Säljö (2009) felt that testing students with questionnaires was problematic as the structure of the questions asked was confusing to students. In their study, they focused on how students accomplish a project through discourse within groups. Such discourses were claimed to be instrumental in allowing students to identify their own sources of alternative conceptions. Both their study and that of McNeill and Pimentel (2010) employed alternative methods of looking closely into students' understanding of global climate change. There was a scarcity in the number of studies focusing on students' and teachers' beliefs about global climate change and the concepts related to it. The beliefs measured through the questionnaires and teacher-made tests were in the form of conceptual understandings that were based primarily from textbook-based knowledge gained by the students from the classroom. There was a 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 light of their personal and social experiences.

Socioscientific Issues in the Science Classroom

Sadler (2004) defined socioscientific issues (SSI) as social dilemmas with conceptual and technological ties to science. These issues often involve expert disagreement on central scientific questions (Kolstø, 2006). Socioscientific issues are controversial 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: (1) the ethical, personal, or social question related to what scenario to prefer or what actions to take; and (2) the decision made on the scientific question involved.

Sadler (2004) claimed that the process of resolving socioscientific issues can be best characterized by informal reasoning. Informal reasoning provides a description of the generation and evaluation of positions in response to differing complex situations. In a critical review of research, he found that the findings reviewed address: (a) socioscientific argumentation; (b) relationships between nature of science conceptualizations and socioscientific decision making; (c) the evaluation of information pertaining to socioscientific issues, including student ideas about what counts as evidence; and (d) the influence of an individual's conceptual understanding on his or her informal reasoning. The following section presents studies on socioscientific issues in the science classroom. The review includes studies of socioscientific issues in classroom contexts involving preservice science teachers, inservice science teachers, and students.

Socioscientific issues and preservice science teachers. Preservice teachers' experiences with socioscientific issues have been examined in recent years. For example, Kolstø, Bungum, Arnesen, Isnes, Kristensen, Mathiassen et al. (2006) asked 89 preservice science teachers to assess the reliability of scientific claims in an article of their own choice, but related to a socioscientific issue, and to present their evaluation in a short text. The analysis of the teachers' texts resulted in the identification of different evaluative criteria used by the students. Forbes and Davis (2010) investigated preservice elementary teachers' critique and adaptation of SSI-based science curriculum materials and identified factors that served to mediate this process. They found that the four preservice teachers in their study navigated multiple learning goals, subject matter knowledge, informal reasoning about SSI, and role identity in their critique and adaptation of the curriculum. Likewise, the teachers recognized the important role of their own values and beliefs in negotiating issues in the classroom.

Barrett and Nieswandt (2010) were interested in identifying and explaining the origins of physics and chemistry teacher candidates' beliefs about teaching ethics through socioscientific issues (SSI). Through a series of in-depth interviews with twelve participants enrolled in a nine-month teacher education program at an urban university in Canada, the data analysis showed 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. Furthermore, the authors found that the justification for belief change required by a particular teacher candidate depended on subject discipline identities identified in the study. In an earlier study about prospective teachers' beliefs on SSI education, Barrett (2008) compared the beliefs of teacher candidates with the beliefs of their instructors on the topic of incorporating ethics and SSI into teaching the physical sciences. It can be gleaned from the findings that the teacher candidates held progressive views about teaching ethics and SSI while the instructor practices were based on a belief that their students held the opposite view, thereby resulting in a mismatch of priorities.

In the context of Thailand's science education reform, Nuangchalerm (2009) claimed that there was a need to prepare science teachers who can face controversial scientific and social issues. Nuangchalerm (2009) investigated the conceptions influencing preservice science teachers in approaching socioscientific issues-based teaching. One hundred and one preservice science teachers participated in a set of peer discussions about science and social reflection, nature of science, and decision making based on moral ethics. Most of the preservice teachers 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.

Socioscientific issues and inservice science teachers. Teachers are often confronted with controversial scientific issues that are embedded in the curriculum. Cross and Price (1996) examined the social conscience of science teachers in relation to the teaching of controversial issues by interviewing inservice teachers in Scotland and the United States. They found that there was a degree of coherence in the manner that teachers handled controversial issues. The teachers were concerned about the tendency to indoctrinate students and their expression of personal opinions to the class.

Christenson (2004) examined the use of children’s literature in teaching environmental issues. An action-inquiry group comprised of five elementary school teachers collaborated on the incorporation of a multiple perspectives approach including environmental issues in their teaching. Questionnaires, weekly meetings and journal reflections formed part of the data. The teachers collaboratively selected children's literature that discussed different perspectives on diverse viewpoints about environmental issues. Then, the teachers used the identified books in their own classrooms. This inquiry resulted in increased and more accurate use of environmental vocabulary and greater opportunities for using critical thinking skills among the students. The authors further demonstrated a professional development process that could influence teacher attitudes and practice in significant ways.

Sadler, Amirshokoohi, Kazempour, and Allspaw (2006) explored teacher perspectives on the use of socioscientific issues (SSI) for dealing with ethics in science instruction. Twenty-two middle and high school science teachers participated in semi-structured interviews in light of two questions: (1) How do science teachers conceptualize the place of ethics in science and science education? (2) How do science teachers handle topics with ethical implications and expression of their own values in their classrooms? Five profiles were developed to capture the views and reported practices of the teachers. Profile A teachers embraced the notion of infusing science curricula with SSI and cited examples of using controversial topics in their classes. Profile B teachers supported SSI curricula in theory but reported significant constraints which prohibited them from actualizing these goals in their classrooms. Profile C teachers were non-committal with respect to focusing instruction on SSI and ethics. Profile D teachers based their perspective on the position that science and science education should be value-free. Profile E teachers felt very strongly that all education should contribute to students' ethical development.

Socioscientific issues and K-12 students. Students in K – 12 science classrooms also hold their personal views about socioscientific issues. The views held by students are often confronted through classroom instruction in the context of argumentation, examination of documents containing conflicting views, decision making activities, classroom discussions, and nature of science instruction.

Sadler, Chambers, and Zeidler (2004) investigated student conceptualizations of the nature of science (NOS) and how students interpret and evaluate conflicting evidence regarding a socioscientific issue. Using contradictory reports about the status of global warming, 84 high school students responded to questions designed to elicit ideas about the subject. Thirty of these students were interviewed based on their written responses. The results revealed that the participants: (1) displayed a range of views on three distinct aspects of NOS such as empiricism, tentativeness, and social embeddedness; and (2) indicated that interpretation and evaluation of conflicting evidence in a socioscientific context is influenced by their own articulation of personal beliefs and scientific knowledge.

In a study about students' informal reasoning, Kolstø (2006) interviewed 22 students from four science classes in Norway about the controversial socioscientific issue of local construction of new power lines and the possible increased risk of childhood leukemia. The study focused on what arguments the students employed when asked about their decision making and the interplay between knowledge and personal values. The findings revealed that the students used a range of both scientific and non-scientific knowledge and that their main arguments were categorized into: the relative risk argument, the precautionary argument, the uncertainty argument, the small risk argument, and the pros and cons argument.

Also interested in the integration of socioscientific issues (SSI) and argumentation in the science curriculum, Sadler and Donnelly (2006) investigated how content knowledge and morality contributed to the quality of SSI argumentation among high school students. Using a mixed-methods approach, 56 participants completed tests of content knowledge and moral reasoning related to SSI topics, which were subsequently scored and shared in interviews. There were no statistically significant relationships among content knowledge, moral reasoning, and argumentation quality. Most of the participants perceived the SSI as moral problems. Qualitative analyses of the interviews also supported the quantitative results; participants very infrequently revealed patterns of content knowledge application.

The relationship between science knowledge and the ability to engage in reasoned discussion of the social consequences of science was examined by Lewis and Leach (2006) through a study involving over 200 school students aged 14–16. Their findings showed that the ability to engage in reasoned discussion of applications of gene technology was strongly influenced by the ability to recognize key issues, specificity of the context under discussion and personal experience. It was also found that the requisite scientific knowledge base was relatively modest and could be effectively taught through brief, well-designed and contextualized teaching.

Relative to the nature of science as a context for the examination of socioscientific issues in the science classroom, Walker and Zeidler (2007) investigated the implementation of an inquiry-based curricular unit designed to promote student discourse and debate on aspects related to the nature of science, using the socioscientific issue of genetically modified foods. Two high school science classrooms participated in the study. The students' views on the nature of science were expressed through their answers to online and interview questions, and features of argumentation and discourse in the final classroom debate. Though it was evident that the students' answers to questions related to the nature of science reflected conceptions of the tentative, creative, subjective, and social aspects of science, aspects of the nature of science were not included in the debate discussions. Rather, students tended to utilize more factual-based content of the evidence that ultimately resulted in fallacious reasoning and personal attacks.

Socioscientific argumentation in class can be an effective way of looking deeper into students' thinking. Albe (2008) employed a micro-ethnographic approach to explore how 11th grade students elaborate arguments on a socioscientific controversy in the context of small group discussions. Using the issue of whether or not mobile phones are dangerous to human health, students elaborated their arguments from scientific data, common ideas and epistemological and strategic considerations. Students' social interactions, personal experiences and cultural truisms also influenced the patterns of argumentation elaborated within the group discussions. In the group discussions the arguments made by the students were categorized into three: acceptance, collaborative argumentation, and contradictory confrontations.

Students' personal epistemology in the context of socioscientific issues was also examined as shown by the study of Yang (2005). This study investigated views concerning evidence and expert opinion of 10th-grade students. Yang (2005) used an open-ended questionnaire in the context of the socioscientific issue: causes of flood disasters, and the *Learning Environment Preference Questionnaire* (LEP) to examine students' views. Most students relied heavily on direct and numerical data to draw their conclusions, and expert opinion represented a source of conclusive information. The LEP scores indicated that students were mostly at the stage of 'multiplicists' in Perry's model of epistemological development.

According to Sadler, Barab, and Scott (2007), students gain worthwhile academic benefits by engaging in socioscientific inquiry that serves as useful context for teaching and learning science content and nature of science as well as an important vehicle for addressing citizenship education in the science classroom. These three scholars introduced socioscientific reasoning as a construct which captured a suite of practices fundamental to the negotiation of SSI. In the second phase of a research project, interviews with 24 middle school students from classes engaged in socioscientific inquiry served as the basis for the development of a rubric for analyzing socioscientific reasoning. In a similar study, Fowler, Zeidler, and Sadler (2009) explored the moral dimension of SSI in science teaching. The study involved four intact 11^{th} and 12^{th} grade classes and was conducted to examine the effects of a SSI-driven curriculum on the development of students' moral sensitivity. The curriculum included different classroom activities that allowed students to evaluate claims, analyze evidence, make moral decisions, and negotiate information with peers. Employing a pretest-posttest design, the results indicated that development of moral sensitivity could be promoted through science learning experiences embedded in SSI, and that moral sensitivity is contextually dependent.

Socioscientific dilemmas surrounding nature and environment were the focus of Castano's (2008) study which explored whether a constructivist science learning environment, in which nine to ten-year old Colombian girls (n=48) had the opportunity to discuss scientific concepts and socioscientific dilemmas in groups, improved their understanding of the concepts and the complex relations that exists between species and the environment. Two groups of fourth graders were identified as comparison and treatment groups. The data collected were in the form of pre and post test scores on the understanding of science concepts and the possible consequences of anthropogenic activities to other living organisms, pre and post test scores on empathy, and transcriptions of group discussions. The results showed that students who had the opportunity to discuss socioscientific dilemmas provided better definitions for scientific concepts and made better connections between the concepts, their lives and nature than students who did not.

In another study about the issue of nature and environment, Menzel and Bögeholz (2009) conducted qualitative interviews that investigated 16 to 18-year-old (n=24) Chilean and German learners' perceptions of biodiversity and its loss. In this context, the topic of biodiversity was given high value because of the interaction of ecological, economic, and social issues surrounding the protection of species diversity. The data obtained reflected that students tended to focus on the ecological and economic aspects of biodiversity loss. Chilean students seemed to have greater difficulties in recognizing the social aspects of biodiversity loss, while German students were largely unaware of biodiversity loss on a local level.

Interested in the influence of socioscientific issues on high school students' conceptual understanding, Venville and Dawson (2010) conducted a study to explore the impact of classroom-based argumentation on high school students' argumentation skills, informal reasoning, and conceptual understanding of genetics-based socioscientific issues that included genetic diseases, genetic engineering, and cloning. The case study was conducted in one school with an embedded quasi-experimental design with two Grade 10 classes (n=46) forming the argumentation group and two Grade 10 classes (n=46) forming the comparison group. Data for this study was generated through a detailed, written pre- and post-instruction student survey. The results revealed that the argumentation group, but not the comparison group, improved significantly in terms of the complexity and quality of the students' arguments and explanations showing rational informal reasoning. Though both groups improved significantly in their understanding of genetics-based issues like genetic diseases, genetic engineering, and cloning, the improvement of the argumentation group was significantly better than the comparison group.

Energy demand, clean sources, and proper utilization are just a few of the topics associated with the environment. In relation to this socioscientific issue, Yuenyong, Jones, and Yutakom (2008) conducted a cross-cultural comparison between the ideas of 49 Thai Grade Nine students and the 30 New Zealand Grade Nine students (approximately 15 years old), about energy related to technological and societal issues. Students' ideas were explored using the Questionnaire for Exploring Students' Ideas about Energy, Technological, and Societal Issues (QSETS). The questionnaire allowed the students to express their ideas about energy related to societal and technological issues. Results showed that the 15-year-old students seem to have difficulty in perceiving the relationship between the study of society and energy. Around 50% of both groups of students did not understand, and did not know enough about questions which referred to the relationship between society and energy. Thai students placed value on decision making concerning the development of the country and strongly believed in scientific application for solving social problems while New Zealand students valued decision making in relation to environmental issues, thinking that science applications could damage the environment.

Implications for the present study. As a summary, the literature on socioscientific issues in the context of teaching reviewed in this section focused on how students and teachers formulate arguments and reasons on different sides of a general topic. Many of the studies reviewed centered on participants' formulation of reasoning and arguments such as morality (Fowler, Zeidler, & Sadler, 2009) and conceptual understanding (Venville & Dawson, 2010). The majority of the studies located in the review focused on how students engage in classroom activities that involve socioscientific issues. In these studies, students were made to consider issues, take positions on the issues, formulate explanations, and present ideas to the class. It was evident that there was a wider lens of socioscientific issues included in the studies. These issues were apparently those that are local in nature and topics that students were very familiar with. These socioscientific issues included energy, environmental and health issues, and community hazards. Sadler, Chambers, and Zeidler's (2004) study used global warming as the central topic. Based on the reviewed literature, this was the only SSI-related study that used global warming as the central topic. It is evident therefore, that there was a gap in the literature in terms of involving inservice and preservice science teachers in socioscientific issues education. Though preservice and inservice teachers were instrumental in the conduct of SSI education in the classroom, their personal participation has not been fully studied yet. It was also apparent that beliefs of preservice science teachers have not been fully examined in light of the use of socioscientific issues in the classroom. There was a scarcity of studies that specifically used global climate change or global warming as a socioscientific issue.

Teacher Beliefs

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. Kagan further noted that content specific beliefs have been found to correlate with a variety of variables. Blake (2002) noted that teacher beliefs may often be related to preconceptions, implicit theories, or orientations. Blake contends that:

> what teachers believe in, as it relates to their philosophy of teaching, their role within that process, the role and expectations of the students for learning, and the role of the school, science curricula, and context for instruction, will be an essential foundation for what occurs in the classroom (p. 36).

This section intends to provide an overview of a number of studies on teacher beliefs that the researcher has deemed relevant to the current study. More specifically, the following review is divided into two parts: beliefs of preservice science teachers; and beliefs of inservice science teachers.

Beliefs of preservice science teachers. Preservice science teachers possess beliefs that may influence their actions during their stay in the teacher education program and in their subsequent roles as classroom teachers. These preservice teachers who enter teacher education institutions tend to bring with them central beliefs which may be shaped by personal experiences and formal schooling (Richardson, 2003). The following discussion aims to provide a review of literature pertaining to the beliefs of preservice science teachers.

The transition from personal beliefs about content to organizing such content into meaningful experiences for students has been explored by several scholars. Veal (2004) conducted a case study to establish a link between preservice secondary chemistry teachers' knowledge base and beliefs about teaching. The case study involved two preservice chemistry teachers who were followed through their methods course, practicum experience, and student teaching internship. A microgenetic model, pedagogical content knowledge vignettes, vignette responses, field notes, interview transcripts, reflective journals and other documents were used to monitor participants' conceptual change over time. The analysis of data revealed that the: (1) participants had well-intentioned beliefs about teaching and chemistry; (2) interaction of epistemologies and beliefs was determined to be synergistic and remained separate epistemological ideas; (3) preservice teachers' beliefs about content were not changed whereas those for teaching changed; (4) preservice teachers' beliefs were related and intertwined with their notions of the nature of chemistry; and (5) preservice teachers' beliefs influenced how they constructed their views of the chemistry content knowledge found in the vignettes, how they instructed using representations, how they integrated their knowledge of students, and how the context of teaching influenced their practice.

Bakar, Bal, and Akcay (2006) were interested in understanding the beliefs of 66 preservice science teachers concerning science, technology and their implications in society. Through a quasi-experimental study, the results indicated that students who experienced a Science, Technology, and Society (STS) approach (experimental group) in their teacher preparation methods course performed better than students enrolled in a section where a traditional approach (control group) was employed. Students in the STS class were engaged in role-playing, debates, library searches, brainstorming, problem solving, class discussion and presentations, and decision making activities in the context of environmental and genetics issues. Through the use of the Views on Science, Technology and Society (VOSTS) questionnaire, it was found that the STS approach had a positive impact on the beliefs of preservice science teachers.

Inquiry-based instruction has been regarded as a central concept in teaching science in light of current reforms in education. Preservice science teachers then are at the forefront of being prepared to implement lessons that align with the tenets of inquiry; their beliefs shape this aspect of teacher preparation. To this end, Bhattacharyya, Volk, and Lumpe (2009) examined the effects of an extensive inquiry-based field experience on 14 preservice elementary teachers' personal agency beliefs, a composite measure of context beliefs and capability beliefs related to teaching science. A combination of quantitative and qualitative approaches, the study involved an experimental group that utilized inquiry methods and a control group that used traditional teaching methods; pre- and post-test scores for the groups were compared. Results indicated that the context beliefs of both groups showed no significant change as a result of the experience; the control group's capability belief scores declined significantly while the experimental group's scores remained unchanged. In addition, the qualitative data revealed that there was a spiral relationship among teachers' ability to establish communicative relationships with students, desire for personal growth, ability to implement multiple instructional strategies, and possession of substantive content knowledge.

Boz and Uzuntiryaki (2006) studied the beliefs of Turkish prospective chemistry teachers about teaching chemistry, using semi-structured interviews with twelve prospective teachers.

Analysis of the interviews showed that most of the prospective teachers held intermediate (transition between constructivist and traditional) beliefs about chemistry teaching and that their interactions with teachers shaped their beliefs. Most of the prospective teachers exhibited inconsistencies in their beliefs about teaching chemistry that were attributed to their traditional-oriented education from high school and university, prior beliefs about teaching, and time constraints.

Images of science teaching and learning may also play a role in shaping preservice science teachers' beliefs. Relative to this, Minogue (2010) conducted a study to answer the questions: (1) What mental images do elementary preservice students have of themselves as science teachers? (2) Do the elementary preservice students' precourse images of themselves as science teachers differ from their postcourse images? Minogue's study with 50 preservice elementary teachers documented the use of the Draw-a-Science-Teacher-Test as diagnostic tool for accessing preservice teacher beliefs about science teaching and the effectiveness of their science methods course. Findings indicated statistically significant shifts in participants' mental models of science teaching and learning. Post-course images showed that more students portrayed student-centered reform minded practices.

Beliefs in relation to teaching practices have been studied in the context of science teacher preparation. To illustrate, Ogan-Bekiroglu and Akkoç (2009) determined the instructional beliefs of six preservice physics teachers' and investigated the relationship between their beliefs and practices. The study examined the preservice teachers' instructional beliefs on classroom environment, teaching activities and assessment, teacher's role, and instructional goals. Employing a multicase study design and using semistructured interviews, observations, and preservice teachers' written documents, it was found that most preservice teachers held instructional beliefs aligned with constructivist philosophy. Some of the preservice teachers' beliefs were consistent with their practices while some of them were not.

Science teacher preparation requires that preservice science teachers are equipped with knowledge, skills, and habits of mind through inquiry as reflected in the study of Osisioma and Moscovici (2008). The authors analyzed the beliefs of nine secondary science intern teachers about inquiry before, during, and following a series of two consecutive science methods courses. The aim of this study was to document the effect of such experiences on the preservice teachers' ability and willingness to infuse science inquiry in their science curricula. Written reflections and various assignments throughout the methods courses were analyzed. The findings suggested the preservice teachers' beliefs changed significantly after the science methods courses and that these beliefs were based on prior experiences in P–12 classrooms and as science majors.

Constructivist science teaching emphasizes the role of teachers as facilitators in the construction of knowledge by students. Preservice teachers' beliefs on this philosophical tenet may influence their thinking about their personal way of employing a constructivist-based teaching approach. Uzuntiryaki, Boz, Kirbulut, and Bektas (2010) explored the beliefs of eight preservice chemistry teachers about constructivism and the influence of their beliefs with respect to their teaching practice. Semi-structured interviews, observations, and lesson plans formed part of the data. The preservice teachers' beliefs were classified as weak (students are passive, teachers transmit information), moderate (no sound understanding of constructivism), and strong (role of teacher as a guide and supporter) conceptions of constructivism. The analysis showed that most preservice teachers did not have a strong conception of constructivism and the relationship between the preservice teachers' beliefs and their practice was not clear-cut. The explanations for this finding included inadequacy of chemistry knowledge, abstractness of the topic, large class sizes, inadequate school facilities, and the difficulty of applying constructivist principles.

Yilmaz-Tuzun (2008) created a scale called Beliefs About Teaching (BAT) to examine preservice elementary science teachers' self-reported comfort level with both traditional and reform-based teaching methods, assessment techniques, classroom management techniques, and science content. In this study, data collected from 166 preservice teachers from three different US universities revealed significant correlations among participants' confidence level with assessment techniques, classroom management, teaching methods, and science content and the number of science methods and science content courses taken. It was found that the more science content courses taken the greater the increase in preservice teachers' confidence levels related to the use of different teaching methods, assessment strategies, management strategies, and content knowledge.

Beliefs of inservice science teachers. Studies on teacher beliefs focused mostly on how action was influenced by beliefs and the relationship of these to actual classroom practice. More specifically, the studies reviewed focused on: the relationship among perceptions, beliefs, classroom performance, philosophies of teaching, and pedagogical skills (Simmons et al., 1999); beliefs about pedagogical and professional issues; relationship between lived experiences and beliefs and practices about teaching and learning (Smith, 2005); and beliefs about science teaching and learning (Tsai, 2002).

A current trend in education over the past decade has been the emphasis on systemic reforms in schools. In view of this priority in schools, Simmons, Emory, Carter, Coker, Finnegan, Crocket et al. (1999) created a national collaborative research consortium of institutions of higher education to investigate the following question about secondary science teacher education: What are the perceptions, beliefs, and classroom performances of beginning secondary teachers as related to their philosophies of teaching and their content pedagogical skills? The three-year study involving 175 beginning teachers yielded detailed descriptions about the knowledge and beliefs held by beginning teachers about science, the nature of teaching and learning, and their philosophy of teaching. Video portfolios of beginning teachers provided classroom-based evidence of their performance in subject matter and pedagogical skills. One of the findings from this exploratory study was that teachers graduated from their teacher preparation programs with a range of knowledge and beliefs about: how teachers should interact with subject content and processes, what teachers should be doing in the classroom, what students should be doing in the classroom, philosophies of teaching, and how they perceived themselves as classroom teachers. Beginning teachers described their practices as very student centered though results of observations of these teaching practices were in contrast with their beliefs.

Beck, Czerniak, and Lumpe (2000) identified the factors influencing science teachers' implementation of constructivism in their classrooms. By mailing questionnaires to 500 science teachers and receiving 203 responses, the authors were interested in assessing the relationship between belief structures and the teachers' perceived implementation of five subcomponents of constructivism: personal relevance, critical voice, scientific uncertainty, shared control and student negotiation. The teachers in this study indicated that they believed that they were already implementing these five subcomponents of constructivist science teaching. In addition, themes emerging from the teachers' beliefs with specific relevance to teacher education included staff development, planning and class time, and curriculum materials.

Another inter-university collaborative study about teachers' beliefs was reported by Brown and Melear (2006). The nine-university collaborative study aimed to explore science teachers' beliefs and practices with regard to inquiry oriented instruction. The researchers analyzed the relationship among secondary science teachers' preparation, their beliefs, and their classroom practices after completion of a course designed to provide authentic inquiry experiences. Results indicated that: (1) seven of the eight teachers professed a belief in teacher-centered or conceptual style with regard to teacher's action (TA) and students' action (SA); (2) seven of the eight teachers displayed a teacher-centered or conceptual style with regard to TA and SA; (3) half of the teachers professed slightly greater teacher-centered styles with regard to TA than what they actually practiced in their classrooms; (4) all teachers reported that an inquiry based science course was valuable; (5) the teachers predominantly professed and displayed teacher centered behaviors, and (6) the teachers expressed beliefs that were not always consistent with their actions.

According to Cheung and Ng (2000), teacher beliefs about curriculum design may tend to affect the quality of science teaching in schools. Cheung and Ng (2000) reported on a quantitative study they conducted about the relationship between secondary science teachers' beliefs and curriculum design. A 33-item Science Curriculum Orientation Inventory (SCOI) was developed to measure five distinct orientations to curriculum, namely: academic, cognitive processes, society centered, humanistic, and technological. Responses from 810 Hong Kong teachers in integrated science, chemistry, physics, and biology indicated that: (1) science teachers' beliefs about curriculum design had a hierarchical structure; (2) the five distinct curriculum orientations were positively correlated; and (3) the difference between beliefs about the cognitive processes orientation and the humanistic orientation increased when teachers had gained more teaching experience.

Professional development effectively assists beginning science teachers in enhancing their knowledge and skills. Different programs have also been studied in terms of the experiences and beliefs of the teacher participants. Fetters, Czerniak, Fish, and Shawberry (2002) examined the beliefs of kindergarten through grade six teachers during the first year of the training phase of a five-year, professional development program designed to prepare them to effectively use exemplary science curriculum materials. These researchers were specifically interested in exploring: (a) the attitudes and dispositions that elementary teachers brought to a summer institute; (b) the impact of a two-week intensive professional development experience on teachers' beliefs and confidence in their science content knowledge; and (c) role of the summer institute in helping teachers adjust to the change in curriculum and move toward activity based science instruction during the academic year. Written reflections, videotape recordings, and interviews with 233 teachers of K-6 were analyzed. It was revealed that three themes emerged from the study: (a) teacher disposition toward teaching science; (b) images of science and individuals who work in science; and (c) key elements of effective instruction.

Forbes and Davis (2010) claimed that science education reform efforts should highlight the importance of engaging students in inquiry-oriented questions as part of elementary science lessons. To understand teachers' beliefs about questions and questioning, four beginning elementary teachers participated in a longitudinal study during their first three years of teaching. Results of the study showed that each teacher: (1) prioritized the use of anchoring questions to promote student sense-making and to make the purpose of science learning opportunities explicit to students; (2) had beliefs about the use of anchoring questions that evolved alongside other goals and beliefs they held about effective science teaching and learning; and (3) articulated perceived challenges in their school settings to their desired use of anchoring questions.

To account for the beliefs of science teachers on the context of science instruction and complement current measuring instruments for teacher efficacy, Lumpe, Haney, and Czerniak (2000) developed and applied a method for assessing teachers' context beliefs about their science teaching environment. Interviews with 130 purposefully selected teachers resulted in 28 categories of environmental factors and/or people who were perceived to influence science teaching, which became part of the items in the Context Beliefs about Teaching Science instrument. The instrument was tested by 262 teachers participating in long-term science professional development programs. It was found that these teachers possessed fairly positive context beliefs and were capable of effective functioning in the classroom.

Curriculum materials often accompany science reforms. Professional development programs about reform-based curriculum are often integral parts of successful curriculum implementation. In view of this, Roehrig, Kruse, and Kern (2007) examined the implementation of a reform based high school chemistry curriculum in a large, urban school district, specifically focused on the role of the teachers' knowledge and beliefs and other school factors in their implementation of the curriculum. Qualitative and quantitative data in the form of interviews and classroom observation were collected from 27 high school chemistry teachers. Results revealed that the implementation of the curriculum was strongly influenced by the teachers' beliefs about teaching and learning, and the presence of a supportive network at their school sites. More specifically, it was found that inquiry teachers all held predominantly transitional and reform-based beliefs; traditional teachers all held predominantly traditional beliefs about teaching and learning; and mechanistic teachers held a variety of beliefs with some predominantly transitional/reform-based and others predominantly traditional.

In another study that related beliefs and curriculum, Van Driel, Bulte, and Verloop (2007) explored the relationships between teachers' general educational beliefs about teaching and learning and their domain specific beliefs about the chemistry curriculum for upper secondary education in The Netherlands. Teachers' beliefs were investigated using a questionnaire focused on the goals of a chemistry curriculum, which was composed of three curriculum emphases: 'fundamental chemistry', 'chemistry, technology and society', and 'knowledge development in chemistry'. Results indicated that, on the whole, the curriculum emphasis 'fundamental chemistry' received the strongest support and the curriculum emphasis, 'knowledge development in chemistry', was considered much more important for pre-university education than for senior general secondary education.

Smith (2005) described the differences in the lived experiences of two elementary teachers and the impact these differences had on their beliefs and practices as teachers of science. The findings revealed that although both teachers experienced traditional, textbook-driven science instruction as students in schools, their experiences with science outside of school were markedly different. For example, the teacher who had rich out-of-school experiences with science was able to embrace reform and teach from a constructivist stance in her classroom, while the other teacher was more comfortable using a traditional model of teaching. The study suggested that the total lived experience or personal life history that teachers brought with them to the classroom exerted a powerful and lasting influence on their beliefs about science teaching and learning.

Tsai (2002) explored the relationships among teachers' beliefs about teaching science, learning science and the nature of science. Through interviews with 37 Taiwanese science teachers, teachers' beliefs were categorized as either 'traditional', 'process', or 'constructivist'. The results showed that most science teachers held 'traditional' beliefs. More than half of the teachers held views about teaching, learning and science that were closely aligned, which Tsai termed as 'nested epistemologies'. 'Nested epistemologies' are believed to affect teachers' perceptions of the practice of science instruction. In a subsequent study about beliefs and practices of science teachers, Tsai (2007) examined the coherence between teachers' scientific epistemological views (SEV) and their (1) teaching beliefs, (2) instructional practices, (3) students' SEVs, and (4) students' perceptions toward actual science learning environments. Four Taiwanese science teachers participated. The results revealed that: (1) there was adequate coherence between teachers' SEVs and their teaching beliefs and instructional practices; (2) teachers with relatively positivist-aligned SEVs tended to draw attention to students' science scores in tests and employ more teacher-directed lectures, tutorial problem practices, or in-class examinations; (3) teachers with constructivist-oriented SEVs tended to focus on student understanding and application of scientific concepts and used more time on student inquiry activities or interactive discussion.

Implications for the present study. As a brief summary, it was found from the preceding review that most studies of teacher beliefs focused on the generalized beliefs of teachers in relation to practice. Based on the literature reviewed, there is an apparent gap with respect to what teachers believe in relation to a specific topic within the subject domain they are expected to teach as well as the nature of such beliefs in relation to curriculum planning. Likewise, previous studies involving preservice teachers often focused on how beliefs were manifested in the enactment of curriculum or any aspect of the curriculum. Based on the available literature, there were three categories of topics in which beliefs of science teachers were examined: (1) beliefs of science teachers in relation to their classroom practices or actions (Brown & Melear, 2006; Ogan-Bekiroglu, & Akkoç, 2009; Simmons et al., 1999; Veal, 2004); (2) beliefs of science teachers in relation to curriculum and instruction (Bakar, Bal, & Akçay, 2006; Beck, Czerniak, & Lumpe, 2000; Bhattacharyya, Volk, & Lumpe, 2009; Boz & Uzuntiryaki, 2006; Cheung & Ng, 2000; Fetters et al., 2002; Forbes & Davis, 2010; Minogue, 2010; Osisioma & Moscovici, 2008; Roehrig, Kruse, & Kern, 2007; Tsai, 2002; Uzuntiryaki, Boz, Kirbulut, & Bektas, 2009; Van Driel, Bulte, & Verloop, 2007); and (3) personal and contextual factors influencing the beliefs of science teachers (Lumpe, Haney, & Czerniak, 2000; Smith, 2005; Yilmaz-Tuzun, 2008). This section showed that while there was a preponderance of studies on science teachers' beliefs these were limited to the examination of the relationships of these beliefs to the teachers' actual classroom practices and curriculum implementation. It is evident that there is a need for science education researchers to expand their research horizons by studying science teachers' beliefs on specific topics that are included in the field of science that the teachers teach.

Theoretical Framework of the Study

The theoretical framework for this study is comprised of assumptions regarding teacher beliefs, socioscientific issues in the science classroom, Hofer and Pintrich's (1997) model of epistemological theories, Louca, Elby, Hammer, and Kagey's (2004) theory of epistemological resources, Gee's (1996) notion of cultural models, Argyris and Schön's (1974/1996) notion of espoused theories of action, and constructionism. This section aims to elaborate the salient points made by scholars, which in turn, theoretically informed the present study.

Teacher Beliefs

Beliefs are most commonly associated with political or religious convictions that a person holds dearly. Changes in these sets of beliefs are oftentimes difficult because of the nature and manner by which they were developed. Teachers also possess various beliefs that influence their actions and decisions regarding the teaching-learning process. This section aims to discuss various definitions and assumptions about teacher beliefs and how they informed the present study.

Focusing on teachers' beliefs, Pajares (1992) posited that teachers possess beliefs about educational matters such as students, subject matters, 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" (p. 316) that is difficult to clarify due to definitional problems and poor contextualizations. Cunningham, Schreiber and Moss (2005) posited that cognition rests on a set of beliefs that guide us in making sense of the world, guide our desires, and shape our actions. To them, "belief is a calm, pleasant state, a habit of mind, available to draw upon whenever we are active in the world" (p. 178). Richardson (2003) claimed that beliefs are psychologically held understandings, premises or propositions about the world that are regarded as true.

Researchers often refer to teachers' attitudes about schooling, teaching, learning, and students as teachers' beliefs. The literature, as noted by Pajares (1992), is replete with various characterizations of the term belief. 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, repertories of understanding, and social strategy" (p. 309). Pajares (1992) likewise found that researchers seldom referred to the teachers' broader, general belief system. Therefore, Pajares (1992) identified possible educational beliefs that are defined in studies. These beliefs are about: (1) confidence to affect students' performance (teacher efficacy); (2) nature of knowledge (epistemological beliefs); (3) causes of teachers' or students' performance (attributions, locus of control, motivation, writing apprehension, math anxiety); (4) about perceptions of self and feelings of self-worth (self-concept, self- esteem); (5) confidence to perform specific tasks (self-efficacy); and (6) subject-specific educational beliefs. This operationalization, Pajares (1992) contends, results in a view of beliefs that signifies individual judgment that can only be inferred from a collective understanding of what human beings say, intend, and do. Van Driel, Bulte and Verloop (2007) added that belief structures are often described in terms of ideologies, orientations, conceptual frameworks, or functional paradigms.

The beliefs of preservice science teachers about global climate change were explored in this study. There is a need, however, to distinguish terms that are related to beliefs, such as attitudes and knowledge. Epistemology helps us to have a clearer view of how knowledge and beliefs are distinct yet related to each other, as this field is concerned with the nature and justification of human knowledge. Jones and Carter (2007) noted that the familiar distinction between beliefs and attitudes is that beliefs are cognitive constructs while attitudes are affective constructs. They further add that attitudes are integral components of a person's belief system. This notion provides an evidence of the close relationship between belief and attitudes. Kaplan and Fishbein (1969) contended that attitude serves as the evaluative component to beliefs. To them, "each belief about an object has some degree of affect associated with it, and these 'evaluative aspects' of the beliefs are seen as influencing the evaluation of, or attitude toward, the object itself" (p. 63). They further held that an attitude is a function of an individual's own beliefs about a specific object. Attitudes are held with respect to a person's world and they represent the person's evaluation of the object being considered (Ajzen & Fishbein, 1977). From these different characterizations, it appears that attitude is a construct that is situated as an evaluative component of a belief system that a person holds. Ajzen and Fishbein (1977) opined that attitudes and behavior are composed of: (1) an action; (2) the target at which it is directed; (3) context where it is performed; and (4) the time when it is done.

Knowledge and beliefs are two related constructs that have motivated scholars to distinguish them based on various perspectives. According to Smith and Siegel (2004), knowledge and beliefs are inseparable, and as Pajares (1992) explained, inextricably intertwined. Furthermore, Smith and Siegel (2004) distinguished beliefs as naïve conceptions while knowledge as something that is supported by scientifically accepted constructs. Pajares (1992) noted that the literature shows that beliefs are characterized as based on evaluation and judgment while knowledge is based on objective fact. Fenstermacher (1994) admitted that knowledge continues to be understood as a form of justified true belief, although without a sense of the absoluteness. This definition then involves three conditions for knowledge: justification, truth, and belief (Smith & Siegel, 2004). According to Smith and Siegel (2004), it is not philosophically controversial to say that belief is a necessary and sufficient condition of knowledge. Ennis (1994) further added that knowledge is based on factual information while beliefs are more personal and experiential in nature.

Focusing on the increasing interest on knowledge and beliefs in educational research, Fenstermacher (1994) argued that 'knowledge' when used as a grouping or classifying term should include insights, imaginings, musings, awareness, understanding, recollections, predictions, anticipations, and a host of other mental activities. In this way, Fenstermacher added, we do not make any epistemic claim. According to Fenstermacher, this will preserve the epistemological distinction between knowledge and belief but provide us a convenient way of categorizing mental events and outcomes. Fenstermacher made a distinction that knowledge has higher epistemic status than beliefs, and that it has justifiable and supportable claims. Since knowledge and beliefs play an important role in teaching and learning, Fenstermacher (1994) proposed that teachers possess either formal knowledge (TK/F) or practical knowledge (TK/P). Formal knowledge (TK/F) is a modification of the notion of knowledge as justified true belief. It is gained from studies of teaching that use conventional scientific methods, quantitative and qualitative; these methods that yield a commonly accepted degree of significance, validity, generalizability, and intersubjectivity. Practical knowledge (TK/P), on the other hand, is developed from participating in and reflecting on action and experience. It is bounded by the situation or context in which it arises, and is closely related to how to do things at the proper time and place.

Particularly interested in the knowledge and belief controversy in science education, Southerland, Sinatra, and Matthews (2001) described the distinctions between these two constructs in light of the tenets of philosophy and educational psychology. In their review, the authors found that Plato's framework still remains an accepted description of knowledge in the field of philosophy, that is, knowledge is justified true belief. Educational psychology, on the other hand, views knowledge and beliefs as psychological constructs, mental state, trait or ability. Southerland, Sinatra and Matthews (2001) further contended that science education research is influenced by foundationalist and objectivist epistemologies. With this, science educators tend to describe knowledge with certainty while beliefs lack such epistemological weight. They opined that educational researchers tend to characterize belief as more subjective and affective than knowledge. In contrast to this view, radical constructivists posited that knowledge and belief are so closely related that “all cognitive claims must be filtered through the experiences and lenses of the learner” (p. 343).

Gess-Newsome (1999) differentiated knowledge and belief by claiming the former as “evidential, dynamic, emotionally-neutral, internally structured and developed with age and experience” (p. 55) and the later as “both evidential and nonevidential, static, emotionally-bound, organized into systems, and developed episodically” (p.55). This characterization shows that knowledge is derived from rational activity and not emotionally-influenced while belief is thought to develop with a significant affective part (Southerland et al., 2001).

In her scholarly work, Kagan (1992, p. 74) advanced two assumptions regarding teacher beliefs: (1) Most of a teacher’s professional knowledge can be regarded more accurately as beliefs. (2) A teacher’s knowledge of his or her profession is situated in context, content, and in person. Kagan’s first assumption is supported by the fact that classroom contexts differ significantly and instructional decisions are often based on these contexts. Hence, there would be no clear-cut and universal principles of how to handle matters in varying school contexts. The present study treated knowledge and beliefs as inseparable and intertwined constructs (Pajares, 1992).

The characterizations and assumptions of scholars about teacher beliefs theoretically informed the present study in a way that these were elaborated by the preservice secondary science teachers through their discourses. However, the study was not designed to formally categorize their personal expressions of beliefs on global climate change as knowledge or beliefs; the primary rationale of the study was to explore their epistemological, pedagogical, and curricular beliefs and how they negotiate these in science instruction. In the present study, there was no category coding protocol used to distinguish beliefs from other constructs. However, identification of beliefs of the preservice science teachers was informally done by making reasonable inferences from their verbal expressions, predispositions to action, and written products (Pajares, 1992). Beliefs were primarily inferred from the available data. These included the preservice science teachers' thinking, understanding, and ideas about the subject matter that they expressed and which were assumed to have been drawn from their personal, social, and academic experiences. In cases where the teachers directly quoted scientific viewpoints from an article or movie clip, or provided descriptions of objects and events, without using these as a basis for their expressions, these were assumed to not be a part of their beliefs. This stance is in keeping with Cobern's (2000) perspective that there is an ambiguous line between knowledge and beliefs. To Cobern (2000), putting aside students' beliefs results in our failure of understanding the reasons students hold such beliefs. In the present study, the terms beliefs, knowledge, and attitudes were not used synonymously, but were recognized by the researcher as closely related constructs that play important roles in the teaching-learning process. In consideration of the different theoretical notions about these three related constructs, this study treated beliefs as the preservice secondary science teachers' premises and propositions about global climate change resulting from significant personal experiences that are mostly emotionally-laden. This does not intend to place belief as a more inferior construct than knowledge. The above characterization of belief provided clarity for the present study and was in keeping with the theoretical notions of Southerland et al. (2001) and Gess-Newsome (1999) in noting the common usage of the term in the field of science education.

In light of the prevailing ambiguity of the demarcation between knowledge and beliefs, this study did not look into this distinction for three important reasons: (1) The personal expressions of preservice science teachers on the issue of global climate change were not analyzed in terms of correctness or incorrectness based on some universally accepted definitions. (2) The primary aim of the study was to gain a clear understanding of the teachers' beliefs from a holistic perspective, that is, personal perspective coming entirely from the teachers' discourses. This is in keeping with Richardson's (2003) assumption that teachers' beliefs are influenced by personal experiences, schooling, and experiences with formal and informal knowledge. (3) The present study focused on how preservice secondary science teachers envision their roles as classroom teachers who will be teaching global climate change to their students. Their personal repertoire of knowledge, skills, habits, and values about the issue and schooling guided the development of their beliefs. Likewise, Kagan (1992) reminded the researcher that the absence of a universal code that dictates how teachers should teach illustrates the reality that teaching is context-dependent.

Socioscientific Issues

Socioscientific issues are social problems or dilemmas that are often complex, open-ended and contentious, posed to students that have ties to science (Sadler, 2004). Infusion of socioscientific issues in teaching traces its roots from the STS (Science, Technology and Society) movement which was geared to make science classrooms reflective of society. The scholarship on socioscientific issues as used in the school context has been focused on students' conceptual and moral reasoning on social issues (Sadler & Donnelly, 2006). In science, technology, and society (STS) education, science teachers engaged students with an emphasis on society as a context for science content learning (Zeidler, Sadler, Simmons, & Howes, 2005). Science teaching involving SSI education is regarded both as a context and pedagogical technique that stimulates and promotes intellectual and moral development as well as awareness of the interdependence between science and society (Zeidler, Sadler, Simmons, & Howes, 2005).

Simmons and Zeidler (2003) contended that using controversial socioscientific issues as a foundation for science teaching provides an avenue for critical thinking and moral reasoning. Students in this case are engaged in considering topics that elicit ethical and moral judgments through individual or group discourse. In addition, Simmons and Zeidler (2003) believed that critical thinking and moral reasoning are enhanced when students are confronted with multiple perspectives to moral and social problems that inherently involve discrepant viewpoints or are at odds with their personal viewpoints. This is so because of the opportunity given for individual or group construction of scientific knowledge based on their exposure to, and careful consideration of scientific data.

Zeidler, Sadler, Simmons, and Howes (2005) developed a framework to guide socioscientific issues education. The framework is composed of the elements: nature of science, classroom discourse, cultural issues, and case-based issues. These issues are claimed by the proponents to be the entry points in science pedagogy which in effect help achieve functional scientific literacy. According to the framework, *nature of science* as an element refers to how students attend to evidence in support of, or in conflict with, their pre-instructional belief systems regarding social issues. *Classroom discourse* stresses the crucial role of discourse in peer interactions and its impact on students' reasoning. *Cultural issues* highlight pluralistic and sociological dimensions of science instruction, thereby encouraging teachers to recognize, acknowledge, and maximize opportunities afforded by diverse assemblies of learners. *Case based issues* reinforce the stance that attention should be paid to the moral growth of the students and involve them with issues and problems that develop both their intellect and their sense of character. Part of case-based SSI is the explicit critical examination of students' personal interests and values in argumentation involving socioscientific issues.

The topic global climate change is a socioscientific issue that has generated different views and actions worldwide. The present study was informed by Zeidler, Sadler, Simmons, and Howes' (2005) framework in the sense that understanding beliefs of preservice science teachers requires an examination of how their thinking on global climate change is framed on the basis of their prior beliefs, commitments, moral and ethical stance, and constructed reasoning. The entire framework as proposed by Zeidler et al. (2005) did not inform the study. Rather, the elements, cultural issues and case-based issues are important aspects of the present study since personal beliefs on a specific socioscientific issue was involved and preservice science teachers in this study examined the issue of global climate change in view of existing scientific evidence and their personal experiences.

Epistemological Theories

Epistemology deals with "what individuals believe about what counts as knowledge and where it resides, how individuals come to know, and how knowledge is constructed and evaluated" (Hofer, 2008, p. 5). 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 (2001) recognized the existence of different paradigmatic approaches in personal epistemology. Hofer and Pintrich (1997) noted that previous studies about knowing and epistemological development stressed a Piagetian notion of going through developmental stages through the process of epistemological development. Hofer and Pintrich (1997) reviewed scholarly works and organized some common grounds to explain epistemological development.

Hence, based from an intensive review of these previous works, they proposed a model that integrates a dimensionality of an individual's epistemological belief system.

In their subsequent scholarly works, the term personal epistemology (Pintrich, 2002) was used as an umbrella construct for the various terms espoused by previous scholars who investigated intellectual and epistemological development. Hofer (2005) posited 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" (p. 98). Hofer (2006) further claimed 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) contended 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. Hofer and Pintrich (1997) 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.

In Hofer and Pintrich’s (1997) proposed model, the following are the dimensions:

1. Certainty of knowledge refers to the degree by which an individual sees knowledge as fixed or fluid, ranging from the perspective that absolute truth exists with certainty to the position that knowledge is tentative and evolving.
2. Simplicity of knowledge is a dimension that shows whether knowledge is as discrete, knowable facts or as relative, contingent, and contextual.
3. Source of knowledge is a dimension that pertains to whether knowledge resides within or outside the self. The evolving notion of self as knower, being able to construct knowledge in interaction with others, is a turning point of most models that explain epistemological development (Hofer, 2000).
4. Justification of knowing involves how individuals justify what they know and evaluate their own knowledge claims and that of others. This dimension includes the individual’s use of evidence, views about authority and expertise, and his/her evaluation of experts (Hofer, 2000).

Hofer (2000) conducted a study to validate the dimensionality of personal epistemology. The study involved first-year college students who responded to a set of questionnaires that included an adaptation of a domain-general epistemological instrument and a discipline-focused questionnaire. The findings suggested that there was an underlying dimensionality to epistemological theories that cut across disciplinary domains, and students discriminated as to how these theories differed by discipline. Through this study, Hofer (2000) posited that the dimensions of an individual’s personal theory of epistemology were related to each other in coherent and internally consistent ways, and such dimensionality made some important distinctions about knowledge, and potentially provided a causal-explanatory framework for thinking about knowledge.

In the present study, the model espoused by Hofer and Pintrich, provided a framework that guided data collection and analysis. The model guided data collection in the sense that case study methods and semi-structured interviews were carefully planned to fully examine the preservice teachers' beliefs. The dimensions of Hofer and Pintrich's model informed the researcher on the manner by which interview questions were formulated. For example, interview questions focused on each preservice teacher's basis of believing whether or not global climate change is happening, hence integrating the dimensions of source of knowledge and justification of knowing. The model indirectly guided data analysis in the sense that data collected were coded, categorized, and analyzed on the basis of the ideas stressed by the preservice teachers in their talk and written requirements, which were reflective of the personal epistemology each teacher holds. Though the analysis did not intend to categorize the data according to the four dimensions, the model helped the researcher in making sensible interpretations that explained the teachers' beliefs as reflected from their interview talk and written products. Likewise, the model theoretically informed this study since it focused on the individual's belief systems and how these are influenced by personal and external factors. The model served as a starting point for the examination of individual beliefs. In this study, a clear understanding of belief systems in relation to the issue of global climate change enabled the researcher to better understand the teaching and learning processes in the classroom, as envisioned by the preservice science teachers (Hofer & Pintrich, 1997).

Epistemological Resources

Louca, Elby, Hammer, and Kagey (2004) provided an alternative view to personal epistemology. These scholars posited that personal epistemologies consisted of cognitive resources for understanding knowledge. They further claimed that epistemological resources made of beliefs compiled in a rich network are activated by differing contexts. In the classroom, Louca et al. (2004) 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.

This view of epistemological beliefs informed the present study by augmenting the model of epistemological theories with the notion of resources being used by an individual depending on the context. Hence, beliefs on global climate change by preservice teachers can be examined using the framework of epistemological resources being invoked by the teachers as they explicated their beliefs about the topic.

Cultural Models

Gee (1996), who comes from the field of language and literacy education, posited that appreciating language in a social context requires one to focus on both the language and Discourse. To him, Discourse encompasses ways of behaving, interacting, thinking, and believing. Discourse is obviously connected to the human language since language helps individuals to scaffold action and cultural affiliations (Gee, 2001).

Understanding language and literacy from a sociocultural perspective involves tools: discourses, social languages, genres, and cultural models. In the present study, cultural models as a concept in literacy studies were given emphasis. Gee (1996) posited that cultural models include assumptions about models of simplified worlds and how we make our choices and meanings to these worlds. The meanings humans attribute are based on their beliefs and values. Cultural models are everyday theories represented by materials and practices that tend to define what individuals regard as normal and natural and those that are unusual or deviant (Gee, 2001).

Cultural models, Gee (1996) added, can be learned by acculturation, by being open to and having personal experiences with the group, using the language, and making interactions with the other members of the social group. One educational implication of cultural models would be the perceived conflict among students who may not share the same beliefs and values. To Gee (1996), teachers should allow these conflicts to be part of the education of the students. In effect, these conflicts become avenues for potential learning experiences. In this study, preservice teachers were certainly part of a group that had potentially established cultural models that they tended to invoke when openly discussing their beliefs about certain issues, like global climate change. Beliefs about global climate change can be communicated by invoking personal knowledge and experiences and attributing meaning to every aspect of human affairs.

Espoused Theories of Action

Understanding organizational behavior has been part of the scholarly work of Argyris and Schön (1974). In particular, they proposed a theory of action in explaining organizational learning. Organizational learning takes place when an individual within an organization encounters a problematic situation and subsequently tends to inquire about it on behalf of the organization (Argyris & Schön, 1978/1996). Likewise, in this problematic situation, there is a mismatch between the expected and the actual results of action thereby necessitating modification or restructuring of organizational action. Robinson (2001) noted that with this characterization of organizational learning, three elements are essential: (1) the role of theory-in-use in organizational learning; (2) organizational learning as a process of inquiry; and (3) organizational learning as a process of error detection and correction. These two scholars' interest in organizational learning stemmed from their studies of organizational behavior and hierarchical structures in business and managerial contexts. In one of their empirical studies, they found that apparent managerial ineffectiveness was related to top-down, hierarchical values, and even though subordinates and workers were given an opportunity to 'take charge' of their own efforts, they still produced the same counterproductive actions (Argyris, 2003). Arygris and Schön (Argyris, 2003) eventually realized the theories of action that human beings held about the effective management of human relationships. From these, Argyris and Schön (1974) regarded deliberate human behavior as the consequence of theories of action.

Argyris and Schön organized their ideas into a coherent theory of action giving primary importance on theories put into practice that help human beings to understand, explain, anticipate, know, and act in the world. In effect, they contended that deliberate human behavior is the consequence of theories of action held by humans. In organizational learning, Argyris (2003) posited that humans use the same theories of action regardless of their position in the hierarchy, gender, race and type of organization.

Part of the theory of action is theories-in-use and espoused theory of action. Based on the assumption that human beings are designing beings, Argyris (1995) claimed that theories of action are governed by a set of beliefs, values, and attitudes, and that such designs guide intentions and actions. Theories-in-use describes how an individual actually behaves (Raelin, 1997). An espoused theory of action, on the other hand, is the theory of action to which a person communicates to others as to what he or she will perform (Argyris & Schön, 1974; Raelin, 1997). It is the theory of action to which a person gives allegiance (Argyris & Schön, 1974). Espoused theories vary widely while theories-in-use have almost no variation (Argyris, 1995).

The espoused theory of action informed this study as the beliefs of preservice science teachers were communicated through the conversations and the unit skeleton assignments that they prepared.

Constructionism

The epistemological stance of a research endeavor informs the researcher about the philosophical grounding for deciding what kinds of knowledge can be generated and for ensuring that these are adequate (Crotty, 2003). Constructionism is one perspective that potentially sheds light on our understanding of social phenomena. Constructionism holds that "all knowledge, and therefore, all meaningful reality as such, is contingent upon human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context" (Crotty, 2003, p. 42). This characterization of constructionism suggests that humans are active participants in the construction of knowledge. Constructionism is distinct and separate from the objectivist point of view that meaning resides in objects which awaits our discovery (Poole, 1995). The process of construction of knowledge is a result of interactions with the environment that progressively build up (Poole, 1995). Longino (1990) adds that scientific knowledge is constructed through interactions among individuals.

Crotty (2003) made a point with the distinction of constructivism and constructionism. Constructivism relates to individual meaning-making activity while "constructionism is a collective generation of meaning" (p. 58). Hruby (2001) claimed that constructivism is associated with psychological meaning making while constructionism with the sociological meaning making. It is important to note that both constructionism and constructivism center on the individual's role in knowledge construction and attempt to move away from the objectivist point of view that an individual needs to find for constructed knowledge, an external truth waiting to be found and discovered.

Constructionism assumes that individuals are conscious of an event which drives them to construct meaning. This requires consciousness of reality. Berger and Luckmann (1989) posited that reality is a social construction, reality being independent of our own volition. But what does reality entail? Berger and Luckmann (1989) argued that the reality of everyday life is meaningful, subjective and shared. They called for a focus not on ideas, but on the common sense knowledge of reality as it is understood by the general public (Hruby, 2001).

Constructionism theoretically informed this study by providing a framework to explain the nature of preservice teachers' mental construction of their beliefs about global climate change and allowing the researcher to examine the preservice teachers' beliefs from their own perspectives.

Summary of the Chapter

This chapter discussed the literature and theoretical underpinnings that informed the present study. The review of literature focused on three areas of scholarship: global climate change as a topic in educational contexts, socioscientific issues in the classroom, and teacher beliefs. The literature review helped the researcher in identifying the gaps that provided an opportunity to design this study. The second part of the chapter discussed the different theoretical perspectives that informed the study, its design, and data analysis.

Chapter 3

METHODOLOGY

Introduction

The methodology of a study elaborates the plan of action, process, or design that informs the methods chosen (Crotty, 2003). A plan of action is necessary to attain the goal of answering the questions raised by a researcher. This chapter provides a detailed description of the methodology employed in this study. In particular, this chapter discusses the context of the study, the participants, the methodology employed, specific methods and data collection techniques, step-by-step procedures followed, and data analysis techniques. Each section includes a detailed elaboration of the process, context and persons involved. No real names of persons and places were used in the following discussion. This is in keeping with the ethical standard of protecting the identities of research participants.

Context of the Study

The study was conducted in the course, Science Curriculum and Learning at a university in the southeastern United States. The course was required as part of the initial certification in secondary science education. The course, Science Curriculum and Learning, emphasized science curriculum models for students in grades 6 through 12 in relation to goals for science education and classroom practice. Through informal conversations with the course professor and personal access to the course syllabus, the researcher learned that the course was typically organized around three significant themes: (1) science is a way of thinking and investigating as well as a body of knowledge; (2) effective instructional planning enables and facilitates student learning; and (3) standards and assessment are inextricably linked, guiding how teachers teach and what students learn. Students in this course were likewise oriented to the development, selection, and evaluation of curricular materials based on research in teaching and learning science. The course stressed different aspects of curriculum design and provided various models of best teaching practices, meaningful student learning experiences, integration of state and national standards, science assessment and other related trends and issues in science teaching and learning. During the Fall 2009 semester, the preservice science teachers worked on a unit plan of a science topic of their own choice. The preservice teachers worked on this plan throughout the semester as each component was elaborated in class. The preservice science teachers also engaged in the design of learning experiences for a specific topic that was not within their field of specialization, but was highly probable to be taught by them in their own science classes. This assignment, called Preparing for the Unexpected, was designed to prepare the teachers in quickly crafting a plan for a specific topic about which they may have little knowledge.

Preservice science teachers in this course were enrolled either in traditional or alternative certification programs. Preservice science teachers in the traditional science education program were those who were pursuing an Education degree with credits in a science content area (biology, chemistry, physics, or earth and space science) and science education courses. In relation to this, the Science Education Program offers an undergraduate degree in secondary science education (traditional) which involves the granting of certification to preservice teachers in order to qualify them to teach science for Grades 6 through 12. This specific degree requires preservice teachers to complete all requirements, and to apply to the Professional Standards Commission. Preservice science teachers in the alternative certification program were those who had finished a Bachelor’s degree in a field of science and were currently taking courses in science education to qualify them for teacher certification, as mandated by the state.

The class met once a week in various settings such as the typical classroom in a university setting and a selected high school for field observation of science classes. In addition to this course, during the Fall semester the students were simultaneously registered in two additional science education courses, namely, Methods of Science Teaching and Practicum in Science Education.

Participants of the Study

The participants in this study are described in this section. In addition, the selection criteria used to identify participants and details about each individual are explained. Four preservice science teachers enrolled in the Science Curriculum and Learning course during the Fall 2009 semester participated in this study. Aside from this course, the four preservice teachers were also registered in the Practicum and Methods of Science Teaching courses. The preservice teachers were engaged in various classroom activities that prepared them for trends, issues, and practices in curriculum development. As part of their class activities, they were asked to design a set of learning experiences for a topic outside of their field of specialization, that is, the topic of global climate change. The preservice teachers were invited to participate in the study, including a set of individual interviews designed to examine their beliefs about global climate change and how they envisioned teaching this topic in a classroom setting.

The four preservice teachers came from different fields of specialization – biology, chemistry, and earth science. This sample of participants was chosen as part of the cases developed to more fully represent preservice science teachers' beliefs on global climate change. It was necessary to have a variation in terms of the participants' field of specialization because of the assumption that preservice science teachers tend to draw upon their knowledge of the topic global climate change based on the perspective in their field. For example, it was assumed that a chemistry major might draw upon chemical principles that explain global climate change. These assumptions were not permanently set to determine data collection techniques, but rather guided the selection of participants. In choosing participants from various fields of science, the similarities and differences in the preservice teachers' belief systems in relation to the issue of global climate change were thoroughly explored. The various theoretical backgrounds of the preservice teachers provided an opportunity to glean an understanding of the multiple perspectives that teachers had on the issue of global climate change, since the level of understanding of environmental issues possessed by the participants was not certain. Jones and Carter (2007) note that though preservice teachers' belief systems are less resistant to change, such changes may be inhibited by lack of content and pedagogical content knowledge. Sadler (2004) found that most studies report that preservice teachers respond to socioscientific issues through valid and opposing arguments synthesized from multiple perspectives. Additionally, the involvement of preservice teachers from various fields of science in this study contrasted with research conducted by Jeffries, Stanisstreet and Boyes (2001) which probed their undergraduate students' concerns about global climate change, perceptions of the extent of their knowledge on the issue and what they had learned about global climate change from different sources. This was done by the researchers to achieve homogeneity needed for comparison with an earlier research study they had conducted.

As mentioned earlier, the preservice science teachers were enrolled in either a traditional or alternative certification program in science education. This study allowed preservice science teachers to communicate their beliefs about global climate change and its place in science instruction. Jones and Carter (2007) claimed that examining the belief systems of preservice teachers from different certification programs allows the researcher to better understand how varying content knowledge, formal and informal learning experiences, and social contexts are linked to personal belief systems and practices. New science teachers, as defined by Davis, Petish and Smitey (2006) include preservice teachers in traditional four-year or alternative certification programs. As such, both groups of new teachers face common challenges in their roles as classroom teachers. Accordingly, preservice teachers in both traditional and alternative certification programs were participants in this study. Darling-Hammond (2000) likewise argued that including preservice teachers from traditional and alternative certification programs in educational research provides them the opportunity to see beyond their personal perspectives and understand the meaning of teaching and learning processes through the lens of a learner.

The present study involved both male and female preservice science teachers. More specifically, two males and two females participated in the study. Gender was included as a selection criterion for purposes of variation in the data collected and not for a detailed basis for analysis and interpretation. The inclusion of both genders in the study allowed the researcher to examine how gender-related factors, if any, influenced the preservice teachers' personal belief systems and instructional decisions. Hofer and Pintrich (1997) noted in their literature review that thinking of gender as different contexts of development may mean providing differing opportunities, affordances and constraints rather than as personal characteristics. Scantlebury (1998) further explained how societal stereotypes and constructed views about gender may have an impact on a teacher's behavior in his/her interactions with students, and may influence a researcher's questions, teaching practices and curricular decisions. Jeffries, Stanisstreet and Boyes (2001) explored the differences in responses of male and female college students about environmental concerns. In this study, the researchers found that more females than males were generally very worried about global warming and that more males than females thought that they knew a lot or at least something about the greenhouse effect.

Pseudonyms were used to protect the identity of the four participants in the study. One of the four participants chose the pseudonym to be used. The rest informed the researcher that he could use any pseudonym to hide their identities. The participants were Cherry, Eddie, Summer, and Vince. Each participant is described in the following discussion.

Cherry

Cherry, is a mother of a teenager who comes from a family that taught her to respect the land. She grew up with experiences in poultry-raising in a rural area in her home state. She is in the Master of Arts in Teaching (MAT) program and is preparing to teach high school biology or chemistry subjects. Her academic preparation in chemistry allowed her to work as a laboratory manager in a university-based research institution. Cherry's work experiences include empirical studies about parasites, and tropical and emerging diseases. As part of her scientific work, she co-authored peer-reviewed articles in a number of journals in her discipline.

Eddie

Eddie, who considers himself as a naturalist, grew up in a rural area in his home state. In terms of academic background, he is an undergraduate student pursuing a degree in science education. He specializes in biology. Fascinated by the excitement of watching animal shows on television, Eddie originally wanted to become a zoologist. In college, he initially enrolled in the Ecology program but later shifted to Education. Eddie explained that he wanted to teach in order to experience biology and at the same time share his knowledge with other generations. His mother influenced his interest in nature and environmental protection. Eddie remembers well that during his elementary school years, his classroom projects usually dealt with animals, rainforests, and other aspects of the environment.

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 in the Master of Arts in Teaching (MAT) program and is expecting to obtain her certification to teach secondary science. With regards to her academic preparation, she holds a degree in geography. In her current program, she anticipates teaching earth science, chemistry or physical science. During her college years, she had the opportunity to be a participant in a Study Abroad program. In particular, she had academic training in France. She specifically identified some differences between the French and the American ways of life. In France, Summer noticed that local products and services were stressed in the community. Likewise, she noticed the volume of people riding on bicycles instead of cars, which to her was indicative of a transition to being environmentally-friendly.

Vince

Vince loves to drive his motorcycle around to save on fuel expenses and to reduce his carbon footprint. He grew up in a suburban community near his home state's capital city. He was nurtured by a family that helped him develop critical thinking about societal issues. He is in the MAT program and is expecting to be certified to teach secondary biology. He finished an undergraduate degree in psychology and took additional biology courses.

Methodology

Interpretive research methodology was employed in exploring the beliefs of preservice science teachers on global climate change. Tobin (2000) asserted that interpretive research is a good way of understanding individuals or a community in terms of actions and interactions, based on the participants' own perspectives. Tobin further maintained that the advantage of employing an interpretive study is its flexibility and emergent nature. In fact, Tobin (2000) claimed that the critical elements of an interpretive study are its emergent nature and sufficient time allotted for interpretation. The primary focus of interpretive research is a clear picture of the central tendencies (patterns) and phenomena that tend to deviate from these patterns (Tobin, 2000). This means that studying the emerging patterns also requires an examination of the events at the periphery of the locale, community, or phenomenon being studied.

The interpretive perspective asserts that "humans create meaningful interpretations of the physical and behavioral objects that surround them in the environment" (Erickson, 1986, p. 126). Action toward these objects follows along the process of creating interpretations. In addition, Erickson (1986) posited that human groups have social organizations that allow individuals to interact and to establish norms. In other words, meanings attributed to actions are shared by the members of such an organization. Erickson (1986) further added that interpretive research is bound to see the relationship between social organizations and individual actions and choices. He illustrated this using the classroom context. The choices and actions of the members of the class constitute an enacted curriculum and the interactions of the teacher and students enable them to make use of learned meaning, take cognizance of the actions of others, learn new shared meanings, and create meanings based on the immediate context.

To better understand the tenets of interpretive research, Willis (2007) provided a comparison of interpretive and postmodern perspectives. In terms of the nature of reality, postpositivists propose that reality is external to the human mind while interpretive researchers assert that reality is socially constructed. Hence, an interpretive methodology allows researchers access to socially constructed reality. Postpositivists believe that the scientific method is the acceptable way of finding out reality. On the other hand, interpretive researchers believe that reality can be found through the use of both subjective and objective research methods. Another basis of comparison stressed by Willis (2007) is the purpose of research. Postpositivists attempt to look for universal laws while interpretive researchers search for understanding of a particular context.

An interpretive perspective informed this study in its attempt to “look for culturally derived and historically situated interpretations of the social life-world” (Crotty, 2003, p. 67). Willis (2007) added that the core belief of interpretive research is that reality is socially constructed and its goal is to understand a particular situation or context. The individual is the focus of interpretive research. Cohen, Manion and Morrison (2007) asserted that an interpretive study begins with individuals and sets out to understand how they interpret the world. They likewise opined that individual actions are meaningful if researchers ascertain the intentions of the actors and how these actors make sense of their experiences. Cohen, Manion and Morrison (2007) further described interpretive research design as a perspective that “gives way to multifaceted images of human behavior as varied as the situations and contexts supporting them” (p. 22). As used in educational research, Cochran-Smith and Lytle (1990) argued that interpretive perspectives presume that teaching is a highly complex, context-specific, interactive activity which values the differences across classrooms, schools, and communities. They further claimed that interpretive research provides detailed, descriptive accounts of complex school and classroom events that allow researchers to fully understand their meanings for the participants involved.

An interpretive approach was employed in the present study because it allowed the researcher to examine and interpret the preservice science teachers' beliefs as reflected from their responses in interviews, informal conversations, and a curriculum planning experience. The preservice teachers' perspectives were of paramount importance as these were analyzed and thoroughly examined to identify emerging patterns within and across the individual cases. The context in which the preservice science teachers were situated was also given importance in this study. Contexts such as family, school, peer groups, and workplace are all potentially important in shaping preservice science teachers' beliefs and conceptions about global climate change. In turn, these beliefs shaped the way the preservice teachers created meanings and made instructional decisions about teaching the topic of global climate change to their prospective students.

Methods

The study employed different research methods in exploring the beliefs of preservice science teachers on global climate change. These multiple methods included case study, interview, observation, and collection of students' written products. Multiple data sources were used to enhance research viability (Mathison, 1988). Marshall and Rossman (2006) added that triangulation, or the use of multiple sources of data enhances a study by bringing together more than one source of evidence to corroborate, elaborate, or illuminate a research question under investigation. To Mathison (1988), "triangulation as a strategy provides evidence for the researcher to make sense of some social phenomenon, but that the triangulation strategy does not, in and of itself, do this" (p. 15). The possible outcomes of triangulation may include: (1) Convergence when a single proposition about the social phenomenon being studied results from analysis; (2) Inconsistency when the range of data sources and methods do not confirm a single proposition about the phenomenon; and (3) Contradiction when contradictory and opposing views of the social phenomenon result. Yin (1994) likewise stated that the use of multiple sources of evidence in case studies allows the development of “converging lines of inquiry” (p. 92) to address historical, attitudinal, and behavioral issues. The following section elaborates on the multiple methods and sources of data employed in the present study.

Case Study

Teachers’ beliefs about global climate change were examined using case study methods. Case study offered a good way of looking closely into the belief systems of teachers regarding the teaching of global climate change. Yin (2009) defined a case study as an “empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (p. 18). This characterization stressed the contextualized approach to looking at things, persons, and events. Yin (2009) likewise defined case study inquiry as an inquiry that “copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis” (p. 18). Researchers doing case studies are interested in understanding the uniqueness and commonality of people, events, or programs (Stake, 1995). Case study is basically a close examination of people, programs, or issues for purposes of illumination and understanding, that requires the researcher to be the primary instrument of data collection and analysis, employs an inductive investigative strategy, and produces rich description of a person, event, or program (Hays, 2004; Merriam, 2002).

Case studies are known by a single most significant characteristic, which is, delimiting the object of study, the case (Merriam, 1998). This implies that a specific boundary for inquiry is set thereby resulting to a focused investigation of a phenomenon. Stake (2000) added that this bounded system provides rich information because it: (1) has working parts; (2) is purposive; (3) is an integrated system; and (4) has patterned behavior. A case may be an individual, a group, an institution, or a program. Stake (2000) added that a case is a complex entity that operates within physical, economic, ethical, or aesthetic contexts. Creswell (2007) elaborated by explaining that a case study allows a researcher to explore a bounded system over time through detailed, in-depth data collection.

The use of case study was appropriate in this study to make reasonable inferences about the preservice teachers' beliefs on global climate change, based on their verbal expressions and predispositions to action (Pajares, 1992). Case study allowed the researcher to generate rich descriptions of the individual cases. In this study, four preservice teachers from three major fields of specialization (biology, chemistry, and earth science) served as individual cases. Through in-depth collection of data, the researcher hoped to describe how beliefs were developed by each preservice teacher. The unit of analysis was the individual. Hence, the study employed a multiple case study design following the replication logic (Yin, 1994). The multiple case study design required the researcher to collect and analyze data from several cases. Based on the data collected from the four preservice teachers, analysis was employed within and across all the cases to identify emerging themes. Observations, interviews, and class projects, as discussed in the succeeding sections served as data collection techniques. Observations were made during group discussion and preparation of concept maps during regular class sessions. The class product included as data for this study was each preservice teacher's final instructional unit skeleton, designed around the topic of global climate change. Interviews, as discussed below, explored each preservice teacher's beliefs about global climate change.

Interviews

Semi-structured interviews were used to explore the general topic of global climate change and its place in science teaching and learning and to uncover the beliefs and experiences of the preservice teachers from their own perspective. Kvale and Brinkmann (2009) claimed that interviewing allows researchers to understand the world from the participants' viewpoint and to unfold the meaning of their experiences. Four semi-structured interviews lasting from 45 to 60 minutes each were used in this study to elicit views about the specific topic of global climate change (Wooffitt & Widdicombe, 2006). In the interviews with the participants, prompts and probes were used to clarify discussion points, ask for examples, or extend a narrative being shared (Gillham, 2000). The interviews were audio recorded and transcribed. Interview protocols for each session are attached as Appendices B1, B2, B3, and B4.

Pajares (1992) noted that most studies on teacher beliefs have traditionally been based on questionnaires and surveys. To illustrate, most studies that focused on examining the conceptions and misconceptions of preservice teachers on global climate change used questionnaires (Dove, 1996; Jeffries, Stanisstreet, & Boyes, 2001; Khalid, 2003; Summers, Kruger, Childs, & Mant, 2001) and pre- and posttest measures (Gautier, Deutsch, & Rebich, 2006). Pajares (1992) argued that additional measures such as open-ended interviews, responses to dilemmas and vignettes, and observations would provide richer and more accurate inference. In investigating socioscientific issues in the science classroom, researchers have used interviews to elicit beliefs and understandings of students (Cross & Price, 1996; Kolstø et al., 2006; Sadler, Chambers, & Zeidler, 2004; Sadler & Donnelly, 2006).

In this study, two interview sessions were aided by various forms of prompts such as movie clips from YouTube, and scientific articles. These aids focused on the various positions of people on the issue of global climate change. These prompts served as springboards for discussion and allowed the participants to share their thoughts on the issues presented in each prompt. During the first interview, preservice teachers were asked questions about their general thoughts and beliefs about the issue of global climate change.

In the second interview, each preservice teacher was interviewed with the aid of two short movie clips from YouTube and a cartoon as prompts. One YouTube clip showed an organization explaining the impacts of global climate change while the other movie clip showed how some climate scientists claim that computer-climate models were flawed. After viewing the clips, questions were asked regarding the movie clips. These questions served to elicit the preservice science teachers' responses that were reflective of their beliefs about global climate change.

The use of movie clips from YouTube in interviews was an interesting innovation with respect to eliciting responses from participants. YouTube is an internet-based site where people can watch and share original videos worldwide (YouTube, 2009). It is an internet-based technological innovation launched in 2005 by Hurley, Chen, and Karim (Burgess & Green, 2009). The website provides a simple technological interface where users can upload, publish and view streaming videos about any desired topic (Burgess & Green, 2009). The present study used YouTube clips since this popular website offered a variety of videos that pertain to almost any topic. Likewise, the preservice science teachers were quite familiar with the YouTube as a site for networking, quick information source, and a commercial enterprise (Burgess & Green, 2009). The clips used in this study were specifically focused on the topic of global climate change. Video clips shown in YouTube are first-hand accounts of current events, any subject of interest, or unusual phenomena. Muellen and Wedwick (2008) reported on a rural middle school teacher's use of YouTube, digital stories, and blogs in a language arts curriculum. The teacher used YouTube in developing language arts lessons and for class grammar review sessions. In this study, though, YouTube clips were used to elicit responses from preservice teachers and allowed them to share their thoughts and ideas.

The first YouTube clip shown was posted on September 2008 and was titled, *Observations on Climate Change in the Arctic – WWF* (2008). The video clip played for 3 minutes and 48 seconds. The clip showed scientists from the World Wildlife Fund (WWF) who were discussing signs of global climate change in the Arctic region, and possible actions that could be taken to avert an impending catastrophe. It was downloaded from the website: http://www.youtube.com/watch?v=Jak1pExql0U. The following description details the contents of the video clip:

> Dr. Martin Sommerkorn (Senior Climate Change Advisor, WWF Arctic Program): We have lost Arctic sea ice at a drastic rate over the last couple of years especially in 2007. 2007 has seen only 40% of the summer sea ice compared to the long-term average. Here we see something like a canary in the coal mine. The Arctic is our indicator of climate change happening. And what concerns us most is that the canary is not only singing anymore, it is actually almost dead. Out of the Arctic that can come feedback mechanisms. These are processes that are triggered by the warming in the Arctic that feed back and accelerate the global warming. They so to say increase the speed or increase the magnitude at which we will experience climate change. There are several mechanisms that come out of the Arctic that can provide this positive feedback. One of which we have already triggered. The Arctic has warmed at twice the global rate over the last 50 years. Half of that heat is actually produced in the Arctic itself and this is already accelerating the global warming. We do see less snow cover and less ice cover, and the exposed dark land and darker ocean water has accumulated that heat. So here we have an effect of change in the Arctic that accelerates the accumulation of heat in the global system and global warming itself.
>
> Dr. Neil Hamilton (Director, WWF International Arctic Program): The Arctic gives us the greatest wake-up call for the need for change. That change needs to occur at all levels.

> For the individual, it's about making choices how you live. For the corporation, it's about seizing the opportunities that we know already exist. For nations, it's about leadership. It's about showing that you can make these changes and that they are politically viable. The Arctic is changing and the Arctic will continue to change for a long period of time as results of the emissions that we have already put into the atmosphere. We have a very short period of time, 5 years, 10 years, in which to make, not just the decisions, but implement the actions that are required. WWF has been working in the Arctic for a long time, for more than 15 years. When we started, it was a more traditional conservation program where we were looking at establishing conservation reserves, trying to prevent impacts. Now, the Arctic is a key climate change issue. So the work we do is global in fact. We try to bring the message about what's happening in the Arctic to the world. We try to explain to people that the Arctic is the first sign of climate change. The impacts are already profound. People know about the polar bear. They know about the sea ice. And now we need to help them understand that they can change. They can make a difference; that we can protect the Arctic.

The second YouTube clip (Mortensen, 2007) shown was posted on March 2007 and was titled, *Global Warming – Doomsday Called Off (Part 5 of 5)*. In this specific clip, three climate scientists shared their knowledge about the limitations of computer models when dealing with climate. They posited that models are unable to account for the different drivers of climate such as precipitation. The video clip played for 6 minutes and 10 seconds. It was downloaded from the website: http://www.youtube.com/watch?v=v2XALmrq3ro. The following description details the content of the clip:

> Dr. David Legates (Center for Climatic Research, University of Delaware): A computer model is a very sophisticated computer program that attempts to simulate all the processes associated with the atmosphere. In particular, therefore, what we need to have is as much data as possible to be able to further the model, to be able to understand the processes. Generally what we find is that many of the processes that are in the climate work in a variety of scales that a computer model simply cannot resolve. One of the things we do not do well on climate models is simulate precipitation. And again, precipitation is affected by virtually every component of the climate system and in turn, every other component of the climate system affects precipitation. So precipitation is a very good diagnostic as to how well the climate models do it. And most climate models don't do precipitation well at all. A computer does only what it's programmed. And in particular, it is important to program it correctly. The problem is we don't a have perfect knowledge of how the earth's system operates. So therefore we're working with an incomplete understanding base to try to put together what we know to see if it in fact

generates the correct conditions. There's an old computer phrase that says, "garbage in, garbage out". And it's very important that we not only have data to drive the model but that we also have an understanding of the processes that the model needs to simulate. As a result, if the climate model cannot simulate the current climate well enough, then we have a condition where we're trying to simulate the climate with a model that is imperfect.

Dr. John Christy (University of Alabama at Huntsville): Climate models can be thought of as a list of rules. And so this climate model when it tries to predict the future just follows specific rules. The real world is a physical system. It follows rules, but there are so many that are not contained in climate models, that I think the climate models are too limited in being able to express what really happens in the real world. So to use them for a long-term projection I think is not wise at this point.

Dr. Sallie Baliunas (Astrophysicist, Harvard University): Computer simulations are the tool that's used to make forecast of temperature into the future. And the latest forecasts have a huge range. They range from just over a degree Centigrade to, my goodness, almost 6 degrees Centigrade for the next hundred years. That large range immediately tells you that the models don't agree with each other and they're very uncertain.

Dr. David Legates (Center for Climatic Research, University of Delaware): The Intergovernmental Panel on Climate Change and treaties such as the Kyoto Protocol are primarily based on climate model forecasts of what's going to happen in the future. Our issue associated with that then is if the climate models are somehow biased or incomplete, then our forecast of what the future might look like is too biased and incomplete.

Dr. Sallie Baliunas (Astrophysicist, Harvard University): Why that then turns into something that means there has to be action now? That, that's confusing to me. I can only imagine that something like the precautionary principle has been adopted as de facto policy.

Dr. David Legates (Center for Climatic Research, University of Delaware): The science in this case is indicating from incomplete models that we need to make political assertions and political changes. But part of the problem is that with incomplete science, we can make mistakes in policy that can have serious ramifications in the future.

Dr. John Christy (University of Alabama at Huntsville): When one talks about climate models and observations, I'm reminded of a climate scientist one time who said, "My model is right. It's the real world that's wrong." And I think that's what we've seen on many cases. And so using observations is not as exotic. It is not as dramatic in many cases and occupies sort of a lower level in the climate hierarchy of who gets attention. Because climate modeling enterprise is a very expensive so they have these constituencies built up that seek to maintain their work. Observationalists generally do not have that same attention and so developing observational data sets is sort of the weak

> sister in the climate community. Yet climate observations are supposed to represent the truth, not the theory against which our theory is to be checked. I believe observations and this is where our basis for climate change should be understood and the perspective from which we should see the future. When you look at the past, I don't think the perspective of the future is all that bad. A findings such as ours that says the satellites show no real serious global warming is not well received in much of the climate community. And I recognize that. But it is never been a goal of mine to be part of the mainstream of the climate community. My goal has been to provide scientists in the world with the most accurate data possible that we can judge and understand what the planet is doing. And so the data and the results are often greeted with skepticism because so many people have a belief that global warming is going to be a disastrous thing and that it is occurring right now to a large extent. That this picture doesn't fit their picture of the world and as a result, I've had a very interesting life dealing with controversies and so on.

In addition to the two YouTube clips, a cartoon was shown to the preservice teachers to elicit their responses to the issues of global climate change as portrayed by the artist. The title of the cartoon was, *The Last Global Warming Non-Believer* (Lane, 2002). The cartoon showed a man on the beach reading a newspaper with a banner headline about Alaska's melting glaciers. The man on the cartoon was partly submerged in water caused by the increased sea level. A child and a woman in the background were scampering for their lives due to the rising sea levels. The cartoon is hereby attached as Appendix C.

Prior to the third interview, each participant was asked to read two scientific articles about global climate change and its impacts. The articles were obtained from highly respected refereed publications in the natural sciences. The first article was authored by Rosenzweig, Karoly, Vicarelli, Neofotis, Wu, Casassa et al. (2008). The article discussed scientific arguments about the physical and biological impacts of anthropogenic climate change. The article showed tables and graphs to support the claim that physical and biological changes are occurring on all continents and that these changes can be attributed to the significant increase in anthropogenic greenhouse emissions. This article is attached as Appendix D. The second article was authored by Lindzen (2006). The article attempted to refute the consensus among climate scientists that there was a potential increase in global temperature by 4 degrees Celsius. The author also noted the prevalence of alarmism to promote the idea that a catastrophe was impending. The article discussed both the points of agreement among scientists regarding climate change and the misleading statements that were being provided to the public. During the third interview, the articles were the focus of the conversation. Each participant was asked questions regarding the articles and their personal thoughts about them and the issue of global climate change and teaching about global climate change in general. This technique of using journal articles to elicit responses from participants was associated with a similar technique used by Sadler, Chambers, and Zeidler (2004) in their investigation of student conceptualizations of the nature of science and how students interpret and evaluate conflicting evidence regarding global warming. In their study, a fictitious 'Science Brief' prepared by the researchers, was presented to the students. The brief reported two opposing positions on global warming in which the students responded in writing to a series of questions. A subset of the group was subsequently interviewed. The present study differs in that the articles used were published in scientific journals.

The final interview was conducted toward the end of the Fall semester. In this final interview, the preservice teachers were engaged in conversations about their beliefs on global climate change, the experiences that have shaped these beliefs, and their personal reflections on the planning of learning experiences they made in class during the semester.

Unit Skeleton Assignment and Concept Mapping Activity

As part of the course requirements, the preservice science teachers were involved in designing learning experiences for a topic beyond their field of specialization. The topic of global climate change was the focus of the learning experiences designed for high school students at a specific grade level. The assignment was titled, Preparing for the Unexpected. The topic of global climate change was used in order to prepare the preservice teachers for teaching a science topic which may not be within their field of specialization. The unit skeleton assignment was intended to help preservice teachers recognize the need to be flexible when the urgency to teach outside of one's academic preparation arises in their respective schools during their career. Likewise, the course professor stressed that the purpose of the unit skeleton assignment, as written in the assignment guidelines, was to provide the preservice teachers with practice in constructing a unit of instruction around a topic that stretches the boundaries of their content and pedagogical understandings. This assignment was accomplished individually by the preservice teachers outside of the regular class period. Guidelines regarding the concept mapping activity and the rubric for the assignment were discussed in class. The set of guidelines for this assignment is attached as Appendix E. The course professor discussed with the whole class the expectations for the assignment. The following was the description of the assignment as written in the course syllabus:

> Preparing for the unexpected – All teachers will be asked, at some time in their career, to quickly craft plans for a topic about which they have little knowledge. When this happens, teachers need to know how to use their content and pedagogical understandings to prepare instruction that will motivate students and enable them to learn. In this assignment, you will be asked to build the skeleton of a science unit suitable for a high school or middle school course. A handout will provide more details about this assignment.

The unit skeleton included the following elements: (1) course description; (2) unit overview; (3) learning outcomes; (4) summative assessment description; (5) learning experience descriptions; and (6) reflective statements. The concept map required of each preservice teacher was designed to be a part of the element, unit overview. However, the concept maps were prepared inside the classroom on the day of the deadline for submission of the unit skeleton assignment rather than being developed outside of class time. The final unit skeletons were evaluated using criteria related to the: concept map, background of the unit and alignment to standards, learning outcomes, learning experiences, assessment, and reflection. The rubric for grading the assignment is attached as Appendix F.

After the preservice science teachers' individual work, they were engaged in a concept mapping activity during the regular class period. The preservice teachers constructed a concept map individually, and then shared and discussed it with other students. The four preservice science teachers in the study formed one group. During the allotted time, they shared with each other the unit skeleton and concept map they each had prepared. This concept map illustrated the preservice teachers' organization of concepts reflecting their understanding of global climate change. At the conclusion of the small group discussions, the course professor asked each group to share with the whole class the salient points discussed in their respective groups.

Observation notes were kept during the concept mapping activity and presentations of the unit skeleton and concept maps to the group. The notes helped the researcher examine the patterns of thinking and beliefs of the preservice teachers while they engaged in individual and collaborative work. Bogdan and Biklen (2007) claimed that observation notes are necessary to provide an account of what the researcher actually saw, heard, experienced and thought in the course of collecting or reflecting on the data.

Novak and Cañas (2007) defined concept maps as graphical tools used to organize and represent knowledge. The concepts are usually enclosed in circles or boxes of some type, and relationships between concepts are indicated by a connecting line linking two concepts. Novak and Cañas (2007) added that concept maps are characterized by a set of concepts represented in a hierarchical fashion and cross-links that show the relationships or links between concepts in different segments or domains of the concept map. Kinchin and Hay (2000) claimed that concept mapping promotes metacognition and allows students to understand the interaction between the new material and their existing cognitive structure. Some researchers have used concept mapping to guide the conceptual framework for planning and evaluation (Trochim, 1989) and elicit teachers' practical knowledge (Meijer, Verloop, & Beijaard, 2002; Zanting, Verloop, & Vermunt, 2003).

Table 1. Research Questions and Data Collection Methods Employed

Research Question	*Methods Used*	*Form of Data Collected*
1. What are the epistemological, pedagogical and curricular beliefs of preservice secondary science teachers about global climate change?	Interviews Unit skeleton assignment Case study Group presentation Informal conversations	Interview transcripts Group presentation transcript Unit skeleton Concept maps Notes Rubric for grading unit skeleton Guidelines for the assignment Course syllabus
2. What experiences influence the development of preservice science teachers' beliefs regarding global climate change?	Interviews Case study Group presentation Informal conversations	Interview transcripts Group presentation transcript Notes
3. How do preservice teachers negotiate and integrate these beliefs in the design of learning experiences about global climate change?	Unit skeleton assignment Group presentation Interviews Case study Observation Informal conversations	Interview transcripts Group presentation transcript Unit skeleton Concept maps Notes Rubric for grading unit skeleton Guidelines for the assignment Course syllabus

The researcher included as secondary sources of data his informal conversations with the preservice science teachers. The researcher was in constant communication with them during the semester. The conversations occurred outside the regular class hours and as the researcher got to know everyone during the first few weeks of class. The conversations centered on academic issues and concerns, personal ideas about their beliefs and thoughts on global climate change, experiences that related to their academic work and the topic global climate change, and other issues surrounding science teaching and learning. Table 1 shows the relationship of the methods employed and the research questions that the researcher attempted to answer.

Procedures of the Study

The study was organized into different phases. As discussed below, interviews were extensively used in this study. Each interview was audiorecorded and transcribed. During the *first phase* of the study, the following steps were followed:

A. Preservice science teachers enrolled in the course, Science Curriculum and Learning, for the Fall 2009 semester, were invited to participate in the study.

B. After engaging the preservice teachers in informal conversations and obtaining consent, four preservice teachers were chosen as the primary participants.

C. These four preservice teachers were individually interviewed from 45 to 60 minutes (Interview 1), to understand their general thoughts and beliefs about global climate change. In the first phase of the study, data were in the form of interview transcripts.

During the *second phase* of the study, the following sequence of activities were followed:

A. Preservice teachers participated in a second interview (Interview 2).

B. In this interview, each preservice science teacher was interviewed with the aid of the two short movie clips from the YouTube and cartoon described previously.

C. As part of the course requirement, preservice teachers were asked to design a unit skeleton with learning experiences on the topic of global climate change. The assignment, referred to as, Preparing for the Unexpected, was described previously. The rationale for this class assignment was discussed in class. The preservice teachers were given one week to work on this assignment.

D. In one class session, all the preservice teachers in the course formed different groups. The four preservice teachers in this study formed one group. During this group activity, each preservice teacher was asked to construct a concept map illustrating his/her basic understanding of global climate change. They were all asked to base their concept maps on the unit skeleton that they had developed previously. The concept maps illustrated each preservice teacher's organization of concepts reflecting his/her understanding of global climate change.

E. After completing the concept maps, each group was engaged in a discussion that involved the sharing of the concept maps and unit skeleton they had prepared. The presentations of concept map and unit skeleton to the group was audiorecorded.

F. In the same class session, each group was given the opportunity to present to the whole class the points discussed in their respective group. Data from the second phase of the study included observation notes, concept maps, unit skeleton, audiorecorded conversations and interview transcripts.

In the *third phase* of the study, the following procedures occurred:

A. Preservice teachers participated in a third interview (Interview 3). Each preservice teacher was asked to read two scientific articles about global climate change and its impacts. As discussed previously, one article discussed scientific arguments about the impacts of global climate change on physical and biological systems, and the other article refuted the alarmism that a lot of climate scientists are promoting.

B. A final interview (Interview 4) was conducted toward the end of the Fall semester. In this interview, the preservice teachers freely discussed their beliefs on global climate change, the experiences that have shaped these beliefs, and their personal reflections on the planning of learning experiences for their unit skeleton. Data from the third phase of the study included interview transcripts.

Data Analysis

The researcher employed an inductive analysis (Charmaz, 2006) of the data obtained 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. The researcher started the formal coding process after the completion of data collection. But throughout the data collection process, preliminary examination of available data was done by the researcher by looking over observation notes, written products and field notes, as well as by listening to the audiorecorded interviews. Data collection and analysis were informed by the tenets of interpretive research. The emergent nature of an interpretive study required the researcher to conduct ongoing analysis of available data. In this way, the researcher formulated interview questions based on preliminary informal analysis of each recorded conversation. The subsequent interview questions were formulated based on the information provided by each participant. This was accomplished by carrying over some of the questions from one interview session to another. Likewise, interview questions suited to a prompt (e.g., YouTube clip, cartoon, and scientific articles) were carefully framed to allow the participants to freely express their thoughts and ideas about the subject of global climate change.

As stated above, coding was done by the researcher 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). Line-by-line coding required naming each line of the written data. Charmaz (2006) claimed that line-by-line coding prompts the researcher to remain open to the data being analyzed. In-vivo coding required the researcher to use the participants' terms as codes. This was necessary to preserve the meanings attributed by the participants to the action they described in the interviews. Focused coding involved the use of the most significant codes made earlier. This type of coding helped the researcher categorize the codes in a meaningful manner. From these, the researcher organized the different codes into categories and built a systematic account of what had been observed and recorded (Ezzy, 2002).

Inductive analysis required reading the interview transcripts, concept map and design of learning experience products over and over again in order to get the gist of each data set. The codes were reduced and synthesized into categories. This helped the researcher in writing the four cases. After completing the process of putting together codes and categories that comprised a case, member checking was done. This was done by providing each participant with the text of the written case and allowing them to mark the document and suggest changes, clarify, or elaborate points. Tobin (2000) asserted that member checking is an integral part of interpretive research since it allows participants to critique the researcher's interpretations and thereby providing additional rich layer of informative description.

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" (p. 11) to know how and why events happened the way they did.

Narratives embedded from interview talk were good avenues in representing the thoughts, ideas and beliefs of participants. The narratives were oftentimes embedded as forms of examples in points that participants wanted to reiterate. Likewise, one advantage of narratives was the potential of these stories in helping the researcher draw codes, and eventually, the emerging themes that answered the research questions asked at the start of the research process. Writing the cases required the researcher to transport the reader to the setting by providing a vividly descriptive narrative of the setting and situation (Merriam, 1998). After an analysis of the individual cases (within-case analysis), emerging themes were identified which helped the researcher to make valid interpretations.

After the completion of the within-case analysis, the researcher employed a cross-case analysis of the four cases. This was in keeping with the notion that a multicase study should build abstractions across cases (Merriam, 1998). This level of analysis resulted in a unified description of the cases, and identification of emerging themes, categories and typologies (Merriam, 1998).

Summary of the Chapter

This chapter provided a detailed discussion of how the data for this study were collected. In particular, multiple sources of data were used in order to allow the researcher to make a thick and rich description of the cases, or the individual participants. As shown in this chapter, interviews were aided by prompts in the form of short video clips, cartoon and scientific articles. This innovation allowed the researcher to obtain rich information from each participant. The data were managed, analyzed and interpreted following the inductive analytic method. This method of analysis preserved the integrity of the meaning provided by each participant and allowed interpretation based primarily on the data obtained. As a whole, this chapter provided a description of the steps followed and specific methods used in obtaining rich data for each case.

Chapter 4

FINDINGS, ANALYSIS, AND INTERPRETATION

Introduction

Organization and analysis of data always follow the collection process. This chapter aims to present the findings that were gleaned from the data collected. The sections that compose this chapter are narratives representing the four cases. As discussed in the previous chapter, case study method was employed. Data in the form of transcripts, field notes, and written products were collected from the four preservice science teachers who participated in this study.

The following sections present four narratives about the preservice science teachers – Cherry, Eddie, Summer, and Vince and their beliefs about climate change and global warming. In each case, pseudonyms were used to hide the participants' identities. No real names of places that potentially identify the participants were mentioned in the narratives. Each case was developed with four important parts: (1) entry vignette; (2) extensive narrative description; (3) closing vignette; and (4) summary discussion/interpretation of themes. Themes emerging from each case were embedded in the discussion and were italicized for emphasis. Themes were allowed to unfold through the storied narrative. In portions where direct quotes from the preservice teachers were used, references were provided. The quotes were generally taken from the data that were collected. Each case was structured in a manner that highlighted the key issues in order to allow readers to understand the complexity of the case and its context. In each narrative, portions of the unit skeleton assignment, prepared by the preservice teacher, were included to allow the researcher and the readers to examine the plans and learning experiences that he/she designed. No original words or format of the unit skeleton were altered. The subheadings used by the preservice teachers in their unit skeletons were italicized for clarity. These should not be mistaken with the italicized themes for each case. In each case, the concept map prepared by the preservice science teacher was shown followed by a discussion of the content and process associated with it.

The Four Case Narratives

Narrative 1: The Case of Cherry

Movies that depict doomsday for humans, apocalyptic scenes that result in the 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; only not limited to what was portrayed in the movies. She said, “I get very frustrated with the whole doomsday scenario.” (Interview #2, line 570) Cherry was not reacting to a Hollywood movie, but rather to the prevailing talk about global climate change. She was basically responding to a video clip and a cartoon that depicted global climate change as an impending disaster. Cherry added: “I feel like it depicts it [global climate change] as something that’s gonna happen tomorrow and we’re all gonna drown because the Arctic is melting. So I feel like it’s a very dire message from them about global climate change.” (Interview #2, lines 237-242) Cherry specifically dislikes depicting an environmental concern as something where humans are left helpless. The following narrative elaborates on the important issues and ideas raised by Cherry as reflected from the interviews, observations, and the written unit skeleton assignment. This case was designed to introduce one of the preservice science teachers who participated in the present study, and provide a synthesis and representation of her beliefs about global climate change. It was evident that there were important themes (in italics) that emerged from the interviews and other evidence, as will be discussed in the subsequent sections. Appendix A1 provides a summary of the emerging themes and categories elaborated in this case.

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 scientific investigations. Cherry's work includes 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. The researcher came to know Cherry better through interviews and informal conversations during regular class sessions. The researcher learned that Cherry comes from a family that taught her to respect the land and to be personally connected with nature and 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 (Field notes, 9/16/09). 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 and less. I feel the responsibility to do that, too." (Interview #1, lines 174-176)

Cherry shared very interesting and enlightening ideas, thoughts, and perspectives about global climate change. The first interview session was focused on Cherry's main thoughts and beliefs 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 is not been that long of period of time." (Interview #1, lines 37-39) 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. But how significant was time in her discussion? There was a caveat Cherry wanted to stress as regards to the data being reported by scientists. According to Cherry, there ought to be caution in presenting data that might have been skewed to appear the way scientists wanted it to be. She noted that instrumentation in the past differs significantly with modern scientific tools and gadgets. She further elaborated: "Well, I know that our instruments are getting more and more sensitive every year. And so we can now monitor temperature changes in the one hundredths of a degree, whereas a hundred years ago, we were lucky if we could change temperature one degree very accurately. And so we've only been keeping records for you know, a few hundred years at the most. And then they weren't very accurate. 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. I know some of the things that we look at to compare changes in temperature and changes in weather patterns are not just recorded temperature but something that we could go back and look at ice records and those sorts of things. But as far as comparing what is recorded, we have to be very careful I think, about recording something today and comparing with something recorded

200 years ago. So you have to keep in mind instrumentation is so different today." (Interview #1, lines 62-74)

Cherry stressed a very interesting point about her beliefs regarding global climate change. Probing some of her responses, it was apparent that she emphasized the need to separate the "what" from the "why" of global climate change. Cherry had "done a good bit of reading from the scientific point of view and believes that there's evidence that there are weather pattern changes and there are temperature changes. I think that there is global change. I think there is evidence that there is change. Now the evidence to whether or not what is causing that change, I have a whole issue of opinions. But I believe there is change. And I think there's definite scientific data showing that there has been change over the past few hundred years that we can actually collect data. But why that change is happening is a whole another story. Well, I think there are changes but I think that we can take the "why" from the "what". And I mean you can show something is happening but showing why something is happening is a whole another ball game and I don't see the proof of why it's happening. I don't think that we have proven beyond shadow of doubt to me why any of this is happening. Or even that we've shown enough proof that it's not cyclic. I don't think there's enough data to show that this is not a cyclic pattern of the earth. It's just happens to the earth because of certain things that are going on. There's been lots of data to possibly show that maybe it's something is going on inside of the earth's core that's causing external problems. There's some magnetic things going on that I've done some reading about the earth's magnetic fields are changing. That can definitely cause some changes on the planet as far as weather pattern changes, temperature changes. I mean I've also seen some correlating data with sunspots. That's interesting theory. Nobody's proven that or disproven that. So until I see one side or the other, I can't really say, 'Oh, this is the reason.' There's too many theories out there right now that I think it's like any other theory that we've sorted out from a long time ago. And I think we're at that point now where we just really don't know what's causing global warming." (Interview #1, lines 106-122)

For Cherry, the "why" is separate from the "what" in regards to global climate change. Cherry noted that scientists are doing their work to provide ideas that explain this phenomenon. Before discussing further what two alternative theories explaining global climate change were all about, Cherry first explained that this phenomenon is often discussed by using increased greenhouse effect as the explanatory reason. She was excited to share her knowledge of two other theories: correlations between the core and magnetic field (Interview #1, lines 278-294), and between sunspot cycle and temperature change (Interview #1, lines 298-315). In the first theory, Cherry explained that the earth's magnetic fields have changed in the past, and such switching had been observed in rock formations. As a result of intensified solar radiation, the magnetic field was disturbed and major atmospheric changes were predicted to happen. Correlating the sunspot cycle with the earth's global temperature was another interesting theory that Cherry discussed. She explained how based on an analysis of records, scientists found a correlation between the number of sunspots and global temperatures, that is, every time the sunspot cycle came up, the earth's temperature increased. Representing their data in graphs, there appeared to be a better correlation between sunspots and global temperature than between sunspots and the amount of carbon dioxide. When asked about the influence of knowing these alternative theories on her perspective of global climate change, Cherry replied that learning about these theories bolstered her idea that there were other explanations that might actually be scientifically sound. (Interview 31, lines 366-367)

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. This is due to the fact that there is an apparent difficulty in testing the validity of the different claims in the laboratory. Added to that is her observation that the two strong opposing groups of pro- and anti-global climate change have seemed to obscure and confuse a genuine understanding of the phenomenon. Cherry’s conviction is shown in her explanation: “I don’t think that anybody has pinpointed exactly what is causing all the change. But I don’t think anybody has got a good grasp of exactly why or exactly what we can do to fix it. I think we’re all still feeling around in the dark, mainly because we don’t have a lot of data and have a lot of interpretable data and we also don’t have a lot of ways to test our theories.” (Interview #2, lines 223-228)

During the study, the researcher asked Cherry to read two scientific articles that discussed perspectives on global climate change. The article by Rosenzweig et al. (2008) focused on the physical and biological impacts of global climate change. In this article, graphs were shown to represent data on aspects of biological systems in different continents that were affected by global climate change. Reacting to this specific article, Cherry noted that the length of time devoted for the research was not enough. She contended: “The fact that the study only encompasses thirty-four years at the max really stands out to me as a very short period of time when we’re talking about global climate change. That’s a really small amount of time. I mean thirty-four years is not even really a good weather cycle. I mean we are usually discussing hundred year cycles here not or climate cycles we’re not really just thirty-four years its less than even my lifetime. So it’s not really a long time. And that kind of thing bothers me.” (Interview

#3, lines 219-226) Cherry drew an analogy between human lifespan and climate to denote the limitation of the study in terms of the time period it encompassed relative to drawing generalizations. Cherry further noticed an inconsistency in the data representation by noting: "Right here they say in the past fifty years but then their study is only thirty-five years so I think that's a big stretch there. But even fifty years isn't that long of time. I think whenever you're looking at different types of science you have to think about the time span you're looking at. When you look at the lifespan of a human fifty years is a long time. But when you're looking at the lifespan of the global climate I mean that's we're talking about millennia and we're talking about changes that we need to observe for more than this. It isn't even a generation of time." (Interview #3, lines 230-239)

The preceding discussion explained what Cherry's beliefs on global climate change were and how uncertainties in evidence influenced her way of thinking. It can be gleaned from the above discussion that when it comes to the issue of global climate change, that for Cherry, the *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.

Who is the source of information about global climate change? This same question was posed by Cherry in clearing things up about her position on the issue of global climate change.

Having a scientific background, Cherry considers herself as a critical reader when presented with information that is of scientific interest, in this case, the topic of global climate change. To illustrate, when Cherry watched a clip about the melting Arctic sea ice and its effect on polar bears, half her brain was looking for any hidden agenda and the other half was trying to listen to the facts. (Interview #2, lines 105-106)

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 said earlier, people can bias their data. And you got to be careful that the person that you’re getting the information from is not biased. Like I said, you don’t, you don’t want to take the word of a scientist that works for the oil company that the oil’s the best way to go, because they’re biased or they can be. I’m not saying they are always biased. But you don’t always say. You don’t always take the scientist who works for the drug companies, word that their drug is the best. Well, they’re gonna say their drug is the best because they have a financial stake in that to say their drug is the best. Maybe, maybe their drug is just as good as aspirin. But it’s the newest, most exciting drug on the market so they’re gonna try to sway you to believe that their idea is best because they have a financial stake in that. So you always want to make sure that wherever you’re getting your information is not based on somebody’s. The person you’re getting it from is not based on the person that has some kind of financial stake or personal stake in swaying you to their side of the argument. I believe that you really want to make sure that that’s not where you’re getting this person’s information is based on good hard facts and they don’t have a personal stake in the information.” (Interview #1, lines 147-160)

In trying to find out the credibility of the source of information, Cherry considers the following questions: “Who is the scientist or person that’s writing this article? Is it a journalist?

Is it a politician? Is it a scientist? If it is a scientist, who do they work for? Where do they get their money from?" (Interview #1, lines 182-187) Cherry considers the internet to be an aid in examining the credentials of individuals presenting information about global climate change. Cherry explained how the internet could be used to access a person's research publications. When asked about the benefit of doing such a task, Cherry replied, "Well, they (credentials) give me information, some of which I know to be true because of things I already know. But they give me information they expect me to take as truth. But I don't know how they got that information. So I'm very skeptical of anybody's information unless I feel like they, I know how they got that information. I could go to their website and check them out at the end to have the option of knowing where they come from." (Interview #2, lines 67-71)

Cherry 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…And so I don't feel like journalists or politicians are the people who have the training to tell me the facts. These people are not going out in the field and testing the weather and testing ice cores, and testing the magnetic fields or testing the sunspots. They're not out in space working for NASA." (Interview #1, lines 210-218)

An interesting instance of singling out politicians as not so reliable and credible sources of information happened when Cherry's group was planning for their unit skeleton assignment. In their discussion, she mentioned that the movie, *An Inconvenient Truth* is playing on people's emotions. Likewise, the group was intrigued by the graphs used in the movie. Cherry and some group members suggested not including Al Gore (referring to the movie) in their unit skeleton which subsequently evoked laughter from the group (Field notes, 9/28/09). In responding to

Lindzen's (2006) article about global climate change and prevailing alarmism, Cherry noted that this author was trying to address the need to be really careful not to skew the idea of what technology can produce, not only to the laymen but to politicians. She added: "And then it gets just amplified I mean you know once you convey an idea to a politician then as far as I'm concerned that's just magnified exponentially once it gets beyond there." (Interview #3, lines 295-298)

Though Cherry considers climate scientists as the experts, she feels that not all may qualify for her standard of credible information. To illustrate, in responding to a video clip of World Wildlife Fund (WWF), Cherry noticed that the presenters were just representatives of the organization. Still on this particular clip, Cherry noted that the clip showing polar bears in the Arctic presented global climate change with a little bit of an emotional nudge. She continued, "And animals are definitely an emotional nudge for people." (Interview #2, line 90)

Cherry feels less skeptical about scientists working in the academe. She explained her reasoning, noting: "Well, scientists who work in academia have less probably less to lose for whatever data they collect. Their money does come from the government, grants usually. Some monies can come from other institutions. You can get money from corporations. And grants come from everywhere. But the majority of the money comes from government grants or a big nonprofit granting institutions that grant too lots of different things, not just one type of thing. And most of the time they don't have any reason or any kind of bias. It's less biased information. Or I feel like it is...If you look at someone in academia a lot of them are doing science for science's sake. 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." (Interview #2, lines 399-415)

As noted from the previous description Cherry regards scientists as authority figures. Her line of reasoning was captured through her words: "Culture teaches I think partly that these people are experts and they know better than the rest of us. I mean when you go to your doctor you don't question him. He says you have this problem and you say yes sir and he writes you a prescription you go home and you take the medicine. And scientists are the same way. I think in our culture and in many cultures I think worldwide, we've been taught that scientists are infallible people." (Interview #3, lines 466-470) She adds that people tend to take a scientist's word as fact.

Cherry also regards published articles by scientists as another viable source of information. She noted that she has access to articles that present condensed information in journals like *Nature* or *Science*. Cherry relies "a lot more for more accurate information in peer reviewed journals". (Interview #2, line 198) Reading critically is the key for Cherry. She reads with an open-mind but critically, maximizing her scientific training by making notes on the paper and going back later.

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, 2000).

The following is a summary of the salient features in the unit skeleton prepared by Cherry. In this unit skeleton, she prepared learning experiences for a high school chemistry class. The complete unit skeleton assignment of Cherry can be found in Appendix G1. The following elaborates on some of the details of the unit skeleton:

> *Course Description:* This unit will be taught in a high school chemistry class to 10th through 12th grade students. This unit should be positioned toward the end of the course during a unit on solutions. The teacher would have already discussed with the students earlier in the solutions unit the idea of the nature of solutes and solvents.
>
> *Unit Overview:* We will discuss that gases are less soluble in liquids as the temperature increases. Through experiments and demonstrations, the students will be able to observe the effect of temperature on a solvent's ability to dissolve a gas. (Standard: SC7a. Explain the process of dissolving in terms of solute/solvent interactions.) This unit will focus mainly on how the solubility of carbon dioxide in water relate to temperature changes information collected by scientists and presented on the web, students will analyze how scientific knowledge is developed and check that information against other information sites. (Standards: SCSh7. Students analyze how scientific knowledge is developed. SCSh3f. Evaluate whether conclusions are reasonable by reviewing the process and checking against other available information.) Students will also discuss how this phenomenon can be utilized by scientists to monitor global climate change. (Standard: SCSh8e. The ultimate goal of science is to develop an understanding of the natural universe which is free of biases.)
>
> *Learning Outcomes, Standards, and Essential Questions*
>
> 1. Explain how temperature affects the ability of a solvent to dissolve a gas.
>
>   Standard: SC7a. Students will characterize the properties that describe solutions; observe factors that affect the rate at which a solute dissolves in a specific solvent. Essential Questions: Is a gas more soluble at a higher or lower temperature? What properties of the ice core allow it to record a historical record of atmospheric conditions?
>
> 2. Describe how scientists use gases stored in ice cores to construct a historical record of atmospheric conditions.

Standards: SCSh7. Students analyze how scientific knowledge is developed. SCSh8e. The ultimate goal of science is to develop an understanding of the natural universe which is free of biases.

Essential Questions: What information do scientists glean from ice cores? What process do scientists follow to construct a historical record of atmospheric conditions?

3. Evaluate data and information collected from various sources.

   Standard: SCSh3f. Evaluate whether conclusions are reasonable by reviewing the process and checking against other available information.

   Essential Questions: How was the data that was represented on the internet sites you visited collected? How does the data you collected from various places correlate? Does this information corroborate your original source's conclusions?

Summative Assessment

Ice cores Lab: Students investigate their own "ice cores", prepared by the teacher. Each level is of different color so students can easily distinguish between layers. Students are given an ice core and develop a data set of CO_2 levels versus time. They will not be able to capture the gas, but can measure the CO_2 levels by measuring the relative pH of each layer. Ask the students to make a graph correlating the CO_2 levels with recorded temperatures. The teacher gives the students a graph of a different data set. Ask the students to compare the graphs, and write an explanation whether the second data set supports their conclusions or not.

Learning Experiences

1. Demonstration of carbon dioxide solubility in a carbonated beverage
2. Laboratory exercise with bottles of soda at different temperatures
3. Lecture on temperature effects on gas solubility in liquids
4. Ice core sample activity: Students explore the website, www.exploratorium.org/climate, in groups. Students will explore the graphs about ice cores.
5. Student presentation of their findings from the website

The above unit skeleton prepared by Cherry shows a structured way of integrating the topic of global climate change in high school chemistry. In explaining the process of designing this unit, Cherry said: "The way I got started with it I thought about where in my chemistry units that I could fit this in. And I decided that we could talk about gas dissolution and ice cores since

CO_2 gets dissolved in ice very well and scientists use that to create a historical record of atmospheric conditions. They can go back hundreds of thousands of years, way before people were taking, keeping records. And so I talked about gaseous solutions and solvents and then went on to specific examples of gaseous solution talking about CO_2 dissolution in water. And then discuss temperature effects on CO_2 dissolution in water, liquid water versus ice." (Group discussion, lines 53-59) When asked about the website included in the unit skeleton, Cherry had this to say: "You go to this website and there are different tabs that describe different types of weather related and climate change related subjects such as I think there was one about oceanography, there was one about the polar ice caps…There were four or five different tabs and I can't remember what they were all of them, they each had different subsets of the earth and the kind of the biosphere different types of things that children can go in and click this websites and get a bunch of different data and actually kind of research data related to that very narrow category compared to the overall wide category of global warming and global climate change in particular." (Interview #4, lines 38-46) As part of their group discussion, Cherry shared with her peers the concept map shown in Figure 1.

Cherry feels that global climate change has an important place in the middle school and high school science curriculum, believing that it is essential for students to understand this environmental concern because it transcends the life of every individual. According to Cherry: "I think that kids are gonna be exposed to it no matter what. They're gonna see that on the newspapers. They're gonna see that on the 6 o'clock news. They're gonna see it. They're gonna hear it. People are talking about it. It's not something that we can ignore. So I think you're gonna be faced with it as a science teacher. I think as a teacher in general, everything that kids gonna are hear or see as part of their lives we're gonna be faced with. Just having a teenager of my own, I know that they're gonna ask you questions about everything in the world. I think that as a science teacher, in order to be the best teacher you can be, is to be the most well-informed about a subject that you can be and the least biased." (Interview #1, lines 377-384)

Cherry further elaborated on the relevance of global climate change to the lives of students by mentioning "climate-gate scandal", a most recent controversy reported on media involving an alleged misconduct of climate scientists. The so-called "climate-gate controversy" refers to an alleged scandal involving scientists who were discussing flaws in their data and attempting to silence critics of global warming as shown in their electronic communications (Fahrenthold & Eilperin, 2009). This controversy started in November 2009 with the posting of 1000 e-mails and 3000 electronic documents stolen from the Climatic Research Unit located at the University of East Anglia in England.

To Cherry, students certainly saw and heard about this controversy and hence should be included in science classroom discussion. Cherry explained: "Especially right now it's (referring to global climate change) definitely in the news since they've been talking about climate gate lately. I think they want to talk about it. They want to talk about things that are in the news. I think it helps because it's an issue. I think it's one of those things that you can discuss in your science class that helps keep them interested because something's in the news but I also think it's something that you could definitely use for critical thinking…And when you talk about climate change they realize that, 'Wait a minute', especially in light of this recent discussion about you know whether or not scientists fudged the data." (Interview #4, lines 584-601) When asked to elaborate on the importance of including this recent news in the science class, Cherry replied: "I think that sometimes people think scientists are kind of like what kids think what teachers are. They're just there. They do their job and beyond that they don't exist. You know, it's like a doctor. What do these people do in their real lives? That they're not real people. That they don't have faults or feelings or ideas or you know. And to see that these emails between these scientists to each other about you know what are we gonna do, that this data doesn't look like we expected or you know how do we feel about this and that's, that's important to think to realize that scientists' data doesn't always look like they expected to be. Or, you know, sometimes they're worried about how to analyze data or sometimes they make mistakes and do something silly like add things in it probably they should have not added to analyze the data. Or, you know, or maybe they don't and they just write an email that makes it look like they did, or maybe they say something that they shouldn't have said or they're people…They're just people. And, I think if you can encourage your students that they're people, all be it people who do a lot of very important work, who are very intelligent, who spend a lot of time in school, who know a lot of stuff, you know, if you wanna be like them, you've got a long way to go and you've got a lot of studying to do but they're still just people, like you. And they get up in the morning and then put on their clothes just like you do. They're not some unattainable goal. I think that's important for a student to understand." (Interview #4, lines 628-653) Based on Cherry's response, it was evident that she thought of incorporating a relevant and timely topic in her science classroom not only to develop a lesson on global climate change but also to allow students to draw a picture of what science is really like, how scientists work, and how personal and social dimensions influence the scientific community. In other words, Cherry thought of using the 'climate-gate scandal' as a spring board for discussing the human side of the scientific enterprise.

Figure 1. Concept Map of Cherry about Global Climate Change

Elements that influence a teacher's desire for *establishing a climate of learning* were revealed in Cherry's explanation of the inclusion of global climate change as an emphasis in the science curriculum. These elements included: (1) seamlessness and continuity of science topics; (2) time; (3) neutrality of the teacher; (4) development of critical thinking; and (5) emphasis on process. When speaking about the factors she considered in writing the unit skeleton, Cherry had this to say: "I really thought about how I could fit this into chemistry class without disrupting the flow of a chemistry class and how I could fit this in…seamlessly, without making it seem like all of a sudden we're just, 'We're gonna stop what we're doing. We're going to talk about climate change', to fit it in so that students would see that climate change fits in with everything else we've been talking about…and connect a lot of dots to get back to your standard so if you can take something and get it right on the standard that also incorporates other outside things like global climate change then that's really good thing that you can kill two birds with one stone." (Interview #4, lines 105-123) According to Cherry, such continuity is essential because "chemistry builds upon itself and that's very important. And you learn one concept and then you learn the next concept that builds on the last concept." (Interview #4, lines 165-166)

For Cherry, time is also of the essence. Time is related to the continuity of topics. Cherry wanted to keep focused on the standards in light of the time schedule that is being observed in most schools. Cherry emphasized that time should be considered if a teacher desires to let students learn chemistry and perform fun things in the classroom. Cherry explicitly mentioned that time is highly valued in schools that observe block scheduling, that is, science topics are covered within a semester.

Teachers, Cherry opined, should be neutral when presenting the topic, global climate change. Neutrality, according to Cherry, requires not explicitly telling students one's personal beliefs and convictions. Cherry's emphasis on neutrality in establishing a climate of learning goes beyond the act of telling students one's views about an issue. Cherry explained: "I think they can learn about that and I would never tell children how I feel about the subject. I would want them to try to come up with their own ideas about what they thought. Because I don't think it's my place to tell them whether or not I believe in global warming or I don't believe in global warming because that's not my place as a teacher. My place as teacher is to teach them how to learn. I would let them make up their own minds." (Interview #2, lines 604-609)

From Cherry's perspective, being neutral when teaching global climate change is an important professional obligation. She explained her belief that when a teacher feeds students with his/her ideas he/she is doing them a disservice. According to Cherry, there is a disadvantage for the teacher who shares his/her position on an issue with students, as shown by her comment: "I think if you give a student too much opinion then they no longer start thinking for themselves. They either totally just believe what you say or just go the other way." (Interview #4, lines 318-319) Cherry added: "So if you do talk about those things, then you need to make sure that you're teaching how to find out how they feel about those things on their own. And I think you need to give them the opportunity or teach them how to go out and form their own opinions about science, about socioscientific issues like global warming or environmental issues." (Interview #1, lines 464-470) Cherry noted that part of being neutral involves "teaching children to be responsible for their own ideas and opinions" (Interview #1, line 501), and "presenting both sides of the issue". (Interview #3, line 705)

Cherry also viewed the development of critical thinking as another element essential to establishing a climate for learning. For Cherry, this meant that students must have opportunities to hone their skills in critical thinking. She elaborated on this with the following statements: "They need to think about critical thinking especially in science. Science isn't just knowing stuff. I mean that's cool and it's important and it's the basis of science but if a student doesn't understand how to think critically not just about science but about life in general. I mean they just really are robots. I mean you have to be able to look at the world around you and think about what's going on and make decisions for yourself that are based on facts that you know to be true." (Interview #3, lines 593-599) Cherry further explained her role as a teacher: "They (students) tend to be very myopic and think only about what they are looking at. And I think getting them to think about these sorts of things and thinking about how everything affects everything else is very important. Because personally my philosophy of being a teacher is that I'm not just teaching them chemistry I'm teaching them to be an adult, to be a fully formed functioning adult. I want them to be able to leave my classroom as a fully functioning adult." (Interview #3, lines 610-615)

In line with Cherry's desire to foster critical thinking, she came up with the idea of starting a journal club in her future classroom. Her vision of a journal club requires students to be engaged in reviewing a scientific article regularly. Cherry explained how, after giving students ample time to read an article, one which is not too technical, she will have them engage in brief discussions, guided questions, and personal research. Likewise, Cherry stressed that it would be important for the teacher to read in advance each of the articles to ensure that they are age appropriate. Cherry believes that this activity serves as a preparation for college. In designing her unit skeleton, Cherry refused to make the lesson a giant debate because of her desire to spend more time honing students' critical thinking skills.

According to Cherry, a climate of learning may also be developed by designing meaningful classroom activities that are process-oriented. Cherry had a lot to share in terms of specific processes that she believes hone students' understanding of socioscientific issues, like global climate change. As a teacher, Cherry desires to present global climate change as well-balanced as possible, and encourage students to learn how to look for good sources of information. Cherry also noted: "I think this is a good place to teach kids how to look at information that they're gonna be faced with as adults." (Interview #1, lines 390-396) The search for good sources of information should be an opportunity for exploration to students "instead of just being spoon fed information from their instructor". (Interview #3, line 555) With the advent of technology and continued knowledge explosion, Cherry explained: "I think that going out and doing some information-searching for yourself just, especially for this seeing where all the information is a good tool to learn. And I think this is a good place to do it. There's so much information out there and I think the kids wouldn't have hard time finding information but maybe we give them some good experience in looking up information for themselves. And asking them to find more than one theory, maybe give them some experience on trying to find out more information than maybe what the 6 o'clock news is gonna feed them. I think that would give them some experience not only on the subject matter but also on how to go out and explore for themselves." (Interview #1, lines 437-445)

The discussion above showed how the emerging theme, *establishing a climate for learning*, was manifested in Cherry's unit skeleton and interview. Cherry had the desire to make both teaching and learning enjoyable and meaningful experiences. Her unit skeleton supported her notion of neutrality by not incorporating debate as a means to resolve differences in claims about global climate change. Cherry was more concerned with students developing an understanding of the scientific process, as shown in her unit skeleton. It is interesting to note that five elements of establishing a climate for learning emerged from the interviews. It was evident that Cherry's "espoused theory of action" (Argyris & Schön, 1974) came into play when she designed her unit skeleton and when explaining her position about global climate change as a science topic. Her unit skeleton clearly projected intentions that were possibly guided by her personal beliefs, values, and experiences. For example, being a mother of a high school student influenced her thinking of the appropriateness of her approach in developing the unit skeleton. Her "espoused theory of action" was clearly communicated through her talk and written unit skeleton. Such theory involved a vision of teaching global climate change in the context of a conducive learning environment rather than an avenue for heated argumentation and debate.

In the preceding development of emerging themes, it was apparent that Cherry stressed critical thinking as an essential element of a climate for learning. Critical thinking, according to her, enables students to filter information from vast resources, especially the internet. Cherry emphasized the importance of letting students explore on their own, with the teacher as a guide, to learn more about global climate change; this is consistent with constructivist-based pedagogy. As Poole (1995) explained, students who explore and interact with the various resources are in effect, active participants in knowledge construction. It is also important to note that Cherry maintains a critical stance with regard to the sources of information on global climate change. She claimed that she reads printed materials carefully and with an open mind. Gee (1996) discussed how cultural models play a significant role in attributing meaning to the world. In Cherry's case, her model of simplified world is mediated by her personal background as a scientist. The cultural model she employs when reading materials dictate that they ought to be based on 'credible science'. Gee further noted that cultural models are learned from interactions with other members of a social group. Hence, having been a member of the scientific community herself, Cherry's cultural model of reputable sources of information reflects an orientation towards objective, and peer-reviewed material.

The opening narrative illustrates how Cherry was "turned off" with global climate change being presented as a whole doomsday scenario. Cherry is definitely not building an ark for her survival. She still holds on to her conviction that using crisis-based forecasts in discussing global climate change does not help in solving the problem. It only encourages complacency and an Epicurean attitude. As Cherry noted: "It makes people feel like, 'Well, if we're all gonna die tomorrow, why should I care? If the Arctic is already defrosting and we're all gonna drown, then I might as well drink out of this plastic bottle…Eat, drink, and be merry 'cause tomorrow we're all gonna die'." (Interview #2, lines 255-257) As an alternative, Cherry believes that teaching is an important means of developing informed citizens who could make wise decisions and choices that affect their environment.

Narrative 2: The Case of Eddie

Eddie is a naturalist, a person who has the heart and affection toward plants, animals, the rainforest, and other living organisms. As a young child, he wanted to be a zoologist. This ambition grew from watching Discovery channel episodes of scientists jumping out of the water with sharks and dolphins. Eddie's love for living organisms can be seen in his recollection: "Like if we had to read a book, I always read a book on some type of animal or something or what not." (Interview #1, lines 149-150)

Eddie's warmth and caring attitude for plants and animals did not diminish as he matured. He is currently an undergraduate student pursuing a degree in science education at a university in the Southeastern United States. True to his passion, his major is biology. In college, he initially enrolled in the Ecology program but later shifted to Science Education. This change in major did not mean a decreased interest with life and nature. Rather, Eddie wished to share the experience and the excitement of biology with his future students.

The researcher had the opportunity to gain insight from Eddie's experiences through interviews and informal conversations. It was evident that there were important themes (in italics) that emerged from the interviews and other evidence, as will be discussed in the subsequent sections. Appendix A2 provides a summary of the emerging themes and categories elaborated in this case. Eddie's personal and academic background shaped most of these conversations, which were focused on his beliefs about global climate change. At the start of the present study, Eddie was asked how he defined global climate change and this was his reply: "Climate is always changing but I mean I would assume that its, 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." (Interview #1, lines 34-38) Explaining further about earth's historical record in relation to global climate change, Eddie said: "I mean I believe that we've gone through multiple climate changes like the earth freezing over and you know, become really cold and the dinosaurs died off and heating back up and what not. There have been periods of like mass destruction to the environment of what not. I guess meteor impact or what not." (Interview #1, lines 54-57)

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." (Interview #1, lines 83-85) Eddie noted that for humans, the issue of global climate change has been a subject of argument. Eddie specifically noted that politicians are dragged into this hot debate to protect their interests. According to Eddie, these politicians are basically divided into two camps, those who believe that humans are harming the environment and those who don't believe this to be the case.

Eddie's *life with global climate 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. Eddie explained: "My mom, my parents spent, mostly just my mom, pushed me like she's always been really in helping animals. I guess one of her things, I guess she kind of helped me have that view that we should try to help everything and stuff." (Interview #1, lines 108-110) His mother's moral support for his schooling was evident when Eddie continued: "I mean my mom just kind of supported me. She always, I think it's my teachers that developed me to want to be involved in animals and stuff 'cause they would like show pictures of like the rainforest and stuff like that. But then my mom always encouraged me to be a part of it. She wanted me to do what I wanted to do so she'd always be supportive." (Interview #1, lines 130-133) Eddie, when he was in either 3rd or 4th grade, told his mother he wanted to be a zoologist and do things like the ones he watched on Discovery Channel. His plans were great. Eddie had this to say: "I've said gonna be like a zoologist and study that for a few years and I was gonna retire from that and herd sheep or something. Like I had a whole mindset of working on animals from the wild, I guess." (Interview #1, lines 152-154)

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. For Eddie, such passion from teachers ignited his zeal and interest in studying further about the environment of living organisms. Eddie explained: "I know that like I had a teacher that, I just actually had her six years or something, every year for like six years. And she always makes us do projects on stuff on like just different environments and different types of animals. She usually made us pick animals that were endangered like dying out or what not. And she, we also did projects on countries normally like you know, so much of the countries we normally pick like an exotic type country. I don't know why. And so we would always have to do research on these animals and these countries. From that like we would learn about the destruction of rainforest is happening 'cause we'd do projects about the rainforest or the coral reefs. We would get all kinds of information from books and online and stuff about how this is happening." (Interview #1, lines 121-132) To add more to this kind of academic engagement, Eddie always read a book on some type of animal and shared it with the class.

Eddie entered into another chapter in his life, with the beginning of his college education. This was when he really embraced the idea of being an activist. His interest in activism was related to his desire to go out and help save the environment, find new species of animals, or save the rainforest. Eddie entered in the ecology program of his university but later shifted his major to science education. What drove the change in major? Eddie reasoned out: "It's just like I don't think I can devote my time to that. And so I think now instead of being complete activist that need to do rallies and stuff that I'm willing to give maybe money towards people to do that but I'm not really wanting to do that myself. I don't know." (Interview #1, lines 111-116) The preceding statement clearly shows Eddie's desire to contribute to the causes of environmental protection. With regard to his changing of his undergraduate major, Eddie explained that he wanted to pursue ecology and help in actual scientific research but he "just don't feel like having the ability to devote himself as much anymore to one particular thought all the time". Explaining his decision to shift to science education, he had this to say: "The science life is kind of boring to me. It seems like a lot of time, computer, reading, stuff like that. It's not like all the excitement that it shows you on TV. You don't scale out and see great white sharks like jumping out of the water and stuff. You're probably on the laboratory room most of your time. And I just didn't see like something I want to do. I still enjoyed science. I still enjoyed the learning of it and what not, as well. So I'll teach it. I think that way I wouldn't be forced to have to study forever. I could just learn about it. I can experience and pass it on to another generation." (Interview #1, lines 169-175)

Eddie had research experiences in the ecology department, which he connected to issues of global climate change. He recalled his exciting and rewarding experience of working with teachers in doing a guided research study about upside down jelly fish, collaborating with a professor. The study was centered on the effect of water temperature in the gulf coast on jelly fish reproduction. (Field notes, 10/05/09) Explaining the research study, Eddie said: "It (jelly fish) changes into a different stage or whatever and it can't really do that at a particular cold environment and a particular warm environment. The Gulf region, particularly for a water source that big, is actually very consistent in temperature. I don't know, 20 degrees Celsius from 10, 20. And it was then as, he was showing me that he was kind of concerned that as the water temperature is starting to kind of get warmer in that region that it could be devastating to certain life forms. They go to these different stages of development and how they have, if it has. For some reason, when it gets warmer these things don't like to turn into their next stage. They stay how they are until they die." (Interview #1, lines 299-309)

The theme, *life with global climate change*, emerged from the different experiences shared by Eddie. This theme does not denote living in an environment experiencing global climate change. Rather, it signifies Eddie's lived experiences and how these influenced his understanding of global climate change. Likewise, life with global climate change, as an emerging theme showed how Eddie's passion for living organisms, became a significant part of his growth and development.

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 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. This belief was supported by his statement: "I think students should be able to, or should learn that we as humans are making choices daily that could or could not be affecting our I guess our future, our climate and maybe how our climate could be affecting like, how we've lived in the future. I mean it's kind of hard to go into like, 'What are we doing now that's affecting global climate change?'" (Interview #2, lines 637-640) The preceding statement shows how Eddie values the need to let students understand global climate change in order to make choices and personal decisions.

According to Eddie, choices about what action to take are a personal matter rather than decisions driven by external influences. This thought emerged from Eddie's reaction to TV commercials about the environment, or endangered species. To him, commercials that use endangered animals to solicit assistance tend to show only the worst situations and not the whole picture. 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 in my nature. I don't like being forced to do anything. I do almost anything if you just let me do it but just don't tell me I have to as kind of. When I see those polar bear videos or like the other videos, 'Send money to Africa to help these kids or something'. It's just something. I would do that if I just came across it on my own sort of but being there put it on my face it kind of makes me withdraw from the subject." (Interview #1, lines 266-271) It may seem that Eddie is reluctant to contribute to noble causes for the environment but that is certainly not the case. As a matter of fact, Eddie shared earlier that he is willing to financially contribute to endeavors related to environmental protection. In his recollection about elementary school, Eddie remembered being an active member of a club that raised money to adopt and protect endangered animals. Hence, it can be gleaned that Eddie's personal responsibility for the environment emanates from his own volition and not from any external influence or pressure.

Eddie extended his point of not wanting to be somewhat forced into doing things about the environment. To Eddie, personal choices are not made based on alarm and crisis. When shown a YouTube video clip about the impact of melting Arctic glaciers on polar bears, Eddie felt that the video only tried to sway him with what the characters were explaining. He added: "I guess they're trying to dramatize what's happening, trying to show that I guess, once again try to maybe reach us emotionally by like, showing us something. So maybe we've never considered before and we look at this and like, 'Wow, that's a lot.' It seems like such a huge deal. I guess they're, to me it seemed like they're trying to shock us, trying to just open our eyes to something like that. It's probably their way of maybe impacting me, the guy who lives in [State] who doesn't really live anywhere around there and doesn't live by the ocean. My house isn't close to the water so it's not like it's. I guess that was their way of trying to show us how much is going on and how scary it could be or something." (Interview #2, lines 248-255) Eddie compared the video clip about Arctic polar bears with the second YouTube clip that showed four climate scientists explaining how computer-based climate models have inadequate capabilities in making predictions. To Eddie, the second video clip did not "preach and tell" him exactly what he should believe. He explained that while watching this video he felt more like a participant in a lecture focused on basic principles in science. Likewise, he claimed that the clip's goal was to reiterate the view, "You can't believe everything you see." (Interview #2, line 389)

In another interview session, Eddie shared his insights about the two scientific articles that he was asked to read. In this particular conversation, Eddie related the impact of alarmism to what actions governments in the world take to reduce the negative effects of global climate change. The following excerpt (Interview #3, lines 371-392) demonstrates Eddie's point:

Eddie: And the fact that we according to him (referring to Lindzen, the author of one of the articles), we went into the, or the Kyoto agreement. People went into it almost blindly. You know with very little evidence I guess supporting why we should join the Kyoto agreement.

Researcher: So you mentioned that the three arguments presented by the author stood out for you. Why did that make an impression on you?

Eddie: Because it kind of gave me a number to look at. It gave me something to look at that was I guess substantial to why somebody would believe or believe against global climate change. But when he presents it I mean how he presents makes it sounds really insignificant I guess. That stood out to me.

Researcher: You also mentioned that the reference to the Kyoto agreement resulted in countries following blindly this treaty. Why did that make an impression on you?

Eddie: It seems like a very big deal. I mean because it's such an influence as economies and like how you know if we're, if America is in the Kyoto agreement then another country isn't, the other country can just mass produce things better, more than we could I guess. And out compete us globally and the economy because they are not worried about putting all these regulations on how they make their products I guess.

The excerpt of the conversation shown above demonstrates Eddie's belief that choices are not to be made as a result of an alarm from scientists. In this case, governments coalesced to curb the impact of global climate change through the Kyoto Protocol. But Eddie noted that not all countries are signatories to the said treaty which then causes an imbalance and unfair economic practices.

Informed citizens make personal choices based on an understanding of the nature and consequences of these decisions. Eddie stressed this point by saying: "I guess an informed citizen can help out. Like having people that are informed; that can understand how to maybe treat the environment properly." (Interview #1, lines 514-516) For example, Eddie explained how an informed farmer would look at facts and figures about pesticides and their production rates. He described this farmer as someone who would really understand what he is doing and how sustainable farming practices could affect not only his living but everything around him. To Eddie, this farmer would be better prepared to make decisions on whether or not to use pesticides. The principle that Eddie was trying to explain was that an informed person has the ability to make decisions in all aspects of life as a result of an understanding of the consequences of his/her action. Eddie specifically mentioned these decisions as matters pertaining to recycling, energy conservation, and forest preservation. In effect, Eddie believes that the personal role of making informed decisions could result in necessary changes that correct the mistakes of past generations.

Eddie made a choice to be prepared as a high school science teacher. In light of Eddie's conversations with the researcher about global climate change, it is evident that 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 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.” (Interview #1, lines 372-378) The above remarks show that Eddie is cognizant of the characteristics of middle school students in regard to issues about the environment. To him, the teacher’s role in presenting information about global climate change is based on a developmental progression. To illustrate, Eddie believes that a simple introduction to the concept of global climate change in middle school would be necessary because the students at that age tend to be “mostly under their parents’ wings”. In this way, Eddie explained, the teacher would get the students thinking about the subject matter. Then in high school, Eddie feels that teachers should engage students in more open discussion and decision making activities since they “start to become like their own person who speak for themselves”.

According to Eddie, a mediator presents information without pushing students to a specific position. This is one of Eddie’s characterizations of the role that a teacher should assume when presenting the topic global climate change. In one of the interviews, Eddie clearly stated: “I don’t think that our role should be to form the students to one side or the other. It shouldn’t push them to one side or the other. I think our role as teachers that matters is just provide the information in a way that the student can start forming their own opinion on the matter. And in that way that they’re more informed citizens of the world when they start hearing information about the matter. They're willing to find out if one side of the story is correct or maybe not correct, one side of the story is something that they can really believe in because they believe that it's true instead of just, 'My teacher told me that this is happening so I got to believe what, this is happening '. I think it's just our role to be like a mediator and just provide information to the students." (Interview #1, lines 459-469) 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." (Interview #4, lines 434-437) It can be seen from the above remarks that Eddie values the teacher's role as mediator who does not push a personal set of beliefs about global climate change on students. For Eddie, this point does not mean that a teacher abandons the duty of presenting concepts with passion and conviction. Rather, according to Eddie, global climate change as a presently hot topic should be presented in class with the purpose of allowing students to explore and examine for themselves the evidence that supports or refutes the issue.

Eddie also believes that a mediator creates and fosters a neutral ground for debate and argumentation. Eddie constantly mentioned in his conversations, with the researcher, the need to engage students in making arguments that are supported by evidence. Debate is one of the specific approaches that Eddie thought would stimulate students' thinking about global climate change. Eddie's interest in this approach might have been influenced by his belief that the topic global climate change is a familiar topic that often polarizes people. In view of this, Eddie claimed that teachers as mediators are like debate adjudicators, as evidenced by his remarks: "It should just, I mean I think it's just our goal as a teacher to be a mediator or like during a debate, just kind of the guy that proposes the questions. And then they, the students are like debaters picking one side and they're trying to support one side. That's how I view it and if I were to be teaching global climate change then I would definitely try to do it that way." (Interview #2, lines 609-612) Eddie shared some specific points about how to foster a classroom environment for debate and argumentation. He explained the importance of making students feel that there is no right or wrong side of the debate. By doing this, Eddie opined: "Students don't feel pressured to believe whatever like the same whatever I'd think I might believe in I guess. I would try my best not to like pick a side and hopefully the students wouldn't know that I believe a certain way or another way. I'd try to keep that from the classroom which may be hard. But I would like to try to make it feel like it's a neutral ground that students can say what they want to say. And I would like for the students…are not feeling pressured by the class majority to believe one way or another. I would just try to make them feel neutral so they could talk and feel how they want to feel. And then maybe later after they've already gone through and done stuff through the neutral ground then have maybe like a debate like I was saying before where they can start arguing against each other and then that way they can get arguments from other students that can help foster their views." (Interview #3, lines 562-576) The above statements show that Eddie views a neutral ground to be something that a teacher establishes in the classroom that allows students to think, express, and talk freely without the fear of rejection. Eddie emphasized that the structure should not be like a grand political debate where emotions and differences of opinions dominate the environment.

Eddie further explained how in letting students argue during classroom debates, it is also important for the teacher to consider a progression of steps. To illustrate, Eddie recommended starting the debate with the broad topic of global climate change. By this, Eddie elaborated: "They have to argue for or against global climate change as a broad topic but the side that they were less supported on like the one that I believe the last sentence. They had just to form an argument for that so that they could maybe counter argue themselves and their own matters so they could have a more educated decision on the thing." (Interview #2, lines 667-670) Then, Eddie suggested that after considering global climate change as a broad topic, students could then explore specific aspects of the issue. Eddie noted that this could be aided by scientific articles to serve as sources for information supporting various arguments. A word of caution regarding sources of information was expressed by Eddie: "But I think it's our job as a teacher to also show the students how to find stuff that's credible, that we shouldn't just throw them on the internet and say, 'Good luck'. It only uses the Wikipedia thing. Try to use something that is not biased, just information that you could go one way or another." (Interview #2, lines 682-687) Eddie believes that engaging students in debate and argumentation about global climate change gives them "a chance to see both sides of the story", allows them to "make an educated decision", and helps them "strengthen or change the way they think about things".

A mediator uses a reasonable approach. Eddie's use of the phrase, reasonable approach, stemmed from his elaboration about the scientific articles about global climate change that he read. Eddie explained: "It (Article 1) didn't depict it (referring to global climate change) as like to me there was a, you know we need to act now like there's a huge alarm we need to be worried about it but I think it took kind of a reasonable approach to it and try to just show that there is a human influence on what might be happening out there because it's just trying to relate statistical data together and help show that it's just not the natural trend that they've seen." (Interview #3, lines 80-85) Then, Eddie contrasted this approach when he recalled a movie that he had watched and said: "Al Gore (referring to the video, *An Inconvenient Truth*) seemed like it was doom and gloom and how we're just going to, if we don't stop now the world is going to just go. But in here it seems like he's (author of Article 2) taking a more reasonable approach. Al Gore's is definitely more scary than this one which like I said the whole point of this one is to disprove the whole scary scenario that makes sense." (Interview #3, lines 290-297) As shown in the above excerpt, Eddie claims that teachers should not employ a "doom and gloom" tactic when presenting global climate change to their students. A reasonable approach would be, according to Eddie, to present adequate information to the students "so that they (students) can start making the considerations of maybe their lifestyles or how they want to live. So they can I guess, would have more informed reasons for what they're doing." (Interview #4, lines 569-571)

The following presents a portion of Eddie's unit skeleton which he submitted as part of his course requirements. The unit skeleton was designed for a high school biology class. The complete unit skeleton assignment of Eddie can be found in Appendix G2.

> *Course Description:* This unit is intended for high school biology. The unit fits into the biology class just after a general understanding of matter and energy flow. The learners should be able to access and use Internet sources.
> *Overview:* This unit allows students to assess the indirect impact humans have on coral reef ecosystems. The students will study the effect of various stresses on corals, specifically heat stress. Then the students will correlate coral bleaching to an overall damaging of coral reef ecosystems due to the removal of key organisms in a local nutrient cycle.
>
> *Standards (Content and Characteristics of Science)*:
> SB4. Students will assess the dependence of all organisms on one another and the flow of energy and matter within their ecosystems.
> SCSh6. Students will communicate scientific investigations and information clearly.
>
> *Learning Outcomes:* Students will understand that human activity can indirectly cause extreme damage to ecosystems as a whole. Students will understand that in ecosystems, there are key organisms that can have an overwhelming impact of its ecosystem.
>
> *Guiding Questions:* What human activities, if any, have the greatest indirect effect on coral bleaching? What role does coral play in its coral reef ecosystem?
>
> *Summative Assessment:* The assessment for this unit is for the students to propose a plan to reduce their impact on coral reef ecosystems and to give valid scientific data that backs

their proposal. This assessment would have students to use scientific information about possible causes of global warming and link that knowledge to how and why corals may become bleached. It is acceptable for students to produce an argument that is supported by valid scientific data against human involvement in global warming, but these students must provide other reasoning for coral bleaching. Grading for this assessment should emphasize the content standards of human impact and relationships of organisms the most. So, the most points should be awarded for having a valid argument for either side with multiple fact based points. Points should be awarded for using credible resources and correct interpretation of data. Then points should be awarded for linking their arguments to the bleaching of coral.

Learning Experiences:

1. Guided discussion: The guided discussion should ask questions such as: What are the students' beliefs on global warming? What do the students believe as the causes of global warming? What do the students believe to be credible resources of information about global warming?
2. Review of resources: Have the students criticize in groups or individually various resources of information. The students should be provided with resources that are misleading in the fact that they seem like good honest sources of information by either the name of the website of the way the information is presented.
3. Internet exploration: Once students are able to criticize a web source you should instruct them to go to the following website: http://www.exploratorium.org/climate. The students should be instructed to explore the website and give a quick critique of the site, verbal or written.
4. Lecture: After the students have had an introduction into coral bleaching, lecture on the overall effect this has on the coral reef ecosystem as a whole. Point out the various reasons for coral bleaching such as water temperature or exposure to various acidities. Then show a before and after video on the destruction of this environment
5. Lab (only when applicable): Acquire some coral species that one could observe. The lab would be done as a class with all students having a few duties such as recorders, time keepers, and cleaners. The students would observe and draw the coral at its healthy state. Then the students would be instructed to raise the temperature of the water by a few degrees Celsius. After bleaching has occurred, the students would observe and draw the coral again.

The researcher had the opportunity to let Eddie explain the process and content of his unit skeleton. Eddie chose the topic of coral bleaching for several reasons. First, coral bleaching is a specific aspect of the broader topic of global climate change. Eddie felt that he needed to develop a lesson that had a narrow, simple, and direct focus to make it interesting to students. Relative to this, his second reason for designing a plan about coral bleaching was his desire to select a unique topic for students to learn. Eddie "thought probably most people, at least in the biology department, probably wouldn't immediately go to coral bleaching". (Interview #4, lines 60-61) The third reason that motivated Eddie to develop a unit on coral bleaching was his personal experience in guided research about jelly fish. Eddie further explained: "The professor, Dr. B*** worked specifically with like I guess the jellyfish. But he's done a lot of work with corals. So I guess he would like to talk about the corals and stuff and relate you know what's going on with those and while we would do stuff with the jellyfish. And I thought that was probably where I got most of my ideas for the coral bleaching part. And felt like it was a good idea to start talking about it." (Interview #4, lines 183-192) This experience of studying jelly fish reminded Eddie of the possible impact of human activities on coral reefs either in the United States or elsewhere in the world.

Eddie prepared the unit skeleton shown above on the basis of the guidelines and rubric discussed in class. Aside from following the guidelines, Eddie shared two important factors that he considered while writing the unit skeleton. It must be noted that the students in the class were only given a week to design unit skeleton about global climate change. The two important factors that Eddie considered in writing the unit skeleton were: (1) State standards aligned with the lesson; and (2) use of hands-on activities. Eddie felt that it was necessary to find standards that fit with the lesson of global climate change. He browsed the internet and found the most appropriate state standards, as shown in his unit skeleton. The standards for biology content and characteristics of science guided his writing of the unit skeleton. When the standards were identified and aligned with the content, Eddie believed that it was essential to engage students in hands-on activities. He elaborated on this by saying: "I wanted to bring like a hands-on effect into the, like a lab or whatever so the students could maybe witness how global climate change could like affect something. And so I have a lab set up to where we would actually bring in these like upside down jellyfish (but corals will be used in the actual lesson) from one of my old professors. He works with those. And like the students could actually see the temperature change really affects like how they morph into their new figures. I wanted to show like a hands-on effect of something so that maybe students can see like a real life example." (Interview #4, lines 86-94)

Given the limited amount of time to work on the unit skeleton, Eddie admitted having encountered some tensions. According to him, there were two specific tensions that arose: (1) ethical dilemmas on the use of organisms in the classroom; and (2) anticipated conflicting views about global climate change. The ethical dilemma surrounding the use of corals in the classroom emerged from his desire to engage his students in a hands-on activity that demonstrates coral bleaching. In one of the learning experiences listed in the unit skeleton (Item 5), he planned to bring to class live corals to show to the students. In the lesson, he planned to ask for sample organisms from his former professor. The tension involved Eddie's concern that the laboratory activity could possibly result in the death of the corals as an evidence of the negative impact of rising ocean temperature on marine organisms. The concern he had would be the reaction of his students in seeing living organisms die in the pursuit of scientific understanding. Interestingly, Eddie dealt with this tension by limiting the number of corals to be involved. Hence, he planned to let the students form big groups with each member having a specific task. As the list of learning experiences in the unit skeleton shows, Eddie planned to engage his students in exploring the topic of global climate change through discussions, laboratory work, and web-based activities.

The second concern of Eddie was the anticipated conflicting views of his students regarding global climate change. He explained: "I know there are students that are going to come in. They're going to be completely anti-global warming or they're going to be completely for, you know, believe in it in like we need to get ready for it, like the world's going to end. And that was one of the tensions I was trying to figure out how I was going to get that both sides like both types of students and then like even the students that are just coming in with just open minds, how was I going to get all of them ready to do everything that I wanted them to go through." (Interview #4, lines 250-256) It is apparent from this excerpt that Eddie was anticipating that students would likely have different views that might impede their learning of the concept. He felt that having students come in and argue for or against global climate change would result in tensions in terms of allowing them to understand the more specific issue of coral bleaching. He addressed this tension by giving the students more freedom when exploring the internet for information about global climate change. Through web-based exploration, Eddie planned to have students read critically information on websites and make an assessment of the information that they would present.

As part of the unit skeleton assignment, Eddie prepared a concept map showing the main topics associated with coral bleaching and global climate change. The concept map was a representation of the main topic he developed in the unit skeleton. Figure 2 shows Eddie's concept map.

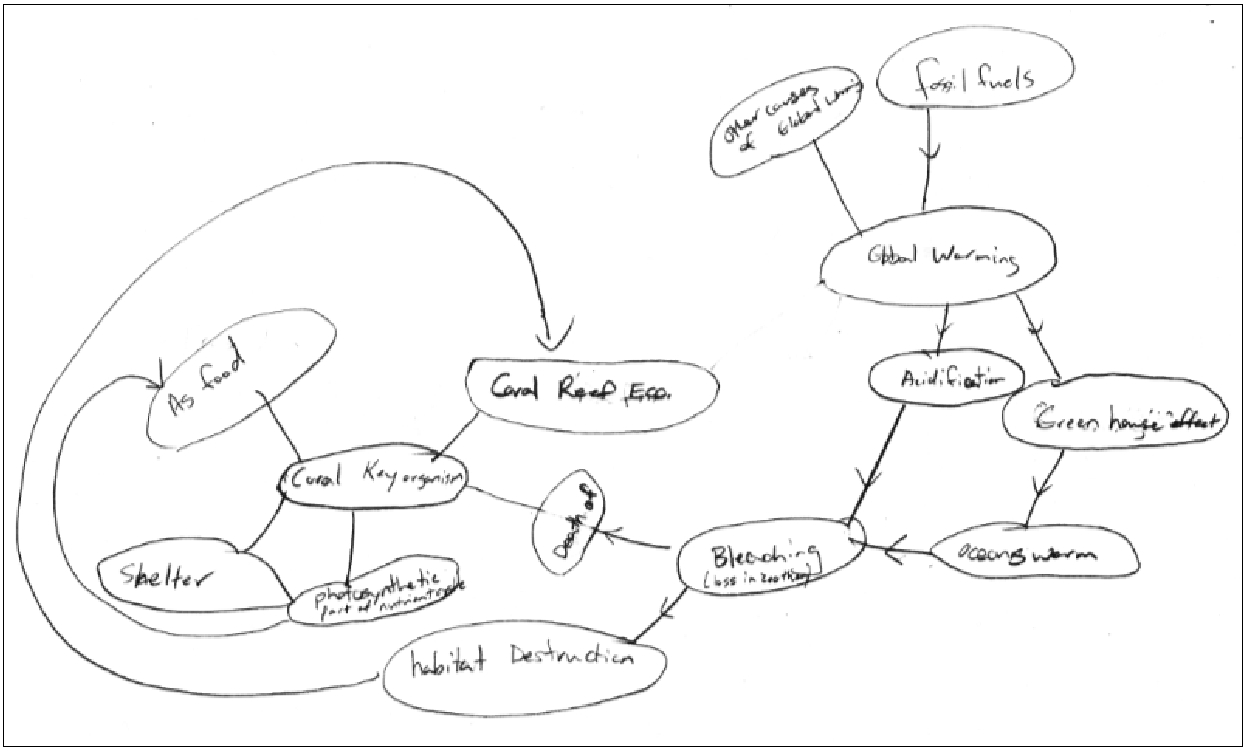

Figure 2. Concept Map of Eddie about Global Climate Change

The concept map prepared by Eddie as shown in Figure 2 was based on the main topic that was developed in the unit skeleton. Hence, the map shows Eddie's organization of the concepts related to coral bleaching in the context of global climate change as the main topic. After preparing the map, Eddie had the opportunity to share it with his group mates. In explaining his map, Eddie said: "Mine was about, I kind of specify and I went to coral reef bleaching and kind of span after there, to global warming and how that causes coral reef bleaching due to like greenhouse effect and rising temperatures in water. And then use that to discuss another topic of key organisms and what the coral, as an overwhelming part in a coral reef system. I mean once it's gone, you know, nothing else really survives there. So the two main topics that talk about really were organism relationships and human activities that cause global warming that affect coral reef ecosystem." (Group discussion, 10/05/09) This excerpt points to Eddie's belief that the seemingly irreparable damage caused by global warming to coral reef systems would be devastating since other marine organisms depend on these systems as a habitat. Eddie admitted that linking the concepts with propositions posed a challenge to him. During his discussion with the researcher about his experience in preparing the concept map, Eddie revealed: "If you look at this you can tell that I believe that global climate change is happening or at least there are the factors that people have preached global climate change and were talking about." (Interview #4, lines 358-360) He continued: "It shows that I believe there is a human involvement in global warming. And that's what I guess I view by looking at that." (lines 386-387) These portions of Eddie's statements show that he recognized the role of human activities in global climate change. To him, writing the broad phrase, fossil fuels, would readily make students think of human endeavors that increase global warming.

Throughout the different interviews, Eddie shared some interesting ideas with regards to the potential role of global climate change, or any socioscientific issue in the context of science teaching and learning. Eddie definitely believes that socioscientific issues, such as global climate change, play an important role in the science classroom. To illustrate, Eddie explained: "I think that like especially in biology, global climate change is something that needs to be mentioned because it's, I mean, as a, if you look at the standards, we have to talk about different environments and you know, animal life. If you're talking about the environments, you can talk about barometric change due to the climate and like it definitely goes together. Global climate change has such an effect on living things." (Interview #1, lines 406-412) The researcher inquired from Eddie about specific approaches in fostering an understanding of socioscientific issues that he had in mind. Eddie constantly mentioned three important approaches. First, Eddie believed that debate and argumentation would offer a good way for students to examine both sides of the issue being considered. The structure of such debate though was not intended to have winners and losers but rather an examination of the issue in the context of science learning. Second, Eddie believed that outdoor activities provide real-life experiences for students when investigating socioscientific issues. Specifically Eddie noted the importance of having the teacher walk through the natural environment together with students. The third general approach involved an intensified community participation of students. To Eddie, it was essential for students to increase their interactions with members of the community and to conduct community-based activities.

Eddie's case was developed on the basis of three significant themes: life with global climate change; making choices; and teacher as mediator. These themes were explained in the preceding sections together with related categories. Eddie's life with global climate change, as shown by his various interactions with his parents, teachers, and peers, can be closely associated with Gee's (1996) notion of cultural models. Through the years, it can be deduced that Eddie has developed a simplistic model about his environment. The data suggests that Eddie is clearly a biocentric individual. His love and warmth of living organisms have drawn him to pursue ecology and science education in college. Through interactions with his parents, teachers, and peers, Eddie consciously and unconsciously created a cultural model that guided his thinking and perspective of socioscientific issues. Making choices, as an emerging theme resonates well with Gee's notion of cultural models. Choices are made by individuals on the basis of the established cultural model that they adhere to. The cultural model of a teacher created by Eddie appeared to be someone who mediates when dealing with socioscientific issues in the classroom. As shown in his unit skeleton assignment, Eddie mediated students' learning of coral reef habitats and the impact of global climate change on them through a laboratory experiment. He intended to allow students to understand the concepts and implicitly show that urgent action is needed to preserve coral reefs. This clearly reflected a biocentric ethic influenced by the ‘cultural model’ he established. Case-based issues, a thematic area in Zeidler et al.’s (2005) model framework for socioscientific issues instruction, also provides an explanation for Eddie’s notion of teacher as a mediator. In case-based issues, students are engaged in experiences about socioscientific issues that develop both the intellect and a sense of character. Zeidler et al. (2005) assert that these experiences focusing on multiple perspectives might confront students’ entrenched beliefs and hence, stimulate an analysis and consideration of the evidence surrounding a socioscientific issue that requires the teacher to mediate learning.

Eddie cares about his environment. In the opening narrative, he was described as a naturalist. His attachment to the environment will likely be carried over to his future science classroom when he embarks in the teaching profession. Eddie certainly shared his vision of how he will engage his students in examining their environment and in examining socioscientific issues, like global climate change. He stressed the point that integrating the topic of global climate change in the biology classroom is essential because the impact of this phenomenon reaches animals, plants, and humans. To engage his future students in socioscientific issues, Eddie explained: “I’ve been trying to think of a way that I could have students do more I guess around their community, maybe just more of an outside type classroom. I feel like if they did do stuff in an outside environment activities; they could start seeing with their own eyes, maybe global climate change. Or they could start at least to feel more concerned about the environment around them to learn more about the issue on their own. Or at least consider or care more about their community and their environment around them so that when we do talk about it in class they will be more willing to learn I guess or more willing to participate." (Interview #4, lines 649-657) True to his passion as a naturalist, as revealed in his remarks, Eddie envisions an outdoor classroom that walks his students through the natural environment.

Narrative 3: The Case of Summer

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. Her travel to France went far beyond seeing the Eiffel Tower and visiting art museums. This travel actually provided her a foreign perspective of sustainability and environmentalism. In sharing her experiences, Summer recalled the people's sense of environmentalism and said: "We go to the grocery store, where now…you would just give out all these plastic bags in grocery stores. And in France you just have to have a bag or a book bag. They actually charge you per plastic bag that you buy at the store. You pay 10 cents for a plastic bag. And I suppose car use; there are more bikes in European countries. We're so dependent on automobiles." (Interview #1, lines 195-199) In her recollection, Summer compared American and French ways of buying groceries and modes of transportation. She made this comparison in the context of her conversation with the researcher about global climate change and the experiences that shaped her views about this phenomenon. Also related to her observation of the French people's environmental consciousness were the seemingly sustainable communities that flourished in France's rural areas. Summer noticed 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 these simple products." (Interview #1, lines 223-224)

Another facet of the French way of living that Summer observed was the people's sense of community and local participation. Summer noted that Americans tend to shy away from openly discussing topics about family, politics, religion, and other issues of general concern. In contrast, Summer recalled: "Their (referring to France) public is more outspoken and active. There's more activism in that European country obviously. They're pretty vocal. You always say, 'Don't talk sex, politics, or drugs, or whatever it is, or marriage or have love, whatever it is.' But they talk more. You see them at tables and they just discuss everything." (Interview #1, lines 201-205) It appears from this excerpt that Summer noticed the active participation of the community members in discussing issues, including those pertaining to the environment, that concern everyone. Summer believed that such participation in healthy discussions increases personal awareness of local issues which in turn incites action.

As an introduction, Summer is enrolled in a Master of Arts in Teaching (MAT) program in a university in the Southeastern United States and is expecting to obtain her certification to teach secondary science. She finished a degree in geography. In her current program, she anticipates teaching earth science, chemistry, or physical science. As discussed in the opening vignette, she had the opportunity to have an academic experience in France during her college years. Summer grew up experiencing the joy of the outdoors through gardening. Summer shared this joy with her family and attributed her childhood experiences to her understanding of the natural environment.

The researcher had the opportunity to talk to Summer about global climate change – her beliefs and thoughts about this environmental phenomenon and the place of this in science teaching and the classroom. There were many interesting ideas that Summer shared through the interviews, unit skeleton, and group discussion. The succeeding sections provide a synthesis of the themes and categories that emerged from the analysis of data. Appendix A3 provides a summary of the emerging themes and categories elaborated in this case.

During the initial interview, 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 I guess contribution to this global change. I do recognize that but I’m not exactly sure completely on the, I guess contributions of humans. But I think that there’s something to do with the urban and rural conditions. I would say as a global climate change what we hear now is just the general increase in climate and I guess decrease of ecosystems because of that or change in the ecosystems.” (Interview #1, lines 52-58) Summer specifically related global climate change with changes in ecosystems as a result of a “domino effect”. According to Summer, changes in ecosystems result from rising temperatures and changing physiological and structural responses of organisms.

Summer further explained her views regarding the evidence of global climate change by saying: “I do believe that the earth is just the way that we’ve lasted. There is a cycle of nature and that’s just how nature works. But then I do certainly believe that the increase spike in temperature does have something to do with human contribution, our consumption of items, industrialization.” (Interview #1, lines 81-84) Based on this statement and other evidence, it appears that Summer attributed global climate change to natural and anthropogenic processes. When referring to natural processes, Summer elaborated that nature undergoes cyclical patterns and that any disruption to these patterns poses a problem. To her, human contributions to global climate change emanate from “abuse and overuse of nature”. Summer further explained that humans tend to contribute to an imbalance of nature through industrialization. Developing countries, Summer noted, struggle to achieve the standards of highly-developed countries such as the United States. She emphasized her concern that the pursuit of industrialization by countries throughout the world is a major contributor to various problems with pollution.

Summer shared some specific insights as to the development of her beliefs about global climate change. As gleaned from the initial interview, Summer mentioned that she grew up in an environmentally-conscious family. She admitted that the subject of global climate change was not a “big topic” for her until she attended college. 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 at the university, she remembered that there were a lot of academic experiences that exposed her to the topic of global climate change. In her stay at the university, Summer remembered doing small-scale research studies in ecology, weather map interpretations in atmospheric science, and class discussion of coffee production and rainforest destruction in geography. Likewise, she recalled having professors who showed passion and conviction about global climate change, but did not turn the conversations into a great debate. She said that these professors presented the facts and worked around the science involved.

Media also played a role in influencing Summer’s way of thinking about global climate change. Aside from television documentaries, global climate change is often portrayed in cartoon or commercial programs. According to Summer, 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". (Interview #1, lines 274-275)

Summer also recalled having read resource materials that were associated with global climate change and the environment, in general. She had the opportunity to read materials about weather, coffee production, and Brazilian rainforests. One of the books she read that had an influence in 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 discussed global climate change and its impact on humanity. In a more detailed description, Summer explained: "But I thought it was a nice read. It was entertaining. But he just, he was so shallow for me and just what he. The data he presented is kind of like he went to a corner and then stopped. And he showed these graphs. They were pretty graphs. But it just didn't really. It was just way too persuasive for me. But I wish I could look at it again. But it was just really, really short just really without any depth in my opinion. It was just, I don't know. I didn't, it was certainly my least favorite of those books in just presenting a wide, a bigger idea of where it all came from. It was basically just pure entertainment in my opinion. I mean it was, I don't know. I just thought the graphs were so simple and it was just. I like, I certainly like it. I liked the pictures, something like that, too. But it may have been 50 pages or something like that. And, but yeah. I didn't think. When I had, when I read it, I remember thinking that it was just fluffed in a way to me. It just wasn't enough. It just kind of seems like he just only showed what he wanted to show. But I've had to look at it again to really get a better example for you. But I liked it. I mean it definitely made me more aware of different things that were contributing, going around the world. So I think from a novice perspective, it would be a really great introductory book to show someone or to watch the movie just to kind of like get them engaged in it." (Interview #1, lines 372-387) Summer felt that though the materials (book and movie) were entertaining the information presented tended to be one-sided. The interesting graphs and pictures added to the convincing power of the book and movie. However, Summer claimed that seeing the movie and reading the book opened her mind to thinking more about the catastrophic effect of global climate change and left her wondering how her actions could lessen these consequences. When asked about the way the learning materials she read and saw shaped her perspective on global climate change, Summer replied by saying that they made her "more knowledgeable" about the topic. Likewise, reading and watching these materials made her less apprehensive in discussing a seemingly untouched subject. Summer added: "But I certainly think that I, if I were to take a poll that said, 'Is global climate change happening?' I would say, 'Yes.' So that's probably something that has changed just getting more knowledge of the information you come across when you hear about global climate change. So it kind of made me say, 'Okay, that makes sense'." (Interview #1, lines 432-435) From these remarks, it is apparent that Summer originally had apprehension about discussing global climate change because of her limited experience and academic engagement with the subject. But to her, having a clear understanding of the subject was like a pass to some forbidden zone of public opinion.

The central topic discussed by Summer was global climate change. It was evident that there were important themes (in italics) that emerged from the interviews and other evidence, as will be discussed in the subsequent sections. As discussed earlier, 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 was particularly speaking about the nature of everyday chemicals she consumes or buys. To explain further, Summer said: "I have this general, much better awareness of my personal health now than before – where my products come from and what's in my products. What chemicals are there? And in a weird way it's kind of a relation to global warming to me just this general umbrella of my contribution and its contribution back to me." (Interview #1, lines 296-300) Summer believed that reducing carbon footprint starts with an awareness of the impact of common substances on personal health and the environment. In particular, it was evident to Summer that the topic of global climate change is often discussed in the context of one's contribution in preventing its negative consequences. To her, the public tries to encourage everyone to reduce carbon footprint in every possible way. Summer pointed out: "You just can't cry all day. You have to find some kind of solution." (Interview #3, line 235)

Summer shared a specific way of reducing one's carbon footprint. She specifically recommended a reduction of demand for products that require the emission of greenhouse gases or cause environmental problems. The following is an excerpt from the second interview (lines 94-107) where Summer explained the nature of her personal questions regarding the YouTube clip about global climate change. The short video clip was focused on the negative impacts of global climate change on Arctic sea ice and polar bears.

Summer: How can you as an individual make a change to prevent global climate change? And how do corporations, larger scale, change their ways to prevent global climate change?

Researcher: You are interested in questions about individual responsibility. Can say more about that?

Summer: I guess, your consumption, use of your, reducing you 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, the gas emissions and all that 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.

Researcher: Very interesting point. What would that possibly do when there is a reduction of the demand?

Summer: That would hopefully make a slow decrease in the production of the corporation, their amount of pollutants. It would spread to the people around you and you would make an impact by your reduction of your consumption and your individual changes could spread.

Global climate change, Summer contended, is a popular topic that is often presented in media and academic settings in different ways. These differences range from limited information to distorted scientific views. 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: "It's not just something that direct, but something just general placement and conversation in a sitcom 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. So 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." (Interview #1, lines 274-278) The preceding excerpt illustrates Summer's belief that television shows provide limited information about the subject. Likewise, Summer noted some limitations of the movie, *An Inconvenient Truth*, by saying: "It was almost like he deleted some data or something. It was just really on the very, the very tip of what he could go into. And he only, he did it on such a larger scale that I just thought that, I don't know. It was just kind of just, just a fluffy way to say it's warming and this is what's going on…But it was the fact that he showed, he showed spikes in temperatures and then now this is what's gonna happen. He only presented just one side." (Interview #1, lines 394-401) Summer noted from the movie that Al Gore only presented the worst situation about global climate change. According to Summer, 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. To Summer, the graphs and visuals were impressive but the presentation lacked the necessary information that would have added to its convincing power.

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. Summer added: "He has years of experience looking at the data and his education, his exposure to things and exposure to the opposite side of the debate too." In elaborating more about Summer's point of view with regard to reputable sources, she opined that when searching for or presenting information on global climate change, it would be a wise move to consider data and explanation from agencies such as NASA, NOAA, and EPA. To her, television sitcoms are poor sources of information. Summer extended the application of her concept of reputable sources by explaining that students should be prepared in understanding how to filter information from scientific articles and media sources. Summer stressed how important it was for the teacher to guide students, helping them to be critical of the sources they read, particularly the internet. Summer believed that "they (referring to the students) just have to understand the difference between a peer reviewed article and *The New Yorker*. And just to understand how scientific journals are reviewed and edited and scrutinized is important just to understand the nature of science in general.” (Interview #3, lines 592-596)

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. Based on the experiences she shared, it was apparent that she was persuaded by her teachers through the manner they presented information and engaged the class in discussions. Summer recalled that she witnessed the enthusiasm of one teacher when she had to perform a small-scale research study in ecology. Likewise, she claimed that her perspective on global climate change was partly shaped by her professors’ conviction and passion about the subject. When asked about why it was essential for her professors to be persuasive in class, she replied: “They want the students to gain this passion. I mean it’s necessary for them because they feel that they wouldn’t be doing their job if they weren’t presenting the material as facts. And you know they’re presenting their research, too. It’s not just what they read. But I mean it’s not necessarily an opinion to them. It is a fact. So it’s how they present it.” (Interview #1, lines 333-341) Based on her remarks, Summer claimed that her professors’ desire to persuade was rooted from their passion about the subject and their perceived responsibility to have their students develop the same passion. It was evident that she attributed her courses as significant opportunities for a transfer of learning, mediated by the professors’ presentation of facts derived from their research work.

Summer felt that persuasion involved a significant emotional dimension. To illustrate, Summer had the opportunity to watch YouTube clips, read scientific articles about global climate change, and explain her insights about these materials. After watching the YouTube clip depicting the impact of global climate change on Arctic sea ice and polar bears, Summer explained how this example persuaded her more than the one that showed scientists discussing the limitations of climate models because it made a “very strong emotional connection”. She added: “It definitely makes a profound statement not just like thinking about it globally but thinking about specifically in the Arctic.” (Interview #2, lines 64-65) In elaborating more about the emotional tone of the video clip, Summer continued: “I think it is emotional because I think about the animals, the species that are up there in the Arctic…It’s funny to say, you cry when animals die in the movie before you cry when a human dies in the movie. That is the emotional part when you talk about the animals that are dying out there in the Arctic region because of climate change.” (Interview #2, lines 73-79) The above remarks showed that Summer recognized that her being persuaded resulted from the general tendency of humans to be easily affected by images of animals undergoing stress or dealing with dangers. When asked why persuasion was important in light of what she watched, Summer replied: “If you are standing on a side, it is important to have persuasion if you hold a side and then debate.” (Interview #2, lines 371-372) In another setting, Summer read two scientific articles about global climate change. One of the articles discussed the physical and biological impacts of global climate change while the other one discussed some of the flaws of alarmism promoted by climate scientists. When responding to these articles through the subsequent interview, Summer explained that the article dealing with impacts of global climate change was not powerful enough to persuade her because it did not have an emotional tone. The content of the said article was limited and similar to a lot of the rhetoric she had heard about global climate change.

Although Summer felt she enjoyed engaging in discussions that persuaded her, she refused to be persuasive. She was specifically referring to not being persuasive as a classroom science teacher. It was evident that Summer could be persuaded by persons that exhibit a passion for the subject matter, reputable sources of information, or emotionally-influenced materials, but did not want to use persuasive skills as a teacher for two reasons: (1) nature of the topic; and (2) contextual factors. The first reason stemmed from Summer's claim that teachers should not be "filling students' minds with opinion". Summer does not wish to persuade her students because of the debate associated with global climate change, and not because she refuses to teach the topic. As a matter of fact, Summer recognizes the relevance of the topic to students' learning. She added: "I certainly won't want to be too overly persuasive of a religious side or political side. Nor should it be anything that is supersensitive. It's not like a uniform consensus that's going on. Maybe in the future it will be understood in the textbook as fact. But right now it's still a debate. So, it is just as interesting as any current event that's being discussed on the news or anywhere. Students should be informed about it." (Interview #2, lines 456-461) These remarks show that Summer believed that students need to be informed about global climate change but not with persuasion because of the uncertainty that is still prevailing. She recognized, however, the importance of including this topic because students see or hear information from media sources. Likewise, she felt that students who are informed about global climate change could be given the chance to reflect whether or not their personal actions contribute to this phenomenon. The contextual factors that Summer pointed to as reasons for not being persuasive included the type of school and parental influence. In probing what she meant by the type of school, the following excerpt from the interview (Interview #2, lines 477-491) showed her views:

Researcher: Okay. You also mentioned that in the school setting or in science curriculum that it should not have this strong emotional or persuasive component. What do you mean by that?

Summer: I suppose that, it's hard not to have a persuasive component with global warming. I just think that since it is still such two strong sides. I guess it depends on where you're teaching to, if you are in the rural or in the city, if you are in the research triangle. It depends on where it is and how progressive your school system is. It is important not just to project belief in children because they are so impressionable that is would be good to just offer them these things. Maybe offer them both sides and let them make their decision. May that's the good thing about what the model and observation movie showing, just kind of make your decision about it.

Researcher: It's interesting that you made a distinction of context of instruction with the rural, urban, city or some other place. What do you mean by that?

Summer: Certain places are more progressive in belief, in research and exposure to the outside world than. Like you are in the north (state) mountains not much have known about the global debates and if you're in a more urban, research, a lot of strong universities around, you are kind of more exposed to that, the different ways of thought and more exposed to a global debate I suppose.

The above excerpt revealed that Summer recognized students' tendency to take what their teachers present as the only truth; hence, she felt that when discussing global climate change, both sides should be given equal importance. Aside from this, the excerpt showed that Summer believed that school environments, policies, or cultural background of the community might influence whether or not socioscientific issues could be integrated in the science curriculum.

Parental influence might also be considered a contextual factor as shown by the following remarks of Summer: “First of all you have to be careful about the opinions of the parents and not being too persuasive…I mean there’s two sides to the issue. You definitely want to be careful about just giving them the information and just telling them to believe it. And you know you want them to form their own opinions. And if their parents have passionate opinions on whether they are on either side that you addressed it. So you also want them to not just believe everything that they hear or see.” (Interview #3, lines 557-568) Based on the above comments, it is clear that Summer acknowledged the right of parents to monitor what their children are learning in school. She further claimed that some parents do not want their children to be indoctrinated with beliefs that differ from their own, especially in such a controversial topic. It can also be gleaned from the quote that Summer desires to display: (1) respect for parental authority over their own children; (2) tact in dealing with controversial issues; and (3) high regard to the possible legal implications of her actions in the classroom.

Summer prepared a unit skeleton as part of the requirements in the course. She designed learning experiences about global climate change that could be integrated into a physical science course. The complete unit skeleton assignment of Summer can be found in Appendix G3. The following excerpts show several portions of the unit skeleton that Summer developed.

> *Course Description*: The global climate change unit is intended for a middle school Physical Science course. Prior to the lesson, I would anticipate that the students have a general understanding of the idea of greenhouse effect from the previous year in Life Science class. I anticipate that the students will struggle with distinguishing between reliable sources on the internet. This unit is not intended to be persuasive towards or against the global climate change debate, but is intended to present the students with knowledge of the issues and prepare them as literate and informed citizens so that they may be able to engage in conversations about the issue or understand the underlying principles of the debate when they come across it in real world settings.

In this unit, students will examine the scientific view of the nature of matter, particularly describing the movement of particles in solids, liquids, gases, and plasmas states (S8P1). The students will also describe how the behavior of light waves is manipulated causing reflection, refraction, diffraction, and absorption (S8P4) through various states of matter that exist on the planet ad how this interaction of light and states of matter play into the global climate change. The students will use will use tools and instruments for observing, measuring, and manipulating equipment and materials in scientific activities utilizing safe laboratory procedures (S8CS4). In doing so, the students will also use appropriate tools and units for measuring objects and/or substances (S8CS10). This unit will also enhance reading in all curriculum areas by discussing books or articles (S8CS10d) and establishing context (S8CS10d). (Note: Codes in parentheses refer to the number of each state standard as it appears on the website.)

Following the unit, the students will have a stronger understanding of reliable versus unreliable sources. The students will have stronger map reading skills and be able to identify the important map components. The students will understand how light behaves against the different states of matter. In application to global climate change, the students will understand the interaction between global states of surface water and the rise of global temperatures in the global climate change debate. In addition, the students will be more informed citizens about global climate change and be made more aware of personal ways to reduce their carbon footprint.

Essential Questions:

1. What are the different forms of water on the planet and how are they distributed globally?
2. What is the correlation between heat and the phase changes of water?
3. How does light respond to the different phases of matter (solid, liquid, gas)?
4. What are greenhouse gases? How are they produced and consumed? And why are they important?
5. How is sea-level affected by increased greenhouse effect?
6. How does a rise in sea-level affect global climate change?

Focus Question: How does the increase in global average temperature affect the global state of water? Based on your knowledge of the behavior of light against water and solid water (ice), how would the daily radiation of the Sun’s heat across the globe impact global climate change?

Performance Assessment: Following the unit, the students will be given a short answer quiz with questions covering all the major topics covered in the unit, but in a more narrative, application sense. An example question may be: “Please describe how sunlight behaves against the frozen ground of Antarctica as opposed to the warm ocean waves of the Bahamas.” or “Please describe how greenhouse gases in the atmosphere could increase global average temperature. Please depict a possible scenario.” Or “Please explain how ocean temperatures can affect global sea-level.” These forms of questions on an assessment allow the students to reflect on the understanding of global warming and the topics covered in their own words and give the teacher the opportunity to see if the students understand the main concepts and topics discussed in application sense. Students will be given a rubric prior to assessment so that they understand the key component to our discussion and can brainstorm their experiences.

Learning Experiences:

1. Investigative Cartography: The students will begin by being introduced to several different global maps and asked to analyze sea-surface temperatures across the globe. This activity will familiarize the students with important map reading skills and terminology. The students will be able to easily recognize, read, and refer back to maps relating to the global climate change debate when involved in classroom discussion and scientific discourse with peers outside of school, which is an important skill for a science literate society. This activity will also introduce the students to key points in the global climate change, such as the distinction between average temperature and daily temperature and climate.
2. Microwave Activity: The students will conduct group experiment where they will observe the behavior of light, or microwaves, on two states of matter, liquid water and ice. Although it only takes an increase of a few degrees Celsius to melt the ice and water about 80 degrees Celsius to boil, the students will observe that the water will boil in less amount of time than it takes the ice to melt.
3. The Earth's Energy Balance: This activity will involve an interactive classroom discussion and group drawing. Perhaps the drawing could be on the overhead, Smart board, chalkboard, or a large roll of paper posted on the wall. With a discussion between teacher and students, we will discuss the balance between incoming sunlight energy (solar energy) that heats the earth and outgoing heat energy (infrared energy) that cools the earth, paying close attention to the reflection or absorption of light on water in the form of clouds, ice, and liquid water plays into the cycle. As we discuss, students will take turns drawing the different components of the cycle. We will then go into discussing the greenhouse effect and how increased CO_2 absorbed in the atmosphere from human activity can increase temperatures. The students will also be encouraged to draw man-made CO_2 pollutants such as cars, or power plants that contribute greenhouse gases. Following the discussion, the students will have a creative and informed picture of the cycle that underlines the global climate change debate.
4. Finding Reliable Sources: The students will be introduced to literature from news sources, such as this NPR article about the impacts of rising ocean temperatures (http://www.npr.org/templates/story/story.php?storiId=12431939) and asked to reflect about their opinions of the article in a journal format. In addition, students will be asked to retrieve and reflect on two additional sources of literature, either in agreement or in opposition to the article topic. With request and guidance from the teacher, this activity will help train the students in critical research values and how to judge a reliable source for support.
5. How Can YOU Do Your Part: Because of the nature of the unexpected unit, I believe that the point is to make the students aware of global climate change, but also to send the students home with a mission to be more environmentally conscious. After a

> discussion about carbon footprints, the students will be asked to come up with ways that they or their household can reduce their carbon footprints.

The unit skeleton shown above depicts how Summer organized a middle school physical science course that integrates global climate change as one of the topics. When the course professor introduced the assignment, members of the class engaged in group discussions in preparation for the unit skeleton. Summer joined a group with another preservice teacher who was intending to prepare a unit skeleton in physics. As they discussed in their group, both agreed that global climate change appropriately fits into the thermodynamics section of earth science, physical science, or physics courses. (Field notes, 09/28/09) Summer ended up writing a unit skeleton for a middle school physical science course. The following discussion presents some important details about the content and process associated with the unit skeleton as gleaned from the final interview with Summer.

Summer remembered that she was working on a unit in one of her classes in school about phase changes so she thought of trying to "lean towards that subject in order to keep on researching ideas to teach the information to students in order for them to have a general understanding of the energy balance within the world". (Interview #4, lines 18-22). In relation to the course assignment, Summer planned for learning experiences that linked the topic of phase changes with the underlying ideas and principles of global climate change. Hence, as shown in her unit skeleton, Summer decided to develop the lesson on global climate change in light of students' understanding of water in its different phases. She further explained: "I could use the different phases of water as in liquid water, ice and essentially those two. And I think possibly you know just general heat of the atmosphere would have corresponded to vapor but we didn't really go into that with the unit. So I used the energy balance, the graph, in order to kind of introduce the general concepts. My essential questions did focus on the different forms of water on the planet. So we started looking at graphs that we got. I'm not exactly sure where I got the graphs but they would be digital graphs that they would look at; and the distribution of water globally and then we looked at how water responds to light with the microwave test. And so you know and ice melts slower or heats up slower than water because it reflects or reflects a lot of water off the ice. And so we kind of use those analogies to kind of put together their idea of how globally with energy balance cycle how all those ideas worked together into you know creating their own ideas of how incoming radiation would respond to ice and then liquid water and then you know how increased global temperature may correspond to higher sea levels." (Interview #4, lines 26-44)

Summer also explained that she selected the topic of energy balance to provide middle school students with a basic level of understanding rather than going into the deeper concepts of pollution and global climate change. The unit skeleton attempted to highlight the concept of light and heat and their influence on earth's climate and energy balance to sustain life. The lesson also showed that a disturbance of the energy balance could result in negative effects. In talking about these negative impacts of a changing climate, Summer included a learning experience that required students to read an article about the effects of rising ocean temperatures in order to prepare them for filtering the information they obtained about global climate change.

As Summer worked on the unit skeleton assignment, she considered three important factors to make the learning experiences meaningful to students. Three factors included: content, emphasis on inquiry and critical research values, and relevance to students' citizenship roles. In explaining content as one factor that she considered when writing the unit skeleton, Summer said: "I certainly thought that I needed to cover content as well as doing global climate change."

(Interview #4, lines 133-134) Summer further explained: "This (referring to the unit skeleton) was meant for a physical science class not an earth science class. So they would have a general understanding about the whole greenhouse effect from a life science class. So my main idea was to cover phase changes. It would be a part of phase change unit. And so global warming would not be in a physical science textbook so I felt like I still needed to cover content even though this was an unexpected thing that students should just be educated about." (Interview #4, lines 140-146) Summer's concern as revealed from the above excerpt stemmed from her belief that content should be covered hand in hand with the usual curriculum content which students are required to read from their textbooks. Summer also emphasized the importance of covering the necessary content in order not to lag behind in covering the sequence of topics. Summer felt that the pacing of lessons in middle school was necessary in light of the standards to be addressed and the high-stakes tests that students would need to take.

The second factor that Summer considered was the emphasis on inquiry and critical research values. In explaining this factor, Summer pointed out that she envisioned learning experiences that were interactive, and involved some sort of guided inquiry. To be more specific, Summer added: "I tell them the scenario and they have to show it on the chart based on what they know about phase changes. And of course you know seeing their own information you know making their own inferences. And so you're not looking at the maps and finding a reliable source was a big one and I guess training the students in critical research values. And then you know they're citizens of this country how they can do their part. I mean I feel like every, I had a few, five learning experiences for this unit but I feel like they all, nothing was too repetitive. They all had their own intention with each activity." As her unit skeleton illustrates, Summer planned for students to engage in guided inquiry activities designed to develop their understanding of global climate change, ocean temperatures, and earth's energy balance. It must also be noted that Summer stressed the point of developing critical research values. By this, Summer was referring to how students find reliable sources of information so that they do not follow blindly what other people say. In her unit skeleton, item 4 on the list of learning experiences specifically required students to read articles, reflect on these, and then make judgments as to the veracity of the information presented.

The third factor that Summer pointed to was the relevance of what she was planning in her unit skeleton to the future citizenship roles of the students. When asked what she meant by this, Summer responded: "Well that was kind of the how can you do your part you know, how just starting at an early age you know how they can do little things environmentally and things like that can you know progress through their ages. You know that's not necessarily in my opinion being persuasive as a teacher but just kind of making them think. You just be a good role model and they can build upon those skills and see the value of you know recycling. 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." (Interview #4, lines 205-217) In the unit skeleton then, Summer included an activity (item 5) that encouraged students to reduce their carbon footprints. From her explanation, Summer believed that though schools are not avenues to persuade students to do things or to believe claims, they should serve as starting points for them to learn for themselves how their personal choices and actions affect their own environment.

Preparing the unit skeleton posed two challenges to Summer. These tensions included the anticipated differences in students' opinions, and the limited number of teacher resources. But according to Summer, she managed to address these tensions. In explaining how the students' opinions posed a tension, she said that the lesson might appear to them as forcing a specific side of the global climate change debate. Summer was concerned that the lesson might trigger a controversy as a result of the different positions of the students and their parents. Summer further explained: "Because everyone has a freedom to think as they think and that's their choice. And I don't think it's, I don't think anything is wrong with being environmental so that wouldn't bother me at all of just being a flaming environmentalist whatsoever. But you know there's still that political undertone with global climate change. And even though so you know I don't know cause I would say political with global climate change or more just kind of then when you think about it environmental is political but I don't necessarily feel like it's something that I need to shy away from." (Interview #4, lines 261-268) Based on Summer's remarks, it appears that her concern stemmed from that fact that middle school students might be unnecessarily engaged in a political issue to which their parents might object. In addition, Summer felt that the learning activities might be construed as a promotion of environmental activism. Though the unit skeleton was intended as a part of the usual science subject, she felt that global climate change was a political issue and that discussing this in class might be interpreted as openly pushing students into a specific side. When asked how she would address this tension, Summer elaborated that she anticipated that at the beginning of the unit, she would engage the students with a discussion stressing the need to respect everyone's opinions, the importance of maintaining an open mind, the local effects of global climate change, and possible ways to avert disasters.

The second tension that Summer encountered was limited number of teacher resources that could be consulted for direction. More specifically, she explained that she could not find models of great lessons that would have provided some guidance for the unit she developed. She pointed out, however, that she was able to address the problem of inadequacy of resources by browsing internet sources like the EPA website. With the resources she obtained, Summer managed to synthesize these and integrate them into her unit. She recalled: “I had to compile my own from different ideas and just filling in the gaps with others.” (Interview #4, line 319)

Figure 3 shows the concept map that Summer prepared. The concept map showed how Summer organized the main topics related to global climate change as reflected in her unit skeleton. She was in a group of four students when she prepared the concept map. After completing her map, she had the opportunity to share it with her peers. In explaining her concept map, Summer told the group: “Well, my unit is about, I’ve kind of stuck to the idea of phase. I’m doing phase changes for my overall unit so I kind of thought about just doing how the incoming sunlight is affect our sources of water on the globe and so. And then I discussed the energy, earth’s energy balance and how additional man-made carbon emissions kind of offset that balance of the greenhouse effect. And so I have just incoming sunlight, the normal balance, ice and water. Some is reflected. Some is absorbed by the oceans. Ice and rising temperatures and then rising temperatures could cause melting of the ice which could go rising sea levels and which could go back to sunlight absorption. And that also could go to a rise in average temperature and additional greenhouse gases trapping more heat, rising temperature. So mine was basically talking about just the phases of water on the planet and how that alone is affected by any kind of rising average temperature and then you know, briefly talked carbon emissions.” (Group discussion, 10/05/09)

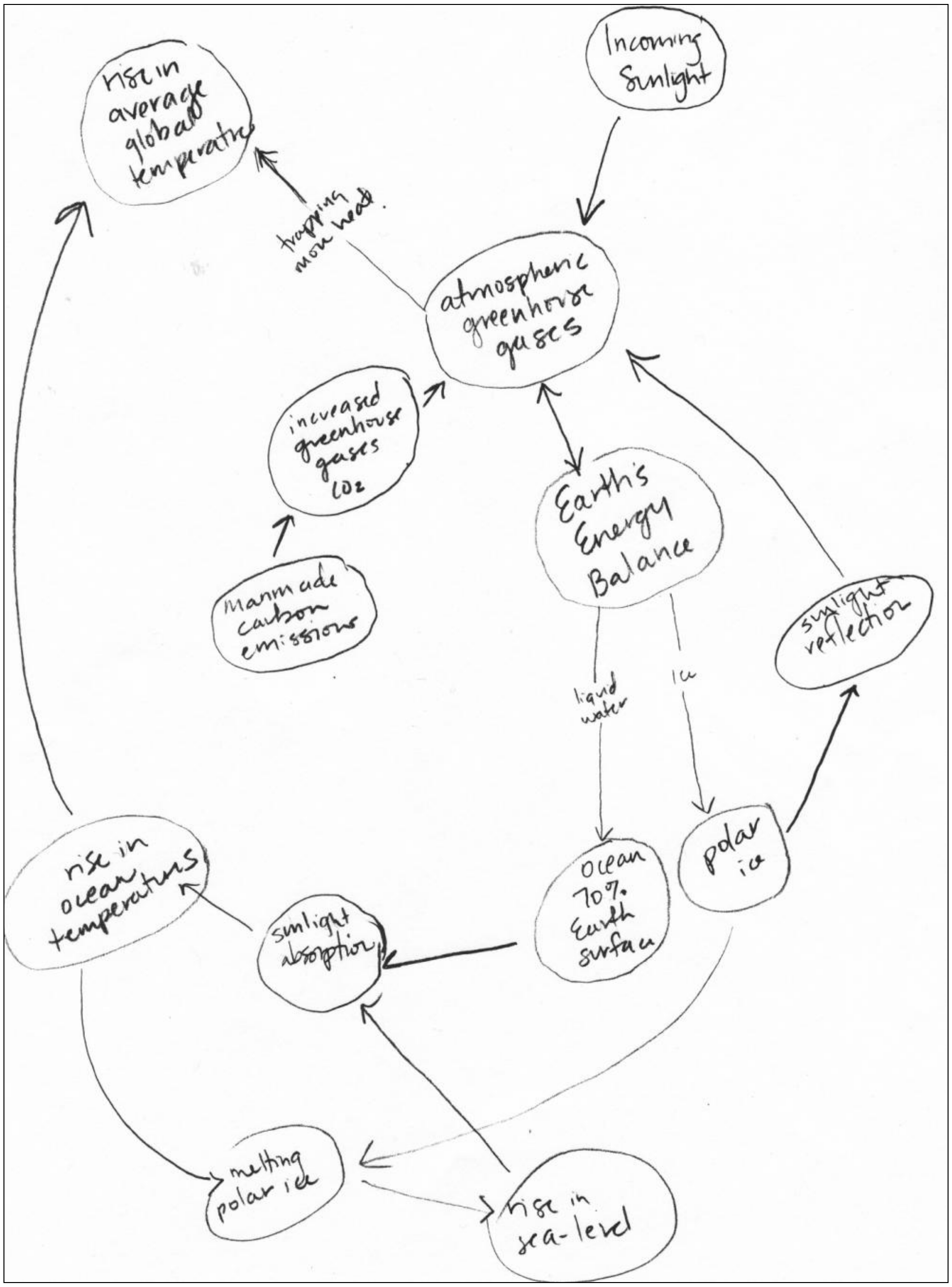

Figure 3. Concept Map of Summer about Global Climate Change

During the final interview, Summer shared her experiences of preparing the concept map. She specifically mentioned that the time constraint and too much content posed a challenge to her. Likewise, she admitted that her concept map lacked linking propositions that would have helped her show a more organized representation of global climate change. As shown from the concept map, Summer believed that global climate change posed negative impacts to humanity. Likewise, she attributed intensified greenhouse effect to human contribution.

The three emerging themes from the case of Summer included: reducing carbon footprint, authority matters, and to be persuaded but not persuasive. The theme, reducing carbon footprint appeared to be a commitment of Summer as shown by her inclusion of this idea in her unit skeleton. As an individual, she specifically mentioned that a reduced demand of manufactured products that are harming the environment might in fact reduce the production. The specificity of this one personal measure of reducing carbon footprint closely relates to Argyris and Schön's (1974) espoused theory of action. In her own way, Summer has an espoused theory of action which focuses on reducing the high demand of a questionable product in order to help the environment. The final decision of not having the demand is an extension of her espoused theory of action. With regard to the theme, authority matters, Summer placed importance on the dimension, source of knowledge, as a key criteria 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 (2000) 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. In addition, Summer's perspective on persuasion aligns closely with Gee's (1996) explanation of cultural models. Summer emphasized that a teacher should not be a persuasive person because the act itself tends to sway students towards a specific position on the issue, without allowing them to explore for themselves. As Gee posited, a cultural model results from a constant interaction with the group in which a person is a member. Summer created her cultural model of a non-persuasive teacher. Gee opined that groups tend to create cultural models that have a unique notion of what is an 'acceptable' or 'valuable' person or action. Summer emphasized that an acceptable behavior of a teacher would be to avoid persuading students when teaching a socioscientific issue.

After completing her official academic work in France, Summer had to say 'Au revoir!' to her colleagues and friends. She brought home to the US the memories and rich academic experiences. As mentioned at the start of this case, she described the environmental consciousness of the French people. Through her trip to this European country, she was able to gain a concrete frame of reference and basis of comparison between French and American ways of living and the differences in their consideration for the environment. Now that she's back in the US, she is resolved to start a noble cause. She may not be able to initiate community gardens, local markets, and sustainable communities like those she saw in France, but she is resolved to be an excellent science teacher who will foster her students' understanding of their environment. More specifically, Summer believes that socioscientific issues, like global climate change play an important role in the curriculum. When asked about her specific approach to foster an understanding of these issues, she replied: "I suppose you would begin with an issue of humanity, in respect, respect for each other, and respect for the environment and how they all play into our responsibilities as humans." (Interview #4, lines 585-587)

Narrative 4: The Case of Vince

Green technology is a familiar term for product manufacturers that claim to be environment-friendly corporations. These green products that companies produce range from small gadgets, computers, or big appliances. The government monitors the quality of these products as shown from their labels. Vince, on his part, enjoys having a green toy. This is his motorcycle. One might classify the motorcycle in the category of green technology since it uses lesser fuel to run than cars. Vince's personal decision to drive a motorcycle instead of a car was driven by the: (1) desire to pay less for fuel; (2) joy of having a toy for fun; and (3) 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: "And 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." (Interview #1, lines 188-189)

Vince is in the Master of Arts in Teaching (MAT) program in science education at a university in the Southeastern United States. He has a psychology background and is currently preparing to teach high school biology. He grew up in a suburban community near his home state's capital city. In his recollection, Vince told the researcher that he was nurtured by a family that helped him develop critical thinking about societal issues.

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." (Interview #1, lines 42-43) Elaborating on his definition, Vince emphasized that the limitations of recorded data on global temperatures poses a problem and opens a "window for debate" about global climate change. Vince's perspectives on global climate change were influenced by his personal experiences and by the people around him. For example, Vince 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. So they showed weather balloon experiments and going around countries to defend in universities and forums, giving speeches talking about the results of these data that he'd been collecting for 30 years." (Interview #1, lines 134-139)

Another source of influence came from Vince's family and friends. According to Vince, his friends tended to engage him in healthy discussions regarding relevant issues, which at times pushed him to think deeply about these. Vince's family also helped him to think critically and to be tolerant of other people's viewpoints. He felt that he enjoyed growing up not having been spoon-fed every idea and belief by his parents and siblings. Rather, Vince appreciated his family for teaching him to recognize other people's opinions and that it was alright to have one's own opinion on something. His family also helped him develop critical thinking, which to him was important in making informed decisions. 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 a drought in (state) that means that global climate change is happening. But once I had been or been made aware of the issue or this idea that global climate change may be occurring I thought, 'Well would that help to explain drought in (state)?' And that's the extent to which I would say that they're related in my mind. I mean it would be a good thing to think about." (Interview #1, lines 291-295) As the preceding remarks suggest, Vince did not directly associate the drought with global climate change, although it did make him think more critically about the subject matter. Vince felt that several factors might have caused the drought and the lack of definitive scientific explanation at that time provided him the opportunity to examine relevant resources on his own. However, Vince did not immediately use global climate change as the ultimate explanation of the drought in his home state.

It was evident that there were important themes (in italics) that emerged from the interviews and other evidence, as will be discussed in this section. Appendix A4 provides a summary of the emerging themes and categories elaborated in this case. 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 that the topic has drawn a debate among scientists primarily because of the lack of standards on methods used to investigate the issue, as revealed in the following excerpt from the first interview (lines 61-97):

Researcher: You mentioned also in your previous statement that there's this source of debate among scientists. And why is it a debate issue among scientists?

Vince: 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. And since it is somewhat of a new topic, there probably aren't as many standards for approaching as an experiment as with other topics.

Researcher: So you said there should be standards of how to test the validity of a certain study.

Vince: Sure.

Researcher: What do you mean by that?

Vince: If you have a whole study you may be conducting multiple little experiments. And I don't know this for sure, of course. But certainly you should make sure the things, that the tests that you are running are going to produce evidence that help you put together something that reveals whether it is you're actually trying to test or what your hypothesis is, more big picture. I'm not sure if the debate is whether these little tests are the wrong ones to be choosing to prove an ultimate point or whether it's just a part of a whole experiment. But I agree with you that probably having a standard for internal and external validity would probably be helpful. So there was less of a debate I guess amongst the other scientific community.

Researcher: So how do you think they would do that standardization of say experiments? Do you have any ideas to share about how they could possibly have a set standard?

Vince: I guess a lot of other fields have groups, council, or summit, or meeting of some sort where people come together and present their findings. And I don't know if that sort of thing does exist for the wide range of scientists who probably do experiments on this topic, whether it's geology, chemistry, or whatever. But you know, a place where people who are interested in this topic, whether they're for it or against it, can come together and express whatever their findings are or their feelings about it so that there's. I would say progress towards some sort of consensus. But at the same time for people who don't accept that it's even a possibility may be able to present what they've found or their doubts. And that might add some sort of strength to the whole movement.

The above excerpt revealed that Vince attributed the uncertainties about the topic of global climate change to the differences of scientists' methods and findings. It is interesting to note from the excerpt that Vince believed that a consensus might be possible to clear such uncertainties. He specifically mentioned the need for standardized procedures of investigating indicators of global climate change through presentations and intensified participation of the members of the scientific community. Vince believed that having a well-established forum for individual studies might clear the differences in the scientists' explanations of global climate change.

On a personal level, Vince admitted that there are doubts and uncertainties lingering in him because of his personal limitation of not having direct experience of doing research on global climate change. Vince believed that he might feel more confident about his positions had he done some scientific work himself. This corroborated his belief that performing scientific investigations on global climate change requires a standard method so that researchers do not simply devise experimental procedures that might skew the results.

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. He believed that a scientist's apparent authority is accompanied by a sense of responsibility and substantiated by research work.

As a preservice science teacher, Vince extended an application of the theme reliance on scientific processes to the science classroom. Vince felt that this was mostly important in preparing students to appreciate the nature of science. In explaining the role of the topic global climate change in the science classroom, Vince said: "I think it's a good issue point. What I mean by that is there's a standard that talks about issues and I think it's a perfect place for it. So there are other standards that you could address with it. But I think it's better addressed covering things like that an issue point and methods of science and perhaps experimentation, what makes good and poor types of science. Okay, use as an example or a teaching point for those things as opposed to setting up labs that have students confirm that it does or doesn't happen. Instead, setting up labs that would allow students to test the validity of the types of experiments that are being done and I think in class a similar question was asked and I think this is good for a debate topic or something like that. Basically having students be able to present their findings and present their viewpoints." (Interview #2, lines 583-591) 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, how science is a more powerful tool than just knowing what phenomena are out there, and being methodical and trying to approach situations or problems without bias." (Interview #3, lines 287-292)

Vince recognized the importance of integrating the topic global climate change in the science curriculum. Due to the nature of this subject matter, he considered it as a controversial issue which should be handled appropriately inside the classroom. 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. Vince further stressed the importance of exposing students to nature of science activities; he explained how involving students in data collection would be valuable in helping them understand and appreciate how scientific investigations function as part of the nature of science. The use of classroom debates was also dominant in Vince's discussion of appropriate teaching strategies. But having debates in the classroom, as Vince cautioned, should not be construed as having huge disagreements among the students. To Vince, 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. These entrenched beliefs, when challenged, might erupt into an unhealthy dispute, and therefore become counter-productive to learning.

Vince prepared a unit skeleton and a concept map as part of his course assignments. The complete unit skeleton assignment of Vince can be found in Appendix G4. The following shows selected portions of his unit skeleton designed to integrate global climate change in a high school biology course.

> *Instructional Context*: This unit is intended for use with an introductory high school biology class (Grades 9-10). It would be best if students already understand that: 1) the earth has a variety of climates; 2) the atmosphere is a mixture of gases; 3) human activities, such as farming and manufacturing, are powerful enough to change earth's lands and oceans; 4) abrupt changes in climate have occurred on earth before.
>
> *Alignment with Standards*:
> SCSh1. Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science.
>
> SCSh3. Students will identify and investigate problems scientifically.
>
> SCSh4. Students use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.
>
> SCSh6. Students will communicate scientific investigations and information clearly.

SCSh7. Students analyze how scientific knowledge is developed.

b. Universal principles are discovered through observation and experimental verification.

d. Hypotheses often cause scientists to develop new experiments that produce additional data.

e. Testing, revising, and occasionally rejecting new and old theories never ends.

SCSh8. Students will understand important features of the process of scientific inquiry.

a. Scientific investigators control the conditions of their experiments in order to produce valuable data.

b. Scientific researchers are expected to critically assess the quality of data including possible sources of bias in their investigations' hypotheses, observations, data analyses, and interpretations.

e. The ultimate goal of science is to develop an understanding of the natural universe which is free of biases.

SB4. Students will assess the dependence of all organisms on one another and the flow of energy and matter within their ecosystems.

SB5. Students will evaluate the role of natural selection in the development of the theory of evolution.

Learning Outcomes and Essential Questions

Outcomes:
Students will increase their proficiency using tools and instruments.
Students will apply scientific thinking to novel situations, critique/construct experimental designs used to test hypotheses, and will appropriately reference data to make predictions.
Students will assemble information from scientific literature and their own experimentation to develop an argument which defends their ideas (about climate change).

Essential Questions:
What types of evidence would support the idea that global climate change is occurring?
What kind of data would refute it?
What should evidence look like?
Strong vs. weak data
Can climate change cause evolution?

Summative Assessment: Student will work together in groups and construct a scientifically rooted argument. Drawing upon their learning about diversity and interdependence of life on earth, heredity, and evolution, students will engage in a debate where opposing sides offer support for or against the appropriateness of various experimental designs to yield meaningful data about global climate change.

Student-centered Debate

The point of this assessment is to have students take concepts and put them together to make sense. Each debate group should include positions with different responsibilities. For example, a speaker, a research team, a fact checker, etc. all of whom will need a strong understanding of the topic for their argument to be persuasive.

Additionally, it may make sense to have students draw an audience from outside of your classroom. A grassroots team could make posters or announcements – even go door-to-door to other classrooms to draw interest in the debate. Doing these things will help classroom science to reflect the world around us. The additional benefits of this type of assessment are that:

Students are called upon to communicate their ideas to others.

Students demonstrate that they are integrating the concepts of climate change by presenting information a public format.

Students and listeners become more informed and understand how the issues' relevance.

Learning Experiences:

1. A traditional lecture including information about Mendelian genetics featuring relevant vocabulary and content. Students will complete dihybrid crosses, explore common ratios and make trait predictions for offspring give random and nonrandom mating of parental generations. Selection pressure introduced.

2. Students will engage in an open discussion about the idea of climate change. The teacher should help to keep things on-topic, but not dictate the direction of the conversation. It may be helpful for the teacher to ask questions in order to illuminate the reasons behind students' views. This will hopefully hook students by presenting ideas in opposition to their own. It will also provide the teacher with a barometer for the trajectory and depth appropriate for the learning experiences to follow.

3. The teacher will provide articles form everyday news sources featuring well designed and poorly designed experiments, and have students decide and sort them accordingly. After discussing, the groups will be surveyed and a list of common positive and negative features compiled on poster paper, a whiteboard, or chalkboard, etc. This will help students to identify and support their own ideas about scientific investigation. Misconceptions make for teachable moments.

4. Students will use a population genetics website to manipulate fitness and compare how the changes they enact affect allele frequencies over time in response to natural selection. This experience should help students to understand what evolution looks like in specific populations and in response to certain variables.
http://darwin.eeb.uconn.edu/simulations/selection.html

5. Students will use the site: http://www.exploratorium.org/climate to investigate the implications that increasing global temperatures may have on the range of malaria. This experience should be a synthesis activity that requires students to connect the dots between changing global temperatures and adaptation and evolution. Extension: Students

> could be asked to imagine for example, "What types of changes might lead to a new parasite or hosts species?"

During the final interview, Vince shared his insights and perspectives about his experiences of preparing the unit skeleton and concept map. As shown in his unit skeleton, his purpose of engaging students in open discussion was to allow them to express freely their personal beliefs without fear of ridicule or reprisal. When preparing the unit skeleton, Vince considered two factors: (1) students' existing ideas or biases; and (2) essential questions. The first factor was related to his desire to understand students' ideas without communicating a message that their ideas and biases are incorrect. Vince likewise recognized the difficulty some students have in expressing their ideas to the whole class; hence, according to Vince, the open discussion would at least provide them a more relaxed venue. Essential questions were also considered because, according to Vince, they provide structure and direction. There was only one tension that arose from Vince's unit skeleton assignment; he struggled with how to balance opposing views on global climate change. To address this tension, Vince included the following in his assignment: (1) Students talk about their views in groups. (2) Students perform an investigation. (3) Students discuss their views in relation to their findings.

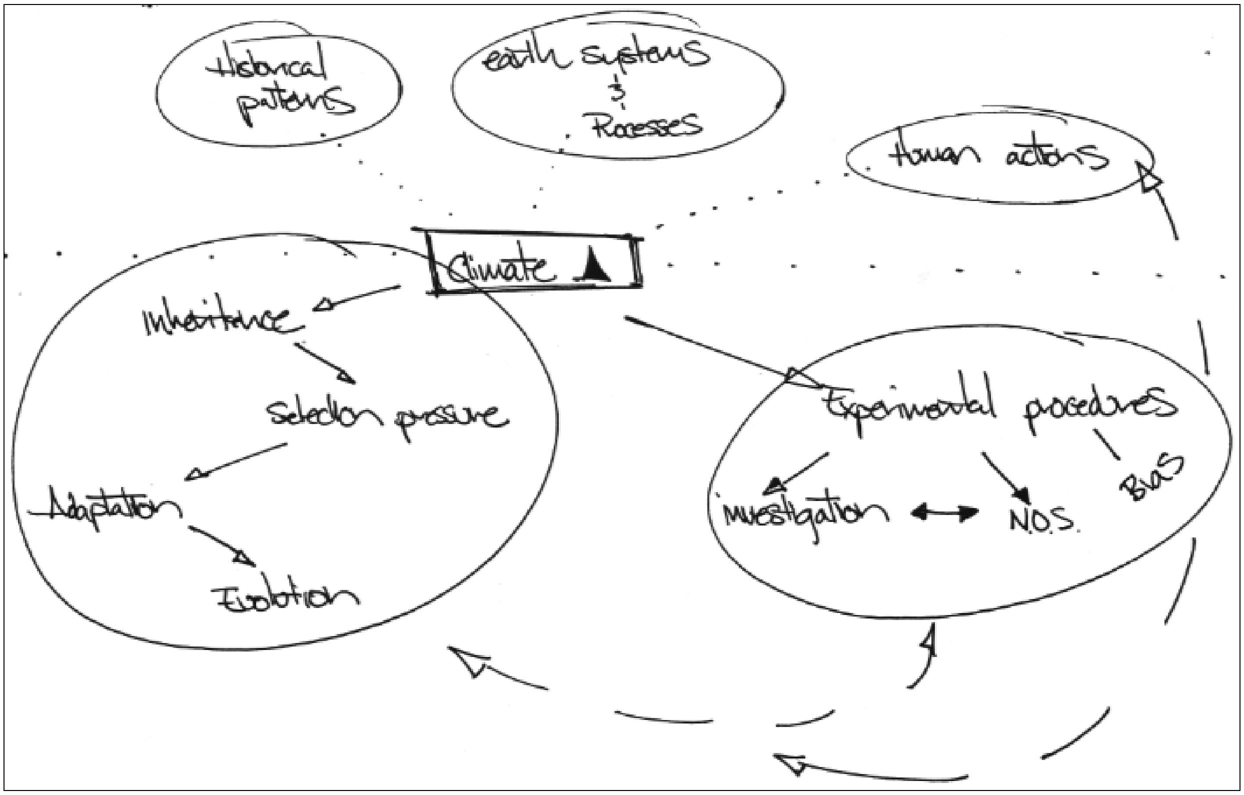

Figure 4. Concept Map of Vince about Global Climate Change

Vince's case highlighted three emerging themes: uncertainties surrounding the issue of global climate change, reliance on the processes of science, and examining 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. Likewise, Vince, having a background in psychology, invoked his knowledge of human behavior when he discussed his perspective of global climate change. To Vince, human beings tend to be skeptical of matters that do not have strong or concrete epistemological certainty. The other two emerging themes, reliance on the processes of science, and examining controversial issues, are associated with the thematic areas in Zeidler et al.'s (2005) model framework for socioscientific issues education. In this framework, nature of science comprises one of the thematic areas that shape socioscientific issues in the classroom. Vince specifically mentioned the need to understand the issue of global climate change in light of scientific investigations and concrete results from the laboratory. This idea is reflective of the nature of science issues depicted in this framework since students are encouraged to attend to details about evidence. Likewise, both Vince's perspective and the framework encourage the teacher to engage students in using empirical and social criteria when drawing logical arguments about a socioscientific issue.

In closing, Vince enjoys riding a motorcycle to satisfy his transportation needs and to be an environmentally-friendly driver. In a larger sense, Vince envisions being a driver, not just of a motorcycle, but of a classroom full of students yearning to learn. He explained that he will be the driver by creating a positive learning environment. Global climate change, according to Vince, will be a classroom topic that is one of the stops in the learning journey he has in mind. Vince has planned out things, as revealed from his remarks: "Basically walking your kids through this, how you do science, of course explanations. Do you agree? Do you disagree? What would you change about your own experiments? What would you recommend for other people in the future to do? And understand that you've only done one experiment like maybe you shouldn't form your opinion based on this either. But continue to think about it." (Interview #1, line 478-482)

Summary of the Chapter

This chapter presented four case narratives that were constructed from data collected in the study. The cases highlighted themes emerging from the storied narratives. The uniqueness of each case was evident from the way the preservice science teachers talked about their beliefs, insights, and perspectives on global climate change. The cases also revealed the differences of approaches that the preservice science teachers would employ when given the chance to teach the topic. Each case was written with the following parts: (1) entry vignette; (2) extensive narrative description; (3) closing vignette; (4) summary discussion/interpretation of themes. This case structure provided continuity for discussing the storied narratives embedded in the data.

Chapter 5

CROSS-CASE ANALYSIS AND IMPLICATIONS

Introduction

The four narratives presented in the previous chapter described the individual cases of Cherry, Eddie, Summer, and Vince in relation to their beliefs on global climate change. As shown in the previous chapter, the narratives were developed around emerging themes that illustrate the uniqueness of each case. This chapter intends to build upon the discussion of the individual cases and to provide an analysis across the four cases. This chapter is composed of the cross-case analysis, the implications of the study, and an epilogue to serve as a formal closure to this dissertation. The first section is a 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. The second section of this chapter explains the implications of the study to secondary science teacher preparation, the existing body of knowledge, methodology, and future research. The epilogue provides a formal closure to the entire dissertation by elaborating on the topic of global climate change and its place in the science classroom and personal reflections of the researcher.

Cross-Case Analysis

A cross-case analysis is the second stage in a multiple case study. In this study, there were four cases involved. Merriam (1998) argued that a cross-case analysis is necessary to build abstractions across cases. She added 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 contended 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 a consideration of the research questions posed at the beginning of the study. As presented in the first chapter, this study aimed to explore the epistemological, pedagogical, and curricular beliefs of preservice secondary science teachers regarding global climate change. This study specifically sought answers to the following questions:

1. What are the epistemological, pedagogical, and curricular beliefs of preservice secondary science teachers about global climate change?
2. What experiences influence the development of preservice science teachers' beliefs regarding global climate change?
3. How do preservice teachers negotiate and integrate these beliefs in the design of learning experiences about global climate change?

Themes, according to Stake (2006), preserve the main research questions. Based on this principle, the researcher organized the emerging themes from the cross-case analysis based on the research questions. By doing this, the phenomenon under study will be understood more clearly and binding concepts can be possibly drawn. Themes emerging from the individual cases were integral components of the cross-case analysis by serving as a basis in synthesizing the detailed description of the answers to the research questions posed in the study. The following sections explain the different themes that emerged from the cross-case analysis. Categories (in italics) that are relevant to the main theme were also included. In this way, the issues or assertions made in each theme were strengthened and clearly explained.

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. In this section, the beliefs are discussed separately as epistemological, pedagogical, and curricular beliefs.

Epistemological beliefs refer to an individual's perspectives about knowledge and knowing. In the present study, 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. Through an analysis, it was found that Cherry, Eddie, Summer, and Vince defined global climate change as a perceived increase of global average temperature resulting from natural and anthropogenic greenhouse gas emissions. Their definition encompasses the characteristics of global climate change, the apparent causes, and the present danger it poses. Their characterizations of global climate change included a change in temperature and weather change, natural process exacerbated by human activities, and ecosystem collapse in some parts of the world.

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 illustrate, Vince considered the uncertainty as "opening a window for debate". As can be recalled from Vince's standpoint, uncertainty and continuing debate on global climate change are rooted from differences in scientific investigations. Vince elaborated his point by saying: "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. And since it is somewhat of a new topic, there probably aren't as many standards for approaching as an experiment as with other topics." Vince, through his remarks, believed that a standard method of investigating global climate change would help put to rest the uncertainties that hound the issue. 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 by the researcher that an emerging theme, *information audit*, was evident as they planned for a unit skeleton. 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. Summer commented on this by explaining to the researcher how only reputable sources, like those who directly work in universities and government agencies, could persuade her. Still speaking on determining the credibility of the source of information, Cherry considered the following questions: "Who is the scientist or person that's writing this article? Is it a journalist? Is it a politician? Is it a scientist? If it is a scientist, who do they work for? Where do they get their money from?"

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 manifested pedagogical beliefs on global climate change by emphasizing the need to teach the topic using *process-oriented and constructivist approaches*. Through the unit skeleton and other evidence, the teachers thought of approaches in developing the lesson on global climate change that were consistent with constructivist epistemology. These teaching approaches included hands-on laboratory activities, internet exploration, debate and argumentation, and science writing tasks. 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. To the preservice teachers, process-oriented activities were 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. For example, Vince elaborated on his concept map the process of scientific investigation by explaining how a research design influences the outcome of an experiment. On a larger scale, Vince contended that climate scientists should come together and agree on a standard protocol for studying climate. Likewise, Cherry employed a student-centered approach in her summative unit assessment, which was designed for students to use processes that would enable them to analyze and make connections between different data sets. The following excerpt from her unit skeleton reflects the process-oriented nature of her lesson design:

> Ice cores Lab: Students investigate their own "ice cores", prepared by the teacher. Each level is of different color so students can easily distinguish between layers. Students are given an ice core and develop a data set of CO_2 levels versus time. They will not be able to capture the gas, but can measure the CO_2 levels by measuring the relative pH of each

layer. Ask the students to make a graph correlating the CO_2 levels with recorded temperatures. The teacher gives the students a graph of a different data set. Ask the students to compare the graphs, and write an explanation whether the second data set supports their conclusions or not.

The summative assessment shown above reveals how Cherry aimed to allow students to investigate ice cores to have a basis for constructing their own ideas about how scientists find clues of climate change from these pieces of evidence. Additionally, Cherry's goal was to let students simulate ice core investigation as one of the most common methods of analyzing climate data.

Curricular beliefs refer to the teachers' views and perspectives on the overall design of learning experiences, curricular goals, innovations, and emphasis. The curricular beliefs of the preservice science teachers were grounded in 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. Cherry added that global climate change has a rightful place in the science curriculum because students will always be exposed to the issue. She noted how students will always hear about the topic of global climate change over the radio, or by watching news and programs on television. Hence, teaching global climate change in the science classroom for these four preservice science teachers goes beyond the development of science process skills and attitudes. According to these prospective teachers, the teaching of global climate change requires classroom teachers to employ approaches that are balanced and less persuasive than the television programs that students often see. In terms of the relevance of global climate change to different areas of science, the preservice teachers believed that this phenomenon clearly encourages a sense of urgency across all disciplines. For example, Cherry claimed that global climate change could be embedded in strategic topics in chemistry. She was particularly interested in making the topic flow seamlessly in order to avoid disrupting the sequence in the set curriculum. Likewise, Summer believed that global climate change could be treated as an overarching concept in earth science. Summer explained how earth science lessons could be developed with global climate change as an overarching theme. Eddie, likewise claimed that global climate change has a definite relevance in biology. Consistent with his biocentric ethic, Eddie believed that all living organisms are affected by global climate change.

A closer examination of the epistemological, pedagogical, and curricular beliefs of the four participants revealed that these types of beliefs played an important role in their design of the learning experiences for students. The four preservice teachers displayed epistemological beliefs on global climate change which were certainly personal in nature, that is, these were based on their academic preparation, and personal experiences. These epistemological beliefs, in turn, tended to complement their pedagogical and curricular beliefs by providing the necessary background information on global climate change. Their personal knowledge and familiarity with the issue of global climate change were invoked and put into use as they developed their unit skeleton assignments and concept maps. However, their pedagogical belief that global climate change should be taken up in the science classroom as a purely objective concept, rather than as a topic of persuasion, remained strong for all four preservice teachers throughout the study. It was clear that their role in mediating students' understanding of the concept was limited to the scientific principles involved and not on persuasion of whether or not students should believe its existence. Likewise, the four preservice teachers' belief that the topic of global climate change has a rightful place in the science curriculum was complemented by their epistemological beliefs. It is now clear that the preservice science teachers' epistemological, pedagogical, and curricular beliefs were in a dynamic relationship. The teachers constantly invoked these beliefs when circumstances dictated. These three types of beliefs were bound by two significant points: (1) Global climate change is a seemingly inevitable topic. Students and teachers alike are going to be constantly exposed to information coming from scientists, politicians, policy-makers, educators, and media personalities. (2) Global climate change has a rightful place in the science curriculum. For the preservice teachers in this study, global climate change as a topic, cuts across all existing school science subjects. As a result, integration of this topic in any of the science courses in middle or high school level would always be possible.

The previous discussions pointed out that the beliefs of the preservice science teachers were based on the uncertainty accompanying the topic of global climate change. As shown earlier, the uncertainties are rooted from the ongoing differences of explanations proposed by climate scientists. It was also evident that the four preservice teachers primarily emphasized the need for 'credible, reliable, accurate, and reputable sources of information' about the subject matter. Hofer and Pintrich's (1997) model of personal epistemology is closely associated with the preservice teachers' position. The dimensions; certainty of knowledge, source of knowledge, and justification for knowing, were displayed by all four teachers. The certainty of knowledge as a dimension shows that the teachers view the topic of global climate change in light of tentative and constantly evolving ideas and notions. Likewise, the preservice teachers' source of knowledge, as a dimension, depended 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) posited that individuals possess epistemological resources which are activated by varied contexts. Relative to this, the preservice science teachers in the present 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., these epistemological resources come in the form of rich cognitive networks that can always be activated by differing contexts.

The strength of the preservice secondary science teachers' beliefs on global climate change also stood out in the study though it was not directly examined. Azjen (1991) defined belief strength as the subjective probability that a specific behavior will result to a particular outcome. Cronen and Conville (1975) claimed that the strength of a belief refers to the certainty with which a person holds the belief about an object. As discussed in the second chapter, beliefs and attitudes are two related but not synonymous constructs. Cronen and Conville further described belief strength as a measure of the strength of relationship between an attitude object and a belief about the object. Kaplan and Fishbein (1969) described belief strength in terms of quantitative measurements of the beliefs listed in a response hierarchy. A response hierarchy could be described as a repertoire of elicited and standard set of beliefs. Participants then are given the opportunity to indicate the degree to which they believe with various statements about the object being examined. They found that there was a strong positive relationship between hierarchical position and belief strength. In the present study, belief strength was not quantitatively measured and statistically computed. No hierarchies of the preservice science teachers' beliefs were established. However, belief strength was qualitatively determined through the available data. Instead of hierarchies, the preservice secondary science teachers' beliefs tended to fall into continua. To illustrate, the preservice science teachers had a strong belief that global climate change was happening. In the four narratives, each preservice science teacher described the phenomenon and did not cast any doubt that it was indeed existent. However, their belief that anthropogenic activities are the main causes of global climate change tended to lie at the middle of the continuum. In the four cases, the preservice science teachers explained the existence of uncertainties as to what the real causes of global climate change were. In terms of the role of the topic global climate change in the classroom, it was found that the preservice teachers strongly believed that such a topic is certainly an essential part of science instruction. Lastly, the preservice science teachers' belief that debate is a viable method of presenting information about global climate change appeared to fall at the middle of the continuum. The preservice science teachers pointed out that debate tended to persuade students to buy into one side of the issue, hence making them vulnerable to criticism.

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

The second research question posed at the beginning of the study was interested in identifying the experiences that have influenced the preservice science teachers' thinking about 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. Activities like gardening and poultry-raising are just a few of the examples of childhood experiences shared by the four preservice science teachers. 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.

To illustrate, consider the case of Eddie. Eddie's mother was very supportive of his endeavors and aspirations. His mother was a perfect example of someone having concern for environments and the living organisms thriving in them. Eddie explained: "My mom, my parents spent, mostly just my mom, pushed me like she's always been really in helping animals. I guess one of her things, I guess she kind of helped me have that view that we should try to help everything and stuff."

All the preservice science teachers in this study admitted that their perspectives on global climate change have been partly influenced by the same popular movie. *Dealing with An Inconvenient Truth*, another emerging theme, emphasizes the fact that their viewing of the movie *An Inconvenient Truth*, showing Al Gore explaining global climate change to a group of people significantly impacted their ideas and positions regarding the phenomena. Cherry, Eddie, Summer, and Vince referred to this movie as an important source of information about global climate change. Their reaction to the movie, however, showed that they viewed its contents as edited, "fluffed", shallow, and "playing with emotions". To them, the movie appeared to present the crisis in a manner that incites the audience to immediate action. They felt that the movie tended to employ a one-sided approach in discussing the issue. The preservice teachers did not criticize the movie as inaccurate but rather called into question the manner of presentation and the sources of information presented. To Eddie, the movie tended to portray a "doom and gloom" scenario of global climate change. Summer's reaction to the movie was captured from her remarks: "But I thought it was a nice read. It was entertaining. But he just, he was so shallow for me and just what he. The data he presented is kind of like he went to a corner and then stopped.

And he showed these graphs. They were pretty graphs. But it just didn't really. It was just way too persuasive for me. But I wish I could look at it again. But it was just really, really short just really without any depth in my opinion."

The last category that could be considered sources of influence for the preservice science teachers is *academic context.* Their experiences in the academic setting exerted influence on the way the four preservice teachers think about life and the environment that surrounds them. Experiences in the academic setting involve interactions with teachers, peers, and administrators. Eddie recalled that one of his elementary grades teacher was very influential for him. As a result, Eddie developed a love for plants and animals, entered the ecology program, and then shifted to science education. As he recalled, this teacher allowed the class to investigate environmental concerns and conduct studies about these problems. Academic context, as a theme, also refers to educational background as an important influence with respect to how the preservice teachers made sense of global climate change phenomena. For example, Cherry has developed a critical reading skill when examining resources about global climate change. Having the scientific experience and educational background, she always remained skeptical about the information presented to her until she learned of the nature of the source.

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. All four noted that parents, teachers, professors, and peers were sources of information and participants in healthy discussion about global climate change. Eddie, for example, was nurtured as a lover of nature by his parents and teachers. His constant reading of materials about plants, animals, rainforests, and his active involvement in environment-related causes made him aware of the issues that affect his surroundings. Vince, Summer, and Cherry also described having grown up with a family that inculcated love of the environment, respect for diverse opinions, and sustainable living. Place was another force in mediating the experiences of the preservice science teachers. Summer had the opportunity to visit France. Her academic experience abroad provided her a significantly different perspective and frame of reference on environmental consciousness. Events, or turning points in the lives of the four teachers, were also strong forces the preservice teachers drew on to explain their present perspectives about global climate change. For example, Cherry's work in the laboratory provided her with opportunities to engage in scientific discourse. Being a scientist, Cherry admitted, commands authority when she is with her family members. Her scientific explanation is often sought by her relatives because of her position as a scientist. Cherry's daily laboratory 'events' shaped her perspective of global climate change and allowed her to filter information and be a critical reader of any material presented to her. Gee (1996) proposed the notion of cultural models as a significant part of discourse. These cultural models, according to Gee, are assumptions about choices and meanings. In the present study, the four teachers tended to invoke their own cultural models when they elaborated their beliefs about global climate change. Their various experiences, academic and personal, were instrumental in shaping these models. As Gee posited, cultural models are developed through acculturation. The four teachers were acculturated through their experiences to approach the issue of global climate change in particular ways. To illustrate, Cherry's critical mindedness was shaped by her membership in the scientific community, a sub-culture to which she belonged.

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*. This theme and their proposed ways of negotiation are developed in this section. All four participants agree that global climate change is a subject of debate in the scientific community. The preservice science teachers recognized that global climate change is not only an issue in science but also in political and economic contexts. Vince noted earlier that the room for debate arose from the differences in the scientists' methods of investigation. Cherry corroborates the controversy in science by pointing out the variation in the level of instrument sensitivity. She explained: "Well, I know that our instruments are getting more and more sensitive every year. And so we can now monitor temperature changes in the one hundredths of a degree, whereas a hundred years ago, we were lucky if we could change temperature one degree very accurately. And so we've only been keeping records for you know, a few hundred years at the most. And then they weren't very accurate. 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 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, Eddie, Summer, and Vince also claimed that global climate change is controversial in the sense that it often stimulates a discussion blended with a political tone.

Students, in particular, were recognized by the four preservice science teachers as either speaking of their parents' position or of their own in regards to global climate change. If a teacher is not alert, they claim, a classroom discussion on this topic might end up as a debate between political affiliations or ideologies. Relative to the political controversy associated with global climate change, Summer noted: "I suppose that, it's hard not to have a persuasive component with global warming. I just think that since it is still such two strong sides. I guess it depends on where you're teaching too, if you are in the rural or in the city, if you are in the research triangle. It depends on where it is and how progressive your school system is. It is important not just to project belief in children because they are so impressionable that it would be good to just offer them these things." The preservice teachers also noted how the topic of global climate change brings out controversy involving the economic aspects of society. Eddie specifically pointed to the effect of blindly adhering to the Kyoto Protocol, as shown in the following excerpt: "It seems like a very big deal. I mean because it's such an influence as economies and like how you know if we're, if America is in the Kyoto agreement then another country isn't, the other country can just mass produce things better, more than we could I guess. And out compete us globally and the economy because they are not worried about putting all these regulations on how they make their products I guess." The preceding remarks of Eddie highlight his belief that economic repercussions result from drastic measures to avert global climate change. As shown from his statement, Eddie is particularly aware of the potential for unfair economic practices since only the signatories are bound to comply with the treaty. To Eddie, this treaty could potentially create controversy because students often hear about the Kyoto Protocol mentioned in printed materials and in television programs. In addition, the controversy might also be attributed to the fact that the United States is not a signatory to the Kyoto Protocol.

All four prospective science teachers wanted to avoid controversies in their future classrooms as much as possible. Cherry, Eddie, Summer, and Vince negotiated this tension by recommending creative ways of integrating global climate change in the science classroom without creating a problem. Eddie, in his unit skeleton, planned to start the learning experiences by asking the students questions about their personal beliefs and ideas on global climate change. It appears that Eddie was thinking of a form of precautionary measure to avoid initiating an unnecessary argument amongst the students. From the four cases, it was apparent that teacher neutrality is of paramount importance to them. 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 to persuade, that is, *emphasis 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 how student-centered activities promote constructivist-based science pedagogy. They also emphasized how these kinds of activities further promote personal accountability of students as regards to their own learning and stance on the issue. Likewise, they pointed out how personal exploration of the topic develops critical thinking.

Global climate change remains a topic of debate in scientific, political, and economic forums, 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. *Classroom debate appears as a microcosm of the larger 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 preservice 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 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.

Persuasion appeared to be an issue with the four preservice science teachers. Their notion of persuasion tended to differ from that of science education scholars. Based on an analysis of the four cases, it appeared that the preservice science teachers equated persuasion to forcing students to take a position in an issue. To them, this manner of presenting science lessons would be problematic as it results to indoctrination of students with a certain ideology or argument. As noted earlier, the four preservice teachers recognized the role of argumentation but always emphasized caution not to allow persuasion of students to be involved in the discussion. For example, Eddie pointed out that a science teacher could act as a mediator when developing the lesson about global climate change. To him, a science teacher serves as an adjudicator who presents the topic for debate. Likewise, Vince acknowledged that debate has an important role in the science classroom when dealing with the topic of global climate change. Aside from learning the content about global climate change, Vince recognized the value of debate as a means of allowing students to hone their skills in gathering evidence to support their side and in defending their specific position. To Vince, classroom debate tends to provide an "accurate picture of science". 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" (p. 67). Freely and Steinberg (2005) added 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" (p.

70). Propaganda is a structured attempt to present an appeal through the use of mass media in order to convince the receiver of the message. Persuasion differs from brainwashing as the latter involves brutality and pressure.

As seen in the preceding discussion, making the discussion of global climate change a venue for indoctrination remained a primary concern of the preservice science teachers about using persuasion in the classroom. Murphy (2001) opined that persuasion is a word that evokes a negative picture of a person influencing, convincing, manipulating, or tempting others about a specific issue. In teaching, Fives and Alexander (2001) claimed that "teaching as persuasion" could be an alternative view to instruction. To them the process of teaching takes the argumentation structure and adapts it to the style and structure of classroom discourse. They also opined that teaching as persuasion is guided by three important principles (p. 244): (1) Characteristics of the learner and message are integral to the persuasive process. (2) Any learning environment has multiple sources of knowledge and information. (3) Learners must be educated about the persuasive process so they are able to recognize the underlying argumentation and evaluate the evidence presented.

Argumentation is a significant point that emerged from the analysis of the four cases. Freeley and Steinberg (2005) defined argumentation as "reason giving in communicative situations by people whose purpose is the justification of acts, beliefs, attitudes, and values" (p. 2). The four preservice science teachers seemed to agree with the role of argumentation in the science classroom. The controversial nature of the topic of global climate change tended to contribute to the position of the preservice science teachers as regards the use of argumentation in bringing the main ideas about this environmental phenomenon. To these preservice science teachers, argumentation should be used in the science classroom to mediate learning of a specific topic in an objective manner and devoid of any persuasion or indoctrination of students. The preservice teachers tended to protect themselves from being an instrument of structuring argumentation that would sway students from one side to another. Although they recognized the value of having students seek out information about global climate change and argue them with the other members of the class, the preservice science teachers still felt that a persuasive component of the activity should not exist. Jimenez-Aleixandre and Erduran (2007) believed that argumentation should be integrated in science education. To them, argumentation has two aspects: (1) justification of knowledge claims; and (2) argumentation as persuasion. These two components are closely associated with the preservice science teachers' stance that allowing students to engage in argumentation hone their skills in attending to relevant information about a socioscientific issue like global climate change. Simonneaux (2007) claimed that socioscientific issues like global climate change provide opportunities for students to bring together perspectives from different disciplines.

Based on the previous discussions, it is evident that negotiations are essential when dealing with socioscientific issues in the classroom. Global climate change is a controversial issue that the preservice science teachers in the study planned to handle with care when they embark in their own teaching careers. As it appeared from the earlier discussion, negotiation of teaching global climate change comes in four significant ways. These are negotiations of: (1) content; (2) context; (3) process; and (4) 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. As pointed out by Cherry, teaching global climate change should be seamless with the main science subject so as not to disrupt the continuity of the curriculum content. Eddie negotiated the content of his unit skeleton by considering the state standards that need to be addressed. Negotiation of context refers to the type of venue where the topic of global climate change is developed as part of class activities. As revealed from the four cases, diverse activities and classroom contexts may be employed so as to develop an understanding of global climate change. For example, negotiation may be necessary when employing outdoor science activities. Also, negotiations may be necessary when conducting classroom debates and argumentation. The preservice teachers stressed that when employing debates, the teacher should take care not to create a learning context as an avenue for clashing ideologies and beliefs. 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. The process of downloading enormous amounts of information might create confusion for students. In their discussion of this issue, the preservice teachers elaborated on how negotiation between the teacher, students, and available resources comes into play in these instances. '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. In this sense, the teacher has to consider the question: What benefit does the learning experience provide? As suggested by the four preservice teachers, lessons on global climate change could be structured to: (1) develop basic conceptual understanding; (2) increase awareness; (3) promote activism; (4) incite action; and (5) simulate scientific investigations.

The different negotiations that science teachers have to make can be examined in light of Argyris and Schön's (1974) notion of an espoused theory of action. As shown in the preservice science teachers' unit skeleton assignments, their espoused theories of action included details of how they would foster students' learning of the topic of global climate change. Their individual unit skeleton assignments revealed their espoused theories of action and communicated their intentions and specific tasks and experiences. The unit skeleton assignments were prepared by the four teachers in view of their beliefs, attitudes, and values, since humans are assumed to be designing beings (Argyris, 1995). In view of the necessary negotiations, the apparent mismatch between an intended plan and the actual result triggers a restructuring of their theory of action.

Implications of the Study

The implications of the present study are discussed in the following section. This section is divided into four areas: (1) implications for secondary science preparation; (2) theoretical implications; (3) methodological implications; and (4) implications for future research.

Implications for Secondary Science Teacher Preparation

Secondary science teachers often attempt to plan and design learning experiences that are meaningful and within the maturity level of students. Aside from this consideration, standards to be addressed also come into play. The present study provided preservice secondary science teachers an opportunity to develop a unit skeleton in a short period of time. With the guidance of the course professor, the students in the class were able to design learning experiences notwithstanding the fact that they had only a week to perform the task. The experiences of the four preservice science teachers (Cherry, Eddie, Summer, and Vince) in designing a unit skeleton revealed that they used initiative and creativity in locating the needed resources. The unit skeleton assignment required in the course, which also became part of the data set, honed the preservice teachers' skill of designing learning experiences around a topic beyond what they might typically be expected to teach. The assignment prepared the preservice science teachers in developing resilience when the need to design a unit with little time is called for in the future.

The preservice science teachers also developed flexibility in aligning their unit skeleton to the standards which most school systems require.

This assignment could offer a creative method of preparing secondary science teachers in planning for topics beyond their comfort zones. The experience was intended to be an educative practice of meeting the actual school expectations.

In addition, this study shed light on the role of socioscientific issues in secondary science teacher preparation. The unit skeleton assignment and concept mapping activity certainly provided the preservice science teachers with the opportunity to reflect on the socioscientific issue, global climate change, and how this topic could become part of a lesson in their own field of specialization. The study allowed the preservice science teachers to re-examine the ethical considerations when teaching controversial topics such as global climate change. The course served as a context for clarifying their beliefs on the role of socioscientific issues in the science curriculum.

The study also provided an innovative context for the structure of the course where preservice science teachers are prepared for their future teaching. With the inclusion of socioscientific issues in the curriculum course, the preservice science teachers were provided the opportunity to examine a specific topic, determine the state and national standards addressed, design age-appropriate activities, and construct alternative assessment techniques. These tasks are important to develop in the context of a standards-driven curriculum prevailing in the school systems across the nation.

The preservice science teachers in the course had the opportunity to examine their own beliefs on global climate change. This aspect of the study helped the preservice science teachers reflect on their beliefs and how these influenced their thinking about teaching and learning. As shown from the previous sections, 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) posited, 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.

The findings of this study suggest that preservice science teacher preparation should bring to the forefront the following considerations:

- 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.
- 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.

Theoretical Implications

The present study contributed to an understanding of the nature of the epistemological, pedagogical, and curricular beliefs of preservice science teachers on a specific topic, global climate change. The findings derived from the four cases revealed that preservice science teachers tended to shy away from persuasive talk when dealing with controversial issues, such as global climate change. An understanding of the teachers' beliefs on global climate change provided simple guidance when negotiating science instruction in light of a specific controversial topic.

The dimensionality of epistemological beliefs is traditionally measured by standardized written instruments. But the present study explained the possible relationship between the dimensions of personal epistemology, as proposed by Hofer and Pintrich (1997) and the preservice teachers' beliefs as revealed from interview data, observations, and their written products. The study also provided an emergent clarification and possible support to Kagan's (1992) assumption that a teacher's professional knowledge is situated in context, content, and person. The preservice teachers elaborated on the negotiations considered to be essential when teaching a socioscientific issue. A teacher's ability to negotiate his or her beliefs reflects the context-dependent nature of teaching.

The preservice science teachers' reference to debate and argumentation provides an insight into the four thematic areas in socioscientific issues instruction as reflected in Zeidler et al.'s (2005) model framework. These thematic areas (nature of science, classroom discourse, cultural issues, and case-based issues) potentially influence students' understanding of a socioscientific issue. Argumentation is a common dimension of socioscientific issues education, and hence, the preservice science teachers tended to structure the lesson as a debate. The primary rationale, as the preservice science teachers contended, was to hone the students' critical thinking and formulation of logical arguments. At first, using argumentation to teach a highly debated issue appeared counterproductive to these prospective teachers because they felt it might polarize the whole class. But through reflection, the preservice teachers reiterated that the debate could be structured such that two sides are given equal attention and that sound arguments could depend primarily on personal exploration of the issue. In this sense, the study shed additional light on the use of argumentation in the science classroom. Argumentation in the context of classroom learning has the ability to confront highly entrenched beliefs, whether or not these are in line with the issue being considered in class.

The study and analysis of the unit skeleton assignments, concept maps, and interview transcripts allowed the researcher to extend the application of the espoused theory of action. Argyris and Schon (1974) developed this theory with the business and entrepreneurial contexts in mind. As used in the study, the discussion of the teachers' unit skeleton assignment added value to the theory as applied in the school setting.

In view of the findings of this study, the following theoretical implications are noted:

- Preservice science teachers' understandings in relation to the teaching and learning of socioscientific issues may benefit from explicit attention to nature of science, one of Zeidler at al.'s (2005) categories in the model framework of SSI education.
- In light of the tension preservice science teachers expressed regarding 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.

Methodological Implications

Interpretive methodology was employed in this study. Using case study methods, beliefs of preservice science teachers were examined. Employing case study with the four preservice science teachers allowed a clear bounded system, by which to concentrate the study. The use of case study methods allowed for a structure and direction in terms of data collection and analysis. The cases were presented as narratives. Using narratives to represent each case allowed the researcher to follow through the storied portions of the data collected.

Interpretive research methodology was essential in the present study since it focused on individual experiences and the patterns of meaning derived from the participants' perspectives.

Tobin (2000) claimed that this methodology aims to make sense of experience and understand meanings and relationships that are linked to varying contexts. Erickson (1986) added that interpretive research has the potential in discovering the immediate and local meanings of action defined by participants and the relationships between culture and the participants' choices and social actions. Through the case narratives, the researcher was able to represent various meanings attached to the experiences and perspectives shared by the preservice secondary science teachers. Generalizability is often a point of critique in regards to the credibility of an interpretive research. Generalizability refers to the applicability of the findings of a specific study to other populations. Merriam (1998) posited that the question of generalizability of qualitative research stems from thinking the meaning of this term in a similar way as it is used in experimental studies. Erickson (1986) argued that interpretive research looks for concrete universals rather than abstract universals. According to Erickson, abstract universals are obtained from a statistical generalization while concrete universals are derived by studying a specific case in great detail and then making comparisons with the other cases in the study. Erickson added that an interpretive researcher is primarily concerned with particularizability and not generalizability. This requires one to uncover the uniqueness of a given situation and to attend to the details of specific cases under examination.

In view of the possible question of the viability and generalizability of the present study, measures were taken to strengthen the credibility of the findings. Viability was enhanced in the present study by following four specific ways proposed by Merriam (1998). First, triangulation was employed by using multiple sources of data. Mathison (1988) opined that data triangulation is an important element of qualitative research that allows an investigator to construct plausible explanations about the phenomenon under examination. These multiple sources of data included interviews, documents, informal conversations, observations, and field notes. Second, member checking was done by the researcher in order to ensure that he represented the participants' perspectives appropriately. The four preservice science teachers were provided a copy of the narratives that they were allowed to read, comment on, and modify. Member checking was an important way of accurately representing the participants and the meanings they made during the interactions. It was also an important way to enrich the data. Third, data were obtained over a period of time. In this specific instance, the researcher conducted the study for one semester. Fourth, the researcher's biases, worldviews, and theoretical orientations were clarified at the beginning of the study.

Generalizability was also taken into consideration in the present study. Merriam (1998) suggested three specific methods of enhancing the generalizability of a qualitative study: (1) rich, thick description; (2) typicality or modal category; and (3) multisite design. The first method of enhancing generalizability was satisfied in the present study by describing clearly and adequately the context. This allowed the readers to determine how closely their situation matches the research context. This is closely related to Tobin's (2000) stance that a research report's transferability in other contexts is determined by the reader and hence could be considered a researcher-reader transaction. Lincoln and Guba (2000) asserted that the degree of transferability is a direct function of the similarity between two contexts of study. To them, a person who desires to judge the transferability of a study needs to have information about the contexts. It is the responsibility of the researcher then, to provide sufficient information about the context and "specify everything that a reader needs to know in order to understand the findings" (Lincoln & Guba, 2000, p. 40). The second method of enhancing generalizability suggested by Merriam was done by providing a detailed description of the typicality of the phenomenon and participants in order to allow readers to make potential comparisons with their own circumstances. Multisite design, the third method of enhancing generalizability according to Merriam (1998), was used through the inclusion of four diverse cases.

In the present study, interviews were extensively used. Three innovative techniques were employed within the interviews. These included YouTube clips, a cartoon, and two scientific articles. The use of different prompts added a rich source of data for the study. Using YouTube clips was a potential way of accessing teachers' unconscious beliefs, as it triggered and elicited various thoughts and reactions that were tacit in nature. Likewise, the preservice science teachers were quite familiar with YouTube since it is a popular website for uploading and downloading short video clips.

According to Liebenberg (2009), the use of images in the research process inspires new collaboration between the researcher and the participants. The use of the different visual prompts in this study was a slight innovation which Liebenberg described as the use of participant-constructed images as communication tools. The value of visual images in research comes from their potential of maintaining focus of interviews and providing meanings of reality based from the participant's perspective.

The present study also provided an explanation of preservice science teachers' beliefs and negotiation about a specific subject, rather than on a general pedagogical practice or philosophical stance. The specificity of the scope added to the richness of the data collected and analyzed for the study.

Another methodological implication of this study was the value of an in-depth examination of teachers' beliefs on global climate change in contrast to numerical scores derived from written objective examinations that have typically characterized previous research. As discussed in the literature review, most studies on global climate change in the school setting have focused on the conceptual understanding of participants using quantitative methods. There were few studies that focused on developing an in-depth understanding of preservice teachers' beliefs specifically in relation to global climate change. The beliefs of the preservice science teachers were embedded and clearly communicated through the interviews, observations, and their written products.

Based on what the researcher learned, the following methodological implications are noted:

- The use of visual images (e.g. YouTube, cartoon, art) may be useful in tapping into some of the unconscious beliefs held by preservice science teachers.
- Contingency plans should be in place when using internet-based communication systems (e.g. Skype, Yahoo Messenger) as alternative to face-to-face interviews because these methods can pose technological challenges which may interrupt the continuity of conversations.

Implications for Future Research

Future studies on preservice science teachers' beliefs regarding any socioscientific issue could be extended to the implementation of the unit plan students prepared in this study. A further study could be conducted with the goal of understanding the entire process of planning and implementing a unit about a specific socioscientific issue. Another potential area of study would be a comparison between pre- and in-service science teachers' beliefs on a specific socioscientific issue. This line of research has the possibility of providing insight into how teachers' beliefs are formed and evolve over time. Likewise, examining the similarities and differences of the beliefs could potentially lead to the development of typologies that could be used to more clearly characterize the nature of teachers' beliefs.

The present study could also be extended into an extensive investigation of the specific roles of preservice science teachers in employing a 'filter mechanism' when reading materials or watching television.

In light of the findings of the study and the insights gained by the researcher, future inquiries should consider:

- studying the overall process of using SSI-based lessons from planning through implementation;
- investigating specific ways preservice science teachers assess information about controversial issues as credible and appropriate for classroom instruction;
- examining the "theory-in-use" (Argyris & Schon, 1974) aspect of teaching global climate change; and
- exploring the relationship between belief and action in teaching about socioscientific issues, particularly in the context of standards-based environment.

Epilogue

Global climate change has been extensively discussed in this dissertation, especially its place in the educational context. In this section, the researcher provides a brief summary of the dissertation, some background information about global climate change, and his personal reflections on the issue and of the whole research process.

This dissertation was conducted to examine the epistemological, pedagogical, and curricular beliefs of preservice secondary science teachers. Using an interpretive research methodology, the researcher conducted the study with four primary participants – Cherry, Eddie, Summer, and Vince. These four preservice science teachers were interviewed, observed in their science teacher preparation class, and asked to share their written products from the course. The data were presented in the form of case narratives. Each case was developed based on emerging themes and categories derived from the data. After a within-case analysis, a clear picture of the four preservice teachers' beliefs was evident. Another layer of analysis was done, that is, the cross-case analysis. In this process, emerging themes and categories were again examined and elaborated. The study revealed that the preservice science teachers possess beliefs on global climate change tempered by their academic and personal experiences. It was also shown from the data that the preservice teachers believed they should act as mediators when presenting information to their students. The teachers showed their espoused theories of action as evidenced by the detailed description of the specific learning experiences and outcomes in their unit skeleton assignments. Their experiences were mediated by people, places, and events, which in turn shaped or influenced their perspectives on global climate change. Negotiation of the teaching of global climate change was felt by the preservice science teachers to be essential because of the controversial nature of the topic. The negotiation involved the content, context, process, and outcomes of the lesson being planned by the teacher.

Global climate change is a socioscientific issue that has been popularized in media. The media usually presents this environmental phenomenon as a catastrophic event. Due to the differing positions of climate scientists on the issue, a debate is continuing to grow and advance. The apparent lack of total consensus often makes people question the truthfulness of the information they are presented with. Some people feel that only the worst things are shown to sow chaos and panic, to scare the world, or to incite immediate action to avert impending disaster. As shown in many publications, global climate change potentially affects the whole gamut of life forms. The Intergovernmental Panel on Climate Change or IPCC (2002) reports that species that have limited ability to adapt to changing temperatures are highly vulnerable to becoming extinct. The panel adds that the stress on organisms results from changes in physiology, habitat loss, or changes in disturbance regime. In addition, the global average surface temperature is predicted to increase by 1.4 to 5.8 ^{o}C from 1990 to 2100, with land areas warming more rapidly than the global average. This scenario is alarming as it will affect agriculture, food security, weather patterns, ocean ecosystems, and energy demands. Helmer (2006) believes that extreme weather conditions result in disasters and so measures for adaptation should be encouraged. Increased temperature and heavy rainfall may also potentially increase the emergence of vector-borne diseases such as malaria and dengue (Hunter, 2003).

The soil is an important natural resource. Global climate change potentially affects plant growth and crop yield. One aspect of crop production that may be influenced by climate change is the susceptibility of plants to diseases. Erratic weather patterns may influence the productivity of crops by disrupting the life cycle of plants.

Coral reefs harbor and maintain marine biodiversity and global climate change is also threatening this ocean ecosystem. Coral bleaching and ocean acidification remain as main threats of global climate change to our ocean environments. In terrestrial ecosystems, the threat of global climate change would be the decreased tolerance of organisms to the heat. Low-lying communities are also threatened by rising sea levels. In the IPCC (2002) predictions, sea level rise would be from 0.09 to 0.88 m.

It might appear that the predictions related to global climate change are all doom and gloom, as Eddie described. The action to mitigate the negative consequences of global climate change lies in the hands of all people in the world. Minimal efforts when added together might be a forceful influence to at least reduce the impact of this environmental phenomenon to humans, animals, plants, and other organisms. Global climate change as discussed in the public arena has caused divisions and polarized feelings. People from both sides sometimes talk about the issue with derision, mockery, and ranting. Also, the seriousness of the issue has been mocked through funny parody on TV programs depicting global climate change as if the urgency of the matter is unimportant.

In retrospect, the researcher has learned a lot from this study. The insights he gained from his conversations with Cherry, Eddie, Summer, and Vince are valuable. These insights helped him to continually examine and re-examine his personal beliefs. Admitting his bias due to his being a citizen of a vulnerable country to global climate change, the researcher thought deeply about his future role as classroom teacher. As a teacher, he will be a mediator. He will facilitate students' explorations of global climate change but let them act on their own volition. Lastly, the researcher needs to be prepared to negotiate his beliefs within the content of the curriculum, learning process, and school context relevant to the Philippines.

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APPENDIX A1

Themes from Narrative 1: The Case of Cherry

Table A1. Summary of Themes Emerging from Cherry's Case

Themes	Related Categories	Sample Evidence Used in the Case
Distinction between the "what" and the "why"	Instrument validity	Observe caution when comparing data collected today from those collected 200 years ago. Instruments today are more sensitive than before.
	"To be on the fence"	There is uncertainty about global climate change. No one has explained it exactly.
	Alternative theories	Explained sunspot and magnetic field theory regarding increasing global temperatures.
Who is the source?	Credibility of source	Observe critical thinking when reading journal articles.
	Academe- versus non-academe-affiliated scientists	Academe-affiliated scientists are more credible because they do not have financial stake on a study.
Establishing a climate of learning	Seamlessness and continuity of science topics	The flow of main topics in chemistry should not be disrupted. Use recent events to develop the lesson (such as the 'climate-gate' scandal).
	Time	Block schedule versus Year-long schedule
	Neutrality of the teacher	Persuasion of students about global climate change is not a role of teachers.
	Development of critical thinking	Use different approaches when teaching the topic.
	Emphasis on process	Do not spoon-feed students with information. Rather, engage them in various hands-on activities.

APPENDIX A2

Themes from Narrative 2: The Case of Eddie

Table A2. Summary of Themes Emerging from Eddie's Case

Themes	Related Categories	Sample Evidence Used in the Case
Life with global climate change	Growing up	Mother's great influence on his being a naturalist and biocentric. Mother showed full support in his endeavors. He told his mother of his ambition related to zoology.
	Elementary schooling	Teachers in elementary involved him in classroom activities about animals, plants, rainforests. (e.g. Adopt-a-Manatee)
	College life	Initial enrolment in the ecology program Research on upside down jelly fish Shift to science education due to the desire to share experiences with high school students
Making choices	Personal matter	"I do not want to be forced to do something."
	Informed citizens	A farmer is informed with the benefits and risks related to pesticide use.
Teacher as mediator	Presenting information without swaying students to one side	It is not the role of the teacher to convince students on one side of the issue of global climate change.
	Creating and fostering a neutral ground for debate and argumentation	The teacher should not let the debate to be a grand argument of political ideas.
	Using a reasonable approach	A teacher does not employ a crisis approach.

APPENDIX A3

Themes from Narrative 3: The Case of Summer

Table A3. Summary of Themes Emerging from Summer's Case

Themes	Related Categories	Sample Evidence Used in the Case
Reducing personal carbon footprint	Reducing the demand	"Lesser demand means lesser production."
	Experiences in France	Comparison between French and American ways of living More bicycle use in France than in the US. Local sustainable communities
Authority matters	An Inconvenient Truth	"The movie presents shallow information. But it is entertaining."
	A professor's passion	Professors think that they are doing their job if they allow their students to develop the same degree of passion.
	Reputable sources	NOAA, EPA, and NASA information versus "The New Yorker' article
To be persuaded but not to be persuasive	Emotional dimension	"We cry when animals die first than humans."
	Not persuasive to students due to the nature of the topic	Parent's position on global climate change is a big factor in the classroom.
	Not persuasive to the students due to context	Progressive schools are usually within the research triangle (close to a university).

APPENDIX A4

Themes from Narrative 4: The Case of Vince

Table A4. Summary of Themes Emerging from Vince's Case

Themes	Related Categories	Sample Evidence Used in the Case
Uncertainties surrounding the issue	Window for debate	Window of debate caused by different opinions of scientists
	Lack of standards	There should be standard methods of conducting experiments about global climate change. Scientists should arrive at a consensus via professional conferences.
Reliance on the processes of science	Lack of personal experience	"I am not personally involved in scientific investigation."
	Preparing students on the nature of science	Emphasis on experimental design and control of variables, how scientists work in the laboratory
Examining controversial issues in the classroom	Inquiry activities	Experiments and community engagement
	Classroom debate	The debate should be structured as a meaningful learning experience rather than a big classroom argumentation of political ideologies.

APPENDIX B1

First Individual Interview Protocol

1. Introductions: Nature of interview, IRB rules on consent, access to transcript and report, right to stop recorder at any time, right to stop the interview session
2. How do you define global climate change?

   Follow-up: You mentioned _____ to describe changes in climate. What do you mean by that?
3. What are your views about global climate change?
4. How have your views about global climate change developed?
5. Kindly describe your experiences, either inside or outside the classroom, that have influenced your views about global climate change.
6. What do you think is the place of the issue, global climate change, in the high school (or middle school) science curriculum?
7. In what specific ways do you think you could develop students' understanding of global climate change in the science classroom?
8. What do you think should be the role of socioscientific issues, like global climate change, in science teaching and learning?

APPENDIX B2

Second Individual Interview Protocol

(Second Interview, with the aid of two YouTube clips and a Cartoon)

Note: Each YouTube clip will be shown and discussed separately.

1. Introduction to the second interview
2. Show YouTube clip 1: http://www.youtube.com/watch?v=Jak1pExql0U
3. What does this YouTube clip mean to you?
4. What questions does the YouTube clip raise for you?
5. Based on what you have seen, what are your personal thoughts about global climate change?
6. From your perspective, how does this clip depict global climate change?
7. Show YouTube clip 2: http://www.youtube.com/watch?v=v2XALmrq3ro
8. Ask questions 3, 4, 5 and 6.
9. Which clip do you think is more convincing to you? Why?
10. Show cartoon on global climate change.
11. What are your thoughts about the cartoon depicting global climate change?
12. How did your thoughts about global climate change develop?
13. What do you think is the place of the issue, global climate change, in the high school (or middle school) science curriculum?

    What about in your specific content area?

    What do students in your specific content area need to learn about global climate change?

14. In what specific ways do you think you could develop students' understanding of global climate change in the science classroom? Please share some examples.
15. Describe the approach you would use to foster students' learning of socioscientific issues, like global climate change.

APPENDIX B3

Third Individual Interview Protocol

(Third Interview, with the aid of two scientific articles)

Article 1 – *Attributing physical and biological impacts to anthropogenic climate change* by Rosenzweig et al. (2008)

Article 2 – *Understanding common climate claims* by Lindzen (2006)

The following questions aim to guide you in thinking about the different points presented in the articles, and to prepare you for the interview session focusing on the two articles you read.

1. In your own words, describe what you think the main point was for article 1 (or article 2).
2. How were your personal thoughts/ideas about global climate change influenced, if at all, by what you read?
3. From your perspective, how does article 1 (or article 2) depict global climate change?
4. What aspects of article 1 (or article 2) were a surprise to you? Why did that surprise you?
5. What questions does article 1 (or article 2) raise for you?
6. What portion(s) of article 1 (or article 2) stood out for you? Why did that/these part(s) of the article make an impression on you?
7. Which article do you think is more convincing to you? Why?
8. What do you think is the place of the issue, global climate change, in the high school (or middle school) science curriculum?

   What about in your specific content area?

   What do students in your specific content area need to learn about global climate change?

9. What do you think is the role, if any, of “scientific reports” (published articles that communicate the results of an investigation, as well as the theoretical and empirical bases of a claim) about global climate change, such as these have in the science classroom?
10. In what specific ways do you think you could develop students’ understanding of global climate change in the science classroom? Please share some examples.
11. Describe the approach you would use to foster students’ learning of socioscientific issues, such as global climate change.

APPENDIX B4

Final Individual Interview Protocol

1. Introduction to the final interview
2. Describe how you designed your course assignment regarding a unit skeleton in teaching global climate change.
3. What specific factors did you consider in preparing this assignment?
4. Describe how your own personal experiences or ideas related to global climate change influenced your design of a unit skeleton.
5. What tensions, if any, arose from your experiences in designing and planning learning experiences about the topic of global climate change?
6. How did you address the tensions in preparing the unit skeleton assignment?
7. What guided you in drawing the concept map about global climate change?
8. What tensions, if any, arose in preparing this concept map?
9. How did you address these tensions?
10. In what specific ways could you further develop lessons or experiences with global climate change in the science classroom? Give some examples.
11. How were your personal thoughts/ideas about global climate change influenced, if at all, by your experiences of preparing a unit skeleton and a concept map?
12. What questions does the experience of designing a unit skeleton and concept map raise for you?
13. What aspect(s) of the assignment stood out for you? Why did that/these aspect(s) of the assignment make an impression on you?

14. What do you think is the place of the issue, global climate change, in the high school (or middle school) science curriculum?

    What about in your specific content area?

    What do students in your specific content area need to learn about global climate change?

15. Describe the approach you would use to foster students' learning of socioscientific issues, such as global climate change.

APPENDIX C

Cartoon Used as Prompt for the Second Interview

Figure 5. Cartoon about Global Climate Change Used as Prompt

Source:

Lane, M. (2002). *Global warming non-believer*. Retrieved July 30, 2009 from http://www.sitnews.us/DaveKiffer/061106_lane.jpg

APPENDIX D

Sample Scientific Article Used in the Third Interview

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nature

ARTICLES

Attributing physical and biological impacts to anthropogenic climate change

Cynthia Rosenzweig[1], David Karoly[2], Marta Vicarelli[1], Peter Neofotis[1], Qigang Wu[3], Gino Casassa[4], Annette Menzel[5], Terry L. Root[6], Nicole Estrella[5], Bernard Seguin[7], Piotr Tryjanowski[8], Chunzhen Liu[9], Samuel Rawlins[10] & Anton Imeson[11]

Significant changes in physical and biological systems are occurring on all continents and in most oceans, with a concentration of available data in Europe and North America. Most of these changes are in the direction expected with warming temperature. Here we show that these changes in natural systems since at least 1970 are occurring in regions of observed temperature increases, and that these temperature increases at continental scales cannot be explained by natural climate variations alone. Given the conclusions from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report that most of the observed increase in global average temperatures since the mid-twentieth century is very likely to be due to the observed increase in anthropogenic greenhouse gas concentrations, and furthermore that it is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica, we conclude that anthropogenic climate change is having a significant impact on physical and biological systems globally and in some continents.

The IPCC Working Group II Fourth Assessment Report found, with very high confidence, that observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases[1,2]. The Working Group II further concluded that a global assessment of data since 1970 shows that anthropogenic warming is likely (66–90% probability of occurrence) to have had a discernible influence on many physical and biological systems. Here we expand this assessment with a larger database of observed changes and extend the attribution from the global to the continental scale using multiple statistical tests. We also consider the part that other driving forces, especially land-use change, might have played at the study locations.

Observed responses to climate change are found across a wide range of systems as well as regions. Changes related to regional warming have been documented primarily in terrestrial biological systems, the cryosphere and hydrologic systems; significant changes related to warming have also been studied in coastal processes, marine and freshwater biological systems, and agriculture and forestry (Fig. 1). In each category, many of the data series are over 35 years in length.

Responses in physical systems include shrinking glaciers in every continent[3,4], melting permafrost[5,6], shifts in the spring peak of river discharge associated with earlier snowmelt[7,8], lake and river warming with effects on thermal stratification, chemistry and freshwater organisms[9–11], and increases in coastal erosion[12–14]. In biological systems, changes include shifts in spring events (for example, leaf unfolding, blooming date, migration and time of reproduction), species distributions and community structure[15–18]. Additionally, studies have demonstrated changes in marine-ecosystem functioning and productivity, including shifts from cold-adapted to warm-adapted communities, phenological changes and alterations in species interactions[19–22].

Detection and attribution in natural systems

Following the definition of attribution of observed changes in the climate system[23], changes in physical and biological systems are attributed to regional climate change based on documented

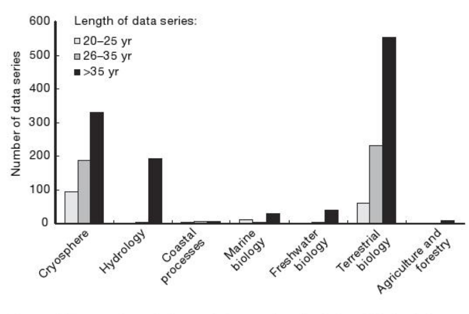

Figure 1 | Data series of observed changes in physical and biological systems. **Length of the data series and types of observed changes in physical and biological systems. COST725 data series of terrestrial biological changes (>28,000 European phenological time series[17]) were measured over 30 years (1971–2000; not displayed).**

[1]NASA/Goddard Institute for Space Studies and Columbia Center for Climate Systems Research, 2800 Broadway, New York, New York 10025, USA. [2]School of Earth Sciences, University of Melbourne, Victoria 3010, Australia. [3]School of Meteorology, University of Oklahoma, 100 East Boyd Street, Norman, Oklahoma 73019, USA. [4]Centro de Estudios Cientificos, Avenida Arturo Prat 514, Casilla 1469, Valdivia, Chile. [5]Center of Life and Food Sciences Weihenstephan, Technical University of Munich, Am Hochanger 13, 85 354 Freising, Germany. [6]Stanford University, Center for Environmental Science and Policy, Stanford, California 94305, USA. [7]INRA Unité Agroclim, Site Agroparc, domaine Saint-Paul, F-84914 Avignon Cedex 9, France. [8]Department of Behavioural Ecology, Institute of Environmental Biology, Adam Mickiewicz University, Umultowska 89, PL-61–614 Poznan, Poland. [9]China Water Information Center, Lane 2 Baiguang Road, Beijing 100761, China. [10]Caribbean Epidemiology Center, 16–18 Jamaica Boulevard, Federation Park, PO Box 164, Port of Spain, Trinadad and Tobago. [11]3D-Environmental Change, Curtiuslaan 14, 1851 AM, Heiloo, Netherlands.

statistical analyses confirmed by process-level understanding in the interpretation of results. For example, a statistical association between poleward expansion of species' ranges and warming temperatures is expected when temperatures exceed physiological thresholds. The observed changes in both climate and the natural system are demonstrated to be: unlikely to be entirely due to natural variability; consistent with the estimated responses of either physical or biological systems to a given regional climate change; and not consistent with alternative, plausible explanations of the observed change that exclude regional climate change.

Attribution of changes in natural systems to anthropogenic warming requires further analysis because the observed regional climate changes must be attributed to anthropogenic causes. Combining these two types of attribution, called 'joint' attribution[2], has lower statistical confidence than either of the individual attribution steps alone.

One approach to joint attribution, which uses what may be called an 'end-to-end' method, has already been conducted in several studies of specific physical and biological systems. This approach involves linking climate models with process-based or statistical models to simulate changes in natural systems caused by different climate forcing factors, and comparing these directly with observed changes in natural systems. When temperature data from the HadCM3 global climate model were used to examine the likely cause for changes in the timing of spring events of Northern Hemisphere wild animals and plants, results show the strongest agreement when the modelled temperatures were derived from simulations incorporating anthropogenic forcings[24]. Other similar studies have shown that the retreat of two glaciers in Switzerland and Norway cannot be explained by natural variability of climate and glacier mass balance[25], that observed global and Arctic patterns of changes in streamflow are consistent with the response to anthropogenic climate change[26,27], and that the observed increase in the area of forests burned in Canada over the last four decades is consistent with the response caused by anthropogenic climate change[28].

Here we conduct a joint attribution study across multiple physical and biological systems at both the global and the continental scale. We demonstrate statistical consistency of observed changes (which are very unlikely to be caused by natural internal variability of the systems themselves or other driving forces) in natural systems with warming and conduct spatial analyses that show that the agreement between the patterns of observed significant changes in natural systems and temperature changes is very unlikely to be caused by the natural variability of the climate (Supplementary Fig. 1). Combined with the attribution of global and continental-scale warming to anthropogenic climate forcing demonstrated by IPCC Working Group I Fourth Assessment Report, this analysis provides strong support for joint attribution of observed impacts.

Consistency with warming

Based on a database of documented responses in physical and biological systems from 1970 to 2004, temperature-related changes have been observed in all continents. Each documented response is a 'statistically significant' signal that is beyond the natural internal variability of those systems. The largest numbers of entries in the database are for Europe and North America, followed by North Central Asia (Fig. 2). Sparse evidence of responses related to temperature changes exists in Latin America, Africa and Australia. Physical and biological systems in regions without data series may or may not be changing, but are not documented in peer-reviewed literature.

Most (about 90% of the >29,500 data series, $P \ll 0.001$) changes in these systems at the global scale have been in the direction expected as a response to warming. Ninety-five per cent of the 829 documented physical changes have been in directions consistent with warming, such as glacier wastage and an earlier spring peak of river discharge. For biological systems, 90% of the ~28,800 documented changes in plants and animals are responding consistently to temperature changes (mostly by means of earlier blooming, leaf unfolding and spring arrival). Warming in oceans, lakes and rivers is also affecting marine and freshwater biological systems (for example, changes in phenology, migration and community composition in algae, plankton and fish).

An evaluation of possible publication bias has been undertaken using comprehensive phenological network data in Europe[29], in which a systematic analysis of all available records (for example, leafing and flowering) documented the percentages of data series that are not changing and of significant changes in both directions (for example, in spring, in 66% there is no significant change, in 31% the onset dates are significantly advanced, and in 3% the onset dates are significantly delayed)[29]. The percentage of data series with significant changes consistent with warming found in Europe (~90%) is close to that found in North America and Asia, providing an indication that the database may represent an unbiased sample of changes in both directions in those continents.

Spatial analyses at global and continental scales

The IPCC Working Group I Fourth Assessment Report concluded that most of the observed increase in global average temperatures since the mid-twentieth century is very likely (> 90% probability of occurrence) to be due to the observed increase in anthropogenic greenhouse gas concentrations[30]. It is very likely that the observed warming patterns cannot be explained by changes in natural external forcing factors, such as changes in solar irradiance or volcanic aerosols; the latter is likely to have had a cooling influence during this period.

At the global scale, agreement between the pattern of observed changes in physical and biological systems and the pattern of observed temperature change holds for two different gridded temperature data sets and two different pattern-comparison methods, and is exceptionally unlikely ($P \ll 0.01$) to be explained by natural internal climate variability or natural variability of the systems; the latter is determined in the individual studies (Fig. 3). The spatial coherence of temperature trends across the globe is taken into account in these pattern comparisons using more than 3,000 years of climate model simulation data. The prevalence of observed statistically significant changes in physical and biological systems in expected directions consistent with anthropogenic warming in every continent and in most oceans means that anthropogenic climate change is having a discernible effect on physical and biological systems at the global scale.

For the first time, IPCC Working Group I Fourth Assessment Report extended its attribution of temperature trends to the continental scale, concluding that it is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica[31]. Similarly, a discernible anthropogenic influence is found in changes in natural systems in some continents where there is sufficient spatial coverage of responses in natural systems, including Asia and North America, and marginally in Europe. In these continents, there is a much greater probability of finding coincident significant warming and observed responses in the expected direction. Despite the presence of strong climate variability related to the North Atlantic Oscillation in Europe as well as its relatively small size, which makes it harder to distinguish signal from noise[31], the plethora of evidence allows a signal to be detected, primarily in biological systems. The statistical agreement between the locations and directions of observed significant changes in natural systems and observed significant warming across Asia and North America ($P<0.05$) and across Europe ($P\sim0.1$) is very unlikely to be due to natural variability alone (Fig. 3). Responses not consistent with warming observed in $5^\circ \times 5^\circ$ grid cells with warming temperature may be due to those systems responding to seasonal rather than recorded annual changes or to local cooling not represented in average cell temperatures; biological variation across species may also have a role (for example, late flowering species tend to be less affected by warming than earlier flowering ones). For the other continents, the sparse coverage of observed response studies makes it difficult to separate the observed responses related to anthropogenic temperature rise from those possibly caused by large-scale natural climate variations.

Discussion and conclusions

The wide variety of observed responses to regional climate trends in expected directions combined with the attribution of climate trends to anthropogenic causes at both global and continental scales[30] demonstrates that anthropogenic climate change is already having a significant impact on multiple systems globally and in some continents. Most observed system changes are found in the cryosphere and in terrestrial biological systems and are consistent with the functional understanding and modelled predictions of climate change impacts. The far fewer data series in Africa, Australia and Latin America are closely co-located with warming, but these cannot yet be attributed to anthropogenic climate forcing.

The issues of other climate and non-climate driving forces are important. In considering other drivers of change for phenology, much of the evidence in plants comes from changes observed in the spring. Even though day length can have a modulating effect on spring phenology depending on the plant species, it is not a factor in these studies because species remain *in situ* for the length of the time series, during which day length has not changed. There is also the possibility that increasing CO_2 is directly influencing plant phenology; however, experimental results show no consistent direction of response (that is, an advance or delay)[32]. Concerning trees, older trees tend to unfold leaves in spring later than younger

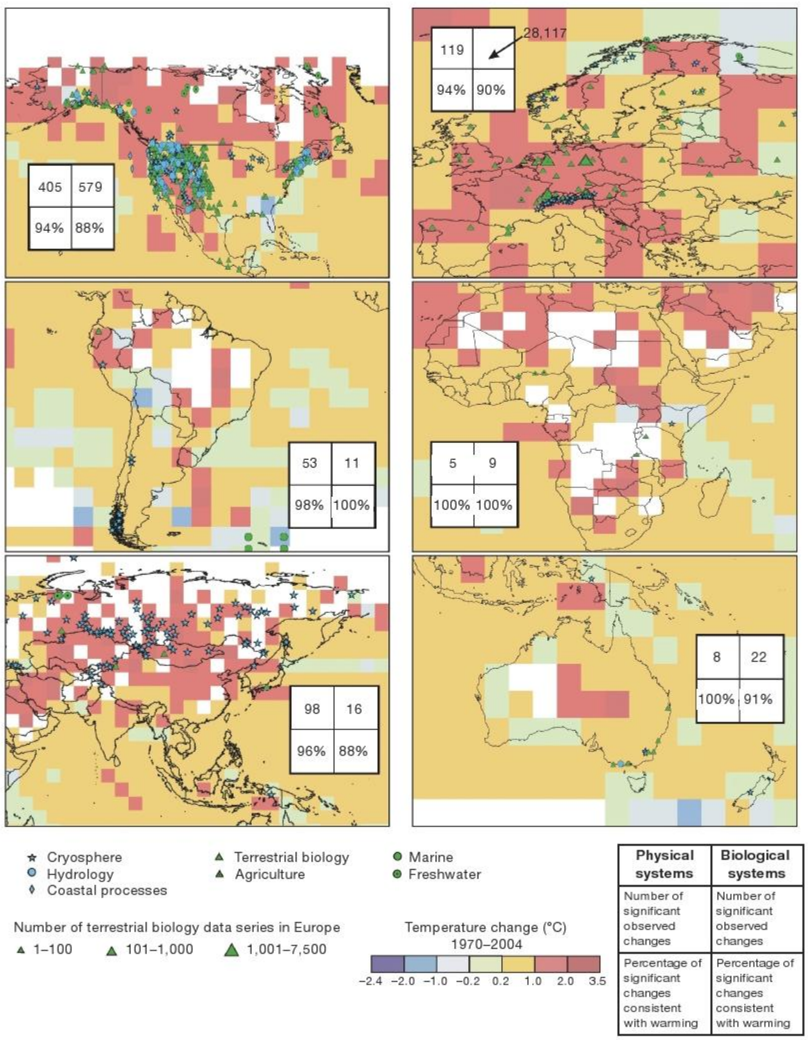

Figure 2 | Location and consistency of observed changes with warming. Locations of significant changes in physical systems (snow, ice and frozen ground as well as hydrology and coastal processes) and biological systems (terrestrial, marine and freshwater biological systems), and linear trends of surface air temperature (HadCRUT3; ref. 35) between 1970 and 2004. Regions are based on data in refs 36 and 37. White areas do not contain sufficient climate data to estimate a trend. Note that there are overlapping symbols in some locations; Africa includes parts of the Middle East.

ones, so with longer time series on one specific object, the onset dates should become later with time owing to ageing, not earlier as observed owing to warming. Finally, some of the plant data, especially in Europe, come from phenological gardens that have been protected from the direct effects of land-use change for decades.

Land-use change, management practices, pollution and human demography shifts are all—along with climate—drivers of environmental change. Explicit consideration of these factors in observed-change studies strengthens the robustness of the conclusions. To determine the role of other driving forces in the data series used in this analysis, we assessed the likelihood of their having a direct effect on the observed system (see Supplementary Table 1). Out of the ~29,500 data series documented in ~80 studies included in the database, effects documented in only 3 studies (9 data series in 4 cells) were likely to have been caused by a driving force other than climate change (for example, habitat destruction, pollution or fishery by-catch disposal). Removing these data series from the statistical analyses does not change the results significantly.

Land-use change can affect physical and biological systems indirectly through its effects on climate. Yet, for recent climate trends on a global scale, the effect of land-use change is small[31]. In addition, because these effects may result in warming in some regions and cooling in others (for example, agricultural expansion tends to warm the Amazon and cool the mid-latitudes)[33,34], they are very unlikely to explain the coherent responses that have been found across the diverse range of systems and across the continental and global scales considered (Supplementary Table 2). Cooling in temperate regions occurs because the clearing of forests for agriculture may increase albedo during periods of snow cover, although recent afforestation may be dampening this effect.

Documentation of observed changes in physical and biological systems in tropical and subtropical regions is still sparse. These areas include Africa, South America, Australia, Southeast Asia, the Indian Ocean and some regions of the Pacific. One reason for this lack of documentation might be that some of these areas do not have pronounced temperature seasons, making events such as the advance of spring phenology less relevant. Other possible reasons for this imbalance are a lack of data and published studies, lag effects in responses, and resilience in systems. Improved observation networks are urgently needed to enhance data sets and to document sensitivity of physical and biological systems to warming in tropical and subtropical regions, where many developing countries are located.

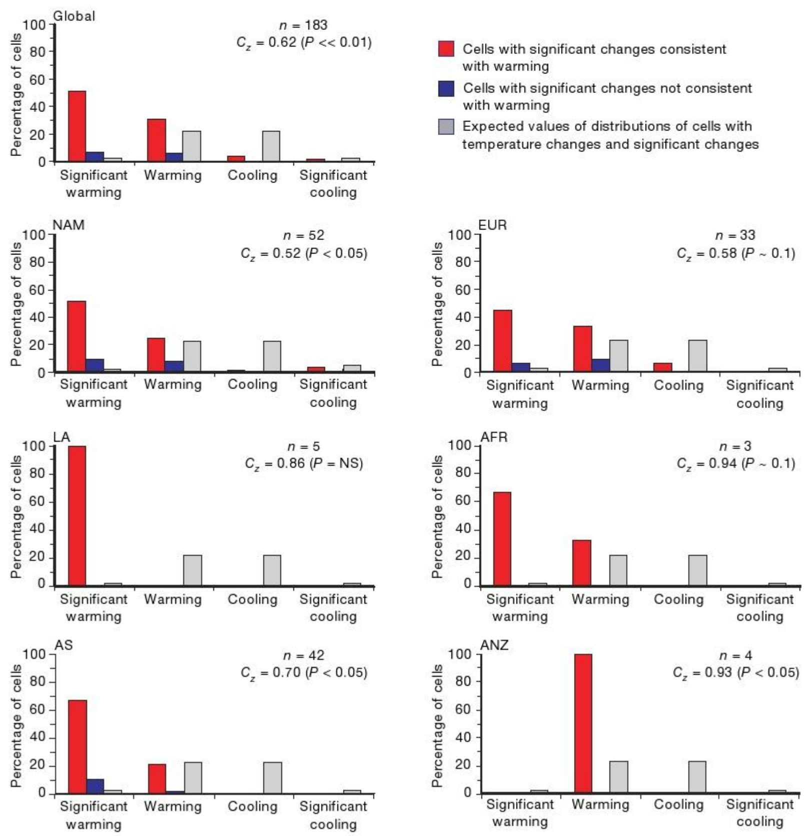

Figure 3 | Distribution of cells with temperature changes and significant observed changes. Expected and observed distributions of cells with significant responses consistent with warming and distributions of cells with significant responses not consistent with warming for 5° × 5° grid cells of temperature change between 1970 and 2004 (HadCRUT3). The global total includes polar regions and marine systems. Shown is the number of cells (n) with observed impacts and temperature data, the pattern congruence between locations of significant responses and standardized temperature trends (C_z), and the probability (P) that pattern agreement could be explained by natural internal variability of temperature fields. Abbreviations: AFR, Africa; ANZ, Australia and New Zealand; AS, Asia; EUR, Europe; LA, Latin America; NAM, North America; NS, not significant.

METHODS SUMMARY

We developed a database of observed changes in natural systems from peer-reviewed papers, demonstrating a statistically significant trend in change in either direction related to temperature and containing data for at least 20 years between 1970 and 2004. Observations in the studies were characterized as a 'change consistent with warming' or a 'change not consistent with warming'. The databases of the observed significant changes in the natural systems were overlaid with two gridded observed temperature data sets and the spatial patterns of the observed system changes were compared with the observed temperature trends using two different pattern-comparison measures.

Full Methods and any associated references are available in the online version of the paper at www.nature.com/nature.

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Author Contributions C.R., D.K., G.C., A.M., T.L.R., B.S., P.N. and M.V. conceived the analytical framework; P.N., M.V., A.M. and N.E. constructed the database; M.V., D.K. and Q.W. performed the statistical analyses; G.C., A.M., T.L.R., P.T., B.S., C.L. and S.R. provided expertise in observed changes in physical and biological systems; and P.N., A.M., C.R. and A.I. analysed other driving forces.

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METHODS

Database of observed changes. We developed a database of observations from peer-reviewed papers (primarily published since the IPCC Third Assessment Report[38]), specifically documenting the data series in terms of system, region, longitude and latitude, dates and duration, statistical significance, type of impact, and whether or not land use was identified as a driving factor (see Supplementary Table 1). Data for the system changes were taken from ~80 studies (of which ~75 are new since the Third Assessment Report) containing >29,500 data series. Studies were selected that demonstrate a statistically significant trend in change in either direction in systems related to temperature or to other climate change variables as described by the authors, and that contain data for at least 20 years between 1970 and 2004 (although study periods may extend earlier or later). Observations in the studies were characterized as a 'change consistent with warming' or a 'change not consistent with warming'.

Spatial analysis. Databases of the observed significant changes in the natural systems and the regional temperature trends over the period 1970–2004 were overlaid in a geographical information system. For Europe, even though there were very large numbers of observed response data series in some cells, these were counted as single cells in the spatial analysis. Two different gridded observed temperature data sets were used: HadCRUT3 (ref. 35) and GHCN-ERSST (ref. 39), both of which were used in the IPCC Fourth Assessment Report. In each 5° × 5° grid cell, the observed system responses were assessed as consistent with warming or not consistent with warming—based on a decision rule of 80% or more of data series consistent with warming within a cell—providing a binary pattern of 183 (HadCRUT3) and 203 (GHCN-ERSST) cells across the globe. There are fewer cells with temperature data in the HadCRUT3 data set because it does not use any infilling of data from adjacent cells, unlike GHCN-ERSST. All cells with observed temperature data are included from each of the data sets, irrespective of the sign of the temperature trend.

The spatial patterns of the observed system changes were compared with the observed temperature trends using two different pattern-comparison measures. To assess the significance of these observed measures of pattern agreement, global temperature trend data were obtained from long control simulations with seven different climate models from the WCRP CMIP3 multi-model database at PCMDI, to represent the range of 35-year temperature trends across the globe resulting from natural climate variations. Details of the different models used are included in Supplementary Table 3. The global temperature trend fields from the climate models represent the spatial coherence and decadal variability of natural internal temperature variations.

Two different pattern-comparison measures were used: a binary pattern congruence (uncentred pattern correlation) between the gridded binary field of system responses consistent (or not consistent) with warming and the gridded field of positive (or negative) temperature trends; and a pattern congruence between the gridded binary field of system responses and the gridded field of standardized temperature trends (the 35-year temperature trends divided by the standard deviation of 35-year temperature trends caused by natural internal climate variations). For each of these measures, the observed values for the two different observed temperature-trend data sets were compared with the distributions obtained using temperature trends caused by natural internal climate variability, as represented by the climate models. Significant attribution was assigned when both spatial statistics methods and both temperature data sets showed significant results. Detailed results are presented in the Supplementary Information and are summarized in the section 'Spatial analyses at global and continental scales' above.

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APPENDIX E

Guidelines for the Unit Skeleton Assignment

Preparing for the Unexpected

All teachers will be asked, at some time in their career, to quickly craft plans for a topic about which they have little knowledge. When this happens, teachers need to know how to use their content and pedagogical understandings to prepare instruction that will motivate students and enable them to learn. In this assignment, you will be asked to build the skeleton of a science unit suitable for a middle school or high school science course.

PURPOSE
The purpose of this assignment is to provide you with practice in constructing a unit of instruction around a topic that stretches the boundaries of your content and pedagogical understandings.

HOW TO BEGIN
Examine the (State) Performance Standards, textbooks, other print material, and Internet sites for information about the topic. Using this information, think about how you might construct a unit to help students develop understandings related to the topic in the context of a middle school or introductory high school science course. Then, discuss your vision for the unit with teachers and classmates. This should help you articulate the ideas and beliefs about how your unit contributes to the goals of a science course, help students learning science, and is relates to other units that are part of the science course.

WHAT TO DO

1. Describe the instructional context for your unit. (Context must be a middle school or introductory high school science course.) Briefly identify the grade level(s) of the students for whom the unit is designed. Also, summarize the understanding of students' probable learning strengths, and any special needs of students who will likely engage in learning experiences described in your unit.
2. To enable your students to perform well on high-stakes assessments, you must align the unit topic and learning experiences with state standards as described in the (State) Performance Standards. Examine the (State standards) and *write out in a clear and unambiguous manner the specific standards* (including both content and characteristics of science) that students are expected to meet as a result of completing the unit.
3. Then, *write the learning outcomes and essential questions* that will be used to frame your instructional unit. These learning outcomes and essential questions should reflect the key concepts and principles that form the content for the unit you want to construct. Be sure to examine (State) and other state frameworks for guidance in writing learning outcomes and essential questions. Your learning

outcomes may include science concepts and principles, skills, and /or dispositions to be targeted in the unit plan.

4. Next, write a description for a summative assessment for your unit. The assessment should provide the information from which a teacher can make decisions regarding the extent to which students have developed a deep understanding of the science concepts and principles included in the unit. The methods used to assess students' deep understanding should be authentic representations of what it means to have an in-depth understanding of the specific science concepts and principles contained in the unit. (Note: Your summative assessment description must be of a performance assessment.)
5. Describe in a bulleted list a minimum of five (5) learning experiences that will help students achieve the learning outcomes set for the unit. Each learning experience description should be 3 or more sentences in length and explain how the learning experience will help students achieve the learning outcomes of the unit as highlighted in your description of the unit's summative assessment.

Describe learning experiences that help students develop a deep, expert-like understanding of the science concepts and principles, skills, and dispositions targeted in the unit plan. These design features include but are not limited to the following aspects of learning and teaching:

- Soliciting and taking account of students' per-existing knowledge regarding key, standards-based science concepts or principles, i.e., the core concepts and propositions contained in your concept map.
- Engaging students in intentional learning activities through the use of questions, problems, situations posed that capture interest and engage students' thinking about core concepts and their interconnections.
- Providing students with "firsthand" experience, when appropriate, in which they make sense of phenomena, articulate their sense-making, and use their understanding of key, standard-based, core science concepts and/or principles to explain phenomena.
- Engaging in intentional teaching, in which students reason for evidence, use scientific tools, think critically, and "think about thinking" while making sense of experience.
- Establishing an environment in which students (and the teacher) understand their learning, through the use of ongoing, formative assessments.
- Assigning textbook readings and abstract problems only when students have developed an appropriate level of understanding needed to successfully complete the assignments.

WHAT TO TURN IN AND OTHER RESPONSIBILITIES

A skeleton unit plan that includes the following elements:

- *Course Description* – Identifies the course in which your unit will be positioned.
- *Unit Overview* – Describes in general the focus of the unit and the standards that the unit is intended to address.
- *Learning Outcomes* – Specifies the understandings that students should construct as a result of instruction associated with the unit. Learning outcomes should be matched with Essential or Guiding Questions; these bring focus to students' learning experiences.
- *Summative Assessment Description* – Makes explicit what counts as evidence of student learning.

- *Learning Experience Descriptions* – Briefly describe the experiences in which students will engage to build knowledge, skills, dispositions, and ultimately understandings. Your unit plan skeleton needs to include a minimum of five (5) learning experience descriptions.
- *Reflective Statements* – Write briefly statements for 3 of the NSTA Standards for Science Teacher Preparation to indicate how they are addressed in your unit skeleton.

APPENDIX F

Unit Skeleton Grading Rubric Used

Table F1. Rubric for Grading the Unit Skeleton Assignment

Criteria	Exceeds Expectations	Meets Expectations	Does NOT Meet Expectations
Concept Map (4 points)	The map shows concepts organized in a hierarchical, coherent and logical manner. Linking words are used to connect concepts. All concepts in the map are related to the topic being developed as a unit. (4 points)	The map shows concepts organized in a hierarchical, coherent and logical manner. Linking words are used to connect concepts. Most concepts in the map are related to the topic being developed as a unit. (2 – 3 points)	The map does not show concepts organized in a hierarchical, coherent and logical manner. Linking words are not used to connect concepts. Most concepts in the map are not related to the topic being developed as a unit. (0 – 1 point)
Background of the Unit and Alignment to Standards (3 points)	The unit skeleton provides an overview of the focus and context of instruction. The overview provides a comprehensive discussion of what the unit is about. It clearly specifies the standards being addressed. (3 points)	The unit skeleton provides an overview of the focus and context of instruction. It clearly specifies the standards being addressed. (2 points)	The unit skeleton provides an overview of the focus and context of instruction but does not specify the standards being addressed. (0 – 1 point)

Learning Outcomes (3 points)	The goals of instruction are clearly stated. The specific understandings that students are expected to gain are explicitly enumerated. The learning outcomes match with the guiding questions. Guiding questions are well-formulated and provides focus for instruction. (3 points)	The goals of instruction are clearly stated. The specific understandings that students are expected to gain are explicitly enumerated. The learning outcomes match with the guiding questions. (2 points)	The goals of instruction are not clearly stated. The specific understandings that students are expected to gain are not enumerated. The learning outcomes do not match with the guiding questions. (0 – 1 point)
Learning Experiences (5 points)	The unit skeleton includes at least five (5) learning experience descriptions. The learning experiences develop students' understanding of the concepts intended in the unit. The activities engage students in thinking critically and in making sense of their experiences. Each learning experience description is clearly explained as to what the teacher and the students are expected to perform. (4 – 5 points)	The unit skeleton includes at least five (5) learning experience descriptions. The learning experiences develop students' understanding of the concepts intended in the unit. The activities engage students in thinking critically and in making sense of their experiences. (2 – 3 points)	The unit skeleton includes less than five learning experience descriptions. The learning experiences do not develop students' understanding of the concepts intended in the unit. The activities engage students in passive mode of learning Each learning experience is not clearly explained. (0 – 1 point)

Assessment (3 points)	The assessment method yields information for teachers about the extent of students' understanding and is aligned with the unit's learning goals. The assessment method stresses authentic performance and output from the students. The way by which the teacher uses results of the summative assessment is thoroughly explained. (3 points)	The assessment method yields information for teachers about the extent of students' understanding. The assessment method stresses authentic performance and output from the students. (2 points)	The assessment method only tests knowledge and does not yield information for teachers about the extent of students' understanding. The method used is not authentic assessment. (0 – 1 point)
Reflection (2 points)	Reflection includes discussion of how the unit skeleton addresses three of the NSTA Standards for Science Teacher Preparation. The reflection also elaborates on the overall learning experiences they had in preparing this assignment. (2 points)	Reflection includes discussion of how the unit skeleton addresses three of the NSTA Standards for Science Teacher Preparation. (1 point)	Reflection does not include discussion of how the unit skeleton addresses three of the NSTA Standards for Science Teacher Preparation. The reflection does not elaborate on the overall learning experiences they had in preparing this assignment. (0 point)

APPENDIX G1

Complete Unit Skeleton Assignment of Cherry

Course Description:

This unit will be taught in a high school chemistry class to 10th through 12th grade students. This unit should be positioned toward the end of the course during a unit on solutions. I would have already discussed with the students earlier in the solutions unit the idea of the nature of solutes and solvents. They should understand that in most cases a solid solute will dissolve more readily in solvent at higher temperatures, and that "like dissolves like". As we move on through the unit to the solubility of gases, this unit will fit neatly in. This unit will engage students with visual learning experiences via demonstration by the teacher. There are also inquiry based class discussions about observations and group web inquiry assignment that allow students to learn from other students and promoting scientific discussion among students. Finally, students will complete a lab experience that will cater to students who learn best through a kinesthetic approach. Students who may be struggling with the concepts can be grouped together on the web search project so that the instructor can give more focused help.

Unit Overview:

We will discuss that gases are less soluble in liquids as the temperature increases. Through experiments and demonstrations, the students will be able to observe the effect of temperature on a solvent's ability to dissolve a gas. (Standard: SC7a. Explain the process of dissolving in terms of solute/solvent interactions.) This unit will focus mainly on how the solubility of carbon dioxide in water relate to temperature changes information collected by scientists and presented on the web, students will analyze how scientific knowledge is developed and check that information against other information sites. (Standards: SCSh7. Students analyze how scientific knowledge is developed. SCSh3f. Evaluate whether conclusions are reasonable by reviewing the process and checking against other available information.) Students will also discuss how this phenomenon can be utilized by scientists to monitor global climate change. (Standard: SCSh8e. The ultimate goal of science is to develop an understanding of the natural universe which is free of biases.)

Learning Outcomes:

1. Learning outcome: Explain how temperature affects the ability of a solvent to dissolve a gas. Contrast gas solubility in liquid water with solid ice. (SC7a. Students will characterize the properties that describe solutions; observe factors that affect the rate at which a solute dissolves in a specific solvent.)

> Essential Questions: Is a gas more soluble at a higher or lower temperature?
> Essential Questions: What properties of the ice core allow it to record a historical record of atmospheric conditions?

2. Learning Outcomes: Describe how scientists use gases stored in ice cores to construct a historical record of atmospheric conditions. (SCSh7. Students analyze how scientific knowledge is developed. SCSh8e. The ultimate goal of science is to develop an understanding of the natural universe which is free of biases.)

Essential Questions: What information do scientists glean from ice cores?
Essential Questions: What process do scientists follow to construct a historical record of atmospheric conditions?

3. Learning outcome: Evaluate data and information collected from various sources. (SCSh3f. Evaluate whether conclusions are reasonable by reviewing the process and checking against other available information)

Essential Questions: How was the data that was represented on the internet sites you visited collected?
Essential Questions: How does the data you collected from various places correlate? Does this information corroborate your original source's conclusions?

Summative Assessment

Ice cores Lab:

Students investigate their own "ice cores", prepared by the instructor. Each level is of different color so students can easily distinguish between layers.

1. Students are given an ice core and develop a data set of CO_2 level in the ice the lower the pH. Students are given a pH probe and a way to melt their "ice cores". They are not given any other directions about CO_2 levels. They are instructed to use the ice core as a scientist would to develop a date set of CO_2 levels verse time. Students should remember from class discussions that scientist melt the ice to release the gases. Students will not be able to capture the gas, but can measure the CO_2 levels by measuring the relative pH of each level. This will illustrate that the student have an understanding of how scientist use ice cores to construct a historical record of CO_2 levels. Ask the students to make a graph correlating the CO_2 levels with recorded temperature (you've given them).

2. Once students compile their own graphs, the instructor should give them a graph with a different set of data. Ask students to compare the data you gave them to their data and write a paragraph explaining how the second set of data either supports their conclusions or not. They must back up their arguments. This shows that the students can evaluate data collected from various sources and evaluate conclusions.

3. Finally have the students answer the following questions: If you find little or no CO_2 in an ice layer give two reasons that would explain the absence of CO_2 in the ice layer, based on what you know about the properties of gases as solutes. Explain your answer. The short answer to this

question could be: 1. There was very little CO_2 in the atmosphere during that year. 2. The ice melted during that year and released the dissolved CO_2.

Learning Experiences:

1. Demonstration of Carbon dioxide solubility in a carbonated beverage. Remove a coke form a cooler full of ice and place in a pan, then take a coke from the bench top that is a room temperature. Open bottles. Show the class how the warmer coke releases more bubbles when opened than the cold coke. Allow the students to discuss what they saw and develop questions based on their observations. (SC7a This helps students begin to look at gas solubility and its dependency on temperature.)

2. Lab exercise with bottles of soda at different temperatures. Allow students to hypothesize about the lab pre-lab based on the soda demonstration. Allow students to observe the soda and write down how "bubbly" the soda is at different temperature. (SC7a reinforces the gas solubility verses temperature)

3. Lecture on temperature effects on gas solubility in liquids with an emphasis on water and $C0_2$. Ask students to suggest environmental examples of this phenomenon. (SC7.a reinforces the gas solubility verses temperature)

4. Ice core samples: Students will get into groups and explore the website: www.exploratorium.org/climate . They will go to "cryosphere" tab and click the link under climate records from Vostok Ice Core Covering graph. Explore the graph and then click on the National Ice Core Laboratory link under the enlarged graph. Assign each group to find new websites (not Wikipedia) to learn more about ice core sampling and give oral resorts about scientific data collection from ice cores. (Students will learn how scientist use ice cores to study climate change SCSh7)

5. Students give reports on their findings. Students should explain why the ice cores are useful for storing historical atrophic conditions (SC7.a). They should also compare and contrast data they found on the different websites. (SCSh3.f)

Reflective Statement:

1. NSTA standard 5 General Skills of Teaching: To show that they are prepared to create a community of diverse learners, teachers must demonstrate they: Successfully organize and engage students in collaborative learning using different student group learning strategies. This unit uses learning experience of a web exploring group activity as well as more than one class discussion learning experience. This allows the students to learn from each other and to collaborate with each other as well as share their ideas.

2. Standard 3-Inquiry: engage students successfully in developmentally appropriate inquiries that require them to develop concepts and relationships from their observations, data, and inferences in a scientific manner. This unit allows students to observe a demonstration then discuss with their classmates what they believed happened. Later, the students will make hypotheses based on

their observations of the demonstrations and then go into the lab and test their hypotheses. Although the students will not make new questions in this unit, they are participating in some student lead inquiry.

3. Standard 4-Issues: Understand socially important issues related to science and technology in their field of licensure, as well as processes used to analyze and make decisions on such issues. This unit is centered on a large social issue of goal climate. The student spends time in the unit learning about how scientists are studying the problem and collecting reliable data. The student gets some experience determining what reliable sources of scientific information are.

APPENDIX G2

Complete Unit Skeleton Assignment of Eddie

Course Description:
This unit is intended for high school biology. It is not a unit made for gifted learners, but it could be tweaked so that it was. The unit fits into the biology class just after a general understanding of matter and energy flow. The learners should be able to access and use Internet sources. Also, students must be informed about laboratory safety, especially when working with heat lamps. This unit is acceptable for most students. The only types of students with difficulty would be the hard of seeing or hearing students, but these students would be able to participate with minor changes of instruction.

Overview:
This unit allows students to assess the indirect impact humans have on coral reef ecosystems. The students will study the effect of various stresses on corals, specifically heat stress. Then the students will correlate coral bleaching to an overall damaging of coral reef ecosystems due to the removal of key organisms in a local nutrient cycle.

Standards (Content and Characteristics):

SB4. Students will assess the dependence of all organisms on one another and the flow of energy and matter within their ecosystems.

a. Investigate the relationship among organisms, populations, communities, ecosystems, and biomes.
b. Assess and explain human activities that influence and modify the environment such as global warming, population growth, pesticides use and water and power consumption.

SCSh6. Students will communicate scientific investigations and information clearly.

a. Write clear, coherent accounts of current scientific issues, including possible alternative interpretations of the data.
b. Use data as evidence to support scientific arguments and claims in written or oral presentations.

Learning Outcomes:
Students will understand that human activity can indirectly cause extreme damage to ecosystems as a whole. Students will understand that in ecosystems, there are key organisms that can have an overwhelming impact of its ecosystem.

Guiding Questions:
What human activities, if any, have the greatest indirect effect on coral bleaching? What role does coral play in its coral reef ecosystem?

Summative Assessment:

The assessment for this unit is for the students to propose a plan to reduce their impact on coral reef ecosystems and to give valid scientific data that backs their proposal. This assessment would have students to use scientific information about possible causes of global warming and link that knowledge to how and why corals may become bleached. It is acceptable for students to produce an argument that is supported by valid scientific data against human involvement in global warming, but these students must provide other reasoning for coral bleaching. This assessment can be as long or short as the teacher deems necessary, but each proposal should include a counter argument. Grading for this assessment should emphasize the content standards of human impact and relationships of organisms the most. This will apparent in the proposal's facts and data. The characteristics standards listed are also important, but for this assessment they should not be weighted as heavily. So, the most points should be awarded for having a valid argument for either side with multiple fact based points. Points should be awarded for using credible resources and correct interpretation of data. Then points should be awarded for linking their arguments to the bleaching of coral. Finally grammatical and scientific writing should be a focus of grading.

Learning Experiences:

1. Guided discussion: The unit would begin with a guided discussion about global climate change. This would be to assess the understandings and misconceptions the students have. The guided discussion should ask questions such as: What are the students' beliefs on global warming? What do the students believe as the causes of global warming? What do the students believe to be credible resources of information about global warming? Once the students start answering these questions, the second experience should be introduced.
2. Review of resources: Have the students criticize in groups or individually various resources of information. The students should be provided with resources that are misleading in the fact that they seem like good honest sources of information by either the name of the website of the way the information is presented. A prime example is *martinlutherking.org* which obviously has a motive. The students should be provided with a guideline of how to judge a resource for its credibility. A guideline is available online or taking from this website *http://mason.gmu.edu/~montecin/critiqueone.html*
3. Internet exploration: Once students are able to criticize a web source you should instruct them to go to the following website: http://www.exploratorium.org/climate. The students should be instructed to explore the website and give a quick critique of the site, verbal or written. They should then be told to focus on the hydrosphere, biosphere, and global effects part of the website. It is here that the beginning of exploration into water temperature change and coral bleaching is introduced.
4. Lecture: After the students have had an introduction into coral bleaching, lecture on the overall effect this has on the coral reef ecosystem as a whole. Point out the various reasons for coral bleaching such as water temperature or exposure to various acidities. Explain how the coral is a key organism in the coral reef environment because it provides both photosynthetically produced food and shelter to many organisms. Then show a before and after video on the destruction of this environment.
5. Lab (only when applicable): Acquire some coral species that one could due a change in water temperature experiment on. For example, ask Dr. F* from (University) for some samples. The lab would be done as a class with all students having a few duties. Some students would

be recorders of information, some would be time keepers, some would help clean up, etc. The reasoning for this is to limit the amount of coral organisms being harmed. The students would observe and draw the coral at its healthy state. Then the students would be instructed to raise the temperature of the water by a few degrees Celsius. After bleaching has occurred, the students would observe and draw the coral again. Then the students would be asked to do the summative assessment assignment and to turn their observations and drawings in a given time period of a few days or weeks.

Reflection:
This assignment was an eye opener. It really plays on ones time constraints and management. I feel that this assignment helped with the content area NSTA standard for biology because I had to research about coral bleaching. The issues standard is definitely addressed in this assignment for the sole reason that global climate change is such a hot topic. The students are forced into decision making about the topic and are made to argue their beliefs. The assessment standard is a part of this activity as well because we had to come up with a performance assessment for the closer of our unit. I only had one grade for this unit is the proposal but the observations, drawings, and critiques would all be reviewed by me, the teacher, and given back to the students with words of advice.

APPENDIX G3

Complete Unit Skeleton Assignment of Summer

Course Description:
The global climate change unit is intended for a middle school Physical Science course. Prior to the lesson, I would anticipate that the students have a general understanding of the idea of greenhouse effect from the previous year in Life Science class. I anticipate that the students will struggle with distinguishing between reliable sources on the internet. My classroom may have students that require special instruction and guidance when reading maps and the various elements of maps, such as legends, scale and contours. This unit is not intended to be persuasive towards or against the global climate change debate, but is intended to present the students with knowledge of the issues and prepare them as literate and informed citizens so that they may be able to engage in conversations about the issue or understand the underlying principles of the debate when they come across it in real world settings.

In this unit, students will examine the scientific view of the nature of matter, particularly describing the movement of particles in solids, liquids, gases, and plasmas states (S8P1). The students will also describe how the behavior of light waves is manipulated causing reflection, refraction, diffraction, and absorption (S8P4) through various states of matter that exist on the planet and how this interaction of light and states of matter play into the global climate change. The students will use will use tools and instruments for observing, measuring, and manipulating equipment and materials in scientific activities utilizing safe laboratory procedures (S8CS4). In doing so, the students will also use appropriate tools and units for measuring objects and/or substances (S8CS10). This unit will also enhance reading in all curriculum areas by (a.) discussing books or articles and (b.) establishing context (S8CS10).

Following the unit, the students will have a stronger understanding of reliable versus unreliable sources. The students will have stronger map reading skills and be able to identify the important map components. The students will understand how light behaves against the different states of matter. In application to global climate change, the students will understand the interaction between global states of surface water and the rise of global temperatures in the global climate change debate. In addition, the students will be more informed citizens about global climate change and be made more aware of personal ways to reduce their carbon footprint.

Essential Questions:
What are the different forms of water on the planet and how are they distributed globally?
What is the correlation between heat and the phase changes of water?
How does light respond to the different phases of matter (solid, liquid, gas)?
What are greenhouse gases? How are they produced and consumed? And why are they important?
How is sea-level affected by increased greenhouse effect?
How does a rise in sea-level affect global climate change?

Focus Question:
How does the increase in global average temperature affect the global state of water? Based on your knowledge of the behavior of light against water and solid water (ice), how would the daily radiation of the Sun's heat across the globe impact global climate change?

Performance Assessment:
Following the unit, the students will be given a short answer quiz with questions covering all the major topics covered in the unit, but in a more narrative, application sense. An example question may be: "Please describe how sunlight behaves against the frozen ground of Antarctica as opposed to the warm ocean waves of the Bahamas." or "Please describe how greenhouse gases in the atmosphere could increase global average temperature. Please depict a possible scenario." Or "Please explain how ocean temperatures can affect global sea-level." These forms of questions on an assessment allow the students to reflect on the understanding of global warming and the topics covered in their own words and give the teacher the opportunity to see if the students understand the main concepts and topics discussed in application sense. Students will be given a rubric prior to assessment so that they understand the key component to our discussion and can brainstorm their experiences.

Learning Experiences:

- **Investigative Cartography:** The students will begin by being introduced to several different global maps and asked to analyze sea-surface temperatures across the globe. This activity will familiarize the students with important map reading skills and terminology. The students will be able to easily recognize, read, and refer back to maps relating to the global climate change debate when involved in classroom discussion and scientific discourse with peers outside of school, which is an important skill for a science literate society. This activity will also introduce the students to key points in the global climate change, such as the distinction between average temperature and daily temperature and climate.

- **Microwave Activity**: The students will conduct group experiment where they will observe the behavior of light, or microwaves, on two states of matter, liquid water and ice. Although it only takes an increase of a few degrees Celsius to melt the ice and water about 80 degrees Celsius to boil, the students will observe that the water will boil in less amount of time than it takes the ice to melt.

- **The Earth's Energy Balance:** This activity will involve an interactive classroom discussion and group drawing. Perhaps the drawing could be on the overhead, Smart board, chalkboard, or a large roll of paper posted on the wall. With a discussion between teacher and students, we will discuss the balance between incoming sunlight energy (solar energy) that heats the earth and outgoing heat energy (infrared energy) that cools the earth, paying close attention to the reflection or absorption of light on water in the form of clouds, ice, and liquid water plays into the cycle. As we discuss, students will take turns drawing the different components of the cycle. We will then go into discussing the greenhouse effect and how increased CO_2 absorbed in the atmosphere from human activity can increase temperatures. The students will also be encouraged to draw man-made CO_2 pollutants such as cars, or power plants that contribute greenhouse gases. Following the discussion, the students will have a creative and informed picture of the cycle that underlines the global climate change debate.

- **Finding Reliable Sources:** The students will be introduced to literature from news sources, such as this NPR article about the impacts of rising ocean temperatures (http://www.npr.org/templates/story/story.php?storiId=12431939) and asked to reflect about their opinions of the article in a journal format. In addition, students will be asked to retrieve and reflect on two additional sources of literature, either in agreement or in opposition to the article topic. With request and guidance from the teacher, this activity will help train the students in critical research values and how to judge a reliable source for support.

- **How Can YOU Do Your Part:** Because of the nature of the unexpected unit, I believe that the point is to make the students aware of global climate change, but also to send the students home with a mission to be more environmentally conscious. After a discussion about carbon footprints, the students will be asked to come up with ways that they or their household can reduce their carbon footprints.

Reflection:
A few NSTA Standards for Science Teacher Preparation that are addressed in this preparing for the unexpected unit are general skills in teaching (Standard 5), nature of science (Standard 2), and issues (Standard 4). Thought the use of various methods of instruction and activities, the teacher present the material to the students in ways that will engage them and keep them motivated and positive and learning. By encouraging the students to research literature online will pose the students to more history of the global climate change debate and will critically examine claims made by both sides by looking at data supported information. The teacher will create a classroom community of informed citizens that will be prepared to engage in scientific discourse and/or adult conversation relating to contemporary topics, such as global climate change, apply relevant, supporting ideas to their case.

APPENDIX G4

Complete Unit Skeleton Assignment of Vince

***Instructional Context*:**
This unit is intended for use with an introductory high school biology class (Grades 9-10). It would be best if students already understand that: 1) the earth has a variety of climates; 2) the atmosphere is a mixture of gases; 3) human activities, such as farming and manufacturing, are powerful enough to change earth's lands and oceans; 4) abrupt changes in climate have occurred on earth before.

***Alignment with Standards*:**

SCSh1. Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science.

SCSh3. Students will identify and investigate problems scientifically.

SCSh4. Students use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.

SCSh6. Students will communicate scientific investigations and information clearly.

SCSh7. Students analyze how scientific knowledge is developed.

b. Universal principles are discovered through observation and experimental verification.

d. Hypotheses often cause scientists to develop new experiments that produce additional data.

e. Testing, revising, and occasionally rejecting new and old theories never ends.

SCSh8. Students will understand important features of the process of scientific inquiry.

a. Scientific investigators control the conditions of their experiments in order to produce valuable data.

b. Scientific researchers are expected to critically assess the quality of data including possible sources of bias in their investigations' hypotheses, observations, data analyses, and interpretations.

e. The ultimate goal of science is to develop an understanding of the natural universe which is free of biases.

SB4. Students will assess the dependence of all organisms on one another and the flow of energy and matter within their ecosystems.

SB5. Students will evaluate the role of natural selection in the development of the theory of evolution.

Learning Outcomes and Essential Questions

Outcomes:
Students will increase their proficiency using tools and instruments.
Students will apply scientific thinking to novel situations, critique/construct experimental designs used to test hypotheses, and will appropriately reference data to make predictions.
Students will assemble information from scientific literature and their own experimentation to develop an argument which defends their ideas (about climate change).

Essential Questions:
What types of evidence would support the idea that global climate change is occurring? What kind of data would refute it?
What should evidence look like?
Strong vs. weak data
Can climate change cause evolution?

***Summative Assessment*:**
Student will work together in groups and construct a scientifically rooted argument
Drawing upon their learning about diversity and interdependence of life on earth, heredity, and evolution, students will engage in a debate where opposing sides offer support for or against the appropriateness of various experimental designs to yield meaningful data about global climate change.

Student-centered Debate
The point of this assessment is to have students take concepts and put them together to make sense. Each debate group should include positions with different responsibilities. For example, a speaker, a research team, a fact checker, etc. all of whom will need a strong understanding of the topic for their argument to be persuasive.

Additionally, it may make sense to have students draw an audience from outside of your classroom. A grassroots team could make posters or announcements – even go door-to-door to other classrooms to draw interest in the debate. Doing these things will help classroom science to reflect the world around us.

The additional benefits of this type of assessment are that:
- Students are called upon to communicate their ideas to others.
- Students demonstrate that they are integrating the concepts of climate change by presenting information a public format.
- Students and listeners become more informed and understand how the issues' relevance.

Learning Experiences:
- A traditional lecture including information about Mendelian genetics featuring relevant vocabulary and content. Students will complete dihybrid crosses, explore common ratios

and make trait predictions for offspring give random and nonrandom mating of parental generations. Selection pressure introduced. This background information is a necessity for further discussion about the topic and I think will well presented as an enriched lecture that includes pictures, stories and specific examples.

- Students will engage in an open discussion about the idea of climate change. The teacher should help to keep things on-topic, but not dictate the direction of the conversation. It may be helpful for the teacher to ask questions in order to illuminate the reasons behind students' views. This will hopefully hook students by presenting ideas in opposition to their own. It will also provide the teacher with a barometer for the trajectory and depth appropriate for the learning experiences to follow.

- The teacher will provide articles form everyday news sources featuring well designed and poorly designed experiments, and have students decide and sort them accordingly. After discussing, the groups will be surveyed and a list of common positive and negative features compiled on poster paper, a whiteboard, or chalkboard, etc. This will help students to identify and support their own ideas about scientific investigation. Misconceptions make for teachable moments.

- Students will use a population genetics website to manipulate fitness and compare how the changes they enact affect allele frequencies over time in response to natural selection. This experience should help students to understand what evolution looks like in specific populations and in response to certain variables. http://darwin.eeb.uconn.edu/simulations/selection.html

- Students will use the site: http://www.exploratorium.org/climate to investigate the implications that increasing global temperatures may have on the range of malaria. This experience should be a synthesis activity that requires students to connect the dots between changing global temperatures and adaptation and evolution. Extension: Students could be asked to imagine for example, "What types of changes might lead to a new parasite or hosts species?"

Reflection:
ISSUES I tried to cover this using a debate-style discussion as student's formative assessment. My goal was that as result of their participation students would be able to connect science to their everyday lives more readily and be more prepared to participate in events in their communities.

NATURE OF SCIENCE is the main purpose of this unit. I felt that climate could be used to teach some biology content, but perhaps a better use of the topic was to highlight the importance of good science more so than giving an absolute answer on the issue. NOS is the focus of the literature review, a partial reason for engaging in the open discussion at the beginning of the unit, and the reason for Mendelian genetics to be presented in lecture format (there is teachable history there about controlled experiments).

INQUIRY is the focus of the summative assessment, which is to be entirely student run. My aim was to create an experience requiring students to engage in higher-order thinking and know enough about the topic from research, observation and inference to be able to elaborate.

I found it challenging to create a cohesive unit. While I feel comfortable designing individual learning experiences, I continue to struggle assembling a smooth flowing unit. This took me way more than three hours and unfortunately I'm certain it doesn't seem that way.

APPENDIX H

Curriculum Vitae

ARIS REYNOLD VERTIDO CAJIGAL
Email: arvcajigal@yahoo.com

U.S. Contact Information:
113 College Station Road, Apartment L-106
Athens, Georgia 30605, USA
Tel: 706-389-6225

Philippine Contact Information:
Ladera Street, Brgy. 3
Badoc, Ilocos Norte, 2904 Philippines
Tel: +6377-670-0159

I. Education

Doctorate:	Ph.D. in Science Education The University of Georgia Athens, Georgia, U.S.A., 2010 Dissertation: *Exploring the Epistemological, Pedagogical, and Curricular Beliefs of Preservice Secondary Science Teachers on Global Climate Change* Major Professor: Dr. Deborah J. Tippins
Certificate:	Interdisciplinary Qualitative Studies Graduate Certificate The University of Georgia Athens, Georgia, U.S.A., 2010
Master's:	Master of Arts in Education (Major: Chemistry) Mariano Marcos State University Laoag City, Philippines, 2006 Thesis: *Problem Solving Strategies and Performance of High School Students in Chemistry*
Undergraduate:	Bachelor in Secondary Education (Major: Chemistry) *(Magna Cum Laude)* Mariano Marcos State University Laoag City, Philippines, 2001

Action Research: *Vitalizing Chemistry Students' Participation in Laboratory Activities through Science Improvisation*

Secondary: Mariano Marcos State University
Laboratory High School
Batac, Ilocos Norte, Philippines, 1997

Elementary: Badoc South Central School
Badoc, Ilocos Norte, Philippines, 1993

II. Employment

Instructor 2, Bachelor in Secondary Education Department, College of Teacher Education, Mariano Marcos State University, Laoag City, Philippines (July 2008 – present)

Instructor 1, Bachelor in Secondary Education Department, College of Teacher Education, Mariano Marcos State University, Laoag City, Philippines (July 2001 – June 2008)

Other Designations:

- Teacher Training Instructor for BSEd-Chemistry Student Teachers, Laboratory High School, College of Teacher Education, Mariano Marcos State University, Philippines (2002 – 2007)
- Faculty Adviser for Student Organizations, College of Teacher Education, Mariano Marcos State University, Philippines (2001 – 2007)
- Faculty Adviser for Undergraduate Action Research, College of Teacher Education, Mariano Marcos State University, Philippines (2001 – 2007)
- Faculty Adviser for High School Science Research, Laboratory High School, College of Teacher Education, Mariano Marcos State University, Philippines (2003 – 2007)

III. Eligibility (Philippines)

Licensure Examination for Teachers, a national examination administered by the *Philippine Professional Regulation Commission*, August 2001 (Passed, Rating: 88.60%)

Presidential Decree 907 – Honor Graduate

IV. Resident Instruction and Continuing Education

Mariano Marcos State University, College of Teacher Education, Laoag City, Philippines (As Instructor)

Course Code	*Course Title*
College Level	
SCIENCE 3	Introduction to Physical Science
NAT SCI 9	Environmental Science and Health
CHEM 114	General and Inorganic Chemistry
CHEM 111	General Chemistry I
CHEM 112	General Chemistry II
CHEM 121	Analytical Chemistry I
CHEM 122	Analytical Chemistry II
CHEM 131	Organic Chemistry I
CHEM 132	Organic Chemistry II
CHEM 150	Physical Chemistry
CHEM 185	Environmental Chemistry
STS 1	Science, Technology and Society
High School Level (at the Laboratory High School, College of Teacher Education)	
SCIENCE III	High School Chemistry (Grade 9)
Elective IV	Advanced Chemistry (Grade 10)

University of Georgia, Department of Mathematics and Science Education, Athens, Georgia, U.S.A. (As Graduate Teaching Assistant)

Course Code	*Course Title*	*Semester/School Year*
ESCI 6420 / ESCI 4420	Science for Early Childhood Education	Summer 2010 Fall 2009 Fall 2008 Spring 2008 Fall 2007

ESCI 6460	Methods of Science Teaching	Fall 2008
ESCI 3450	Practicum in Science Education	Fall 2008 Spring 2010
ESCI 6450	Science Curriculum and Learning	Spring 2010
CHEM 1060	Physical Science for Middle School Science Teachers	Spring 2009

Seminars, Trainings, Conferences, Lectures, and Fora Attended (Philippines)

1. Research Dissemination Forum, February 24, 2006, MMSU – College of Teacher Education, Laoag City
2. Seminar – Workshop on Instructional Materials Development, November 2-3, 2005, MMSU – College of Teacher Education, Laoag City
3. Symposium: "Crisis Management Towards Economic Recovery", September 17, 2005, MMSU – Graduate School, Laoag City
4. Division Training on SCI-DAMA for Secondary School Science Teachers, June 30, 2005, Ilocos Norte National High School, Laoag City
5. Regional Science Leaders' Congress, November 17-19, 2004, Pangasinan National High School, Lingayen, Pangasinan
6. Research and Development Forum, September 18, 2004, MMSU – Graduate School, Laoag City
7. Lecture – Forum: "Gender and Ethics in Health Social Science Research", April 24, 2004, Palazzo de Laoag Hotel, Laoag City
8. Regional Science Leaders' Congress and Super Quiz Bee, November 6-8, 2003, Ilocos Sur National High School, Vigan City
9. Regional Workshop on the 2002 Basic Education Curriculum, November 5-6, 2003, MMSU – College of Education, Laoag City
10. Action Research Seminar – Workshop, September 29, 2003, MMSU – College of Education, Laoag City
11. Symposium: "S and T for Health and Wealth", September 20, 2003, University of Santo Tomas, Manila
12. Research and Development Forum, August 30, 2003, MMSU – Graduate School, Laoag City
13. Joint Philippine-American Academy of Science and Engineering (PAASE) and Philippine Association for the Advancement of Science (PhilAAS) Meeting and Annual Conference, July 11-12, 2003, Manila Hotel, Manila
14. Division Training of Secondary School Teachers in English, Filipino, Science and MAKABAYAN, June 26-28, 2003, Ilocos Norte College of Arts and Trades, Laoag City
15. Research Dissemination Forum, January 24, 2003, MMSU – College of Education, Laoag City
16. APEC National Workshop on Digital Content Development, October 14-24, 2002, University of San Carlos, Cebu City

17. Research Dissemination Forum, October 3, 2002, MMSU – College of Education, Laoag City
18. Echo Conference on the Basic Education Curriculum, August 8, 2002, MMSU – College of Education, Laoag City
19. Induction Seminar for New Faculty of the Mariano Marcos State University, July 1, 2002, MMSU – University Training Center, Batac, Ilocos Norte
20. Panlasigui Lecture Series: "Bracing for Curriculum 2002: Content-Based Instruction", May 23-24, 2002, Benitez Theater, University of the Philippines – College of Education, Diliman, Quezon City
21. Conference on TIMSS – R, August 21, 2001, MMSU – Regional Science Teaching Center, Laoag City
22. 6th President Ferdinand E. Marcos Lecture Series (Organic Chemistry), August 6, 2001, Teatro Ilocandia, MMSU – Batac, Ilocos Norte

Seminars, Trainings, Conferences, and Lectures Attended (USA)

1. Lecture on *YouTube* – A Genre Approach, September 18, 2009, University of Georgia, Athens, GA
2. Centers for Ocean Sciences Education Excellence (COSEE)-Southeast Ocean Sciences Education Leadership Institute on Global Climate Change, July 20-25, 2009, Baruch Marine Field Laboratory, Georgetown, SC
3. Fire Safety and Fire Extinguisher Training, October 10, 2008, University of Georgia, Environmental Safety Division-Fire Safety Program, Athens, GA
4. COASTLINES 2008-Georgia Teacher Quality Higher Education Program (Workshop for Science Teachers), June 13-24, 2008, University of Georgia, Marine Extension Services, Savannah, GA
5. Fulbright Enrichment Seminar, March 13-15, 2008, Albuquerque, NM
6. Georgia Science Teachers Association (GSTA) Annual Conference, February 14-16, 2008, Athens, GA
7. Association for Science Teacher Education (ASTE) Annual International Conference, January 10-12, 2008, St. Louis, MO

V. Scholarly Activities

Publications

Cajigal, A.R.V., Chamrat, S., Tippins, D.J., Mueller, M.P., & Thomson, N. (Under review). Beyond the movie screen – An Antarctic adventure. *Science Activities*.

Britton, S., Tippins, D.J., **Cajigal, A.R.V.**, Cox, M., Cole, G., Vasquez, M., Trejo, M.C. & Guzman, A. (2010). The adventures of the gray whale: An integrated approach to learning about the long migration. *Science Scope, 33*(8), 27-33.

Grants

STEM Education, Improving Instruction and Enhancing Student Success in STEM Disciplines, University of Georgia, *Ethical Decision Making in the Education of Future Teachers: Exploring Citizen Science through Popular Culture Videocases* (Co-principal Investigators: D. Tippins, M. Mueller, & **A. Cajigal**, 2008-2009, $4000).

Honors, Awards, and Scholarship Grants

Honors: Magna Cum Laude (College)
With High Honors (High School)
Second Honors (Elementary)

Awards: Rep. Imee R. Marcos Academic Excellence Award
Alfonso Yuchengco National Award for Discipline
Student Services Award
Proficiency in Chemistry Education Award
Organizational Leadership Award
Best Action Research in Chemistry
YMCA Academic Excellence Award
YMCA Leadership Award
Citation Award for Academic Excellence from the Juan Luna Civic Association of Badoc, Ilocos Norte, Philippines

Scholarships: Fulbright Scholarship Grant (Foreign Fulbright Student Program), Georgia, USA, sponsored by the United States-Department of State and the Philippine-American Educational Foundation, 2007-2010
University Scholar, Mariano Marcos State University, Philippines, 1998 – 2001
College Scholar, Mariano Marcos State University, Philippines, 1997

Experiences as Lecturer, Resource Speaker, Trainer, or Facilitator

1. Trainer/Resource Speaker/Facilitator, Ocean Awareness Day Workshop for Teachers on Global Climate Change, March 13, 2010, Georgia Aquarium, Atlanta, Georgia, USA
2. Resource Speaker/Facilitator, Teaching Global Climate Change in Early Childhood Education, October 26, 2009, ESCI 4420 Class, University of Georgia, Athens, Georgia, USA
3. Regional Trainer, Certificate Program for High School Teachers in Chemistry, April 16 – June 2, 2007, Mariano Marcos State University (MMSU) – Regional Science Teaching Center, Laoag City, Philippines
4. Regional Trainer, Certificate Program for High School Teachers in Chemistry, November 16, 2006 – April 7, 2007, Mariano Marcos State University – Regional Science Teaching Center, Laoag City, Philippines
5. Regional Trainer, Certificate Program for High School Teachers in Chemistry, April 17 – June 3, 2006, Mariano Marcos State University – Regional Science Teaching Center, Laoag City, Philippines

6. Lecturer, MAEd - Science Education Graduate Class (Topic: Use of Historical Vignettes in Science Teaching), January 21, 2006, MMSU – Graduate School, Laoag City, Philippines
7. Resource Speaker, Briefing for Off-Campus Student Teaching, January 6, 2006, MMSU – College of Teacher Education, Laoag City, Philippines
8. Lecturer, Natural Science Undergraduate Class (Topic: Basic Concepts in Chemistry), October 4, 2005, MMSU – College of Teacher Education, Laoag City, Philippines
9. Resource Speaker / Lecturer, 2005 Teaching Competency Enhancement Seminar, July 4-5, 2005, MMSU – University Training Center, Batac, Ilocos Norte, Philippines
10. Resource Speaker / Lecturer, Division Level Science Leaders' Congress and Science Camp, January 29-31, 2005, Ilocos Norte Regional School of Fisheries, Laoag City, Philippines
11. Resource Speaker / Lecturer, 2004 Teaching Competency Enhancement Seminar, June 15-16, 2004, MMSU – University Training Center, Batac, Ilocos Norte, Philippines
12. Regional Trainer, Intensive Training for Elementary School Science Teachers in Region One (Project – RISE 2004), April 12 – May 8, 2004, MMSU – Regional Science Teaching Center, Laoag City, Philippines
13. Resource Speaker, Orientation Program for On-Campus Teaching for BSEd Student Teachers, November 3, 2003, MMSU – College of Education, Laoag City, Philippines
14. Facilitator, Action Research Seminar – Workshop, September 29, 2003, MMSU – College of Education, Laoag City, Philippines
15. Facilitator, Division Level Youth Science Camp, September 4-6, 2003, Ilocos Norte Regional School of Fisheries, Laoag City, Philippines
16. Facilitator, Gender Sensitivity Training, March 1, 2003, MMSU – College of Education, Laoag City, Philippines

Conference Presentations

A. Paper Presentations

Cajigal, A.R.V., Tippins, D.J., & Mueller, M.P. (2010, March). *An Examination of Ethical Decision Making of Beginning Secondary Science Teachers through Citizen Science Methods*. Paper accepted for presentation to the Annual International Conference of the National Association for Research in Science Teaching, Philadelphia, PA.

Reeves, M., **Cajigal, A.R.V**., & Cole, G. (2010, March). *Conceptual continuity in chemistry: Connecting multiple topics.* Paper presented during the Annual National Conference of the National Science Teachers Association, Philadelphia, PA.

Reeves, M., **Cajigal, A.R.V**., & Cole, G. (2010, February). *One model of weaving conceptual ideas using laboratory work.* Paper presented during the Annual Conference of the Georgia Science Teachers Association, Savannah, GA.

Tippins, D., Thomson, N., **Cajigal, A.R.V.**, Hodges, G., Doney, P., Cole, G. et al. (2010, January). *Towards the development of an international science teacher education course: Some strategies, issues and experiences*. Paper presented during the Annual International Conference of the Association for Science Teacher Education, Sacramento, CA.

Cajigal, A.R.V., Tippins, D.J., & Mueller, M.P. (2010, January). *Exploring ethical decision making of beginning science teachers through citizen science methods*. Paper presented during the Annual International Conference of the Association for Science Teacher Education, Sacramento, CA.

Cajigal, A.R.V. (2009, December). *Constructionism and epistemological theories – Looking for theoretical intersections.* Paper presented during the 2009 SQUIG Conference in Qualitative Research, Athens, GA.

Cajigal, A.R.V., Tippins, D.J., & Mueller, M.P. (2009, October). *Ethical decision making in videos – Beginning science teachers' experiences with videocase simulations and citizen science*. Paper presented during the Annual Conference of the Southeast Association for Science Teacher Education, Kennesaw, GA.

Cajigal, A.R.V. (2008, October). *Teachers as environmental protectors: Thinking of the potential role of community-based experiences of preservice teachers*. Paper presented during the Annual Conference of the American Educational Studies Association, Savannah, GA.

Tippins, D., Thomson, N., **Cajigal, A.R.V.**, Hodges, G., Doney, P., Cole, G. et al. (2008, October). *Towards the development of an international science teacher education course: Some strategies, issues and experiences*. Paper presented during the Annual Conference of the Southeast Association for Science Teacher Education, Columbia, SC.

Cajigal, A.R.V. (2008, October). *Strengthening preservice science teachers' sense of stewardship through a community-based environmental education*. Paper presented during the Annual Conference of the Southeast Association for Science Teacher Education, Columbia, SC.

Cajigal, A.R.V. (2008, July). *EcoJustice in the Philippines: Revitalizing prospective teachers' understanding of the environment through their experiences in the local community and the Earth's natural systems*. Paper presented during the Provoking Research, Provoking Communities International Conference, Windsor, Ontario, Canada.

Cajigal, A.R.V. (2008, March). *Strategies and performance of high school students in problem solving*. Paper presented during the Georgia Graduate Students Interdisciplinary Conference, Athens, GA.

Cajigal, A.R.V. (2007, October). *Problem solving strategies and performance of high school students in chemistry*. Paper presented during the Annual Conference of the Southeast Association for Science Teacher Education, Valdosta, GA.

B. Poster Presentations

Cajigal, A.R.V. & Mueller, M.P. (2009, October). *Beginning science teachers' experiences and visions with citizen science*. Poster presented during the Annual Conference of the Southeast Association for Science Teacher Education, Kennesaw, GA.

Cajigal, A.R.V. (2009, January). *Community-based environmental education experiences of preservice elementary science teachers in the Philippines*. Poster presented during the Annual International Conference of the Association for Science Teacher Education, Hartford, CT.

Handa, V.C., **Cajigal, A.R.V.**, Tippins, D.J., & Thomson, N.F. (2008, April). *Bridging communities and preservice science teacher preparation: Narratives from a Philippine barangay*. Poster presented during the 2008 University of Georgia – Educational Forum for Globalization, Research and Teaching, Athens, GA.

Tippins, D.J., Handa, V.C., **Cajigal, A.R.V**., & Thomson, N.F. (2007, October). *The community immersion model of preservice science teacher preparation*. Poster presented during the Annual Conference of the Southeast Association for Science Teacher Education, Valdosta, GA.

VI. Membership to Scientific, Professional, Honor, and Non-Government Organizations

1. Member, Pi Lambda Theta International Honor Society and Professional Association in Education, USA (2010 – 2011)
2. Member, National Scholars Honor Society, USA (2008 – present)
3. Member, American Educational Studies Association, USA (2008 – 2009)
4. Member, Association for Science Teacher Education, USA (2007 – present)
5. Member, Southeast Association for Science Teacher Education, USA (2007- present)
6. President, Region One Organization of Science Club Advisers (ROSCA), Division of Laoag City, Philippines (2004 – 2007)
7. Auditor, Region One Organization of Science Club Advisers (ROSCA), Division of Laoag City, Philippines (2002 – 2003)
8. Member, Region One Organization of Science Club Advisers (ROSCA), Philippines (2002 – present)
9. Member, Samahan ng mga Kurikularista (University of the Philippines-Diliman), Philippines (2002 – 2005)
10. Member, Philippine Association for the Advancement of Science (PhilAAS), Philippines (2003 – present)
11. Member, American Studies Association (ASA – Ilocos), Philippines, (2001 – present)
12. Member, Philippine Association for Teacher Education (PAFTE), Philippines (2005 – present)
13. Member, Philippine Health Social Science Association (PHSSA), Philippines (2004 – present)
14. Member, Young Men's Christian Association (YMCA), Ilocos Norte – Laoag City Chapter, Philippines (2002 – present)

VII. Service

- Rules Judge and Time Keeper, Science Bowl, University of Georgia, Athens, GA, USA, 2010
- Graduate Student Member, Association of Science Teacher Education (ASTE) Awards Committee, USA, 2010

- Member, Planning Committee, SQUIG Conference on Qualitative Research, University of Georgia, Athens, GA, USA, 2009
- Volunteer, Georgia Science Teachers Association (GSTA) Annual Conference, Athens, GA, USA, 2008
- Facilitator, YMCA Provincial and Regional Academic Olympics, Ilocos Norte, Philippines, 2003-2006
- Faculty Adviser, College-Y Annual Cleaning of MMSU-College of Teacher Education Mini-Forest (in collaboration with the Department of Environment and Natural Resources), Ilocos Norte, Philippines, 2002-2007
- Faculty Adviser, College-Y Annual Tree Planting Activity, Mariano Marcos State University, Laoag City, Philippines, 2002-2007
- Adviser, Laboratory High School Science Club, Mariano Marcos State University, Laoag City, Philippines, 2002-2007
- Adviser, Laboratory High School Debate Society, Mariano Marcos State University, Laoag City, Philippines, 2006-2007
- Adviser, College of Teacher Education Men's Club, Mariano Marcos State University, Laoag City, Philippines, 2002-2005
- Adviser, College-Y (MMSU-CTE Chapter), Mariano Marcos State University, Laoag City, Philippines, 2002-2007
- Adviser/Coach/Trainer, UP Namnama Provincial and Regional Quiz Shows (High School Level), Ilocos Norte, Ilocos Sur, La Union, and Abra, Philippines, 2003-2006
- Adviser/Coach/Trainer, UP Patalansanlahi National Quiz Show (High School Level), University of the Philippines, Quezon City, Philippines, 2004-2006
- Adviser/Coach/Trainer, UP Bannuar Regional Quiz Show (High School Level), Vigan City, Philippines, 2005
- Adviser/Coach/Trainer, Department of Education Division Level Science Quiz (High School Chemistry), Laoag City, Philippines, 2003-2007
- Adviser/Coach/Trainer, Philippine National Chemistry Olympiad (High School Level), Ateneo De Manila University, Quezon City, Philippines, 2005
- Adviser/Coach/Trainer, Parliamentary Procedure, Division Level STEP Competition, Ilocos Norte Regional School of Fisheries, Laoag City, Philippines, 2005
- Adviser/Coach/Trainer, Parliamentary Procedure, Regional Level STEP Competition, Sta. Barbara, Pangasinan, Philippines, 2005
- Adviser/Coach/Trainer, Provincial Science Quiz Show, Ilocos Norte Science Community, Mariano Marcos State University, Batac, Ilocos Norte, Philippines, 2005
- Adviser/Coach/Trainer, Provincial Biotechnology Quiz Show, Ilocos Norte Science Community, Mariano Marcos State University, Batac, Ilocos Norte, Philippines, 2005
- Adviser/Coach/Trainer, Provincial Science and Mathematics Olympiad, Mariano Marcos State University, Batac, Ilocos Norte, Philippines, 2005
- Adviser/Coach/Trainer, Department of Education Regional Level Science Quiz (High School Chemistry), Binalonan, Pangasinan, Philippines, 2005
- Adviser/Coach/Trainer, Regional YMCA Team Quiz (College Level), Baguio City and Cabanatuan City, Philippines, 2004-2006
- Reviewer for Chemistry, Physical Science, and Professional Education, Licensure Examination for Teachers, Mariano Marcos State University, Laoag City, Philippines, 2002-2007

VIII. References

Dr. Deborah J. Tippins
Professor
Department of Mathematics and Science Education
The University of Georgia
212 Aderhold Hall
Athens, Georgia, 30602 U.S.A.
Contact Number: 706-542-1763

Dr. Miriam E. Pascua
President
Mariano Marcos State University
Batac City, Ilocos Norte
2906 Philippines
Contact Number: +6377-792-3191

Dr. Eduardo T. Borja
Dean
College of Teacher Education
Mariano Marcos State University
Laoag City, Ilocos Norte
2900 Philippines
Contact Number: +6377-771-4143