The Complexities, Persistence, and Relationships among Middle School Students' Climate Change Stances and Knowledge

by

Michelle Reicher Newstadt

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Doctoral Committee:

Professor Nancy B. Songer, Drexel University, Co-Chair
Assistant Professor Leah A. Bricker, Co-Chair
Professor Brian P. McCall
Professor Richard B. Rood

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Abstract

Perhaps the most pressing set of challenges facing the field of science education today is the facilitation of fruitful understanding of climate change and helping individuals to make informed decisions associated with mitigating the impacts of climate change. Due to both the relative newness of teaching climate change and the socio-scientific nature of the topics, there is a dearth of studies that focus on characterizing students' climate change stances, messy middle concepts or knowledge development. Using mixed methods research approaches, this dissertation addresses research questions associated with characterizing students' knowledge and stances and the persistence and relationships amongst students' climate change knowledge and stances. Participants include middle school students from different geographic regions and types of schools who participated in a curriculum that focuses on climate change and its impacts on ecosystems. The curriculum aligns with the climate change performance expectations in the Next Generation Science Standards. Data collection instruments include a pre/post stance survey, pre/post knowledge assessments, and a post semi-structured interview protocol completed approximately five months after students completed the curricular module. Statistical approaches such as multivariate regressions, generalized linear models, and graphical models are used to analyze the survey and knowledge assessments. Transcribed and coded interviews reveal the complexities and the persistence of climate change stances and knowledge and the messy middle knowledge concepts that students exhibited across all climate change stance categories. The variety of data collection instruments and multiple time points to gather data add to the breadth and depth of current work by identifying middle school students' level of worry regarding

climate change issues, the complexities of students' knowledge and stances, specifically identifying messy middle knowledge, and the intricate relationship between climate change knowledge and stances.

The study reveals that students' climate change knowledge and stances are positively correlated. Interacting with the evidence-based curriculum is correlated with a positive stance shift regarding the existence of anthropogenic climate change. However, the majority of students remain not worried about the impacts of climate change, except in the case where a student felt (s)he has experienced the impacts of climate change, in which case (s)he was more likely to be worried. Interview data demonstrate that students with negative stances tended to have weak knowledge while students with positive stances exhibited a spectrum of knowledge (e.g., high, messy middle, and weak).

These findings are valuable in guiding specific secondary school curriculum design. For example, climate change curricular units should strive to make the curriculum more relevant to students' lives and prior experiences, specifically challenge messy middle knowledge with repeated exposures of correct scientific ideas, and targeting specific climate change vocabulary, such as using the term excess greenhouse gases instead of air pollution. Moreover, pre-service and in-service teacher training should address common climate change misconceptions and common productive and unproductive stances, and policy makers should be lobbied to build on the current Next Generation Science Standards by placing climate change topics at the forefront of secondary education and assessments.

Chapter 1: Introduction

Rationale for Dissertation Work

"What they've (scientists) found, year after year, is that the levels of carbon pollution in our atmosphere have increased dramatically. That science, accumulated and reviewed over decades, tells us that our planet is changing in ways that will have profound impacts on all of humankind. The 12 warmest years in recorded history have all come in the last 15 years. Last year, temperatures in some areas of the ocean reached record highs, and ice in the Arctic shrank to its smallest size on record -- faster than most models had predicted it would. These are facts." (President Obama, June 25, 2013).

There is consensus amongst the international science community regarding a massive body of irrefutable evidence (IPCC, 2013) that anthropogenic climate change is happening. At the same time, climate change curricula have entered United States' K-12 classrooms and have been met with some conflict, similar to past and present discussions about evolution (Morrison, 2012), with at least 16% of Americans taking the climate change denial stance (Leiserowitz, Maibach, Roser-Renouf, Feinberg, & Howe 2013). In order to respond to the urgent threat of climate change, we need to educate middle and high school students on crucial climate change and sustainability issues. The Next Generation Science Standards (NGSS), new national standards in the United States that are arguably the most rigorous national science standards ever seen in the United States, include climate change topics beginning in middle school curricula. The standards include disciplinary core ideas (e.g., content) on weather and climate, sustainability, and human impacts on the environment (NGSS Lead States, 2013) in the middle and high school guidelines. The NGSS suggest teaching these content areas with science practices, such as data collection and analysis and constructing explanations, and crosscutting concepts, such as scale. Thus, as states adopt these standards, middle school students will be required to learn about complex climate science in conjunction with science practices and crosscutting themes. Grappling with and challenging students with these topics is important, since the current secondary school students will soon be our decision-makers on issues such as energy sources, and carbon emissions standards. However, mere exposure to these topics and practices is not enough. In order to design effective learning environments and curricular activities to help students become informed decision-makers, we need to identify students' stances, knowledge and messy middle conceptions (e.g.,, encompasses a spectrum/ mixture of correct and incorrect complex science knowledge) (Gotwals & Songer 2010), regarding climate change. How do stances and knowledge vary between and among individuals and groups of students? Are stances and messy middle knowledge stable even after working with irrefutable climate evidence? What factors are influential on students' views and knowledge?

Climate change is a complex, interdisciplinary science, and a student's conceptions and views are likely influenced by factors beyond the school walls, including political, religious, and/or cultural factors. Socio-scientific issues, such as climate change, should be included in science classrooms because they aid in the development of creating responsible citizens with using science knowledge for decision-making (Driver, Newton, & Osborne, 2000). Moreover, we need to go beyond identifying stances and knowledge; we need to explore the relationships among students' knowledge and stances. It is imperative to unpack the complexities, persistence, and development of knowledge, messy middle concepts, and stances prior to, during, and after a purposeful climate change curricula. The nature of students' stances and knowledge need to be further studied in order to effectively modify existing curriculum and to build new climate change and sustainability activities.

Overview of My Dissertation Work

My dissertation work explores middle school students' climate change stances and knowledge before and after participating in purposeful evidence-based curriculum. The main research questions that guide my work are found in Table 1.1. These questions explore the nature, stability, and complexities of students' climate change stances and knowledge. To answer these questions, I examined the correlations and relationships between students' climate change stances and knowledge using multiple data collection instruments and time-points. All students in the study participated in an eight week Climate Change and Its Impacts curricular unit that was developed by the ChangeThinking research team and funded by the National Science Foundation (Songer, et al., 2012). I used three main data collection instruments: (a) a pre/post stance survey taken before and after the 8 week curricular unit, (b) a pre/post knowledge assessment items taken before and after the curricular intervention, and (c) a post semi-structured interview conducted 4-5 months after completing the curriculum with a subset of the sample population.

Table 1.1
Research Questions Guiding The Mixed Methods Dissertation Study

Overarching Research Question	What is the nature, persistence, and relationships among middle school students' climate change stances, knowledge and messy middle concepts? Sub-question: What does knowledge and stance development look like?
Research Question 1	What is the nature, stability, and patterns of students' climate change stances?
Research Question 2	What are the relationships between students' climate change stances and climate change knowledge? Sub-question: Does knowledge change from before and after participating in the curriculum?
Research Question 3	How do we characterize the complexities and stability of students' climate stances and knowledge?

To explore the nature, stability and patterns of students' climate change stances (e.g., research question 1), I analyzed pre and post closed form and open-ended responses from the stance survey. For the second research question, I analyzed student responses on abiotic items (e.g., climate and climate change questions) from the pre and post knowledge assessment to identify knowledge content that changes. Then, to explore statistical relationships between climate change knowledge and stances, I created statistical models to identify quantitative predictors. Finally, to characterize the complexities of students' climate change stances and knowledge, I analyzed students' semi-structured interview data collected 4-6 months after they had completed the curriculum. The post semi-structured interview further explored the complexities of the climate change stances and knowledge categories.

Using a mixed methods approach, I used multiple statistical and qualitative data analysis techniques to explore this complex socioscientific phenomenon (Greene, 2007). Qualitative coding of student interviews complemented the quantitative approaches used to analyze the pre and post surveys and knowledge assessments. Through the use of rich statistical models and qualitative data analysis, the findings revealed information on the persistence of stances, knowledge and messy middle concepts. Additionally, the findings illustrate the complexity of climate change knowledge development through the characterization of a range of partially correct and/or incomplete science knowledge, also called the "messy middle" (Gotwals & Songer, 2010). The messy middle knowledge is knowledge that is a blend of knowledge that is accepted by the scientific community and knowledge that does not align with accepted scientific theories (e.g.,, incorrect scientific principles). It is messy because it is not clearly a right or wrong concept; it is a spectrum and blend of misunderstandings and accepted scientific principles.

Based on my research questions, data collection and analysis, my work contributes to the following areas in the field of climate change education: (a) identifying the nature and stability of climate change knowledge and stances in association with a an evidence-based curricular intervention, (b) exploring the complexities, relationships, and persistence of both students' stances and knowledge about climate change through post-curricular intervention interview data, (c) identifying patterns of stances and knowledge as well how students justify their climate change stances, and (d) exploring the relationship between stance and knowledge development (e.g., do stances act as a foundation for knowledge development?).

Major Findings and Contributions to the Field of Education

My findings add both to the depth and the breadth of current works studying middle school students' climate change knowledge and stances. While my work cannot be generalized across the middle school population in the United States, my findings speak to trends in my sample population (n=326). The results speak to developing more targeted climate change curricular activities and interventions, to creating additional pre-service and in-service teacher resources and learning opportunities/environments to help effectively teach climate change, and to encouraging educational policy makers to make climate science education a greater priority in secondary school.

I found that there was a positive correlation between students participating in the Climate Change and Its Impacts on Biodiversity (Songer et al, 2012) curriculum and having positive climate change stance development. Conversely, students' level of worry remained stable after the curriculum, where students were generally not worried about climate change impacts. In interviews and open-ended questions, it appeared that students were personally detached from climate change issues. Indeed, they discussed climate change as an issue that affected other locations, animals, and/or would happen in the distant future. However, students who felt that they have experienced the impacts of climate change were statistically significantly more worried about climate change impacts than those students who stated they had not experienced the impacts. Additionally, students across all stances categories (e.g., positive to negative climate changes stances) expressed messy middle knowledge content. These findings specifically speak to designing evidence based curricula that has students work with transparent data sources, creating projects and activities that are relevant to students' lives and communities to begin to see potential personal impacts of a changing climate, and allowing for repeated interactions with this material in multiple, targeted contexts to the complex science to guide students through the messy middle knowledge and to build constructively on students' concepts.

The findings also indicate that there is a positive, statistical correlation between a student's pre climate change knowledge and post stances. Additionally, extreme pre climate change stances (either positive or negative) were significant predictors of post stances. The interviews, which were conducted 4-6 months after completing the curriculum, revealed that students with negative stances also exhibited weak climate change knowledge. However, students with positive climate change stances expressed a spectrum of weak, messy middle, and positive knowledge. This speaks to the potentially multifaceted nature of the relationship between climate change knowledge and stances as well the complexity of climate science. My results suggest more data needs to be collected to speak to the ordering of climate change knowledge and stance development (e.g.,, which is developed first?)

My dissertation findings can guide my future work and the work of others interested in secondary climate change science education, as well as the work of those involved in policy decisions about climate change education. "It is important that science educators interested in supporting the teaching and learning of climate change science attend to the complex relationship between climate science knowledge and beliefs and the persistent public perception of controversy that is the current context for climate change education" (Walsh, 2012, p.11). By studying the complexities and influences in how middle school students grasp and think about climate change science, teachers and other community members can more effectively guide students in becoming informed global citizens who will make important energy and policy decisions moving forward.

From a policy perspective, we can inform where and how money should be spent to help students develop knowledge and critical decision-making skills associated with formal and informal climate science education. Moreover, it is unclear if stances about climate change might be analogous to previous debates on either evolution or the anti-smoking campaign. In the latter, education and mass media efforts have been successful in deterring and reducing smoking (Jochelson, 2006). In contrast, scientific backing did not dissuade deniers in the evolution debate (Sadler, 2004). This work aims to identify the stability of students' climate change perspectives. Can a greater push in secondary science that informs young thinkers be successful like the anti-smoking campaign where individuals acknowledge the threat of climate change and alter current behaviors?

As discussed earlier, anthropogenic climate change is a critical global issue. Citizens around the world have started to experience its impacts. Through scholarship that provides a characterization of students' climate change knowledge and stances, as well as relationships and statistical predictors of students' stances and the development of knowledge and messy middle concepts, we can create more effective and targeted curricular interventions. In other words, before the educational community can create more effective learning environments and resources in this challenging and controversial area of science, we first need to identify and analyze the nature, complexities, persistence, and relationship between students' climate change knowledge and stances. This dissertation intends to close this gap as outlined below.

Organization of Dissertation

My dissertation work is comprised of eight chapters and is organized to investigate and to attempt to answer the research questions found in Table 1.1**.** In Chapter 2, I focus on the context of the study, including a detailed description of the curricular intervention and the participants in my work. I also include an extensive literature review where the constructs of knowledge and stances are defined. Moreover, climate change specific knowledge and stance studies and literature are discussed. In Chapter 3, I review the data collection methods, instruments and analysis techniques.

In Chapters 4 and 5, I present quantitative analysis for answering the first two research questions. In Chapter 4, I focus on the first research question that addresses the nature, stability, and patterns of students' climate change knowledge. To approach this research question, I analyze data from the pre and post stance surveys. In Chapter 5, I address the second research question by analyzing the pre and post knowledge assessment to see if students' climate knowledge changed from before and after the curricular intervention in three knowledge categories. Moreover, I explore the statistical relationship between knowledge and stances using the pre and post surveys and knowledge assessment data.

I focus on the third research question in Chapter 6 with qualitative analysis. Through analysis of the post semi-structured interviews, I present results that further explore the complexity and relationship between students' climate change knowledge and stances. In the chapter, I provide ordinal climate change stance categories based on student responses and give student exemplars for each discrete group to illustrate patterns across students' stances and knowledge.

In Chapter 7, I lead a discussion across all the findings from Chapters 4, 5, and 6. I present major patterns and themes regarding the nature, stability, and complexities of students' climate change stances and knowledge. I compare my results to other literature in the field. Moreover, I compare and contrast my findings to work in the hot conceptual change literature to discuss stance and knowledge development. This discussion leads to the final chapter.

I offer implications and suggestions from the study in Chapter 8, specifically with regard to curriculum improvements, teacher and professional development suggestions, and the role of the policymaker. I also talk to the limitations of my work regarding the mode and type of data collected. Finally, I discuss future work to build on my findings.

Chapter 2: Study Context and Conceptual Framework

Overview of Chapter 2

In this chapter, I give an overview of the study. I first offer a description of the larger National Science Foundation (NSF) study within which my dissertation work is situated (Songer, Myers, & Beach, 2009). This includes a brief discussion of the Climate Change and Its Impacts on Biodiversity curriculum (Songer et al., 2012) in which all study participants took part in during the 2012-13 school year. To complete the research context section, I describe the students who participated in my dissertation work. Please note that all student, teacher, and school names have been changed to pseudonyms to ensure anonymity.

In the second part of Chapter 2, I discuss the conceptual framework that undergirds my dissertation work. In the conceptual framework section, I first illustrate that my work is grounded in modern day constructivist learning theory while taking into consideration the social aspects of learning. Moreover, when defining the problem and scope of research, I emphasize that climate change is a socio-scientific issue, making it potentially both controversial and personal. I define major constructs in my study, such as knowledge, stances, and messy middle knowledge. For my study, I adopt messy middle knowledge, but use the term alternative concept when discussing other literature to align with the terminology used in other studies. I also discuss how knowledge is situated in the brain, specifically that knowledge is held in small contextualized pieces (diSessa, 1988), and illustrate the difference between hot and cold conceptual change. Then, I cite specific works on climate change knowledge and alternative concepts of secondary students and climate change beliefs and stances. Finally, I illustrate how my work is situated in the current literature and findings in the field.

Part 1: Research Context

My dissertation work is situated within a larger National Science Foundation-funded research project that was created and implemented by the Center for Essential Science (Songer, Myers, & Beach, 2009). My work had three data collection points (before starting the curriculum, immediately after curricular intervention, and 4-5 months after the curriculum) and three data collection instruments (pre and post stance surveys, pre and post knowledge assessments, and semi-structured in-depth post-interviews). The sample population was students who participated in the spring 2013 implementation of Climate Change and Its Impacts on Ecosystems middle school curriculum (Songer et al., 2012). Data collection started in winter/spring 2013 and finished in fall 2013 with post semi-structured interviews.

To give some perspective on the larger research project, the development of the Climate Change and Its Impacts on Ecosystems curriculum was guided by several major principles. We focused on exemplifying the Next Generation Science Standards (NGSS) performance expectations by designing curricular activities that engage students in learning disciplinary core ideas (DCIs) (e.g., the content) through practices (e.g., the doing of science), such as constructing explanations (NGSS Lead States, 2013). Through both off and online activities and labs, the curriculum challenged students to develop fused knowledge, i.e. knowledge that inextricably links disciplinary core ideas, crosscutting concepts, and science and engineering practices (Gotwals & Songer, 2013).

An example of fused knowledge is constructing an explanation to a scientific question, such as “Is the climate changing in the Northern Hemisphere?” In this example, students are required to read a graph that illustrates a trend over the last 150 years and determine if the climate is changing by applying the disciplinary core idea of weather versus climate. Just applying the definition of climate or merely reading a graph and determining the trend is a simpler task. Combining the practice of data analysis (e.g., graph reading) with the disciplinary core idea is more complex than the separate pieces and it is hypothesized that this leads to knowledge development (NRC, 2011) .Each lesson incorporated at least one practice outlined in the NGSS, such as constructing explanations and designing solutions, using mathematics and computational thinking, engaging in arguments from evidence, analyzing and interpreting data, or developing and using models to make a prediction (NGSS Lead States, 2013).

Moreover, the curriculum development and assessment teams worked to make the curricular intervention more engaging and flexible in order to reach multiple zones of proximal development (ZPD; Vygotsky, 1978). Through the use of scaffolds (i.e., points of guidance (Resier, 2004)) and more knowledgeable others, such as the curriculum and teachers, the curriculum team hypothesized that multiple ZPDs can be met and a sweet spot can be found. A goal was that all students participating in the curriculum were guided to develop more complex and abstract knowledge. Another guiding principle through the many iterations of curriculum design was the idea of learning progressions. Learning progressions, created by the curriculum team that mapped the disciplinary core ideas and practices side by side, helped to define the sequence of content and practices taught over many lessons to construct a progressively more sophisticated way of thinking and doing science (Songer, Kelcey, & Gotwals, 2009). Within a learning progression, students are guided to systematically revisit and extend previous fused knowledge DCIs and practices towards capstone conceptions that are usually quite interdisciplinary and/or complex (Songer, 2006).

Climate Change and Its Impacts Curriculum

This section outlines a brief description of the curriculum program in which the students in my study participated. The middle school version of the Climate Change and Its Impacts on Ecosystems (Songer et al, 2012) curricular unit is an 8-10 week classroom and Internet-based curriculum intended to foster the development of fused content and practices knowledge about the impact of climate change on organisms. In the online resource, each student had a username and password where they interacted with maps and data in web-based lessons. The offline student notebooks provided lessons associated with science labs and other data collection and analysis activities. The teachers could track students' online responses in real-time, which allowed for immediate feedback and discussions. The curriculum was purposefully scaffolded (e.g., guides/supports put in place to help students do more sophisticated science than they can do on their own (Reiser, 2004) and sequenced to progressively develop more sophisticated knowledge of climate change and biodiversity disciplinary core ideas through the engagement in practices, such as explanation-building. In one of the early lessons (Lesson 2), students chose a focal species, such as the black bear, to follow throughout the curriculum. This choice was provided to help middle school students to find a relevant context or the development of understandings of the abstract and difficult science content. In other words, as students learned about the changing climate through studying weather versus climate, the greenhouse effect, natural and anthropogenic carbon, and simplified IPCC scenarios, students explored how their focal species will fare as the Earth's atmosphere changes. Students took a pre knowledge assessment and an online pre climate change stance survey prior to starting the curriculum. Immediately after completing the curriculum students took a post assessment and a post stance survey.

Part II: Overview of Conceptual Framework

The conceptual framework is grounded in literature across a variety of fields, including education, psychology, and science communication. The goal of the literature review is to situate my work in a broad range of fields and to give context to my overall study. In the conceptual framework, I first outline the learning theories in which I ground my work. I take a modern day constructivist approach where knowledge is organized in pieces (diSessa, 1988; Smith, diSessa, & Roschelle, 1993/1994; Hammer, 1996) and knowledge is constructed from prior knowledge and experiences. Complex, sophisticated knowledge is developed through repeated exposures in multiple contexts with purposeful guidance over period of time (Songer, Kelcey, & Gotwals, 2009; Songer, 2006). Knowledge that is a blend of accepted scientific ideas and knowledge that does not align with current scientific concepts is referred to as messy middle knowledge. In addition to the learning theories, I situate my work in the current literature in knowledge and stances to define these constructs. Then, I have sections dedicated to knowledge and stances in the literature specifically on climate change. These sections include literature that has identified climate change alternative concepts and a discussion of the role of religion and political ideologies in the climate change conversation.

Knowledge and Stances Defined

Knowledge

Prior to Kuhn's work on science knowledge in 1962, science knowledge was thought to be objective and unbiased. It was thought to be built on data and facts that accumulate in a methodological manner. However, Kuhn (1962) discussed the idea that "normal science" is part of cultural norms; there is a human component. Therefore, science knowledge is not completely objective. The normal or accepted science of the time can undergo a paradigm shift where revolutionary science is introduced and the new science becomes the accepted knowledge paradigm in the scientific community. Kuhn's argument introduces a human component of knowledge. Sadler (2004) builds on Kuhn's argument and states, "All aspects of science are inseparable from the society from which they arise" (p. 513). While there is an overwhelming consensus in the scientific community that anthropogenic climate change is happening, some people in society do not see climate change as the normal science of the times. While Kuhn's argument addresses normal science within research groups and does not incorporate people's opinions outside of the scientific community, I discuss the science knowledge and stances of the general population. Science knowledge in these two communities is not necessarily equivalent, but in both the research community and the public they both incorporate a human and cultural component. Moreover, the existence of anthropogenic climate change is overwhelmingly the accepted science by both the scientific community and general public.

Lederman, Khalick, Bell and Schwartz (2002) build on the above discussion because they incorporate both the empirical and creative aspects of science.

> Science is empirical. The development of scientific knowledge involves making observations of nature. Nonetheless, generating scientific knowledge also involves human imagination and creativity. Science, contrary to common belief, is not a lifeless, entirely rational, and orderly activity. Science involves the invention of explanations and theoretical entities, which requires a great deal of creativity on the part of scientists (p. 500).

Lederman and colleagues speak to the nature of science. Just as Kuhn discusses, there is a lack of the objective nature that people often discuss in regards to science knowledge. Lederman and Lederman (2004) continue this discussion by defining the Nature of Science (NOS). The nature of science “refers to the values and assumption inherent to science knowledge and the development of science knowledge” (p. 37). This references the idea that science can change. It is constructed on observations made by scientists, which means knowledge is socially and culturally rich.

Moreover, Deanna Kuhn and colleagues (2000) discuss that knowledge theory is developed through the coordination of objective and subjective dimensions. Figure 2.1 shows Kuhn et al.’s (2000) levels of epistemological understanding and sources of knowledge. It shows that there are varying positions on the level of objectivism about knowledge. For my work, I believe the important take-away is that there is a human component to knowledge development. Specifically, I am interested in climate science knowledge in the middle school population. To build climate science knowledge in the public, there needs to be an understanding of the Nature of Science.

Table 1
Levels of epistemological understanding

Level	Assertions	Reality	Knowledge	Critical thinking
Realist	Assertions are COPIES of an external reality.	Reality is directly knowable.	Knowledge comes from an external source and is certain.	Critical thinking is unnecessary.
Absolutist	Assertions are FACTS that are correct or incorrect in their representation of reality (possibility of false belief).	Reality is directly knowable.	Knowledge comes from an external source and is certain.	Critical thinking is a vehicle for comparing assertions to reality and determining their truth or falsehood.
Multiplist	Assertions are OPINIONS freely chosen by and accountable only to their owners.	Reality is not directly knowable.	Knowledge is generated by human minds and is uncertain.	Critical thinking is irrelevant.
Evaluativist	Assertions are JUDGMENTS that can be evaluated and compared according to criteria of argument and evidence.	Reality is not directly knowable.	Knowledge is generated by human minds and is uncertain.	Critical thinking is valued as a vehicle that promotes sound assertions and enhances understanding.

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Figure 2.1. The levels of epistemological understanding that shows knowledge at each level has been reproduced directly from the following work: Kuhn, D., Cheney, R., & Weinstock, M. (2000). The development of epistemological understanding. Cognitive development, 15(3), 309-328.

Even though science knowledge is not completely unbiased and objective, there is a systematic approach to collecting data and to forming scientific knowledge. Scientific knowledge is grounded in scientific theories that are testable and reproducible. While science knowledge can change, T. Kuhn discusses that the normal or accepted science at the time has an objective component; there is a scientific process to produce the body of knowledge.

Definition of Knowledge

In this work, knowledge is defined as the currently accepted scientific theories and facts that are constructed through interacting with the material and topics in school, personal experiences, and social interactions. A knowledgeable other helps to construct and continually build on previous knowledge. Moreover, society and technology, which can be considered knowledgeable others (Vygotsky, 1978) influence the currently accepted scientific knowledge. For my study, scientific knowledge is deemed correct if it is accepted by the majority of the scientific community (e.g., the normal science of the times) due to repeated experiments that were conducted in a methodical and reproducible manner.

Specifically, I discuss climate change knowledge in terms of three content area categories that were prominent in the curricular intervention: (a) weather versus climate, (b) carbon and anthropogenic carbon emissions, and (c) relationship between greenhouse gases and temperature and other results of an enhanced greenhouse effect. These categories of climate change knowledge are developed based on questions that are analyzed from the pre and post knowledge assessment. Questions that comprise these three categories include disciplinary core ideas (the science content) items and fused knowledge (e.g., the inextricable link between science disciplinary core ideas, crosscutting concepts and science and engineering practices) (Songer & Gotwals, 2013) questions (e.g., constructing a scientific explanation about climate change disciplinary core ideas). In my dissertation work, I group knowledge by content area (e.g., the three categories above) rather than the type of knowledge constructed (e.g., disciplinary core ideas or fused knowledge).

Alternative Concept and Messy Middle Knowledge

Modern day constructivists call science that does not align with the accepted scientific theories and principles as an alternative concept (Smith, diSessa, & Roschelle, 1993/1994) rather than a misconception, as it is recognized that parts of the unsophisticated ideas might be accurate while other parts are not.. Driver, Guesne, and Tiberghien (1985) discuss that children come to “class with ideas and interpretations concerning the phenomena that they are studying, even when they have received no systematic instruction in these subjects.” (p.2). Students can hold alternative concepts about science topics, such as climate science, before a formal introduction to evidence and data on the topic.

Driver et al., (1985) illustrated that student alternative concepts are often stable, appear to be incoherent, and are personal. Since alternative concepts connote an incorrect response and focus on stability of ideas, instead I have adopted the term messy middle knowledge. Messy middle knowledge indicates the complexity of the science and encompasses a spectrum of knowledge with correct and incorrect concepts as endpoints. Moreover, messy middle knowledge aligns with the phenomenological primitive (p-prim) (e.g., general, contextualized knowledge fragments) (diSessa, 1988) literature indicating that all knowledge and experiences can be constructively built upon.

Since p-prims are often partially or fully incoherent, they may be used sporadically in different contexts and responses (diSessa, 1988; Hammer 1996). Furthermore, Smith et al. (1993/1994) discuss the importance of students’ prior knowledge and experiences being taken into consideration in the classroom learning environment. The prior knowledge is also contextualized and situational. It is important in the learning process and needs to be considered because connections are made with a student's prior knowledge and experiences. By identifying students' prior knowledge, productive and customized instructional approaches can be developed to help students make the connections between p-prims and constructively build on pre-existing knowledge.

Messy middle concepts and accepted scientific views can co-exist because connections between p-prims are often nested within certain contexts. Therefore, it is not necessary (or even productive) for a teacher to provide discrepant events to confront messy middle concepts (Smith, diSessa, & Roschelle, 1993/1994). For example, a discrepant event would be a teacher specifically telling a student that carbon dioxide does not create a hole in the ozone layer. Rather students should work with data and have continual interactions with the topic to draw his or her own scientific conclusions based on his/her personal p-prims.

If messy middle knowledge exists, the teacher can probe students' prior knowledge and reasons behind the ideas. With the perspective that knowledge is held in pieces, the task for the teacher is focused on "modifying the organization and use of prior knowledge" (Hammer, 1996 p. 117). If the ideas were thought to be misconceptions in stable, coherent schema, then the task of the teacher would be to dismantle and replace the knowledge structures. Instead, one should take an approach such as the one proposed by Minstrell (2001), where the teacher and student interact to identify students' knowledge spectrums on a given topic. The teacher then places students' ideas, including a mixture of correct and incorrect conceptions, on a continuum (e.g., facets of students' knowledge). Subsequently, the messy middle knowledge is identified and categorized so that the teacher can build strategic curriculum to aid productive growth based on the existing p-prims. By identifying the spectrum of knowledge, the teacher and student can interact in a more productive and focused way in an attempt to constructively build on the students' prior knowledge and experiences.

The way each student processes the experience and activity is personal, because prior knowledge and experience shape each student's interpretation of the knowledge/activity. For example, a topic, such as climate change policy, might be discussed at a student's dinner table. At one table a parent's job might be associated with an industry that heavily relies on fossil fuel use and climate policy may jeopardize the parent's job. Whereas, another student's conversation regarding climate change policy is in the context of developing more clean energy because his/her parents study the benefits of wind energy. These students would have a different approach and/or mindset when they subsequently are introduced to a classroom activity that works with the Intergovernmental Panel on Climate Change's scenarios that highlight fossil fuel use and clean energy. Moreover, since this dissertation is taking the position that knowledge is held in pieces, accepted science and messy middle knowledge can be held in parallel.

In this study, I explored the spectrum of students' climate change knowledge and stances and the persistence and stability of these knowledge and stances. I confirmed and identified new messy middle concepts, which are sometimes called alternative concepts in the existing literature, that students express about climate science. I also examined situations in which students hold a spectrum of correct and incorrect knowledge concepts in parallel in order to justify their climate change stances. It is imperative to identify the messy middle situations to inform targeted curriculum development and to help students move out of the messy middle for climate science topics.

Stance

Carey (2000) discusses the difference between belief revision and cognitive change. In this distinction, she highlights the example of how a young child perceives an animal (e.g., what is alive) versus the theoretical framework an adult would use to approach comprehension of an animal. In her work, she illustrates that a young child's belief system is not necessarily constructed based on scientific theories and/or principles. However, these beliefs systems help in forming stances to understand the world and circumstances. Building on this idea, Ratcliff and Grace (2003) discuss teaching socio-scientific issues in the science classroom and state that, "Our beliefs, both religious and otherwise, are based on our upbringing, education, and social influences. These are mediated by social norms of home, school, and wider community (p. 14). Ratcliff and Grace (2003) focus on the importance of beliefs being formed from experiences and norms outside the classroom (e.g., upbringing, social interactions, and community).

The Yale Project on Climate Change Communication (YGCC) discusses climate change beliefs, attitudes, and views (Leiserowitz, Malbach, Roser-Renof & Smith, 2010). Under this umbrella, the YGCC group poses questions about both intellectual aspects of climate change stances, such as the existence and causes of climate change and the perceived threat of climate change impacts, as well as social aspects such as public opinions on energy and climate change policies and consumer choices/social norms regarding climate. The studies also incorporate personal opinions, such as whether climate change it happening, their level of worry, and their attitudes towards policies and spending money on these socio-scientific issues.

McCright and Dunlap (2011a) approach beliefs from a different perspective. They discuss climate change beliefs systems in regards to an adult's political ideology. Their work found correlations between self-identified political ideologies and the belief in the existence of climate change. Within each identified political ideology, they found opposite correlations between education level and belief regarding the existence of climate change. Walsh's (2012) study suggests a correlation between student climate change beliefs and political dialogue and orientations.

Bandura's social cognitive theory focuses on one's self-efficacy. Self-efficacy is a person's belief system about their ability to succeed (1994). A person's self-efficacy mediates how a situation is perceived and approaches situations and issues. His work in self-efficacy speaks to motivation to learn and achieve. Moreover, self-efficacy is developed through observations and social interactions. Bandura (1994) illustrates that a person's belief system can set the foundation for how a person thinks, behaves, and feels. Pintrich (1999) also discusses student motivation. The environments in which students interact influences students' achievement; there is a social factor involved in the belief formation, which in turn is influential in achievement (Pintrich, 1999). Both Bandura and Pintrich and Schunk (2002) discuss belief structures, such as motivation, which is formed from many inside and outside of school factors. As discussed earlier in the chapter, self-efficacy/motivation and climate change stances are not synonymous, but parallels can be drawn. These beliefs and stances are socially constructed and potentially mediated by both inside and outside of school factors and experiences.

Definition of Stance

For my work, a stance is defined in the context of climate change. A person's stance regarding climate change is constructed from personal experiences from both inside and outside of the classroom. It incorporates the idea of one's own convictions that are grounded in intellect, personal upbringing, and emotions. The stances can be built upon prior experiences and experiences from different communities, everyday life experiences, and formal education. As

Carey (2000) illustrates, science stances (e.g., belief systems) can be revised as students are exposed to and understand other scientific theories and ways to interpret the world around them. Like motivations and self-efficacy, personal experiences and sociocultural interactions shape student stances. This includes stances such as the existence of anthropogenic climate change and worry, both of which are probed in the Yale studies.

In my dissertation work, I focus on climate change stances, specifically regarding the existence of anthropogenic climate change, the level of student worry about the impacts of climate change, and if students feel there are solutions and/or the possibility to mediate climate change. These socio-scientific stances in my work are defined as belief systems that are potentially mediated by outside of school factors, such as prior experiences in the community and home, and inside of school variables, such as working with climate science principles. Personal, emotional, and intellectual components may play roles in influencing an individual's climate change stance.

Learning Theories

I situate my dissertation work in the conceptual change literature. Specifically, I take the theoretical perspective that knowledge is held in small, contextualized pieces called phenomenological primitives (p-prims). Furthermore, knowledge is situated and constructed socially (e.g., Vygotsky, 1978). Learning and cognitive development do not happen in a vacuum. These require social interactions and are likely influenced by students' motivations and beliefs.

Theoretical Stance on How Knowledge is Situated in the Brain

According to diSessa (1988) knowledge is held in pieces. Students' prior knowledge, whether it aligns with scientific principles, does not match scientific thinking, or is a blend of the two, can be used as a foundation for building scientifically accepted knowledge. The knowledge in pieces perspective is a constructivist approach. On the other side of the spectrum is the theory-theory perspective (Carey, 1985). In this idea knowledge is situated in large, coherent structures (i.e. complete scientific theories). In theory-theory, a radical reconstruction (e.g., complete change and replacement) would need to occur for knowledge to become productive (Chi & Roscoe, 2002). In contrast, in the modern day constructivist approach, small pieces and structures are systematically added or replaced from prior ideas, observations, and perceptions (Smith et al., 1993/1994). These small, general knowledge structures are called p-prims (diSessa, 1988). These are intuitive ideas that are grounded within contexts and experiences. The p-prims are abstract and encoded in the brain with context sensitivity. Based on the question a student tries to answer, different p-prims are activated (Hammer, 1996). Connections are made between the p-prims and can be reorganized based on interactions with different activities and experiences. Even if the knowledge structures do not align with expert and/or accepted science, they do not necessarily inhibit knowledge construction and therefore many argue it is more productive to work with rather than eliminate p-prims (Smith et al., 1993/1994). Carey (2000) discusses that these "misunderstandings" are an important and expected part of the learning process.

Since knowledge is organized in small knowledge structures, each structure is connected based on personal experiences to different contexts and materials. Science concepts that are consistent with accepted science and a spectrum/blend of correct and incorrect knowledge can co-exist. The mixture of correct and incorrect science knowledge is termed messy middle knowledge (Songer & Gotwals, 2012; Gotwals & Songer, 2010). The messy middle refers to the idea that students do not necessarily transition from knowledge that is inconsistent with accepted scientific principles to aligning with expert knowledge.

For some students to develop complex, sophisticated knowledge there is a middle stage or multiple stages of knowledge development. This transition is not necessarily linear and not necessarily the same for each student. Moreover, messy middle concepts are not always inhibitors to productive knowledge development (Carey, 2000). The messy middle knowledge is supported by the idea that knowledge is organized in pieces that need to be connected for knowledge to be voiced and coherent. Piaget (1995; Gruber & Voneche, 1995) also discusses that the learning process is not necessary linear. Students are expected to exhibit messy middle knowledge and that there is a great deal of back and forth in the development and learning process (Piaget, 1995; Carey, 2000).

Additionally, learning is social and contextual. There are external factors that can enhance a learner's potential. Vygotsky focuses on knowledge construction as a social experience and process. A knowledgeable other, such as a teacher, a parent and/or a curriculum, helps the learner to reach a level that he/she could not attain without guidance. The social interaction allows the learner to stretch what they are capable of relative to what they could do on their own (Vygotsky, 1978). The knowledgeable other is critical in the learning experience. Furthermore, knowledge is situated within a context, activity, and/or culture in which it is used (Browns, Collins, & Duguid, 1989). Learning has cultural and situational aspects; it is not just a cognitive, objective process. The idea that each piece in a person's head is situated in an experience and/or context is discussed in more detail in the next section. For my work, it is important to remember the role of the knowledgeable other and that knowledge is situated in a context and culture. These ideas are relevant when I analyze and discuss findings regarding students' climate change knowledge and stance development and variables that statistically predict students' stances and knowledge.

Socio-scientific Issues

Building on the ideas of Vygotsky (1978) and Browns, Collins and Duguid (1989) that learning is social and contextualized, Sadler (2004) states that socio-scientific topics such as climate change, evolution, and stem cells must also be considered when discussing cognition and learning. Climate science is a socio-scientific issue, because it is inseparable from societal issues in terms of decision-making, consequences, and level of interest (Sadler, 2004). Bell (2004) suggests that socio-scientific issues such as climate change can be seen as a learning opportunity for the science education community. Climate change is at the "intersection of science, technology, and society" and gives students and teachers the opportunity to develop an "integrated understanding of scientific issues across the numerous contexts in which they experience them in the classroom, on television and radio, in print media, on the Web, and in conversation" (Bell, 2004, pp. 234-235). Prior experiences and learning of socio-scientific issues occurs both inside and outside of formal school settings.

Socio-scientific issues are grounded in social and scientific factors, such as informal reasoning, perceptions of evidence, conceptual understandings based on personal experiences, and cultural backgrounds. Therefore, separating climate change knowledge from climate change stances can be challenging. However, there are distinct differences between knowledge and stances, which I discuss in the following sections.

Theoretical Discussion of Knowledge and Stance Development

One of the main research questions of my dissertation study explores the relationship between climate change stances and knowledge and the complexities between the two constructs. In this section, I offer curricular models to encourage conceptual change. Then, I discuss stance and knowledge development and the relationship between the two from a hot conceptual change perspective. This sets the foundation to compare my findings in Chapter 7 to existing hot conceptual change literature as well as ground my curricular suggestions based on my findings in Chapter 8.

Curriculum Models: Learning Progressions

Learning progressions help to define the sequence of content and practices taught over many units and years to construct a progressively more sophisticated way of thinking and doing science (Songer, Kelcey, & Gotwals, 2009). It is built on the work of Bruner's (1977) spiral curriculum where students are guided in a systematic way to develop knowledge. Knowledge is logically developed from the basic to the more complicated scientific principles. Bruner's spiral curriculum is built on the idea that a child can learn complex science if students and teaches revisit the subject/topic multiple times throughout their years of schooling, each revisitation becomes increasingly more complex and difficult, and prior learning has a relationship to the students' new learning. Similarly, in learning progressions, exposure to and interactions with the content occurs over multiple curricular units to develop continuously more complex knowledge. Knowledge builds on previous knowledge that was actively learned. The learning progressions in the Climate Change and Its Impacts Curriculum (Songer et al, 2012) had students revisit science content and practices through a series of fused knowledge performance targets throughout the eight week unit. The practices and content became progressively more complex and scaffolds, such as hints, were gradually faded (e.g., taken away), which allowed students to master the performance expectations without the aid of a knowledgeable other.

Songer (2006) shows that students struggle to properly engage in complex material without proper scaffolding – i.e., guidance for students that is progressively faded to promote fused knowledge development. "Development of complex understandings of science takes time, guidance, and repeated exposures… Deep understandings of the content develops as a result of organized recycling" (Songer, 2006, p.357). Students should continually and systematically revisit DCIs and practices in more complex, cyclic ways to build a more sophisticated understanding of fused knowledge (Songer et al., 2009). Furthermore, topics need to engage students' interests to connect to their lives and to create a continuum of experiences that encourages further growth (Dewey, 1938). Continuity of experiences requires that experiences should be linked (i.e. not disjointed). The quality and connections made amongst the experiences is imperative for them to be educative.

Learning progressions specifically provide a plan for the development complex, sophisticated science knowledge over time. Since climate change is a socio-scientific issue, I discuss work that goes beyond a cognitive focus of building complex knowledge and incorporate students' beliefs, motivation and learning environments in regards to stance and knowledge change and development. The learning progression as a curriculum model helps to give structure to curriculum design to encourage complex knowledge development and to help guide students through messy middle knowledge.

Hot and Cold Conceptual Change

In the work of Piaget and others during the 1960-1980s, conceptual change focused exclusively on the development of knowledge. As Sinatra (2005) discusses, beginning in the 1990s there was a trend in conceptual change research to include the influence of students' belief systems, specifically motivation and the role of environments on knowledge development. Hot conceptual change as discussed by Pintrich, Marx, and Boyle (1993) moves from the isolated discussion of cognitive development (e.g.,, "cold" conceptual change) to incorporate students' motivational beliefs (e.g., goals, values, self-efficacy, and control) and the role of beliefs in contributing and/or inhibiting conceptual change.

A student's efficacy belief is not the same as a student's stance on a socio-scientific issue, such as climate change. However, parallels can be drawn between self-efficacy and climate change stances. Specifically, self-efficacy and climate change stances are both potentially influenced by outside of school factors. They can both hypothetically be impacted by interactions with a child's teacher, additional knowledgeable others and other inside and outside of school factors. While the two constructs are not the same, I believe they might be influenced by similar factors and can be discussed in parallel in terms development and its relationship to knowledge.

In addition to drawing parallels among contextual factors between self-efficacy (i.e. motivation beliefs) and climate change stances, I draw comparisons between these belief concepts and how knowledge is developed. Hot conceptual change work discusses how beliefs correlate to knowledge development. Eccles, Adler, Fetterman, Goff, Kaczala, Meece, and Midgley (1983) and Wigfield and Eccles (2000) find that beliefs are the foundation for knowledge change. Belief change precedes knowledge change and/or beliefs mediate knowledge development. For example, if one looks at student's motivation level, a student with a positive self-efficacy correlates with and sets the foundation for high academic achievement (Bandura, 1994).

Eccles et al. (1983) explored student math achievement in relation to belief change. The data suggest that student beliefs changed prior to student achievement. Wigfield and Eccles (2000) build on the prior work and states that "individuals' choice, persistence, and performance can be explained by their beliefs about how well they will do the activity and to what extent to which they value the activity" (Wigfield and Eccles, 2000, p.68). The beliefs directly influence persistence and achievement (e.g., productive oriented views, stances, and beliefs exist before creating productive knowledge).

Hot conceptual change findings directly state the positive relationship between stance and knowledge development where stances changes precede knowledge changes. In my work, I explore if climate change stances set the foundation for climate change knowledge development. Then, I compare my findings to the hot conceptual change literature.

Part III: Knowledge and Stances in Climate Change Literature

Climate Change Knowledge and Identified Alternative Concepts in Secondary Education

There has been significant research showing that students have limited knowledge and alternative concepts about climate change and sustainability, which is discussed below. Climate change is a complex, interdisciplinary science in which students often hold knowledge concepts that do not align with the accepted scientific theories. Many researchers have sought to understand how secondary students discuss the causes of climate change, the greenhouse effect, and global warming related issues (Rye, Rubba, and Wiesenmayer 1997; Shepardson, Niyogi, Choi, and Charusombat, 2009; Koulaidis and Christidou, 1999; Andersson and Wallin, 2000). Below is a discussion of several studies that identify secondary school students' climate science knowledge and knowledge that does not align with the accepted science.

The majority of studies and research discussed below explore students' alternative concepts about climate science either before or after a curricular intervention. However, the studies did not track pre and post differences, which is important to see if knowledge changed from before and after participating in the curriculum. Furthermore, the studies relied on a single mode of data collection (e.g., interviews, surveys, or assessments). The lack of multiple data sources, time points, geographic locations, and smaller sample sizes limits the generalizability of their findings. However, I discuss and analyze the findings and research approaches to ground my own work, results, and discussions. These specific studies are discussed for a multitude of reasons. Several of the studies examine middle school students' climate change knowledge. They also identify messy middle knowledge constructs for climate change, which is discussed in the studies as alternative concepts. Moreover, the works use a variety of data collection instruments to target either climate change knowledge or stances. At the end of the chapter, I illustrate how my work builds on the breadth and depth of these studies. Then, in Chapter 7, I compare my findings to these studies.

Rye, Rubba, and Wiesenmayer (1997) explored middle school students' alternative concepts about global warming. Their research sought to identify alternative concepts on global warming, and believed that instruction could clarify issues. To evaluate students' alternative concepts on global warming, the researchers interviewed 24 students in grades 6-8 (two 6^{th} grade classes, one 7^{th} and one 8^{th} grade class) in rural Pennsylvania after completing four different two-week long Science, Technology, and Society (STS) units on global warming. The results from this study indicated that the majority of students (75%) held the alternative concept that ozone depletion and/or increased UV solar radiation is part of the cause of global warming. Furthermore, 54% of the students state ozone deterioration and increased sun rays as the predominant cause of global warming. There was no statistically significant difference between the relationship of global warming alternative concepts to a student's ability level and/or gender. Since the sample size was relatively small, it was challenging to make distinctions between varying degrees of alternative concepts across different curriculum units. Interviewers asked questions about ozone and global warming within the same interview context, which could be perceived as leading the student. However, 75% of the students mentioned ozone when discussing general questions about global warming, prior to questions about ozone depletion. Furthermore, 70% of the students illustrated that they understood the relationship between carbon dioxide and greenhouse gases. However, 50% of the students interviewed stated an alternative concept by describing an association with carbon dioxide and ozone depletion. There was a statistically significant correlation between students who believed that carbon dioxide depletes the ozone layer and that a destroyed ozone layer is the predominant cause of global warming.

The Shepardson, Niyogi, Choi, and Charusombat (2009) article comes from an interdisciplinary atmospheric science and social science perspective. They sought to answer the research question: *What are seventh grade students' conceptions of global warming and climate change* through a qualitative research approach. Students' written language and drawings were used as symbols and signs to interpret students' conceptual understandings of climate change and global warming. Three 7^{th} grade rural classrooms in the Midwest (n=91) were surveyed prior to participating in climate change and global warming unit. The assessment had five items: four open-ended questions and one draw and explain item. When students were asked to interpret a graph that showed evidence for global warming, 68% of the students agreed with the scientific view that the atmosphere is warming. However, 17% were not sure the data supported this claim. Thirty two percent of the students did not make the correlation between rising CO_2 levels and increased atmospheric temperatures. To build on this concept, 52% of the 7^{th} graders discussed that the temperature would change regardless of carbon dioxide concentrations. When exploring impacts of global warming and climate change, approximately 40% (n=36) students said the ocean levels will increase due to increased precipitation and/or melting ice caps and 41% (n=37) of the students also said that the ocean levels will decline because of increased evaporation.

The researchers explored students' views on potential societal impacts and 22% of the students thought there would be no impacts while 33% thought global warming and climate change would increase human death. Furthermore, only 13% had a fully developed concept of the greenhouse effect. Students attributed driving cars, general air pollution, and factories to the top causes of increased carbon dioxide in the atmosphere. Finally, most did not fully comprehend the greenhouse effect and that greenhouse gases are both natural and anthropogenic. Several alternative concepts were identified. Students believed greenhouse gases trap all the heat. Additionally, there was an association with general pollution and the greenhouse effect. This idea contributed to students' stated resolutions to climate change, such as driving and polluting less. Students did not feel that climate change and global warming will greatly impact them or society.

The authors (Shepardson, Niyogi, Choi, & Charusombat, 2009) acknowledged the social and cultural influences on students' conceptions of global warming, but the data collection was limited to three classrooms in the Midwest. The findings reinforced results of similar studies. However, they also found contradictory results. Few students in this study stated an association to ozone depletion and the greenhouse effect. Additionally, the researchers exposed the idea that students do not fully comprehend the implications of climate change.

Koulaidis and Christidou (1999) explored the root and mechanisms of students' alternative ideas about the greenhouse effect. The authors sought to identify and create categorical models of Greek middle school students' perceptions about this environmental phenomenon. By identifying and then classifying students' alternative ideas, Koulaidis and

Chistidou (1999), offered a discussion about what may cause these alternative concepts and offered teaching strategies to address them. Their work added to the current literature and research in the field by going beyond the identification of students' alternative ideas on the greenhouse effect and offering potential causes and instructional tactics to build on students' ideas. Through two semi-structured interviews, the researchers interviewed 40 Greek eleven and twelve year olds who had not been explicitly taught the greenhouse effect, but had been exposed to tangential topics that can impact understanding of the phenomenon

The study identified certain characteristics of students' alternative ideas, such as the ideas that (a) the greenhouse effect occurs in a specific zone of the atmosphere, (b) the interchangeability between UV and solar radiation, and (c) the lack of understanding and distinction between terrestrial and solar radiation. However, by asking students to make causal paths by placing labeled cards on cardboard next to other labeled cards to make a concept map, all of the students created cause and effect models using terms, even if they did not know the concepts or definitions. Thus, all students created a concept map and causal paths, but did not have to explain them. This interview structure/approach does not identify the depth of the answer or if the students even know the complex concept that they are mapping.

Andersson and Wallin (2000) sought to identify 9^{th} and 12^{th} grade students' understanding of the greenhouse effect and various impacts of increasing carbon dioxide concentrations. Their work was grounded in the claim that for high school students to fully comprehend environmental issues they need to understand the complex relationships of the systems of Nature, Science, and Technology. The study was situated in a larger study where students in three different age groups took three different Internet based-tests on Earth System themes that had a mixture of multiple choice and open-ended items. This study focused on two age groups (9th Grade n=201 and 12th Grade n=222) in various locations in Sweden. With an open-ended question structure, students were given a chance to explain the process and why-aspects of the questions.

When the students answered questions about the greenhouse effect, only 10% discussed that it was a natural process, whereas 40% of 9th graders and 50% of 12th graders referred to the enhanced greenhouse effect. Furthermore, less than 10% of both age groups' first responses discussed carbon dioxide's role in increasing average global temperatures. They captured pictorial student responses to explain the greenhouse effect after an introduction paragraph that discussed the anthropogenic increase in CO_2 resulting in an enhanced greenhouse effect and the necessary reduction of emissions to keep climate change in check. Finally, students were faced with the scenario that they were international policy makers creating suggestions to both industrialized and developing countries emissions standards. The vast majority of students (73% Grade 9 n=309 and 77% Grade 12 n=328) said that both industrialized and developing countries need drastic limitation on carbon emissions. Furthermore, 60% of the students stated that the reduction for industrialized countries needs to be met within 10 years and the maximum was 25 years. Finally, when students were asked about societal impacts of reduction of carbon dioxide, 19% of the 9th graders (n=318) and 28% of the 12th graders (n=334) thought it would change the labor market, potentially lower standards of living, and/or invoke protests. However, on a positive note, 23% and 19% of 9th and 12th graders thought it would increase public transportation and 23% of the 9th graders discussed better environmental health with lower emissions.

Summary of Climate Change Knowledge Studies

The research that I discussed above all sought to better understand students' climate change knowledge and alternative concepts. All the articles are similar in that they discuss student ideas that do not align with the accepted science as alternative ideas rather than misconceptions. Moreover, similarities emerged in that students struggle with the complexities of climate science, such as mechanisms of climate change and the role of ozone with regards to the greenhouse effect. Furthermore, it is evident that students do not perceive the urgency/threat of the impacts of climate change now, as specifically addressed in the Andersson and Wallin (2000) piece.

The authors sought to identify knowledge through surveys, interviews, and assessments at a single time point. Even when a curricular intervention is mentioned, data were not presented to illustrate potential knowledge development or change as a result. Moreover, the articles discussed focused primarily on students' content knowledge. Both the knowledge discussed and curriculum suggested in the studies did not explore students' stances on climate change and/or the relationship between stances and knowledge.

My work builds on the literature discussed above in several areas. First, I use multiple data collection instruments (e.g., pre/post stance survey, pre/post knowledge assessment, and a semi-structured interview protocol for a subset of the sample). Using these instruments allows me to examine change and/or stability of knowledge and stances after participating in the Climate Change and Its Impacts curriculum. Moreover, I identify students' climate change stances in addition to knowledge. This allows for some analysis of the relationship between students' climate change stances and knowledge. Furthermore, I characterize a spectrum of correct and incorrect climate science principles (e.g., messy middle concepts), which adds to the current discussion of climate science alternative concepts.

Climate Change Beliefs and Stances in the Literature

Climate change is going to impact the global community. The Intergovernmental Panel on Climate Change Communication (IPCC) unequivocally states that climate change is happening (IPCC, 2013). However, like many belief systems, people have different stances about climate change. Is it happening or not happening? What are the causes? Are there solutions? Some in the scientific community can argue that these are knowledge structures, as opposed to stances, because anthropogenic climate change is grounded in science and statistical models that are supported by a vast; the scientific community argues that the current rapid climate change is unequivocally the result of human actions, such as increased greenhouse gas emissions. However, there are other factors that are discussed when forming stances on climate change. These factors include, but are not limited to cultural backgrounds, social contexts and religious and political ideologies.

Yale Group on Climate Change Communication Studies

The Yale Group on Climate Communication and George Mason Center for Climate Change Communication has explored American's views and beliefs on climate change. They are at the forefront of conducting and analyzing studies regarding peoples' climate change stances and attitudes. In one study they surveyed 2,164 adults to explore their positions on energy policy, belief and concern about global warming, and how they would prioritize environmental policies (Leiserowitz, Malbach, Roser-Renof & Smith, 2010). The majority of Americans sampled articulated that global warming issues were important to them and that action should be taken to reduce it. However, there was low support for policies such as cap and trade. Moreover, there was uncertainty if we (the global we) will actually act to reduce global warming. The study also illustrated that people often support that something should be done about global warming, but support dwindles when actual actions are proposed. This study sets the foundation for the student pre and post survey, which has greatly influenced my design artifact and is discussed in detail in Chapter 3.

Another study conducted by the same group (Leiserowitz, Smith, & Marlon, 2011) explored middle and high school students' knowledge on global warming. The study was composed of multiple choice questions to probe students' knowledge about climate systems, the causes of change, and potential solutions for global warming. With 25% of the teens and 30% of the adults receiving a passing score, the study illustrates the clear need for K-12 education on climate systems and global warming. Several questions in the study are also used in the pre and post stance survey, which is discussed in Chapter 3 and cab seen in Appendix A.

The study design and data collection instrument in both Yale studies consisted only of multiple choice survey items. The *American Mind* study had adults take two questionnaires that were given two weeks apart. It explored views about issue priorities, policy preferences, consumer and political activism, risk perception, perspectives if climate change is happening and its causes, desire for more information, achievability of emissions standards, and trust in different messengers (Leiserowitz et al., 2010, p. 8). The survey had over 300 questions, but was limited to adults' views (n=2,164). Additionally, it did not capture adults' knowledge on the subject. *The Americans Teens' knowledge of climate change* (Leisorowitz et al., 2011) survey asked 517 teens from 13-17 years of age and 1,513 adults. There were more adults because households with and without teens were in the sampling frame. The results were weighted to have a representative sample based on the US Census Bureau demographic data. Unlike the previous study, the 2011 study focused on content knowledge with only few climate attitude questions.

The *Six Americas* study from the same research groups mentioned above, interviewed American adults about their interpretations and responses to climate change (Leiserowitz, A., Maibach, E., Roser-Renouf, C. & Hmielowski, J., 2012). The researchers from the Yale and George Mason Universities' Groups on Climate Change Communication analyzed the interview data. They divided the respondents into six groups on a continuum about concern and engagement regarding climate change. The endpoints on the spectrum were *Alarmed*, if people are very concerned and would promote global warming mitigation policies and actions and *Dismissive*, which included climate change denialists and promoted inaction. It was a longitudinal study conducted from 2008 to 2012. The researchers tracked changes in frequencies of responses within the six segments over the four year period. To give a brief perspective, 13% of the population surveyed was coded as *Alarmist*, 26% as *Concerned*, 29% as *Cautious*, 6% as *Disengaged*, 15% as *Doubtful* and 10% as *Dismissive.* I used the *Six America's* study as a guide to creating and analyzing the post semi-structured interviews.

Longitudinal Survey of American Youth

Another study was conducted based on data from the Longitudinal Survey of American Youth. It was an annual survey that explored young adults' opinions and positions on a vast array of topics. Included in this survey was Generation X's awareness and concerns about climate change and where/how they get information about the information and make sense of climate change (Miller, 2012). One major finding was that young adults were not interested in climate change; only 2% of the population followed climate issues closely and over 80% of the young adults sampled either occasionally or do not closely follow climate issues. Moreover, teenagers were not extremely concerned about climate issues (22% high concern, 42% moderate concern, and 37% less concern) (p. 2). To build on this idea, concern levels have dropped since

2011. The level of issue understanding illustrated that only 11% of the sample feels well-informed compared to 47% moderately-informed and 42% less well-informed, which is illustrated by the finding that only 11% of Generation X strongly agreed with the concept that the primary cause of global warming is humans burning fossil fuels. It is evident that Generation X is disengaged, unconcerned, and uniformed about climate change. The ideas of disengagement and detachment are discussed in my findings in Chapter 7 and suggestions to modify the curriculum in Chapter 8.

Additional Studies Exploring Climate Change Stances

The studies mentioned above began to identify American's climate change beliefs. However, there is a debate about how and when climate beliefs are formed. Which came first: the belief that climate change is happening or an individual experiencing climate change, such as an extreme weather event? Also, what is the relationship between perception that one has experienced global warming and the belief that it is happening (Myers et al., 2012)? In a longitudinal study using survey data in 2008 and 2011, it became evident that for Americans, the answer is quite complex. The researchers found that "experiential learning', where perceived personal experience of global warming led to increased belief certainty, and 'motivated reasoning', where high belief certainty influenced perceptions of personal experience" and "motivated reasoning occurs primarily among people who are already highly engaged in the issue whereas experiential learning occurs primarily among people who are less engaged in the issue, which is particularly important given that approximately 75% of American adults currently have low levels of engagement." (Myers et al., 2012, p. 343). From the literature discussed above, it appears that a perceived personal connection to the topic is correlated to positive climate stances. I explore results similar to this idea in Chapter 4 and the concept is revisited in Chapter 8 in curricular suggestions based on my findings.

The results of this study have several implications. First, the issue of believing in climate change is complex. Your prior convictions, such as understanding the topic and engagement in the issues, can influence the relationships. Second, the researchers argued that this low engagement and certainty of climate change was due to the abstract nature of the concept. Climate change and climate concepts, in general, are abstract, statistical models that do not have tangible characteristics. However, the complicating and contradictory aspect of this statement is that the impacts are felt and are not abstract like the statistics and models for the general population. Again, this reinforces the complexity of this construct and the factors involved. Finally, the study has influenced my work from a methodological perspective. The study used multiple time points to explore relationships between stances, such as certainty of climate change, concern about impacts, and if one feels they have experienced climate change.

Pruneau et al., (2001) conducted a study to explore children (3rd graders), teenagers (7th graders), and adults' (over 18 years of age) knowledge, opinions, and feelings about climate change. The study participants were from two cities in Canada. The authors describe both locations as geographic areas that had experienced severe weather events just prior to the study. Data was collected through a semi-structured interview protocol. The findings suggest that the participants discussed the topic of climate change without being able to state the causes and/or consequences of this phenomenon. Moreover, there was a lack of concern across all age groups regarding climate change. The authors reasoned that participants had a low level of worry, because they did not see how climate change would personally impact them.

Nisbet (2009a) illustrates that climate change consistently ranks low on Americans' priority list for President Obama and Congress to address. Topics about climate change and the environment fall behind the economy and other categories that people feel have a greater impact on their everyday lives. The author states that climate change does not get top billing because of its complexity, people cannot see and/or understand it, which means it is difficult to see the immediate impacts. It is necessary to find different ways to communicate and engage the community in climate change. The authors found that America is divided into two categories along ideological lines concerning climate change: (a) accept climate change and are concerned or (b) reject that climate change is happening and are not concerned. The American media system is cited as a cause for the fragmentation on this topic.

Political Ideologies and Climate Change Stances

Climate change is often discussed as a politically charged issue. Policy decisions regarding climate change often align with political agendas. From a general perspective, democratic or liberal politicians are more often labeled as pro-environmental versus conservative or republican publically elected officials tend to be labeled as having an anti-environmental agenda. These groupings are quite broad and general and need to be explored in more detail. In this section, I provide a brief overview of literature that explores the public's views on global warming and potential political correlations on one of the greatest environmental issues to be debated in our history.

McCright and Dunlap (2011a) explored if there was a correlation between United States populations' political orientations and beliefs about global warming. They found that a person's political affiliation is correlated to his global warming beliefs and concerns. The ten year longitudinal study (2001-2011) was based on responses from nationally representative Gallup polls of adults in the United States. Self-identified democrats reported climate change views that aligned with accepted science more than Republicans and conservatives (they identified Republicans and conservatives as two different groups in the survey). Moreover, there was a positive correlation between educational attainment levels and democrats who claimed to understand global warming beliefs and concern. A self-identified Democrat with a college education is more likely to have views that align with the scientific community as compared to a Democrat with a lesser education level. However, this correlation was negative for conservatives (i.e. higher educational attainment had a negative correlation to beliefs that climate change is happening). Different geographic locations had varying political orientations.

Another McCright and Dunlap (2011b) study built on the more general empirical article discussed above (McCright & Dunlop, 2011a). It also explored the data from the 2001-2010 Gallup Polls from an environmental sociology perspective. It explored what the researchers term the *white male effect*. This article asked the following question: Are white conservative males as compared to the rest of the U.S. adult population more likely to take a position of climate denial? Within the Gallup polls they identified five indicators of climate change denial. The authors found that even when controlling for factors, such as political orientation (authors assume conservative is not a political ideology), conservative white males, on average, often take the climate denial perspective on all five items. Those who identified as conservative white males and reported having a strong understanding of global warming from a science perspective, were statistically significantly more likely to be a climate change denier.

Walsh (2012) examines the opportunities and challenges of teaching climate change in high school classrooms. She suggests that, “Educators need to attend to students’ political and other ideological belief systems when supporting student’s scientific understandings of climate change" (p. 43). Walsh's (2012) dissertation findings suggest the importance of students' political ideologies and family conversations in how students approach scientifically controversial issues in the classroom. It is important for students to be guided and to help navigate the tension between a belief system, such as a political or religious ideology, and the scientific evidence they encounter in school.

Religion and Climate Change

Political ideology and religious convictions are often discussed with regards to one's stance on climate change. Politics and religion, while there is overlap, are two different entities that are worth noting and discussing in regards to climate change stances. It needs to be noted that there cannot be overarching, general statements that strong religious convictions are correlated with climate change skepticism. In fact, the majority of religious organizations have supported anthropogenic climate change and behaviors to encourage climate mitigation and/or adaptation (Hulme, 2009). However, religious convictions, particularly those of the far right in the United States, have been found to correlate to climate change skepticism (Schultz, Zelezny, & Dalrymple, 2000)

Wardekker, Peterson, and van der Sluijs (2009) discuss the role of religious groups in the climate policy debates. The authors focus on a Christian voice where the convictions are grounded in ethical discussions regarding climate change and point to the idea that it is too simple to directly relate religious beliefs to climate change issues. Schultz, Zelezny, and Dalrymple (2000) found a negative correlation between pro-environmental stances and Christian beliefs. However, the authors note that the correlation might not be solely on religious grounds. There might be other factors, such as political and moral conservatism that are underlying the religious and environmental correlation. Their findings also suggest that the manner in which participants interpret the Bible correlates to the type of environmental concerns one holds. For example, those who have literal Bible beliefs have lower ecocentric environmental concerns, but higher anthropocentric environmental worries (Schultz et al., 2000). Student discussions of religion and climate change are discussed in Chapter 7.

Communicating climate change and taking into consideration climate change stances. The above discussion of religion and climate change brings in literature on science communication. Nisbet (2009a) discusses how framing a science issue is extremely important, specifically regarding socioscientific issues that have religious and political components as part of the discussion. In the Nisbet (2009a) study, when an expert committee was tasked to communicate evolution, they attempted an audience-based perspective. For example, in a religious context, the argument that evolution is the building block for modern-day advances in medicine was better received rather than discussing the separation of church and state. Framing the science issues to particular audiences goes beyond the traditional approach of informing the public. This paradigm shift has the potential to encourage more public engagement in science issues. This approach stresses framing the discussion around the personal relevance and meaning of climate change and other science topics to individual audiences. Many science topics have generalizable features that help media frame the issue that overlap with the public's disposition. The article discusses that framing the issue is important for scientists, media, and policymakers. I would argue that framing the issue is also extremely important in education. The article approaches framing from a sociological perspective. Nisbet (2009) argues that even if people have varying ideological perspectives on the issue, they can share the same interpretive frame. The idea of framing is revisited in Chapter 8 when I discuss curriculum suggestions based on my findings.

Similarities to Evolution?

Climate change curricula have entered United States' K-12 classrooms and have been met with some conflict, similar to past and present discussions about evolution (Morrison, 2011). Like evolution, many state boards of education are debating how and if climate change should be taught in public schools. In March 27th, 2009, the Texas State Board of Education voted to amend language in a textbook chapter on Environmental Systems to include the phrase, "analyze and evaluate different views on the existence of global warming" (Environmental Defense Fund, 2009). Furthermore, the Texas State Board of Education has implemented education standards that require public school teachers to teach the denial of climate change as a scientifically valid position. Other states, such as Louisiana and South Dakota have passed similar bills.

There are many similarities between climate change and evolution that also go beyond if and how these topics will be taught in K-12 settings. Morrison (2011) illustrated that the similarities include (a) well-financed campaigns by the denial communities, (b) popularly-known villains (Charles Darwin and Al Gore, respectively), (c) partisan positions where conservatives tend towards a denial perspective, and (d) wide use of pseudoscience to explain it away. More broadly, both evolution and climate change are overwhelmingly accepted as truths by the scientific community. The vast amount of scientific evidence has not dissuaded the Creationist voice in the evolution debate. Climate change also is also backed by irrefutable evidence. However, it is a relatively new debate in political and educational circles. Will it continually be met with a strong denial voice, similar to evolution? Or will it be more like the history of the anti-smoking campaign? With tobacco, the general public learned the facts that smoking causes cancer, tobacco became heavily taxed, and the courts became involved in lawsuits against big tobacco, leading to a successful anti-smoking campaign. The resistance to teaching climate change education is discussed in Chapter 4 with regards to one school in my sample.

Additionally, I discuss the idea of evidence-based curricular (e.g., analogous to the anti-smoking campaign) changing stances in Chapter 8.

Summary of Climate Stances in the Literature

The studies and literature I discussed in the climate change stance section illustrate the complexities and variations in people's climate change beliefs. The studies from the YGCC, through large-scale representative, longitudinal samples of the United States population, quantitatively characterize the range of people's climate change beliefs. As discussed in Chapter 3, the works from the YGCC guided my survey and interview development as well as how I approached data analysis for the interviews.

Miller (2012) and Pruneau et al. (2001) suggest that teens and adults are detached from climate change. While teens and adults discuss climate change, they are not informed about the causes and consequences of climate change. Moreover, there is a general lack of worry as discussed in the work regarding climate and its personal impacts. This idea is discussed and confirmed in multiple chapters in my work. Furthermore, Nisbet's (2009) builds on the previous work in the field, illustrating the lack of priority that Americans place on climate change issues. Moreover, his argument suggests that if the issue is framed properly (Nisbet, 2009), specifically aligning with religious and political convictions, climate change issues would be better received and communicated to a larger portion of the society. Finally, both political and religious ideologies are found to correlate with climate change stances (McCright & Dunlap, 2011; Schultz et al., 2000).

The literature on climate change stances above sets the foundation for different variables that I explore in my dissertation work, such as a student's level of worry about the impacts of climate change and if a student believes in the existence of anthropogenic climate change. As mentioned earlier, one's climate change stance is a complex construct with a wide variety of potential influences from outside and inside of school. By probing students' climate change stances, I identified middle school students' perspectives on climate change and see if these stances are stable or can change after participating in a climate change evidence-based curriculum. I also probed to see how they justify their climate change stances.

Situating My Study

My dissertation findings add to breadth and depth of the literature discussed above by discussing the nature, persistence and stability of climate change knowledge and stances through multiple forms of data collection instruments, time-points, and analysis. Through the data analysis, I further explored the messy middle knowledge discussion by characterizing how students discuss and/or reason through climate change topics. Moreover, I explored students' justifications for why they were not worried about climate change impacts. The findings from my work can continue to help guide curriculum design to help guide students through messy middle knowledge and to see the relevance and importance of climate change science in his/her everyday lives.

The already existing literature guided my study design, specifically the stance surveys and post semi-structured interviews. Moreover, the studies that focused on climate change knowledge, alternative concepts, and stances, were used in my work to identify potential start codes for analysis of open-ended questions for the survey and interview transcripts (Miles & Huberman, 1994). As a reminder, in my work I discuss alternative concepts as messy middle knowledge. The knowledge was on a spectrum of aligning with accepted scientific principles and theories.

My study confirmed and built on previous work by combining the exploration of both climate change stances and knowledge in a middle school population. The studies that examine climate beliefs and knowledge (Leiserowitz et al., 2010; Leiserowitz et al., 2011; Leiserowitz et al., 2012; Miller, 2012) did not differentiate between and/or explore knowledge and beliefs together. Furthermore, in these studies, students did not participate in a purposeful intervention to explore stability of knowledge and/or stances. My study had students take both pre and post stance surveys and knowledge assessments, as well as participate in Climate Change and Its Impacts on Ecosystems (Songer et al., 2012), a purposeful, evidence-based curricular intervention that explored topics on climate change and biodiversity. The curriculum was designed to be completed over an 8-10 week period. With this extended time period, I tested for change in both climate change knowledge and stances.

Along the same lines, my work added to the field by gathering data at multiple time points with the same students, and by using several different data collection instruments. I captured stances and knowledge before and after curriculum completion, and then again 4-5 months after the curriculum through a semi-structured interview.

Additionally my dissertation work combined large scale, multi-time point quantitative analysis with qualitative methods to further explore the complexities, persistence, and nature of students' climate beliefs and knowledge. By incorporating open-ended responses as well as multiple choice answers, I employed a variety of data analysis techniques. A mixed method approach allowed for triangulation of the data and helps to identify unique complexities of climate change stances and knowledge (Creswell, 2013). These methods of data collection and both quantitative and qualitative analysis approaches helped me to identify correlations and other statistical relationships. Finally, I used student interview responses to create ordinal stance categories and unpacked these categories through student exemplars.

Based on the conceptual framework, including defining my main constructs and reviewing the literature and findings in the field, my work built on the existing literature and attempts to fill-in gaps that currently exist. Below is how I believe my work adds to the existing field:

- Investigating climate change knowledge and stance changes and stability through the use of multiple data collection instruments and time points.
- Comparing findings and results to existing and studies in science education, science communication, psychology, and sociology.
- Adding to and building breadth and depth to the existing studies regarding the lack of worry about climate change impacts as well as messy middle knowledge that students have regarding climate change topics.
- Exploring the complexities, relationships, and persistence of both students' stances and knowledge about climate change.
- Comparing findings to existing conceptual change literature, specifically the relationship between stance and knowledge development.

Chapter 3: Methodology

Overview of Chapter 3

In Chapter 3, I discuss in detail the methods used to collect and analyze my dissertation data. I begin by explaining each data collection instrument (e.g., pre/post surveys, pre/post knowledge assessments and post semi-structured interviews). For each instrument, I explain the types of questions and knowledge and stance categories probed. Moreover, I explain how I approached coding the raw data. In the second section, I discuss the specific analysis techniques that I employed to approach each research question. The purpose of this chapter is to make my methodologies completely transparent to the reader and to explicitly discuss how I approached my data analysis. Finally, I reference all of my data collection instruments and rubrics, which can be found in full in the appendices. As a reminder, see Table 3.1 for my research questions

Table 3.1
Dissertation Research Questions.

Overarching Research Question	What is the nature, persistence, and relationships among middle school students' climate change stances, knowledge and messy middle concepts? Sub-question: What does knowledge and stance development look like?
Research Question 1	What is the nature, stability, and patterns of students' climate change stances?
Research Question 2	What are the relationships between students' climate change stances and climate change knowledge? Sub-question: Does knowledge change from before and after participating in the curriculum?
Research Question 3	How do we characterize the complexities and stability of students' climate stances and knowledge?

Participants in the Study

My study included participants from the larger ChangeThinking research study (Songer, Myers, & Beach, 2009) implemented by the Center for Essential Science research team at the

University of Michigan. The research team developed the curriculum described in Chapter 2 as well as a high school 12 week version. The Center for Essential Science team members have previously developed learning progressions, six other curricular units six other learning technologies and conducted research studies on student learning for over 15 years.

Participants in these studies were a self-selected subset of the larger ChangeThinking research population. These student participants were selected as a result of their classroom teachers' voluntary participation in this additional set of studies. These study participants included students and teachers from 9 out of the 11 participating middle schools from the larger ChangeThinking study (n ≈400).

Table 3.2a shows the number of participants and the basic student demographics by participating teacher in my work. The overall sample size was the following: n=326 for the pre and post stance survey, n=232 for the pre and post knowledge merged with the pre and post stance survey, and n=25 for the post semi-structured interviews. The effective sample size for the quantitative analysis was much larger because each student took a pre and post stance survey and pre and post knowledge assessment, which means there were at least at least two recorded time points per stance and knowledge category (Rabe-Hesketh & Skrondal, 2008).

Even though my study did not focus on teachers' knowledge and practices, I argue that it is important to provide some information about teachers and their classrooms in order to give additional context to the learning environments of students in the study. Table 3.2a provides the participating teachers' information, including information such as the number of years teaching and if they have taught climate change before participating in this curriculum. Table 3.2b shows the expectations for teaching climate change, global warming, and/or climate science (e.g., the state standards) for each state represented in the sample. At the time the students participated in the curriculum, none of the states had adopted the new United States national science standards, the Next Generation Science Standards (citation) so teachers were held accountable for the individual state standards. As a result, there was a dearth of climate change topics in the middle school state standards in our participating geographies. However, the topics of weather and climate, global cycles and systems, and the impacts of humans (e.g.,, overpopulation) are included in many of the science standards. The Kansas standards mentioned global warming as an opportunity to allow students to express uncertainty about science topics through evaluating the accuracy and validity of results, and encourages that conclusions are based on scientific evidence.

Table 3.2a
Summary of Sample Participants who Took Both the Pre and Post Stance Survey (n=326 students).

School	Teacher	State	Frequency of Students in Sample	% Minority	Type of School	Taught Climate Change Before?	Years Teaching Science	% Students Free and Reduced Lunch
Main St.	Ms. B	Michigan	4.6	87	Public, Suburban	No	0-1; student teacher	75
Main St.	Mrs. T	Michigan	2.76	100	Charter, Suburban	No	6	88
Circle MS	Mrs. H	Northern Kentucky/Cincinnati, OH suburb	23.01	16	Public, Suburban	Yes	25	31
Circle MS	Mr. W	Northern Kentucky/Cincinnati, OH suburb	22.39	21	Public, Suburban	Yes	7	31
South Kernel MS	Mr. C	Kentucky	3.99	20	Alternative Public, Rural	No	6 s	53
South Kernel MS	Mrs. E	Kentucky	20.55	15	Public, Rural	Very little	10	53
Village MS	Mrs. R	Virginia	6.13	25	Parochial, Small City	No	20	-
King St.	Mrs. M	Kansas	8.9	15	Public, Rural	Very little		27
North Central MS	Mrs. C	North Carolina	7.67	14	Public, Suburban	No.	9	51
	Total		N=326					

% minority includes students who self-identified as non-European white in the stance survey background questions. This is a subsample of students in the larger ChangeThinking study.
% Free and reduced lunch was identified based on school reported data to the state.

Table 3.2b

Climate Change and Climate science in State Standards (2012-13) for Participating Geographies

State	Climate Change in State Standards (Directly from State websites)
Kansas 2013-13 (before adopting NGSS)	**(http://community.ksde.org/Default.aspx?tabid=4658)** **The term climate change is not mentioned** **Students will develop scientific habits of mind:** Student practices intellectual honesty, demonstrates skepticism appropriately, displays open mindedness to new ideas, and bases decisions on evidence. Example: d. shares interpretations that differ from currently held explanations on topics such as global warming and dietary claims. Evaluates the validity of results and accuracy of stated conclusions (p. 60)
Kentucky 2013-13 (before adopting NGSS)	**(http://education.ky.gov/curriculum/docs/pages/kentucky-core-academic-standards---new.aspx)** **Climate Change and Global warming not specifically in the standards** **Grade 5**: Compare weather and climate and describe the factors that influence each **Grade 6:** oceans have a major effect on climate, because water in the oceans holds a large amount of heat. Ecosystems are more than just the organisms they contain: geography, weather, climate and geologic factors also influence the interactions within an ecosystem. **Grade 7:** Investigate a variety of Earth systems that are powered by solar (e.g., water cycle, climate, carbon cycle) and/or geothermal (e.g., plate tectonics, volcanism) energy **Grade 8:** Solar energy influences global climate in a number of direct and indirect ways. Patterns of global climate can be determined through analysis of climatic data. Analyze multiple sources of data to identify global climate patterns
Michigan 2013-13	**(http://www.michigan.gov/mde/0,4615,7-140-28753_64839_38684_28760---,00.html)** **Terms No mention of terms climate change and global warming in middle school science standards** **L.EC.06.42** Predict possible consequences of overpopulation of organisms, including humans, (for example: species extinction, resource depletion, climate change, pollution) **E.ES.M.7 Weather and Climate-** Global patterns of atmospheric and oceanic movement influence weather and climate.
North Carolina 2013-13	**http://www.dpi.state.nc.us/curriculum/science/scos/** **No mention of terms climate change and global warming in grades 6-8 science standards** **7.E.1** Understand how the cycling of matter (water and gases) in and out of the atmosphere relates to Earth's atmosphere, weather and climate and the effects of the atmosphere on humans.
Virginia 2013-13	**http://www.doe.virginia.gov/testing/sol/standards_docs/science/** **LS.10** The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic, change over time, and respond to daily, seasonal, and long-term changes in their environment. Key concepts include: c) eutrophication, climate changes, and catastrophic disturbances. **Introduction paragraph for Earth Science in middle school:** Major topics of study include plate tectonics, the rock cycle, Earth history, the oceans, the atmosphere, weather and climate, and the solar system and universe. **ES.11** The student will investigate and understand the origin and evolution of the atmosphere and the interrelationship of geologic processes, biologic processes, and human activities on its composition and dynamics. Key concepts include: d) potential changes to the atmosphere and climate due to human, biologic, and geologic activity. **ES.12** The student will investigate and understand that energy transfer between the sun and Earth and its atmosphere drives weather and climate on Earth. Key concepts include: d) weather phenomena and the factors that affect climate including radiation, conduction, and convection

Data Collection Sources and Instruments

My work had three major data collection points and instruments: pre/post stance surveys (Appendix A), pre/post knowledge assessments (Appendix B), and semi-structured in-depth post-interviews (Appendix C). The data gathered from these instruments guided how I explored the nature, complexities, and relationships among students' climate change knowledge and stances. In this section, I discuss the details of each data source and instrument. For each instrument, I give an overview of the types of questions and how the questions are coded to prepare for data analysis. Finally, I outline the data analysis techniques employed to analyze the data collected. I would like to note and remind the reader that all names (except my own) are pseudonyms throughout my dissertation work. This includes school and student names that areused in quotes and exemplars. Moreover, there have been no edits made to grammar and/or spelling in student quotes to maintain authenticity.

Part I: Pre and Post Stance Survey and Data Analysis RQ 1

Overview of Pre/Post Stance Survey

The pre and post survey was a 28-item online assessment that probes students' personal stances on climate change before and after participating in the curriculum. The complete survey can be seen in Appendix A. The survey was designed to allow students to express his/her stances on climate change. The three main categories probed are (a) is anthropogenic climate change happening and its causes, (b) climate change in students' lives (worry, impacts, and discussions), and (c) actions/solutions to mitigation and/or adapt to climate change. There were both multiple choice and open-ended items for each stance category. This helped to track the complexity of student responses. Specifically, the open-ended items help to identify the words and ideas that students used to justify a stance. They helped to characterize students' stances as well as track stability and/or change after participating in the curriculum.

The pre and post stance items were identical to each other to allow for analysis to track if stances have changed. Additionally, students were asked four questions on the pre and post survey to assess the students' science self-efficacy. As discussed in Chapter 2, self-efficacy is a motivational belief and is often stable. These items were included to test the stability and/or change and to draw parallels between climate change stances and self-efficacy beliefs. There are four background items that are asked on the pre survey, but not repeated on the post instrument. The background questions included items regarding students' race, mother's and father's education level, source of news (both on and offline), and self-reported science grade. The students' responses to these items were used as control variables in the statistical models and to explore differences between groups (e.g., do males' climate change stances differ from females in this sample population?). Students took about 20-30 minutes to respond to eight open-ended questions and 20 closed form/multiple choice items.

The Group Project on Climate Change Communication has published two studies that guided the design of my stance survey: *American Mind: Americans' climate change beliefs, attitudes, policy preferences, and actions* (Leiserowitz, Malbach, Roser-Renof & Smith, 2010) and *Americans Teens' knowledge of climate change* (Leiserowitz,, Smith, & Marlon, 2011). These studies were discussed in greater detail within the conceptual framework in Chapter 2. Four bounded items were identical to the Yale studies, and four items are variations of those studies. The six open-ended questions that follow the multiple choice items diverged from the Yale design, which only used closed form (e.g., multiple choice) items. These free-form responses were included to capture the students' justifications of their climate change stances.

The open-ended questions allowed students to use their own words, which helped to better characterize and identify the complexities of students' climate change stances and knowledge.

The multiple choice items were constructed as closed-response items to bound potential answers. The answer options were intended to be relatively exhaustive for the specific stance categories. The multiple-choice items were used as primers and prompts for the free-response questions that follow. For each of the categories, there were open-ended questions on the surveys. The free response items attempted to extend the work of the Yale Group on Climate Change Communication studies. They were also created to align with aspects of the Climate Change and Its Impacts on Ecosystems curriculum and assessment (Songer et al., 2012). Much of the curriculum had students work with data to illustrate the unequivocal trend of increasing average global temperatures. The curriculum specifically had students engage in explanation and prediction building to look at the mechanisms of climate change and its impacts on animals. The open-ended items had students justify their stances and students could draw on curricular knowledge as evidence and/or to ground their stances.

Prior to distributing the survey to the sample population, I tested the items with a small sample of middle and high school students. I asked them to mark questions that they did not understand. Then, I reviewed these questions with them to guide me in the modifications. Moreover, I reviewed their answers to ensure that I was probing the concept and stance in which I intended. Modifications were made to make each item to be as clear as possible.

Comparison to Yale Studies

As I discussed earlier, the Yale studies and questions guided the creation of the stance survey. Four of the items in the student survey were identical to those asked on previous Yale surveys. Major differences between my dissertation work and the Yale studies are summarized in

Table 3.3. It needs to be noted that the years that my dissertation study was conducted and the Yale studies were administered were not the same. Students took the pre and post survey in the 2012-13 school year. The Yale Studies in which student responses are compared were conducted in 2010 and published in 2011. While the frequencies are compared across studies because several identical questions were used, views on such a current topic might be year sensitive depending on many factors including, but not limited to, severe and extreme weather, political debates, media attention and/or policy agendas.

Table 3.3.
Major Differences between Dissertation Work Surveys and Yale Studies

	Dissertation Work	Yale Studies
Year survey conducted	2013	2010 & 2011
Types of questions	Multiple choice and open-ended	Multiple choice
Number of time points for same sample population	Two (before and after curricular intervention)	One
Type of Sample	Convenience (students who participated in curriculum)	Simple random sample—representative of US population
Age of Sample	Middle school students (ages 11-14)	Adults (18 years and older)

While similar questions were asked in multiple years, the same people were not sampled in the Yale Studies. It is more of a statement of the overall global warming stances and beliefs in the American Public. The difference between a weighted, simple random sample of the adult population and a convenience sample of the middle school population is worth noting. The classroom teachers volunteered his/her classrooms to participate in the curriculum and my dissertation study. Additionally, all students sampled submitted permission slips signed by his/her parent or guardian to participate in the studies. Thus, my population was self-selected and voluntary. A small minority (less than 10% of the students) opted to not participate in the study.

Since I did not analyze the data of students who declined to participate, I do not know if those students had similar patterns of stances to each other or aligned with the overall findings of the sample population. The Yale studies had large enough numbers to generalize their findings. While my dissertation work does not specifically study the difference between secondary students' climate change stances versus the adult population, in Chapter 4, I compare the frequency of student pre/ post survey responses to frequency of responses to identical questions in the Yale studies. However, it should be noted that middle school students have different prior experiences and motivators than the adult population, which could potentially encourage differences between responses (c.f. Carey, 2000).

Coding the Stance Surveys

The coding rubric was used to create a systematic approach to help answer the research questions. The rubric can be found in Appendix D. It had several components. On the left side of the chart, the item from the survey was duplicated. The right side of the chart is the coding rubric with numbers assigned to each response. The first part of Appendix D is the coding rubric used for each question. Additionally, student example responses listed by code received were included for the open-ended response items**.** Sample student responses to the open-ended questions are in the second part of Appendix D. There are sample responses for each of the collapsed categories for the open-ended items. I achieved 90% internal rater reliability (IRR) before coding the pre and post survey responses. By giving sample student responses for the open-ended responses, it helped achieve inter-rater reliability.

Multiple choice questions were all coded by assigning numbers to each response option. For example, the response options for the question "*Is anthropogenic climate change happening?*" are *No, Yes,* and *Don't Know*. Values of one, two, and three points were assigned respectively. The numbers assigned to each response option do not place a value on student responses, but rather were used to create a non-ordinal categorical variable. Frequency counts were then calculated for each category based on the assigned numbers. Moreover, analysis was conducted on the entire item when it was treated as a categorical variable.

The first step in coding the open-ended questions was to develop start codes for the rubric. This provided the first pass to begin coding student responses (Miles & Huberman, 1994; Marshall & Rossman, 2010). The start codes allowed for a first read of the responses. During this process, other patterns/responses become evident in the data. For the open-ended questions, I created the start codes with broad categories that captured the vast majority of responses. The start codes were created based on the documented responses in the literature discussed in Chapter 2. Moreover, common messy middle concepts that were documented in the conceptual framework were also included in the list of start codes. For example, for the item: *In one to two sentences explain why you think climate change is happening, not happening or you do not know?* The start codes are the following categories: *religious views, political views, correct scientific evidence for why it is happening, it is not happening, incorrect scientific evidence,* and *don't know. The* start codes also included enhanced greenhouse gases/effect, increased fossil fuel use, and ozone depletion (to name a few). During the initial read through of the answers, additional codes emerged, such as *animals are dying and/or migrating, pollution and littering,* and *on average it is getting hotter* (note: the entire code list for item 6b can be found in Appendix D). When appropriate, the multiple choice options that preceded the free-response question were also included as codes for the open-ended questions. Stances that did not align with the accepted scientific principles were also coded. Then, with a complete code list and student examples for the open-ended responses, I achieved 90% IRR. Once IRR was achieved, I coded all pre and post survey responses using the coding rubric.

Data Analysis for Chapter 4 (Research Question 1)

In this section, I review the analysis techniques that I used to analyze research question 1, *What is the nature, stability and patterns of students' climate change stances*? I begin with an overview of the pre-analysis and descriptive statistics used. In the next sub-heading, I discuss finding the frequencies of pre/post responses to the stance categories and individual questions to explore stability. I also compare these findings to those in the Yale Studies. Next, I discuss the Pearson's chi squared test, graphical models and general linear models, which are used to explore the statistical relationships between variables and are a means to visualizing these complex relationships. These data analysis techniques are discussed in greater detail below.

Pre-analysis and Descriptive Statistics for Pre/Post Stance Surveys

I first cleaned and coded the data set. The pre and post responses were then merged into a single data set. Only students who took both the pre and post climate change survey were included in the merged data set (n=326). The codes applied to the open-ended questions were collapsed into bigger themes and a fewer number of codes for analysis purposes. The collapsed categories can also be seen in the coding rubric in Appendix D. Moreover, new variables were created by collapsing Likert-type responses, such as the worry scale, to binary variables of worried and not worried, which are used in the logistic regression models. Dummy variables were created for all categorical variables for use in linear regression and generalized linear models in Chapters 4 and 5.

Frequencies for Stance Categories and Individual Questions

I calculated descriptive and overview statistics for the three major climate stance categories: (a) is anthropogenic climate change happening and its causes? (5 items), (b) climate change in students' lives (3 items), and (c) actions and solutions to mitigate and/or adapt to climate change (three items). The categories were created using only the closed form items; the open-ended questions were evaluated in other tests, which I describe below.

To report overall trends in stance categories, I centered all individual responses around zero by recoding the variables. Positive scores correlate to responses that (a) take the stance that climate change is happening and caused by anthropogenic actions (b) there is worry and discussion about climate change, and (c) stances about actions to mitigate and/or solve climate change issues with changes in human behavior. Negative numbers on the scale indicate opposite stances, such as climate change is not happening. A score of zero correlates to a neutral overall position. I calculated the overall score for each category by summing codes for all items within each category. The overall scores on pre and post surveys were graphed to illustrate positive, negative, or neutral responses for each climate stance category.

To calculate if there was a significant change (post or negative) from pre to post, I conducted a two sample mean comparison test to explore significant changes. In order to do this, I set the change variable to zero. The two sample mean comparison tests, also known as a paired t-test, were used to test for significance between dependent samples with continuous variables, such as pre and post test scores. Note that the pre and post variables were treated as continuous because there were 10 consecutive count integers for each score. The null hypothesis for the paired t-test is that there is no difference or change from pre to post scores (Acock, 2010; Agresti & Finlay, 2009). The test indicates whether there was a significant difference between means. If the null hypothesis was rejected, then the results can be interpreted to see where the shift occurred (e.g., positive or negative). A positive significant change indicated a shift towards stances that are generally accepted by the scientific community. Conversely, a negative change meant a shift from pre to post to a less accepted climate change perspective by scientists. The trend was also confirmed using a change variable.

Then, I calculated a change variable for each of the three climate stance categories.

$$Change\ variable = Post\ Total\ Score - Pre\ Total\ Score$$

I plotted a frequency distribution to illustrate the overall change in each climate stance category. Since there was a large spread in this variable for each stance category, the change variable was collapsed into three major categories of trends: (a) positive, (b) negative, and (b) neutral. Then, a frequency for each category was calculated in order to characterize what kind of trends occurred in each stance category.

Individual questions. I calculated frequencies for the background questions, such as age, geographic location, parent education levels (both for mother and father), science achievement this year and last year, how often they watch or read the news online and/or in print and what news sources they accessed. These variables were used in the data analysis process to explore statistical relationships to various responses and were control variables in regression models in Chapters 4 and 5. For items that were identical to the Yale Group on Climate Change Communication (YGCC) survey items (Leiserowitz et al., 2010; Leiserowitz et al., 2011), I compared frequencies to my sample population.

Testing for Statistically Significant Changes between Pre/Post Responses

Frequencies were then calculated for all individual closed-form stance questions on both the pre and post instrument. The frequencies were then used to test if there was a change in student responses on individual items from before and after curricular intervention. A test for marginal homogeneity was conducted between pre and post items to account for dependence between the responses (Stuart, 1955). The null hypothesis states that the marginal probabilities are the same. Thus, a significant test indicated that the pre and post responses for the categorical questions are significantly different. To further elaborate on student responses from the Likert-type multiple choice items, I showed student responses to the open-ended questions in tables to illustrate frequencies of responses from pre to post. The tables include the codes assigned to the responses and show sample student responses.

Pearson's Chi Squared Test

With significant findings that students' climate changes stances changed, specifically regarding the existence of anthropogenic climate change, I conducted further analysis to see if there are differences in groups within the sample population. A chi squared goodness of fit test was used to explore if the proportions of categorical variables differed. The groups in this pre and post survey responses were divided by both males and females (two separate chi squared tests).

I conducted Pearson's Chi Squared Tests to test for dependence between categorical variables (Acock, 2010; Agresti & Finlay, 2009). Specifically, I explored the dependence or independence between the closed form Likert-type questions on the pre and post-test. My goal was to identify potential statistical relationships between categorical variables in my data set. With identified relationships, I formed additional models which are presented in Chapter 4.

Graphical Models

I used graphical models in my analysis to capture patterns and illustrate complex relationships that exist in the students' open-ended responses. Graphical models are a general term used to describe a flexible and powerful approach to illustrating real-world phenomenon through the use of networks (Koller, Friedman, Getoor, & Taskar, 2007) to infer patterns visually. More specifically, in this study, graphical models were used to explore if 'communities' of students are created by responses to the questions: *Why do you think climate change is happening or not and Why are you worried or not worried about climate change?* I created a different model for each question. The graphs were constructed using the collapsed codes from the open-ended questions from the pre/post surveys.

There are two main aspects to the graphs: the nodes and the edges. The nodes represent student responses by category. For cross analysis purposes, I standardized the sizes of the nodes for all the graphs. Thus, the size of the node correlates to the frequency of the response. This means node size can be compared across all graphs and more importantly between pre and post responses to see changes in response frequencies. More specifically, a test for marginal homogeneity was conducted for each pre and post node to explore if changes were significant while accounting for correlations between student responses. A larger node indicates a response that occurred at a higher frequency. The color of the node also indicates frequency of response. A darker color blue indicates a higher frequency of occurrence. The number within the node, correlates to the actual student response and matches a number in the key below the graph. The edges indicate number of shared responses. The thickness of the edge correlates to the number of students who shared responses. The edges help to define the communities and shared relationships or common patterns in responses across the sample on the pre and post surveys. To aid in interpretation of the multiple components of the graphs, the two main graphs are constructed in three stages: (a) Nodes→size of nodes to represent frequency of responses, (b) Nodes→ color and size represent frequency of responses, (c) Edges + Nodes→ show shared responses and patterns between nodes. I used a modified version of the Matlab wg-Plot package to create the graphs (Wu, 2009). The graphs and results are found in Chapter 4.

Generalized Linear Models

Then, I used generalized linear models to explore statistical relationships between variables while controlling for background coefficients. The logistic regression (logit) is a specific type of generalized linear model. In my study, logistic regression models were constructed to explore potential relationships between binary dependent variables and independent variables (Long & Freese, 2006; Everitt & Rabe-Hesketh, 2006). The logit function's parameters represent the probabilities of the function in log-odds. For interpretation purposes the results are reported in odds ratios. An odds ratio greater than 1 indicates that that the binary outcome labeled as one (e.g., worried or anthropogenic climate change is happening) is more likely to occur. Whereas an odds ratio below 1 tends toward the binary outcome that is defined as zero (e.g., not worried or anthropogenic climate change is not happening). An odds ratio nearing 1 means that each binary outcome is just as likely to occur (Eliason, 1993). Significance of independent variables as predictors in the model is reported as p-values. Note that categorical independent variables were declared significant only if they were jointly significant in the model (i.e. as opposed to only a single category), where the p-value of the F-test for joint significance was less than or equal to 0.05.

In Chapter 4, I constructed and conducted two main logistic regression models. Model one has a binary dependent variable of worry or not worried about the impacts of climate change. The model is paneled by pre and post stance time-points for student responses and clustered by student identification number. The model accounts for correlated standard errors. It estimated statistical predictors of students' worry about the impacts of climate change while controlling for background variables. F tests were conducted to test for joint significance of the covariates. Model two explored statistical variables for the binary variable climate change is happening or not happening for males in the sample. The population was separated into males and females based on findings from the chi squared results where the stability of male and female responses were different.

Part II: Pre and Post Knowledge Assessment and Data Analysis RQ 2

Overview of Pre/Post Knowledge Assessment

The middle school pre/post assessment used in this study is the third iteration of an assessment given to students participating in the Climate Change and Its Impacts on Ecosystems curriculum (Songer et al., 2012). For this study, I used seven items that specifically focused on climate science knowledge to identify achievement (learning gains) on abiotic climate change topics. The responses from the pre/post knowledge assessment were used in conjunction with the pre/post stance surveys to explore research question 2 in Chapter 5.

The pre/post knowledge assessment was given to all students who participated in the Climate Change and Its Impacts on Ecosystems curriculum. This assessment was used to analyze students' climate knowledge and learning gains in each of the three knowledge categories (e.g., weather versus climate, carbon and anthropogenic carbon emissions, and the relationship between greenhouse gases and temperature). Specifically, Sania Zaidi, a doctoral student in the research group, and Professor Nancy Songer, a Principal Investigator of the project, created this assessment. There were fifteen items from the complete assessment used by the research group to assess students' learning gains. Nine of the items were content questions (i.e. assessing students' knowledge) and six items explore students' fused knowledge on climate change and biodiversity.

The assessment construction was guided by the literature in assessment design (Gotwals & Songer, 2010); and the purpose of assessments (Mislevy, Steinberg, and Almond, 2003) as well as the previous iterations of the curriculum and assessment (Cohorts 10 and 11). Gotwals and Songer (2010) state that, “Being able to make claims about what students know and can do in science involves gathering systematic evidence of students’ knowledge and abilities” (p. 259). The assessment allowed the researchers to gather information either in written, verbal, and/or project-based work about how students articulate a concept. Then, the researchers attempted to make evidence-based inference about what a student can do more generally (Mislevy, Steinberg, and Almond, 2003). It was not a direct measure of what students know, but the assessment attempted to capture enough evidence to make inferences about student knowledge development and learning gains. Moreover, since the curriculum design was guided by learning progressions where students continually build more complex, sophisticated understanding of science, the assessment should not just reflect students’ endpoints of knowledge development. The assessment for the Climate Change and Its Impacts on Ecosystems was designed to capture different levels and points of knowledge development (i.e. beginning, middle, and endpoints) by using questions of varying levels of difficulty (Gotwals & Songer, 2010). Finally, there were considerations taken into account to ensure the performance assessment is valid, specifically in regard to construct validity (Messick, 1994). To do this, think aloud interviews were conducted by doctoral student Sania Zaidi and myself to ensure that the assessment instrument measured the constructs it was intended to evaluate.

Furthermore, The SPECIES curriculum revisions were made in summer 2012, which in turn guided the assessment revisions. This assessment is in its third iteration. Like Edelson’s (2002) discussion of design work, after careful reflection on previous iterations and based on feedback from students' and teachers, the assessment was modified for the Cohort 12 implementation. First, there are items that are identical to the curriculum and/or use the same graphs/charts as items/activities created within the curriculum (e.g., questions: 1, 4, 6b, 7b, 8, 9, 10). Many of these items were new to this iteration of the assessment and were based on curriculum revisions. Other items were identical to state, national and international exams to allow for comparisons to be made about percentage of correct responses.

All items from the SPECIES knowledge assessment that covered abiotic topics (e.g., asked about climate, carbon, carbon dioxide, temperature, and/or climate change) were analyzed. The items excluded from this study were items that focused on biotic content. The following were the specific pre/post assessment items that were analyzed in this study: Q2 (result of climate change), Q3a (two human activities that contribute to climate change), Q3b (two human activities that reduce CO_2), Q4a (change in average temperature), Q5 (weather versus climate), Q6b (greenhouse gases and impact on temperature), and Q7b (carbon sinks). Appendix B gives the pre/post knowledge assessment items that were analyzed and used as data points in this study. The assessment items are on the left-side and the codes and point values for each item are on the right side of the tables in Appendix B.

Coding Pre/Post Knowledge Assessment

The knowledge rubric has a similar format to the stance survey coding rubric. The assessment items are on the left side of the table and the number of points received with guidelines for scoring and sample student responses are in the right column. All items on this assessment achieved inter-rater reliability (IRR) of at least 90% by the members of the ChangeThinking Research team (Songer et al., 2012).

On the knowledge assessment, there was a total possible score of 17 points from 10 items. As I discussed earlier, the three main categories of knowledge that were tested in the assessment are: weather versus climate (5 points), carbon and anthropogenic carbon emissions (6 points), and the relationship between greenhouse gases and temperature (6 points). At the bottom of the coding rubric for the knowledge assessment there is a breakdown of the test items that comprise each knowledge category and the points received per item.

Statistical Relationship between Knowledge and Stances Data Analysis for Chapter 5 (Research Question 2)

In this section, I discuss the statistical methods I used to approach the second research question: *What are the relationships between students' climate change stances and climate change knowledge? Sub-question: Does knowledge change from before and after participating in the curriculum?* To analyze the statistical relationship between climate change knowledge and stances, I discuss how I calculated descriptive statistics for the knowledge variables to explore stability from before and after participating in the curricular module. Second, I show how I explored the correlations between and across the pre and post climate change knowledge and stance variables. Then, I illustrate how and why I conducted principal component factor analysis to create latent variables with reduced noise. I, then, show how I used those factors in the multivariate linear regression using a simultaneous equation solution. These techniques are described in depth below.

Descriptive Statistics

For the pre and post knowledge assessment students earned an aggregate score for all items coded and assessed. Each student's pre and post score were calculated for the three knowledge categories. Then, I calculated and analyzed frequencies and changes in responses for each specific question. Through paired t-tests and tests for marginal homogeneity, I explored which knowledge structures remained stable and which categories of knowledge changed significantly from pre to post curricular intervention.

The same procedures were followed as discussed in Data Analysis of RQ 1 in Chapter 4, where the pre and post scores were constructed for major categories. However, the scores for each category were not centered around zero since the points on the knowledge assessment indicated a score earned on the pre or post-test. The mean scores for each knowledge category were calculated for both pre and post-test scores. The results were graphed for visual comparison and paired t-tests were conducted to explore significant differences between means while accounting for dependence of scores from pre to post (Agresti & Finlay, 2009).

Changes in scores, also known as learning gains (post score for each category minus pre score for each category) were calculated and centered around zero. A positive learning gain is indicated by a score greater than zero, whereas a negative learning gain is a score below zero. A score of zero indicated no learning gain. I calculated learning gains for each category and each participating school to explore differences in gains between schools.

Pairwise Correlations

I probed the four stance categories probed on the pre and post survey and three knowledge categories on the pre and post knowledge assessment. I calculated and constructed a correlation table to see potential two-way relationships between all knowledge and stance categories on both the pre and post instruments. The correlation matrix indicates if relationships between variables are strong, weak, positive or negative (Agresti & Finlay, 2009). The range of values is -1 to 1 with 0 indicating no correlation/relationship between variables. For example, a strong positive correlation is a positive value tending towards 1. Identifying correlations acted as a primer to begin exploratory factor analysis.

Factor Analysis

Exploratory factor analysis was conducted as a means of data reduction where there are correlated variables within the data set. It reduces the amount of noise and variance in the data set by identifying potential latent factors that exist. A factor is an unobserved variable that is created based on inter-correlations in the data set to explain variance among a larger number of variables (Walkey & Welch, 2010). The following steps were taken to conduct factor analysis.

1. Two separate exploratory factor analyses were conducted: (a) Variables from pre knowledge and pre stance instruments and (b) Variables from post know and post stance instruments. *Note the steps below were done for both the pre and post set of variables.
2. All variables were standardized in order to have all variables on a comparable scale
3. Kaiser-Myer-Olkin (KMO), measure of sampling adequacy over all variables were conducted to proceed with factor analysis
    a. Values of 0.9 to 0.6 indicate adequate sampling (Walkey & Welch, 2010).
4. Scree plots were created to graph the eigenvalues of the potential factors. The eigenvalues are proportional to the variance explained by the factors
    a. Eigenvalues above 1 are considered for the creation of a factor. Moreover, when the scree plot levels off/creates an elbow, values below the elbow are not considered.
5. Once factors are created a qualitative check is done to make sure the variables make sense together.

Multivariate Linear Regressions

To explore the statistical relationship between knowledge and stances I created a multivariate linear regression using simultaneous equation s. The system of equations took into account the correlated standard errors across the equations. This analysis allowed for comparisons across the equations (e.g., from pre to post changes). Estimating a joint model helped to reduce noise in the sample and created a more powerful test than conducting individual linear regressions for each dependent variable. The null hypothesis is that there is not difference between group means. With the reduction of noise (i.e. error) and the greater power of the test, a significant finding suggested that there is a difference between groups (Mertler & Vannatta, 2002).

The multiple dependent variables in the model were pre and post knowledge scores and pre and post stance scores. The independent variables included control variables, such as mother's education level, gender, and science grade. Additionally, to explore the statistical relationships between knowledge and stances, pre stance and knowledge variables were evaluated as independent variables.

The construction of the model can be seen in Figure *3.1* using the names of the variables to illustrate the simultaneous equation. This model accounted for correlated standard across the equations. Furthermore, posttests were executed to evaluate changes from pre to post variables as well as to explore if a covariate had a different statistical effect on the pre and post variable. Additional post tests were performed to identify whether the effect of an independent variable was significantly different for each dependent variable (for example, did pre stances have a significantly greater impact on post-stances as compared to post knowledge).

While the results cannot be discussed as causal because there was not a control group enacted in this study, I evaluated and discussed statistical relationships between climate change knowledge and stances before and after participating in the curriculum. The results are conditional on the other covariates in the model.

$$\text{EQ 1:}\quad \begin{bmatrix} Pre\ CC\ Stances \\ Pre\ CC\ Knowledge \end{bmatrix} = \begin{bmatrix} \boldsymbol{\beta}_{pre,stances} \\ \boldsymbol{\beta}_{pre,knowledge} \end{bmatrix} \begin{bmatrix} School \\ Gender \\ Gender \times Science\ Grade \\ Science\ Grade \\ Mother's\ Education\ Level \end{bmatrix}$$

$$\text{EQ 2:}\quad \begin{bmatrix} Post\ CC\ Stances \\ Post\ CC\ Knowledge \end{bmatrix} = \begin{bmatrix} \boldsymbol{\beta}_{post,stances} \\ \boldsymbol{\beta}_{post,knowledge} \end{bmatrix} \begin{bmatrix} g(Pre\ CC\ Stances) \\ Pre\ CC\ Knowledge \\ Gender \times Pre\ CC\ Knowledge \\ School \\ Gender \\ Mother's\ Education\ Level \end{bmatrix}$$

$$g(x) = sign(x)x^2$$

Figure 3.1. The figure provides equation (EQ 1) and (EQ 2) used in the multivariate linear regression using simultaneous equations to take into account correlated standard errors. The coefficients of the system of equations are jointly estimated to explore the statistical relationship between climate change knowledge and stances across pre and post time points. Then, post tests are conducted to estimate change of responses from pre to post instruments and the statistical impact of covariates on the dependent knowledge and stance variables.

Part III: Semi-Structured In-Depth Post Interview

Overview of Semi-Structured Interview Protocol

The qualitative data semi-structured interview was designed to explore the persistence of and further characterize both students' climate change stances and knowledge and to complement and unpack the findings of the quantitative data set. The interview protocol can be found in Appendix C. The interviews helped to further characterize students' knowledge and stances through deeper probing of students' ideas and justifications for their stances. Students who attended Village MS, (private parochial school), King St. MS (rural public school), and Circle MS (large suburban public school) were interviewed (n=25). The schools were chosen because the classrooms completed at least 80% of the 2012-13 Climate Change and Its Impacts Curriculum. Moreover, all students were in 6th or 7th grade while completing the curriculum.

They remained in the middle school building for the following school year, which allowed for easier access for the interviews. The interviews were conducted 4-5 months after the students completed the curricular module.

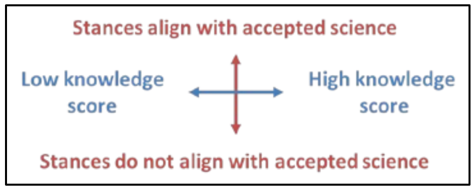


Figure 3.2. Categories created by students' responses from pre/post knowledge and stance assessment. These four categories are used as pre-processing tool to choose a diverse group of students to interview at each location.

To determine students to interview at the three locations, I pre-processed the data and divided the students into four categories based on responses to the stance survey and knowledge assessment as seen in *Figure 3.2*. The pre-processing results can be seen at the top of Appendix C (e.g., knowledge and stance changes and scores for each student in the three locations). Mean scores and standard deviations for pre and post data instruments were calculated and students were placed in a stance category relative to peers in their classes. The four categories from pre-processing are given in Figure 1, which included (a) high knowledge with positive stances, (b) low knowledge with positive stances, (c) low knowledge with negative stances, and (d) high knowledge with negative stances. I would like to note that findings students to fill the negative stances and positive knowledge category was difficult, but the students were chosen relative to their peers so compared to other peers with negative stances, these students had relatively high knowledge scores. Moreover, these categories were only used to select students to interview to give structure to the selection process. The groupings were not used for analysis purposes. At least two students from each location from each category were interviewed to capture a diversified sample based on climate change knowledge and stances from the pre/post instruments. A total of twenty five interviews were conducted.

Semi-Structured Interview Protocol

The interview protocol was a semi-structured in-depth interview with purposeful flexibility built into the structure (Wengraf, 2001). The in-depth interview approach was chosen for several reasons, but specifically because the “person interviewed is more a participant in meaning making than a conduit from which information is retrieved” (DiCicco-Bloom & Crabtree, 2006, p. 314). The interview structure allowed for flexibility to further probe a student’s specific stances and/or knowledge that were written in the pre/post beliefs and/or knowledge assessment. A semi-structured interview also allowed me to create an environment that is more relaxed for the student to express himself/herself about topics that some see as sensitive and/or emotionally charged. A positive rapport created with the student is essential to create a safe environment where the student can share his/her personal experiences and beliefs (Douglas, 1985). I also created this interview structure because it: (a) it encourages conversational interaction, (b) it is planned ahead and prepared for, but with only half to a quarter of the questions pre-planned it gives flexibility to have the conversation with the students, and (c) and a main purpose of this structure is to go into more depth about a specific topic (Wengraf, 2001).

The protocol was a semi-structured in-depth interview which means there were pre-determined organized questions. As the interview was conducted, other questions and ideas emerged, giving me the flexibility to ask follow-up questions based on student responses. This allowed me to gain insights and greater depth into how students discussed and thought about these topics being probed (DiCicco-Bloom & Crabtree, 2006). By interviewing students, I was able to better characterize the complex nature of potential influences on students' climate change knowledge and stances. Who did students talk to about climate change and what was discussed? Also, I was able see how they are justifying their climate change stances. Moreover, what knowledge was used to explain 4-5 months after the students completed the curricular module? What contextual and cultural components enter into a face to face discussion that did not emerge in a traditional assessment instrument?

The semi-structured interview included stances and knowledge questions. The same knowledge and stance categories from the surveys and assessment were used to guide the interview construction. The interview was a mix of conversation, reading responses, and written work. The mixed mode of data collection (e.g., verbal, written, and drawing items) was meant to allow the students to express themselves in multiple formats. The protocol had at least 50% of the questions set and identical for all participants, but it had the flexibility to follow-up with students on many of the items. Each interview took approximately 20-30 minutes depending on how conversant the student was.

The stance questions included items that probed students' views on anthropogenic climate change, the potential causes, certainty of responses, level of worry regarding impacts, discussions with friends and family, and solutions to mitigate and/or adapt to climate change. For the questions regarding worry and certainty students placed themselves on a scale with six categories, which I created based on the Six Americas' Study conducted by the Yale Group on Climate Change Communication (Leiserowitz et al., 2012). The item where I probed students' stances on the existence of anthropogenic climate change was repeated from the survey. However, on the interview it was an open-ended question where students stated their stances, and were then asked to elaborate and discuss why they stated that position.

I used follow-up questions to have students elaborate on their responses. The elaboration questions included items that asked students to discuss who has had the greatest influence on their stances, what is discussed with friends and family, why they think climate change is happening or not, what other evidence would they need to see/explore to be more certain of their responses. The semi-structured interview protocol can be found in Appendix C.

Interview Data Analysis for Chapter 6 (RQ 3)

In this section, I discuss the data analysis techniques that I used to assess research question three: *How do we characterize the complexities and stability of students' climate stances and knowledge?* To begin this section, I explain how the post semi-structured interviews were coded and I outline the coding method. Then, I summarize my approach to analysis of the interviews and ground some of my methods in the Yale Six America's Study. In this discussion, I talk about the construction of the climate change stance ordinal categories, which leads into the section highlighting the student exemplars and how students were chosen.

Coding of Interviews

The initial codes/start codes were generated prior to analysis of the interview transcripts (Miles & Huberman, 1984). The initial start codes were generated from: (a) the closed form options on the survey for similar questions, (b) categories that students were given as part of the interviews probing their level of worry regarding climate change and certainty of response in regards to the existence of anthropogenic climate change, and (c) The *Six America's* study (Leiserowitz, Maibach, Roser-Renouf, & Smith, 2011).

To code the follow-up questions, which were additional open-ended items, a second level of codes were generated. The second generation of codes came from the collapsed coding categories from student responses on the open-ended questions on the survey. These codes were used as start codes for the initial read through of the interview transcripts. During the open-coding process, other codes emerged. The interviews were coded using the first and second levels of codes. Once the interviews were fully coded, I collapsed several of the categories where larger themes emerged from the coded data. Below are the specific steps taken to code the transcribed interview data, and Table 3.4 shows the start codes for each question

- Read each transcript through once to get a sense of the data
    - Took notes on major themes and categories from the interviews
- Chose focus questions to code to build on and complement findings from previous chapters' results
- Generated initial start codes and first level of codes for questions with closed form responses (e.g., similar questions to the survey and scale items)
    - Code using first level of codes)
- Read interviews and added to start codes (themes that emerge) from the open-ended student responses
- In second level and second round of coding, used codes from open-ended questions from the surveys and the codes that emerged from the second read through to code the open-ended questions.
    - Recorded responses that were beyond the scope of the coding rubric
- Next steps: Data analysis including frequency counts and creating the climate change stance categories.

Beyond the Scope of the Coding Rubric

Both the initial codes and those that emerged during the open-coding process did not capture all of the data perfectly. There were several outlier ideas and concepts that went beyond the scope of the codes used. Responses beyond the scope of the rubric included the following responses: not answering the question asked/off-topic responses, student states he/she is pretty sure and then states uncertainty within the same responses, there is agreement in the family on mechanisms of climate change but not the solutions or how humans should change actions. Also, there was a student who started to do the interview but gave one word responses and did not want to continue. This student's interview could not be coded in the outlined rubric.

Analyzing the Student Interviews

The interviews were analyzed using the codes and approaches that I discussed above. For each question and follow-up sub question, the frequency was calculated. The Six America's study (Leiserowitz, Maibach, Roser-Renouf, & Smith, 2011) was used as a guide to create ordinal climate change stance categories based on student interview responses. Since the climate change stance categories was a result of the interviews, the creation of the scale is discussed in greater depth at the beginning of Chapter 6. As a brief overview, the student stance categories were created based on student responses to two questions from the interviews: (a) Is anthropogenic climate change happening and (b) How worried are you about climate change impacts? All students interviewed were placed into one of five categories based on their responses to the two questions. The discrete, ordinal stance categories can be seen in *Figure 6.5* in Chapter 6 and the creation of the five categories is discussed in greater depth.

The interview questions that were not included in the creation of the stance categories were also analyzed to give greater insights into the complexities of students' climate change stances and knowledge. Frequencies of each response were calculated. Moreover, student responses were compared relative to stance category placement. This analysis allowed for discussions comparing student responses within and across the five climate change stance groups To fully illustrate student stances and how they were justifying their stances, student responses are given in tables after the frequency figures.

Table 3.4

Start Codes for Post Semi-Structured Interviews.

<table>
<tr>
<td rowspan="2">Question 1
a) What do you think? Do you think that anthropogenic climate change is happening?
    i. Start codes from question on stance survey: *Yes, No, Not sure/I don't know*
b) When asked to elaborate on the response—Why do you think anthropogenic climate change is happening OR Why do you think anthropogenic climate change is not happening?
    i. *Second level codes for Happening*
        1. Pollution/Dirtying
        2. Carbon dioxide/ Fossil fuel use increase (gas/cars, not recycling)
        3. Natural Changes/Cyclic
        4. Getting hotter on average
        5. Off-topic response: Learned in school
        6. Conflation weather and climate
        7. Alternative concept—Ozone depletion
        8. Abiotic Impacts (storms, droughts, floods, changing seasons)
        9. Biotic impacts (animals, environment)
        10. Alternative concepts (e.g., ozone, sun getting closer, change in the Earth's axis tilt).
        11. Additional alternative concepts—sun getting closer, change in the earth's tilt
    ii. *Second level codes for not Happening*
        1. Humans polluting
        2. Conflation of weather and climate concepts
        3. Climate change is natural process/cyclic
        4. Off-topic response: Learned in School
        5. Abiotic impacts
c) Followed by: Looking at this diagram please pick the oval that best answers the question: How certain are you that climate change is happening or not happening?
    i. Start codes based on stance categories: *Definitely happening, pretty sure happening, somewhat sure happening, Doubtful happening, probably not happening, definitely not happening*</td>
<td>Question 2
a) Looking at this diagram please pick the oval that best answers the question: How worried are you about climate change impacts in your lifetime?
    i. Start codes: *Alarmed/highly worried, worried, cautious (somewhat worried), not very worried, not worried, definitely not worried at all*
b) Follow-up: Can you explain why you chose that oval?
    i. *Second level of coding—Why are you worried about climate change impacts?*
        1. Not impacting me
        2. Distant future/Impact children/grandchildren
        3. Happening somewhere else (arctic)
        4. Biotic impacts (animals and environment)
        5. Abiotic impacts: increased intensity and frequency of storms, ice melt, sea level rise
        6. Biotic impacts: Animals dying/worried about impacts on environment
    ii. *Why are you not worried about the impacts of climate change?*
        1. Not impacting me
        2. Distant future/Impact children/grandchildren
        3. Happening somewhere else (arctic)
        4. Not in human's control
        5. Nothing major happening
        6. Will find solution and/or adapt
        7. Biotic impacts (animals and environment)
        8. Abiotic impacts: increased intensity and frequency of storms, ice melt, sea level rise</td>
</tr>
<tr>
<td>Question 3
a) Do your friends and family discuss climate change?
    i. Start codes for Discuss: *Happening, not happening, natural causes, other*
b) If so what is said? If not, why do you think it is not discussed?
    i. Start codes
        1. Explain climate change and its impacts (go into discussion on topics discussed at school)
        2. Disagree with parent or friend about climate change stances
        3. Climate change is not happening; or natural changes
        4. Off topic response: Discuss with my father
    i. If Don't discuss, start codes
        1. Not important/nothing to worry about, it is not impacting us
        2. Talk about more serious/more important topics so does not come up
        3. When discuss it with friends and family they are not aware of climate change issues</td>
</tr>
</table>

Student Exemplars from the Interviews

I chose student exemplars from each stance category to illustrate the different views across all categories and the climate change knowledge students were using to justify their views. Since there were only two students in one of the categories and their stances and knowledge differed within the category, both students' interview responses were reported as exemplars. Additionally, when choosing the exemplars, not only did I choose students from each stance category, but there were other considerations taken. First, to ensure a variety based on the school the student attended, at least one student from each school was chosen as an exemplar. Second, both males and females were represented. Finally, each exemplar needed to be conversant in order to fully illustrate their stance and knowledge relative to the stance categories and other students in the sample. The student exemplars are illustrative examples to highlight that there are similarities and differences in both stances and knowledge, across a wide variety of climate change stances. In Chapter 6, I highlight patterns that emerge from the interview data.

Conclusion

My mixed methods study to explore students' climate change stances and knowledge before and after a curricular intervention employed many different data collection and analysis techniques. The pre and post online stance survey with closed form and open response questions was designed to capture students' climate change stances in three categories: (a) anthropogenic climate change and its causes, (b) climate change in the students' lives, and (c) solutions to adapt and/or mitigate climate change impacts. With over 300 of the same respondents on the pre and post survey, I was able to analyze the data set to look at stability of stances and statistical relationships between variables and stances.

Furthermore, the abiotic items on the pre and post knowledge assessment from the Climate Change and Its Impacts on Biodiversity curriculum (Songer et al., 2012) allowed me to explore students learning gains in three knowledge categories: (a) weather versus climate, (b) carbon and anthropogenic carbon emissions, and (c) the relationship between greenhouse gases and temperature. Merging the stance surveys and knowledge assessment allowed for the statistical analysis of the relationship between students' climate change stances and knowledge. Finally, the post semi-structured interview was designed to capture more of the complexities of students' knowledge and stances. The interviews afforded a more in-depth analysis of a smaller sub-sample of the population. The responses allowed for a creation of the stance categories and illustrative examples of students' climate change stances and knowledge. The interviews gave greater insights into how students were justifying their climate change stances and common messy middle knowledge that existed across all stance categories.

The analysis of students' climate change stances are presented in Chapter 4. The results in Chapter 5 begin with learning gains in regards to students' climate change knowledge. Then, findings for the statistical relationship between knowledge and stances are presented. The results for the interview data are presented in Chapter 6 as a stance scale with ordinal categories, frequency figures, and student exemplars. Chapter 7 is a cross discussion of the results from the Chapters 4, 5, and 6 with comparison of my findings to literature in the field.

Chapter 4: Students' Climate Change Stances (Research Question 1)

Overview of Chapter 4

The results and analysis I present in chapter 4 investigates the following research question: *What is the nature, stability, and patterns of students' climate change stances?* In the first part of the chapter, I focus on the descriptive statistics for the background variables in the stance survey. I then characterize the students' stance categories using descriptive statistics, tests for marginal homogeneity, and student responses to open-ended questions as illustrative examples of the findings. Additionally, I show the results of several Pearson Chi Square tests to demonstrate dependence or independence between the climate change stance variables in both the pre and post surveys. In the next section, I illustrate the process I used to construct the graphical models and then I display the final product and results. In the same section, I present open-ended responses to the question that were analyzed by different categories (e.g., male female or specific climate change stance) and student example responses are given. In the final results section, I employ generalized linear models to explore statistical correlations between stance variables and use background variables as controls. At the end of each major section in this chapter, I give an overview table to summarize major findings. Finally, at the end of the chapter, I recap the findings and patterns illustrated by the results and offer context to my findings.

Overview of Results Section

The results are based on student responses to a pre and post online survey probing their climate change stances. The merged data set, which includes students who took both the pre and post survey has 326 respondents from nine different teachers and five states. As discussed in more detail in Chapter 3, the survey consisted of eleven multiple choice questions and six open-ended responses probing students stances on climate change, four multiple choice questions on a student's science self-efficacy, and background questions. The items on students' climate change stances are divided into three major categories (a) is anthropogenic climate change happening and its causes? (b) climate change in students' lives (level of worry, impacts, and discussions with friends and family)? and (c) actions/solutions to mitigate and/or adapt to climate change.

In the first part of the results section, I give an overview of the responses within the major categories discussed above. Then, I report frequencies for individual questions as well as compare my results from the surveys to studies conducted by the Yale Group on Climate Change Communication (YGCC). In this section, I discuss the stability of students' climate changes stances. I report major changes and/or stability from pre to post-surveys by stating the results of tests for marginal homogeneity, which takes into consideration the dependence between a student's pre and post responses. In the next section, I show the results from Pearson's chi squared tests for independence. I report results to illustrate dependence between different variables within the sample.

In the next section of results, I focus on graphical models to explore complex relationships. A graphical model is composed of two types of relationships. First, the nodes represent student reasonings to open-ended questions. Second, the edges (i.e. lines) between nodes represent shared reasons for students' stances on the existence of anthropogenic climate change and their level of worry regarding climate change impacts. Each node was tested to explore if there was a statistical change from pre to post survey responses. Prior to the graphical models, I show frequency graphs to illustrate trends of open-ended responses by gender and by how a student responded to a closed form item prior to the open-ended question. Additionally, I give examples of student responses for each open-ended category to give illustrations of answers for each start code (See Appendix D for additional student responses).

Finally, in the last part of the results section, I report statistically significant predictors of students' worry about climate change impacts and predictors of male and female students' responses regarding the existence of anthropogenic climate change. The results are intended to characterize the pre and post survey data set and to identify the stability of stances and patterns within the sample.

Background Variables

In the pre survey, I asked students background information. The questions probed included information on where students access news, how often they read and/or watch the news, and education level of their parents. Students self-reported the race in which they identify and what grade they earned in science. The background variables are used throughout the data analysis as ways to characterize and group students as well as control variables in generalized linear models.

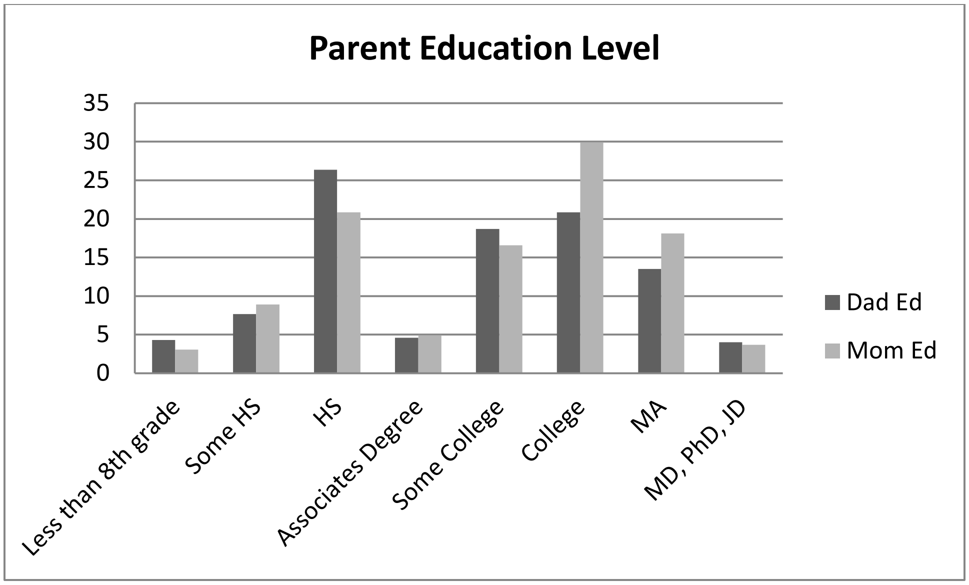


Figure 4.1. Frequencies of mother's and father's education level completed (n=326).

As seen in *Figure 4.1***,** students' mothers on average have completed higher levels of education than the fathers in my study. Over 45% of the mother's completed at least a college degree as compared to 38% of the father's. The highest frequency of education completed for fathers is high school.

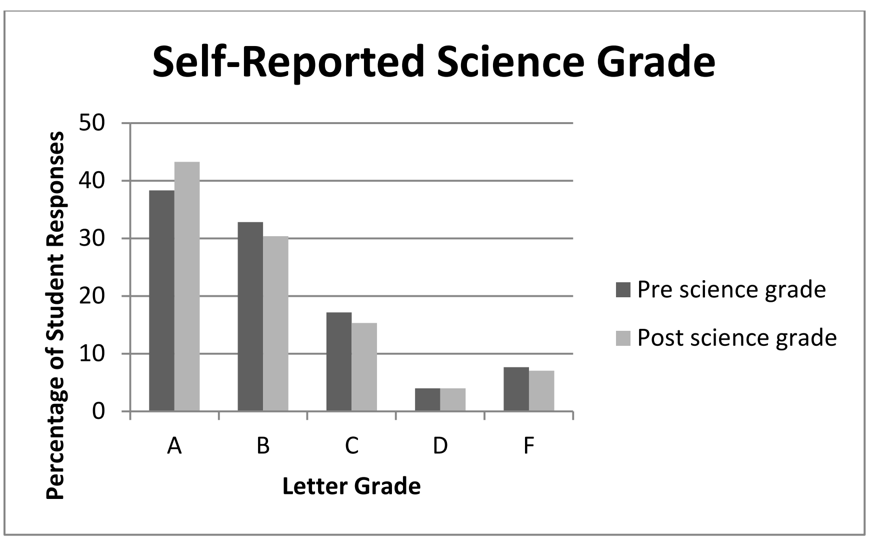


Figure 4.2. Self-reported science grade. This figure illustrates student self-reported science grades at the time when the pre and post surveys were taken.

Students were asked to self-report their current science grade when they took the pre and post survey. The grades are self-reported and are not confirmed by the teachers. While a letter grade is not the only indicator of achievement in a science class, in this chapter and in Chapter 5, it is used as a control variable in the models. The majority of students stated that they received A or B with over 20% of the students in the sample reporting a grade of C or below in science class (see *Figure 4.2*)

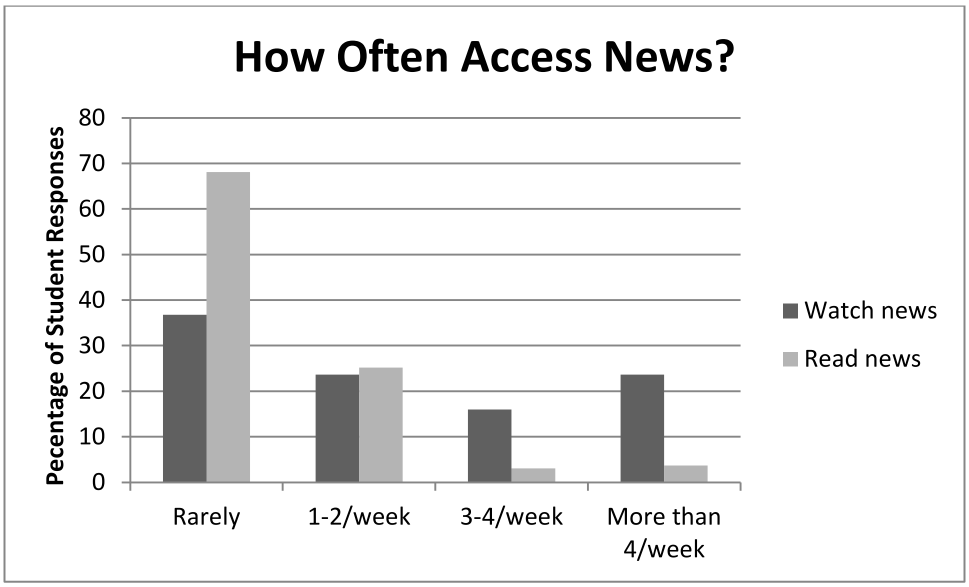


Figure 4.3a. Often access news. This figure shows how often students state that they watch and read the news (n=326).

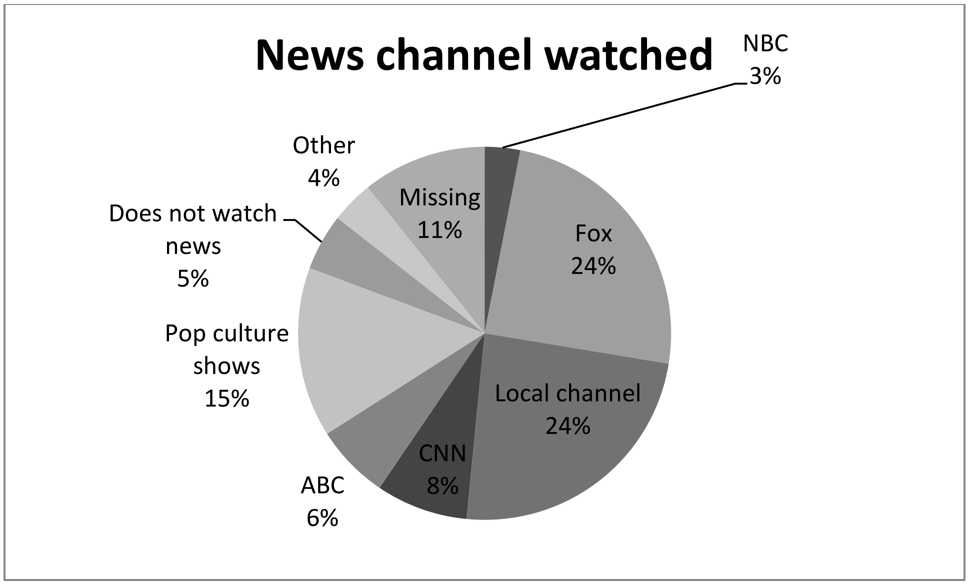


Figure 4.3b. Watch news. This pie chart illustrates the channels that students watch for news (n=326).

There were several questions that probed how and where a student searched for news. As indicated by *Figure 4.3a***,** students more frequently watch news as compared to read news. *Rarely watch news* is the most frequent response, but at least 50% of the students watch the news at least once per week. Approximately 70% of the students rarely read the news. When asked what news channels students watch, the most frequent responses are local news and Fox news (see *Figure 4.3b)*. The category local news consisted of responses when students gave a station number and/or named a local news broadcaster. Moreover, when asked about news watched the popular culture category is comprised of responses, such as Sport Center and Entertainment tonight.

Characterizing Students' Climate Change Stances by Category

The first section of results illustrates overall trends and patterns in the multiple choice questions from the pre and post survey. I have reported results by climate chance stance categories and science self-efficacy as mentioned above. To report overall trends in stance categories I centered all responses around zero. Then, I summed the multiple choice items in the categories to calculate a total score per category. Positive scores correlate to responses that (a) take the stance that climate change is happening and caused by anthropogenic actions (b) there is worry and discussion about climate change, and (c) stances about actions to mitigate and/or solve climate change issues with changes in human behavior. Negative numbers on the scale indicate opposite stances, such as climate change is not happening. A score of zero correlates to a neutral overall position.

As a reminder, for each stance category a change from pre to post survey responses was calculated (post total score for each category- pre total score per category) to illustrate trends and shifts in responses from pre to post. Since the change variable calculated consisted of more than ten consecutive integers for each category, it was treated as a continuous variable to test for positive, negative, or no significant overall changes in each specific category.

Stance Category: Is Anthropogenic Climate Change Happening and What are its Causes?

The category: *Is anthropogenic climate change happening and what are its causes?* contains five questions: three exploring personal stances on if climate change is happening/do scientists think it is happening and two items that probe the causes of climate change (e.g., anthropogenic, natural, don’t know, and climate change is not happening. *Figure 4.4* shows the pre to post trends for this category.

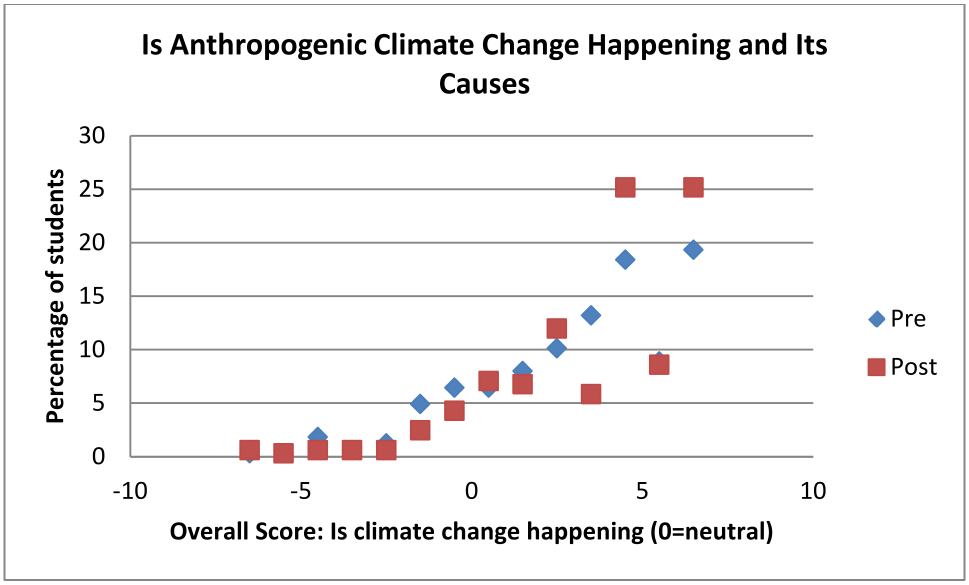


Figure 4.4. Is climate change happening? *Figure 4.4* shows the responses on the pre/post survey category of is climate change happening and causes? (n=326).

The scatterplot (Figure 4.4) shows that there is a general shift towards the positive direction (climate change is happening and is caused by human actions), but also there is an increase on the post survey on the left tail. A two sample mean comparison test was conducted where the change variable was set to zero to test for positive, negative, and/or overall statistically significant change from pre to post responses. The test shows a statistically significant change in mean responses ($p \leq 0.001$) and that there is statistically significant positive shift from pre to post responses in this category ($p \leq 0.001$) (μ=0.54. σ=2.92, 95% CI=0.22⇔0.85).

Figure 4.5 shows the cumulative frequency plot of overall change for students in this stance category. *Figure 4.5* illustrates that there is an overall positive change in this category where zero indicates no change, less than zero shows a negative trend, and positive numbers illustrate a change towards responses that align with the stance that climate change is happening and caused by/enhanced by human activities. When the overall change variable is collapsed into three major categories (negative for scores less than -3, positive for scores greater than 2, and neutral otherwise), the sample population exhibited the following frequencies of change: negative (<8.89%), neutral (71.78), and positive (19.33%).

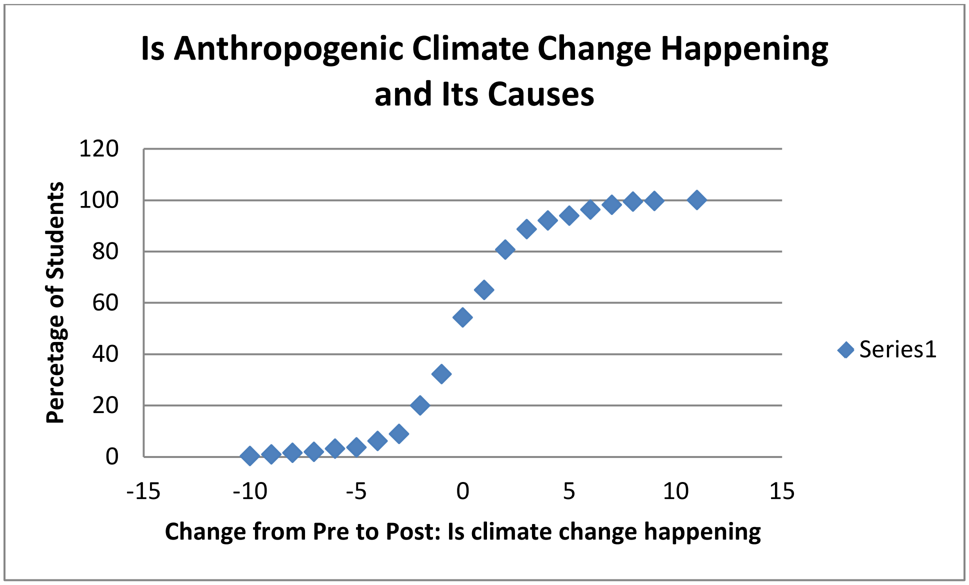


Figure 4.5. Cumulative frequency change pre to post. The curve in this figure illustrates the change from pre to post scores for the category: Is anthropogenic climate change happening and its causes. (n=326).

Stance Category: Climate Change in Students' Lives

The next stance category discussed is: *Climate change in students' lives*. This includes multiple choice questions on if students are worried about climate change impacts (e.g., level of worry), if they feel that they have experienced the effects of global warming, and how often the topic is discussed at home. The positive numbers in the overall variable indicate that climate change is an active part of a student's life as seen in *Figure 4.6a.* Conversely, a negative overall score in this category indicates that climate change topics and impacts are not an active part of student's lives including worry and discussions with friends and/or family.

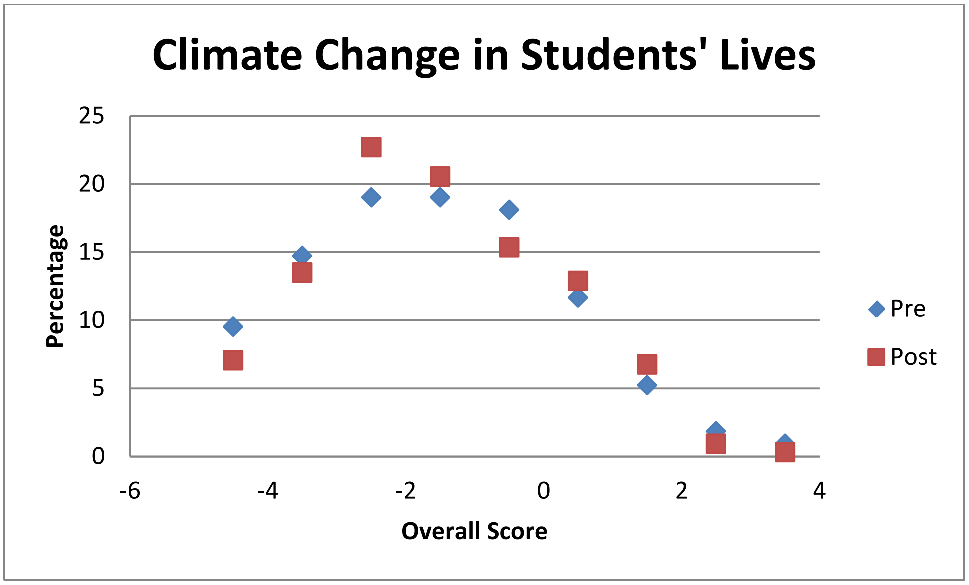


Figure 4.6a. Climate change in students' lives. This figure illustrates pre and post responses in category exploring climate change in students' lives. Overall there is a greater negative trend (higher percentage in negative values) indicating that climate change discussions are not often, worry is not high, and effects are not often felt and/or acknowledged (n=326).

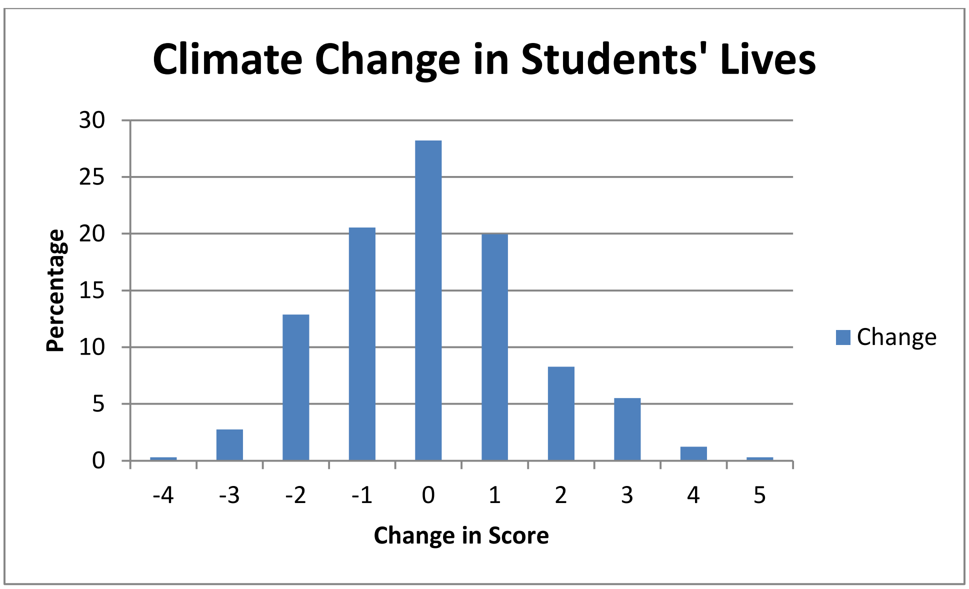


Figure 4.6b. Change in students' stance on climate change in students' lives. This figure shows the change from pre to post survey scores in the category climate change in students' lives (n=326).

The variable created to asses changes in responses from the pre to post survey indicates that while a higher frequency of students are in the negative score, students do not have a statistically significant change in responses from pre to post (*Figure 4.6b***,** n=326) regarding climate change in their lives. The change variable is normally distributed with a slightly widened left tail indicating a slight negative shift, but one that is not statistically significant.

Stance Category: Actions to Mitigate Climate Change and Potential Solutions

The final climate change stance category on the survey explores students' views on actions to mitigate and/or adapt to climate change and possible solutions. This category was constructed with the following three items, which had multiple choice options: (a) stance on if a single individual's actions can make a difference to reduce climate change, (b) view on if new technologies can solve climate change, without individuals having to make big changes in their lives, and (c) perspective if humans are willing to reduce climate change. Positive summed scores correlate to students who indicated an optimistic view that individuals and humans can make a difference to reduce climate change, which would require some kind of behavioral changes. A negative overall score indicates students who are pessimistic about climate change reduction and that technology can be the solution without changes in behaviors (*Figure 4.7*).

The change variable for the actions and solutions category to mitigate climate change indicates no statistically significant change in the category from pre to post. There is an overall shift in a positive direction, but not significant from pre to post responses. The peak is at zero (3.6%) indicating that there are no changes on s student stances regarding actions to mitigate and/or adapt to climate change.

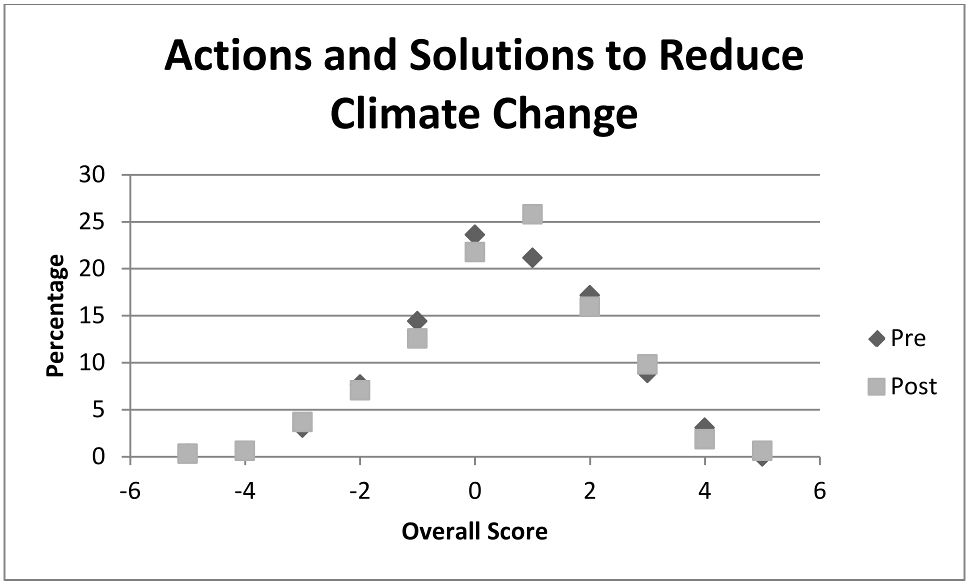


Figure 4.7. Actions and solutions to reduce climate change. Pre and post responses within the category stances on actions and solutions to reduce and or mitigate climate change (n=326).

Stance Category: Science Self-Efficacy

In addition to student stances on climate change, students were asked questions regarding their science self-efficacy on both the pre and post survey. The questions asked students multiple choice questions on the following topics: (a) do they feel that they are a strong science student, (b) do they do well on science projects, (c) do they give up when the problem gets tough, and (d) overall do they feel like they do well in science?

Figure 4.8 shows pre and post responses for the science self-efficacy category. There is a great deal of overlap between responses from the pre and post survey. Science self-efficacy is a stable stance in my study as confirmed from the statistically insignificant t-test on the continuous variable measuring changes in self-efficacy. There was no significant difference between males and females in this sample.

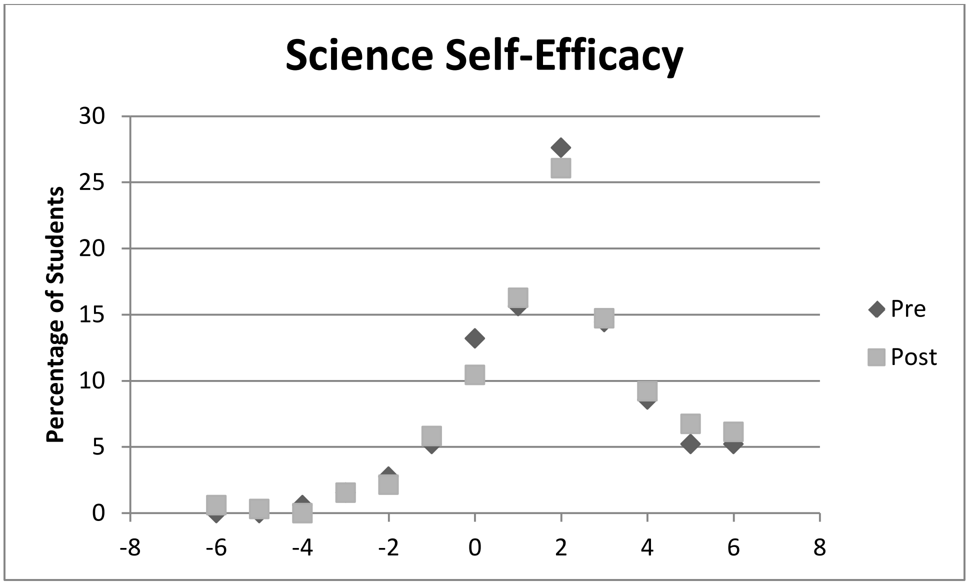


Figure 4.8. Overall self-efficacy score. This figure shows students' overall science self-efficacy score on pre and post surveys (n=326).

Part II: Frequency and Stability of Stances for Individual Items

The pre and post survey items discussed in the frequency and tests for marginal homogeneity are from the merged data set (n=326). First, students' climate stances in this study are characterized through frequency of responses to questions. Second, once I report the frequencies, I show the results of the tests for marginal homogeneity. Marginal homogeneity tests explore whether responses statistically significantly change from pre to post surveys while accounting for dependence among pre and post sample responses. I discuss both statistically significant and insignificant results because both changing and stable stances are important to characterize middle school students' climate change stances.

Is Anthropogenic Climate Change Happening?

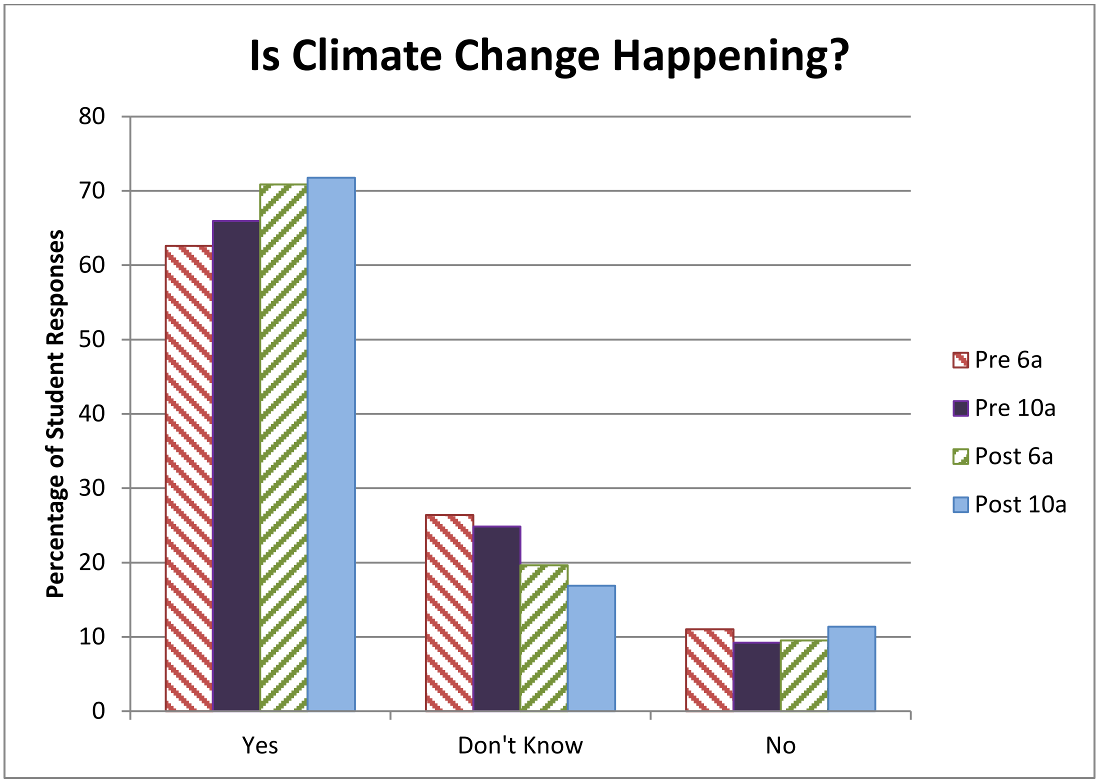


Figure 4.9. Is climate change happening? Frequency of responses on pre and post responses to is climate change happening (n=326) for two questions on the surveys.

Figure 4.9 shows the frequency of responses on the pre and post survey question to the question: *Is anthropogenic climate change happening*? Two items on the survey asked this question and I graphed both results in *Figure 4.9*. I compared the responses from both items (pre and post) and the results indicate that the responses to both items are statistically the same. Or said another way, there is not a statistical difference between responses on both items. Thus, since students answered consistently on both items, I use the responses to item 6a on the pre and post survey in other tables, figures, and models.

Furthermore, there is a statistically significant change from pre to post responses, where a greater frequency of students responded that anthropogenic climate change is happening after participating in the curriculum. On the pre survey, 62.58% of students stated climate change is happening as compared to 70.81% on post responses. Moreover, there is a decrease in students who mark the *Don't know* response (26.38% reduced to 19.63%) and *No* climate change is not happening (11.04% reduced to 9.51%). The overall change in responses from pre to post survey is highly statistically significant (test for marginal homogeneity, $p < 0.001$). The biggest shift is the increased frequency in students who responded in the affirmative that anthropogenic climate change is happening.

Is climate change happening? By gender. The significant change in response from pre to post survey regarding the existence of climate change is further explored in this section. Specifically, I look to see if the change in responses were dependent on a student's gender. Male students' responses in the survey remained stable on this item. However, the changes in pre to post responses on this item are statistically significant ($p < 0.05$) for females. After participating in the curriculum, there is a higher trend for female students to say that anthropogenic climate change is happening.

Table 4.1
Post Survey Data for Females to the Questions: Is anthropogenic climate change happening? (n=167).

Female Is climate change happening? Row % (Cell %) (n=167)			
Pre Survey	Post Survey		
	No (8.4)	Don't know (18.0)	Yes (73.7)
No (7.8)	30.8 (2.4)	15.4 (1.2)	53.8 (4.2)
Don't know (30.5)	9.8 (3.0)	33.3 (10.2)	56.9 (17.4)
Yes (61.7)	4.9 (3.0)	10.7 (6.6)	84.5 (52.1)

*Note: Row % refers to the frequency of responses for the given response in that row (number of responses in cell/total responses in that row) and cell% refers to the overall frequency of responses for this questions (response in cell/total number of responses for the table).

Specifically, 52.1% of all of the females in the sample said *Yes* on both pre and post (see Table 4.1**)**. Additionally, 84.5% of those who said *Yes* on the pre survey also said *Yes* on the post survey. Furthermore, 6.6% who said *Yes* on the pre said *Don't know* on the post. Only 4.2% said *No* on the pre survey and *Yes* on the post. The vast majority of people showed positive improvement. Only 30% of the females that said *No* on the pre survey also said *No* on the post survey. Over 50% of the females regardless of what they said on the pre said *Yes* on the post survey. 22.8% of females had a positive (going from *No* to *Don't Know* or *Yes* and *Don't Know* to *Yes*) stance change compared to 12.6% with a negative shift. The change in female responses indicates a statistically significant change from pre to post survey answers (marginal homogeneity $p \leq 0.01$). Red indicates that in the post survey the response is more negative than in the pre survey. Green indicates a positive shift in stances towards the accepted position of the scientific community (the same color scheme is used in Table 4.2).

Table 4.2.
Post Survey Data for Males to the Questions: Is anthropogenic climate change happening? (n=159).

Male Is climate change happening? Row % (Cell %) (n=159)			
Pre Survey	Post Survey		
	No (10.7)	Don't know (21.4)	Yes (67.9)
No (14.5)	43.5 (6.3)	13.0 (1.9)	43.5 (6.3)
Don't know (22.0)	8.6 (1.9)	37.1 (8.2)	54.3 (11.9)
Yes (63.5)	4.0 (2.5)	17.8 (11.3)	78.2 (49.7)

Overall, there was also a positive shift for the male students. However, it was not statistically significant (p = 0.37). 20.1% of the males had a positive shift in stances compared to 15.7% with a negative shift. Moreover, there was more stability in the *No* responses for the male students.

Causes of Global Warming and Climate Change

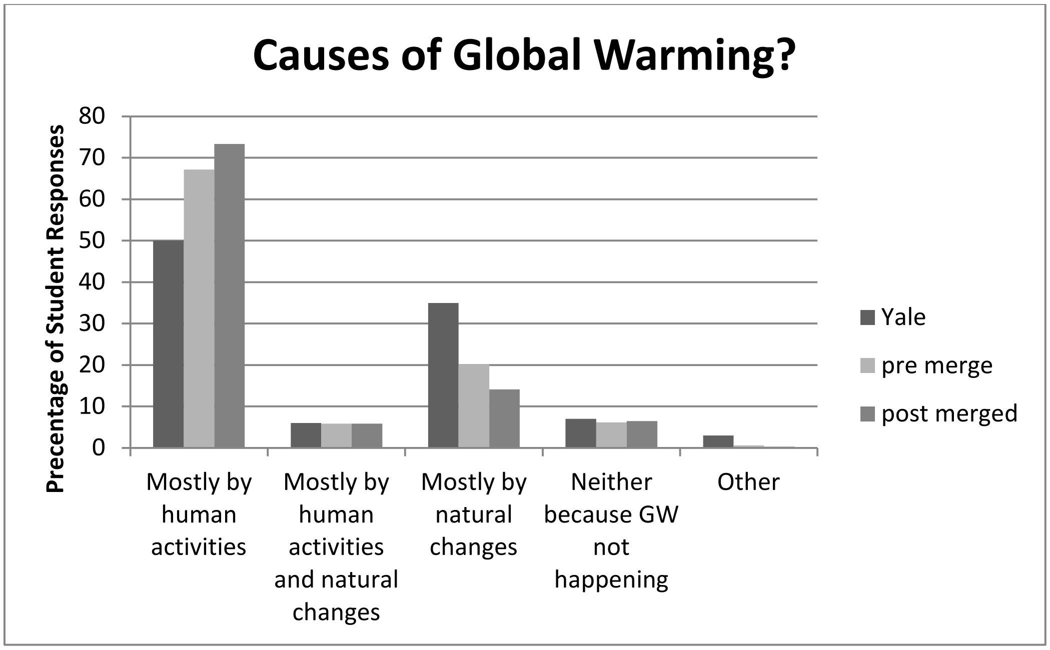


Figure 4.10a. Causes of global warming. Frequency of responses of pre and post survey items compared to Yale results to the question: Assuming global warming is happening do you think it is…? (n=326).

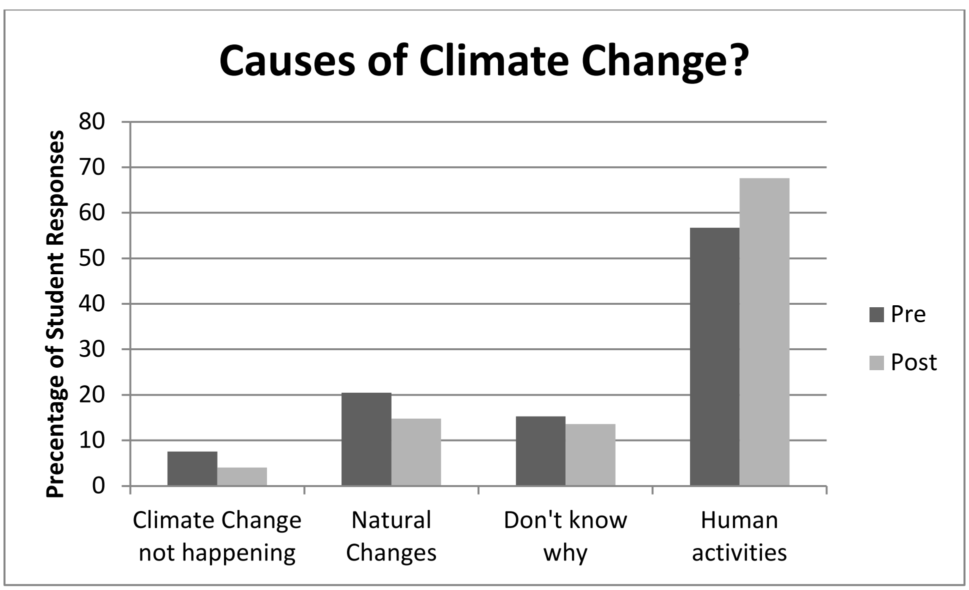


Figure 4.10b. Causes of climate change. Frequency of pre and post responses to the question: What do you think is causing climate change? (n=326).

Figure 4.10a illustrates the comparison of frequencies of pre and post survey responses from students in this study to results from a larger study conducted by the YGCC. Both studies asked identical questions, which allows for comparisons of responses. Qualitatively, both studies have similar trends for responses to this item. However, a greater frequency of middle school students (pre: 67.18% and post 73.31%) compared to 50% of the Yale participants said that global warming is caused mostly by human actions (anthropogenic). The pre, post, and Yale results are strikingly similar for responses that include global warming is not happening (approximately 6.5%) and it is a combination of natural changes and human activities (approximately 6%). A greater frequency of respondents from the Yale survey reported that global warming is mostly caused by natural changes in the environment.

When I explored the difference in student responses from pre and post surveys, there is statistically significant (p<0.001) change in answers. As can be seen in *Figure 4.10a*, there is an increase on the post survey in frequency of students who stated that the cause of global warming is anthropogenic. To build on this idea, there is a decrease of students that state that global warming is caused by natural changes in the environment. While Figures *Figure 4.10a* and *Figure 4.10b* do not ask the exact same question, they seek to find out students' stances on the causes of global warming and climate change respectively. *Figure 4.10a* uses the terminology global warming and *Figure 4.10b* used the terminology climate change. Both items gave the multiple choice options that climate change is the result of human activities or the result of natural changes. There were statistically similar responses for both options. Approximately 70% of students on the post survey for both items said it is caused by human activities and about 15% responded it was caused by natural changes. Overall, the items present similar trends and responses on the pre and post survey.

Consensus in the Scientific Community?

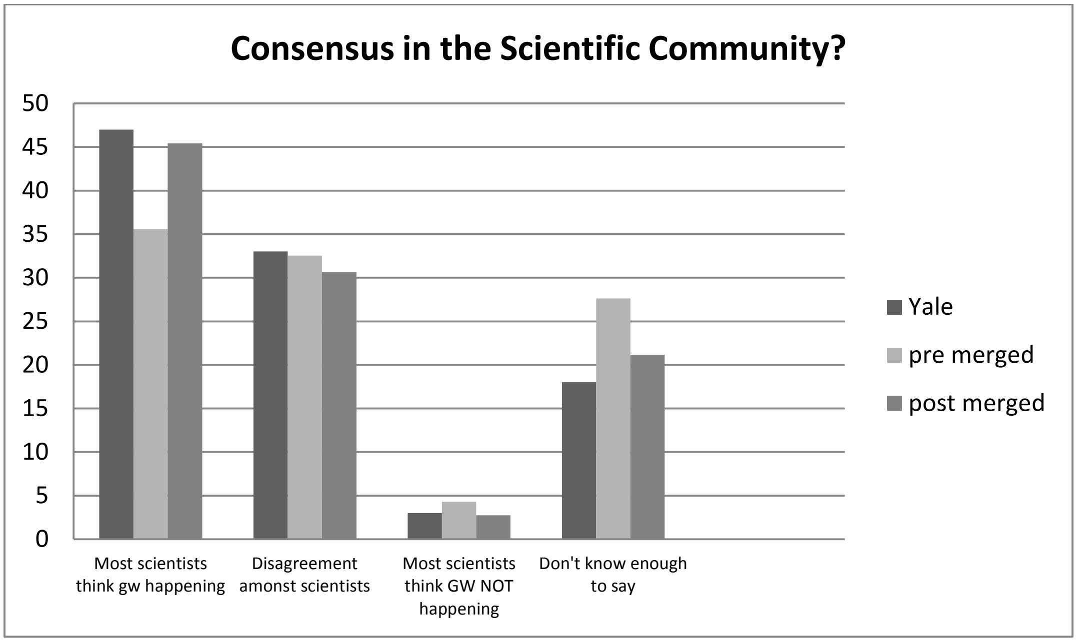


Figure 4.11. Do scientists agree? Frequency of responses from the pre/post surveys and Yale survey to the question: *Which comes closest to your own view* (n=326)*?*

Figure 4.11 shows that the pre and post survey student responses have similar frequencies to the Yale Group on Climate Change Communication's large-scale, nationally representative response to the question: Which comes closest to your own view? The question seeks to get respondents' views if the scientific community has accepted the idea of global warming. For the response that *Most scientists think global warming is happening* the frequencies for the Yale study and students' post survey responses are similar: 47% and 45.4% respectively. After participating in the curriculum, the frequency of students who responded that there is consensus within the scientific community increased by 10%. However, the majority of respondents do not think there is consensus in the scientific community that global warming is happening. Along the same lines, there was a decrease in students who responded that they did not know enough to say after participating in the curriculum. However, *not knowing enough to say* was still a response for over 20% of the students. Respondents who stated that there is disagreement amongst scientists on the issue of global warming remained stable (pre survey: 32.52%, post survey 30.67%) and was similar to the Yale results 33%. The test for marginal homogeneity indicated an overall statistically significant ($p < 0.05$) change in responses from pre to post answers.

Individual Items that Remain Stable

The following results remained stable from before and after participating in the curriculum. The stability of stances and views for this study is just as important as the changing characteristics of middle school students' climate change stances. Stability potentially indicates areas of focus for more curricular activities and/or exploration of other factors, such as outside of school variables. The stances that remained stable are the following: (a) students' worry about climate change, (b) the ideas on the role of technology to solve the problem, (c) the frequency that climate change topics are discussed at home, (d) the actions of a single individual making a difference in the climate change impacts, and (e) the feelings of experiencing the impacts of climate change.

Worry. For the question: *How worried are you about climate change?*, student responses on the pre and post survey remained stable. In fact, responses became slightly more central on the post survey. The lowest frequency of responses was seen for the answer *Very worried* (pre: 6.75% and post: 5.83%). On the post survey, students responded *Not very worried* and *Somewhat worried* on with frequencies of 38.96% and 39.57% respectively. The frequency of responses to *Not at all worried* decreased on the post survey by less than 1%. Both the stability and lack of extreme worry is discussed later in the chapter and in Chapters 6, 7, and 8.

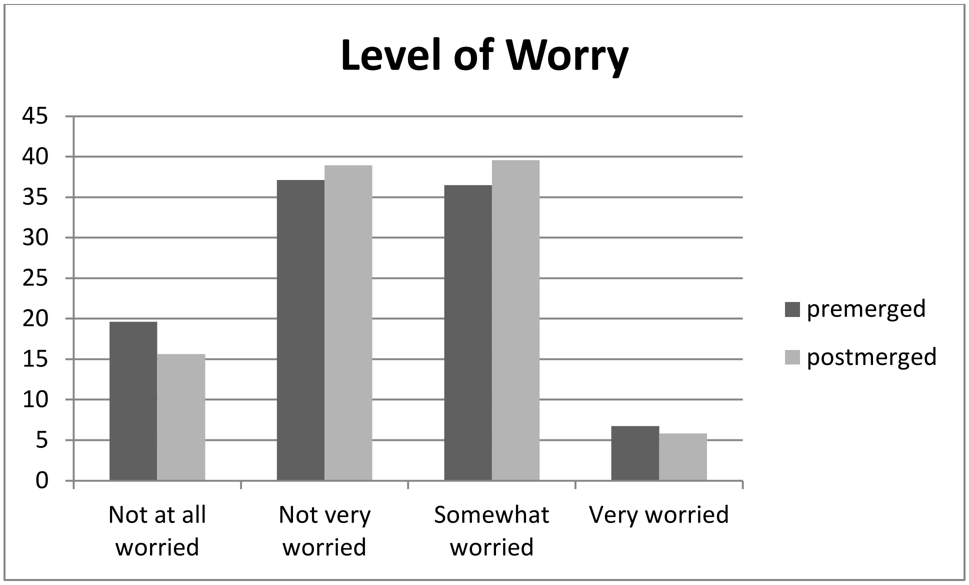


*Figure 4.12***.** This figure shows the responses to the pre and post surveys to explore students' stances to the question: How worried are you about climate change (n=326)?

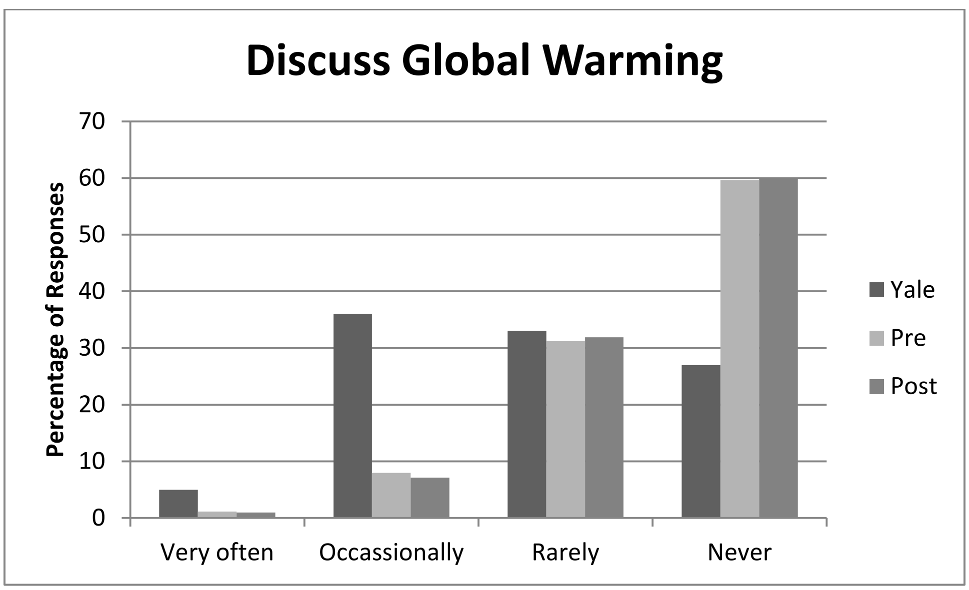


Figure 4.13. This figure illustrates frequencies for responses to the question: How often do you discuss global warming with your friends and family (n=326)?

Discuss global warming. *Figure 4.13* shows that student responses on the pre and post survey differed greatly from responses from the Yale study that asked: *How often do you discuss global warming with your friends and family*? The vast majority of students (over 90% on pre and post survey) said that they *Rarely* (approximately 30%) or *Never* (60%) discuss global warming with their friends and/or family. Even after participating in the curriculum, the frequency of discussions that occurred outside of school remained stable and low. Moreover, it appears that the adult population sampled in the Yale study has a more even spread of responses from *Occasionally, Rarely, and Never* discussing global warming. However, just like the students in this study (<1%), a small percentage (5%) of participants in the Yale study *Very often* discuss this issue with friends and family. Finally, the test for marginal homogeneity is not statistically significant. Thus, there is not a significant change in responses from pre to post survey results.

While approximately half of the students surveyed stated that they do not discuss climate change with friends and family, others do discuss the topic. Below are sample responses from the post-survey to the question: *When you discuss climate change with your family and friends, what is said about climate change?* They have been coded and then collapsed into meta-categories to give an overview of type of student responses (see Table 4.3).

Actions to reduce climate change. In *Figure 4.14,* students' pre and post responses are compared to results in the Yale survey to probe participants if they think the actions of a single individual will make a difference in climate change. The pre and post surveys and Yale results illustrate similar trends, yet the students in my sample are more pessimistic about what a single individual can do to impact climate change compared to the Yale results.

The follow-up item to the above question is: Name two actions that you can do to reduce your personal carbon emissions. Figure 4.15 illustrates student responses on the post survey to actions they can personally do to reduce carbon emissions. Note: the frequencies sum to more than 100% because each respondent gave two answers. The most frequent responses are *Recycle,* *Drive less (bike and walk more), and Use less energy*. These responses are more frequently given by females in the sample. A higher percentage of males suggested lowering carbon dioxide emissions and stated messy middle knowledge concepts, such as holding one's breath, farting less, and/or using less hairspray (aerosol cans). The drive less/walk or bike more, had the greatest overall frequency of responses on the post survey (46.18%). These responses are further explored in the post semi-structured interview results in Chapter 6 and in discussions in Chapters 7 and 8.

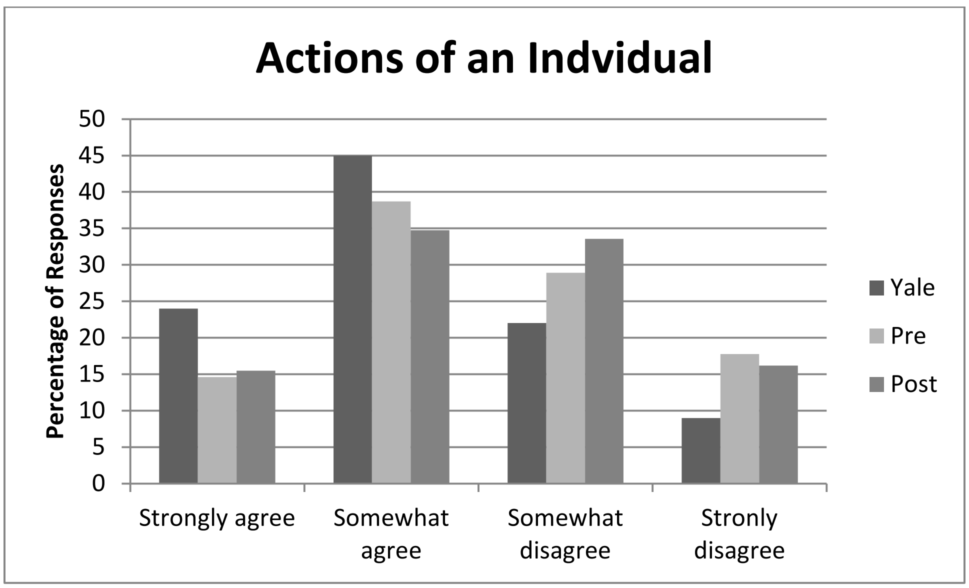


*Figure 4.14***.** Actions of an individual. This figure shows frequency of responses to the statement: The actions of a single individual won't make any difference in climate change (n=326).

Table 4.3.

Post Survey Student Responses Describing Discussions They Have With Friends and Family about Climate Change.

When you discuss climate change with your family and friends, what is said about climate change?	
Category of Response	**Sample Student Responses**
Don't discuss it	"Only in class NEVER with family or friends its a boring subject and in class it very little time spent on it" (Male, Circle, 7th grade). "We never say "Oh I should stop using carbon dioxide." I don't think anybody says that and we just want to care about something else than the environment and plus we hear enough of that environment from Obama" (Female, Circle, 7th grade).
Climate change is happening—correct science discussed	"The greenhouse effect, the melting ice caps, and animals" (Male, King St, 8th grade). "If we do talk about climate change, it is mostly about alternative energy or severe storms and weather" (Female, Circle, 7th grade).
Climate change is happening—incorrect science discussed	"When climate change is dicussed in my family, we think that it is caused by natural resources on the earth. Recycling can produce heat on the earth which could be make climate change happen along with other resources on the earth" (Female, Village, 6th grade). "the world might go into the ocean" (Female, Main St, 6th grade).
Climate change is happening—mixture of correct and incorrect science discussed	"Me and my family, friends, etc. don't talk about climate change that much but when we do, it is about human activities. We all believe that humans have caused the climate changes. We talk about how our factories and transportation vehicles are putting out so much pollution" (Male, Circle, 7th grade). "like how we should make people stop smoking & like stop all the awful gases that are put in the air" (Female, Circle, 7th grade).
Climate change is happening—No science discussed	"i do it b/c i want them to be aware of it happening" (Male, Circle, 7th grade). "about how bad its getting and about the money invold" (Male, King St rural, 7th grade).
Climate change not happening--Natural	"That the government is just telling us that" (Male, Circle, 7th grade). "That it is a huge waste amount of money and attention that could be used towards something better" (Male, King St, 8th grade). "Most of my family think that global warming is a bunch of bologna" (Male, Circle, 7th grade).
Confusion between weather and climate	"Just how hot or how cold it's gonna be that day" (Male, North Central, 8th grade). "Uhhh. How it will be sunny and hot than about 2 minutes later cold, windy, rainy" (Female, South Kernel, 8th grade). "We barley do,but when it probably about how quickly the weather changes" (Female, Main St, 8th grade).
Other	"When I rarely discuss climate change with my family, we think about things that people claim are friendly to the environment. We think about the electric car and where the electricity comes from, how the car was made and where it will go when it breaks down for good" (Male, Village, 6th grade). "i beleive that our world will end by the sun will get to close to the earth and we will all die and the earth will be reborn with all the good people and try to keep out all the bad people" (Female, Circle, 7th grade). "I hardly ever discuss climate change with friends or family. What is said about climate change is stuff like "The new biofuel is more expensive than normal gasoline." Or, "The spiral lightbulbs are slightly cheaper and are more energy efficient"" (Female, Circle 7th grade). "We never talk about global warming... if something is said, it is always said as a joke" (Male, King St, 7th grade).

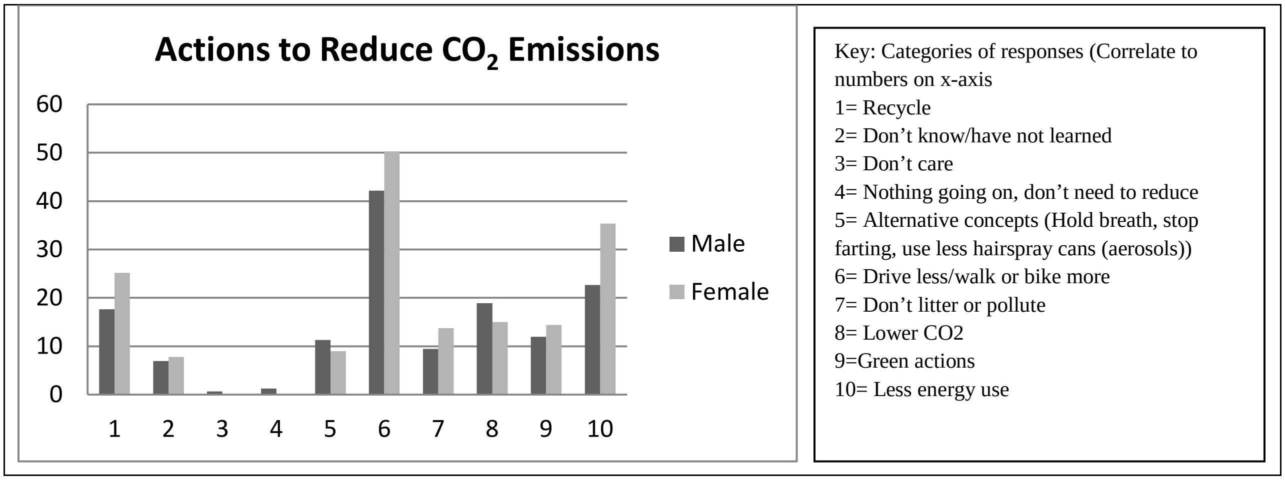


Figure 4.15. Actions to reduce carbon emissions. This figure illustrates the frequency of responses by gender to the open-ended question: Name two actions that you can do to reduce your personal carbon emissions. The x-axis numbers correlate to the response categories to the right of the figure.

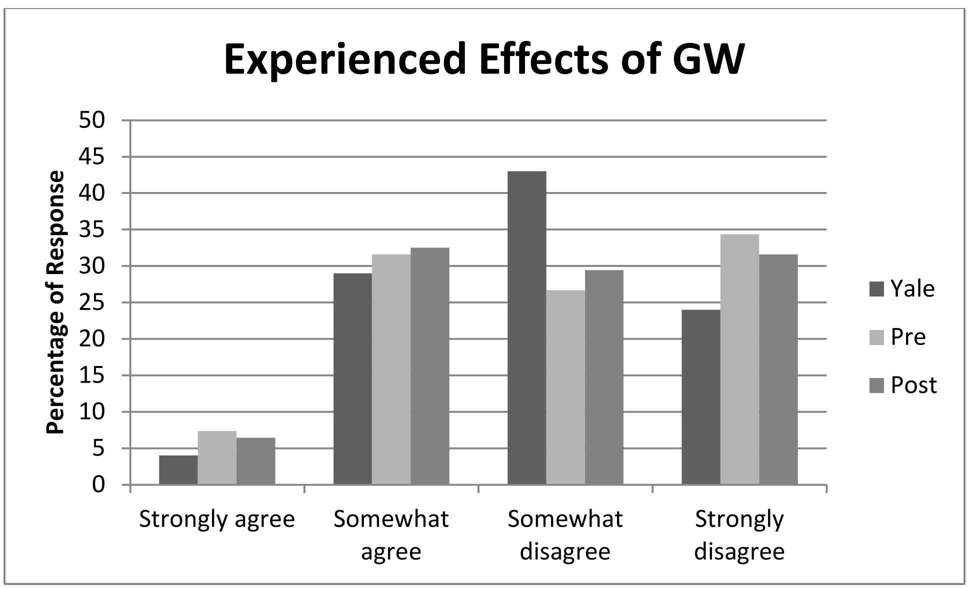


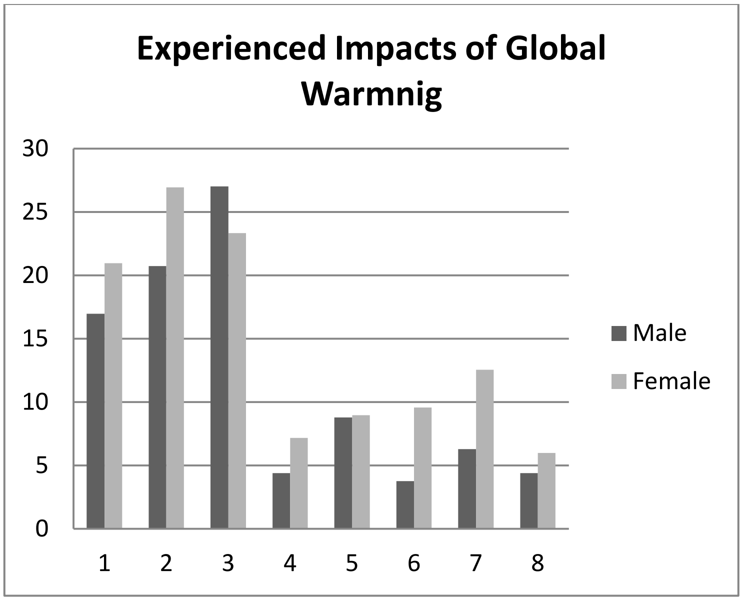
Figure 4.16. Experienced effects of global warming. Comparison of frequencies on pre/post survey and responses to the Yale survey conducted by the Yale Project for Climate Change Communication to the question: I have personally experienced the effects of global warming. (n=326).

Experienced impacts of global warming. *Figure 4.16* compares the pre and post responses to the YGCC results to if people feel they have personal experienced the effects of global warming. Again, the middle school students' responses and those in the Yale study have similar trends where participants more frequently state that they have not personally experienced the effects of climate change. Moreover, students' responses remained stable from pre to post survey. To expand on the idea how students feel they have experienced the effects of climate change, there was a follow-up open-ended question that asked: If you have experienced the effects of global warming, describe how you have experienced them. Otherwise, if you have not experienced the effects of global warming, explain why you feel this way. Student responses to the item can be seen in Table 4.4**.** The categories have been collapsed into larger general themes (see the details of the coding rubric in Appendix D).

In Table 4.4, there are exemplars of students' responses to how they feel they have been experienced the effects of climate change or not. *Figure 4.17* looks at the frequency of student responses by gender to better characterize why students feel they have or have not experienced the impacts of climate change. The most frequent response for males is that they feel that they have experienced abiotic impacts of climate change, such as over average temperatures are warmer, more severe storms, earlier spring (i.e. the impacts stated by the IPCC). While abiotic impacts is also a high frequency response for females, the most frequent response was the following: *they are not experiencing global warming because it is happening too slowly and/or it is happening in another region/another part of the world*. Commonly students stated evidence of snow melt in the Arctic and glacial retreat, but did not see it happening in their own regions in the United States. Also, in the study, females more than males stated that they would not know what experiencing global warming would look like. This speaks to the abstract nature of the phenomenon as well as the idea that scientists state impacts of global warming, but cannot tie a single event specifically to a changing climate.

Table 4.4.
Student Post Survey Responses Describing How and Why They Feel They Have or Have Not Experienced the Impacts of Global Warming

If you have experienced the effects of global warming. describe how you have experienced them. Otherwise, if you have not experienced the effects of global warming, explain why you feel this way.	
Category of Response	**Example student responses**
Not experiencing the impacts	"I have never felt the effects of global warming. I feel this way because I havent felt a huge temperature change or less heat in the environment" (Male, Circle, 7th grade). "the reason i say i have not experienced global warming is beacuse it hasent gotten hotter" (Female, Circle, 7th grade).
Not impacting me—happening too slowly or happening in other regions	"I don't live in the arctic so I have never experienced global warming" (Male, Cincinnati suburb, 7th grade). "I have not really personally experienced the effects of global warming, it may be because I am not paying to much attention to climate change or it isnt effecting my area or daily activities" (Female, Circle, 7th grade).
Feeling the heat and/or seeing the melting ice, more severe storms, earlier spring, less snow	"I have somewhat experienced the effects of global warming because over the years the temperatures risen and could feel a difference in the winter and summer" (Female, Village, 6th grade) "I play baseball for a team in *Rural KY* and in the past couple years we have been able to start outside practice much quicker because of the fact there is not much snaw and if there is it melts fairly quick" (Male, South Kernel, 8th grade). "One way i've experinced them is because there has been more hurricanes because if the temperutare get hotter the oceans get hotter and creat hurricanes. Another reason is that there has been more snowstorms" (Male, Village, 6th grade).
Not happening/just a scare tactic/getting colder	"i feel this way because its useless global warming is fake" (Male, Circle, 7th grade). "Nothing has happened to prove that it is happening" (Male, South Kernel, 8th grade). "I feel that i have never experienced Global Warming, because it's not real" (Female, Circle, 7th grade)
Confusion weather vs. climate, seasons	"I have had a day when the temperature was 105 degrees F" (Male, Village, 6th grade) "in Ky. weve been ex[eincing weird weather, as in it'll be hot one day, then frezzing the next" (Female, Circle, 7th grade). "Because I don't see the difference in the weather changing. I mean it just has been acting up" (Female, South Kernel, 8th grade).
Don't know what it would be like to experience GW	"i feel that i have not experinced climate change before because i never know when its happening" (Female, Circle, 7th grade) "I don't know how it feel or what I should feel" (Female, Main St, 8th grade).
General—impact felt is not good	"I feel that i somewhat have because of the hurricane in november....that is not normal...we got the after rain/storm, but other than that i dont feel anything different has happened" (Female, Circle, 7th grade)/ "i feel that climate change is not that good because they have to find out what's going to happen" (Female, North Central, 8th grade).



Key: Categories of responses
(Correlate to numbers on x-axia_
1=Have not experienced
2=Not impacting me (happening too slowly, happening in other regions)
3= Feeling the heat and/or seeing the melting ice, more severe storms, earlier spring, less snow
4= Not happening/just a scare tactic/getting colder
5= Confusion weather vs. climate, seasons
6=Don't care
7=Don't know what it would look like to experience GW
8= In general impact not good

Figure 4.17. Experienced effects of global warming by gender. This figure illustrates student responses by gender to the open-ended question: If you have experienced the effects of global warming. describe how you have experienced them. Otherwise, if you have not experienced the effects of global warming, explain why you feel this way.

Table 4.5.
Overview of Findings for the Frequencies and Pre/Post Climate Change Stance Comparisons to Test for Stability of Stances.

Overview of Findings for Frequencies and Pre/Post Change Comparisons		
Question	**Main Finding**	**Statistically significant?**
Is climate change happening?	Shift to is happening	Yes
Is climate change happening? For Males	Positive trend, but not significant. Responses are stable from pre to post	No
Is climate change happening? For Females	Positive shift from pre to post towards more reporting happening; stances not stable	Yes
Worry	Stable stance (tending towards central position—not extremes)	No
Scientists reach consensus?	Align with Yale results but less than majority think scientific consensus on global warming	Yes
Cause of climate change?	Majority chose anthropogenic	Yes
Is climate change discussed with friends/family?	No and remains stable—well below results for Yale	No

Part III: Dependence between Categorical Variables

In Part III, I explore the dependence between categorical variables using Pearson's chi squared tests. I first examine if responses regarding the existence of anthropogenic climate change and worry share a statistical dependence. I then report if there is a statistical relationship between the school a student attends and the students' stance on anthropogenic climate change. Finally, I show that there is dependence between students' level of worry regarding climate change impacts and if the students feel they have personally experienced the impacts of climate change. Tests, such as chi squared tests, identify relationships between non-continuous variables in the sample.

Is Anthropogenic Climate Change Happening and Worry About the Impacts

As seen in Table 4.6, chi squared results indicate a statistically significant dependence ($p< 0.001$) between a students' stance on the existence of anthropogenic climate change and their level of concern. The significant dependence remains strong ($p<0.001$) on the post survey. Although it cannot be determined where the specific dependence exists within the different responses of the categorical variable, it can be seen that on average those students who say climate change is not happening are not worried about climate change. However, most students are *Not very worried* or *Somewhat worried* for both the pre and post responses.

Is Climate Change Happening? By School

Table 4.7a is a table that first appeared in Chapter 2 when discussing the context of the study. It has been repeated in this chapter as a reminder of the participants and the school level variables. As a reminder, there are nine different teachers in the sample. For the majority of the analysis and results I discuss the models and findings at a school level. Two teachers teach at

Table 4.6.
Chi Squared Testing for Dependence between Level of Worry and the Existence of Anthropogenic Climate Change.

	How worried are you about climate change?			
Is climate change happening?	Not at all worried (21.6)	Not very worried (36.2)	Somewhat worried (34.9)	Very worried (7.3)
No (10.7)	51.1 (5.5)	36.2 (3.9)	10.6 (1.1)	2.1 (0.2)
Don't Know (28.0)	35.8 (10.0)	40.7 (11.4)	20.3 (5.7)	3.3 (0.9)
Yes (61.3)	10.0 (6.2)	34.2 (21.0)	45.7 (28.0)	10.3 (6.2)

$* \, Note: Pearsons \ \chi^2(6) = 79.59 \ p \ \leq 0.001 \ (Pre \ survey); Pearsons \ \chi^2(6) = 30.14, p \leq$ 0.001 (*Post survey*); cell percentages in () and row percentages stated first

Table 4.7a.
Summary of Characteristics of Study Participants (n=326).

School	Teacher	State	Frequency of Students in Sample	% Minority	Type of School	Taught Climate Change Before?	Years Teaching Science	% Students Free and Reduced Lunch
Main St.	**Ms. B**	Michigan	4.6	87	Public, Suburban	No	0-1; student teacher	75
Main St.	**Mrs. T**	Michigan	2.76	100	Charter, Suburban	No	6	88
Circle MS	**Mrs. H**	Northern Kentucky/Cincinnati, OH suburb	23.01	16	Public, Suburban	Yes	25	31
Circle MS	**Mr. W**	Northern Kentucky/Cincinnati, OH suburb	22.39	21	Public, Suburban	Yes	7	31
South Kernel MS	**Mr. C**	Kentucky	3.99	20	Alternative Public,	No	6 s	53
South Kernel MS	**Mrs. E**	Kentucky	20.55	15	Public, Rural	Very little	10	53
Village MS	**Mrs. R**	Virginia	6.13	25	Parochial, Small City	No	20	-
King St.	**Mrs. M**	Kansas	8.9	15	Public, Rural	Very little		27
North Central MS	**Mrs. C**	North Carolina	7.67	14	Public, Suburban	No. Teaches grades 7/8 General Science	9	51
	Total		**N=326**					

Circle MS and have four large classes each. The two teachers in Michigan teach at different schools within 10 miles of each other and share a similar. Two teachers teach at Circle MS and have four large classes each. The two teachers in Michigan teach at different schools within 10 miles of each other and share a similar demographic profile. With the similar ethnic, geographic, and percentage of curriculum completed profiles, the two classrooms are combined into one school for analysis for purposes. Similarly, there are two different teachers in the rural Kentucky in the same county and with similar demographic profiles. Mr. C's students comprise less than 2% of the sample population. These teachers' classrooms have been combined into a South Kernel MS. The other schools are single teachers within a single school. While this is just one way to categorize students' in the study, the school the participants attended was used as a control variable and to estimate potential differences by school.

Table 4.7b.
Pearson's Chi Square Testing for Dependence between Stance on the Existence of Climate Change and School Attended (n=326).

Participants' School	***% row***	***No***	***Don't Know***	***Yes***
Circle MS	Pre	7.2	21.1	71.7
	Post	8.1	14.2	77.7
Main St. MS	Pre	0	34.3	65.7
	Post	12.5	20.8	66.7
South Kernel MS	Pre	12.1	30.3	57.6
	Post	10	36.3	53.8
North Central MS	Pre	18.2	38.2	43.6
	Post	8.0	12.0	80.0
Village MS	Pre	0	23.8	76.2
	Post	5.0	0	95
King Street MS	Pre	30	33.3	36.7
	Post	17.2	20.7	62.1

$* Note: Pearsons\ \chi^2(10) = 37.33\ p\ \leq 0.001\ (Pre\ survey); Pearsons\ \chi^2(10) = 27.65, p = 0.002\ (Post\ survey)$

While the Pearson's chi squared test for independence does not indicate where the significant dependence is amongst the variables, I can discuss qualitatively the trends and patterns that appear in data Table 4.7b. The smallest percentage of students per class to state that climate change is not happening as well as the smallest percentage to definitively say that climate change is happening post curricular intervention is King Street Middle School. Moreover, students from Southern Kernel have the highest percentage of students who *Do not know* if anthropogenic climate change is happening on the post survey. Finally, students who attend Village MS responded most affirmatively that anthropogenic climate change is happening.

Level of Worry and Experienced Impacts of Climate Change

Another variable explored is the idea of students' level of worry about climate change impacts. While there are likely many complex influences on this variable, there are several variables that indicate a significant statistical relationship to students' concerns or lack of concern. On the post survey, there is a statistically significant dependence between the categorical variable exploring worry and the stated impacts of climate change. For the impacts variable, students were asked to explain how they feel they have experienced or not experienced the effects of climate change. The variable was coded and after initial categories were created, the categories were collapsed into the following three responses: (a) *have not experienced the impacts*, (b) *stated an impact recognized by the IPCC as potential impacts of a changing climate*, and (c) *stated an impact that is not recognized by the IPCC as a potential impact of climate change*.

Table 4.8.
Pearson's Chi Square Testing for Dependence between Level of Worry and Experiencing the Impacts of Climate Change (n=326).

	How worried are you about climate change?			
Experienced the impacts of climate change?	*Not at all worried* (15.2)	*Not very worried* (37.4)	*Somewhat worried* (40.7)	*Very worried* (6.7)
Have not experienced (59.3)	19.7 (11.7)	43.0 (25.5)	32.9 (19.5)	4.4 (2.6)
Impacts align IPCC (17.9)	8.0 (1.4)	21.3 (3.8)	57.3 (10.2)	13.3 (2.4)
Impacts do NOT align IPCC (22.9)	9.4 (2.1)	35.4 (8.1)	47.9 (11.0)	7.3 (1.7)

$* \; Note: Pearsons \; \chi^2(6) = 32.28 \; p \; \leq 0.001 \; (Post \; survey)$

The results from Table 4.8 indicate a significant statistical relationship between level of worry about climate change and how a student perceives he or she has experienced the impacts of climate change. Looking at respondents who stated that they are *Somewhat* or *Very worried* about climate change impacts, the highest frequency is found for students who have stated one or more impacts that align with the IPCC impacts of climate change, followed by students who stated experiencing the impacts, but the impacts did not align with potential impacts offered by the IPCC (e.g., conflation of weather and climate topics) Along the same lines, the lowest level of worry in the study is for students who claim to not have experienced any impacts from climate change. Extrapolating from these results, it appears that those students who state experiencing the impacts in some form exhibit a higher frequency of worry regarding climate change impacts.

Table 4.9.
Overview of Findings for Pearson Chi Square Tests Conducted in Chapter 4.

Overview of Findings for Pearson Chi Squared Tests		
Test for Dependence between Stances	**Main Finding**	**Statistically Significant?**
Is climate change happening? vs. Students' level of worry about climate change impacts	If said climate change is not happening are not worried about climate change. However, most students are not very worried or somewhat worried	Yes
Is climate change happening? vs. School attended	Highest frequency of Yes-Village MS; Highest frequency of No South Kernel (based on post-survey responses)	Yes
Have students experienced the impacts of climate change? vs. Students' level of worry about climate change impacts	If stated that experienced climate change impact (one that aligned with IPCC list) or what they perceived as an impact (conflation weather and climate), then higher frequency of being somewhat or very worried	Yes

Part IV: Graphical Models and Exploration of Students' Reasons

The majority of results reported above are based on closed form multiple choice student responses. On the pre and post survey, there were six open ended questions as follow-up prompts to the multiple choice items. These responses helped to capture the nature and patterns of the students' climate change stances. The open form questions gave an enhanced perspective on what students are thinking to articulate and justify their climate change stances. To quantify and illustrate communities and patterns that emerge from the sample, I used graphical modeling.

For each graph, I constructed the models in a step by step approach in order to highlight the major contributions from each part of this data analysis approach. There are two main models: (b) reasons regarding students' stance on the existence of anthropogenic climate change (2) reasons regarding students' about the impacts of climate change. For each model, I start with an illustration of just the nodes, which are the categories of student responses. In the second step, I add colors to the nodes. The node color indicates the frequency of students who gave that response. Both the size of the node and the color of the node are illustrations of the frequency of response for each coded category. Finally, the third model includes edges in the graphical models. The edges indicate number of shared responses. The thickness of the edge correlates to the number of students who shared responses. The nodes and edges have been standardized on the same scale to allow for comparability across models.

Graphical Model: Students' Reasons for Stance on the Existence of Anthropogenic Climate Change

Nodes

For *Figure 4.18a* shows the frequency of student responses to the open ended questions on the pre and post surveys that asked students to justify their stance on the existence of anthropogenic climate change. In the original coding, the responses were divided into over twenty categories. For the graphs, the categories were combined and collapsed into more general, meta-level themes for the responses. The size of the node correlates to frequency of each response. The number inside the node is the category of the student response, which can be found in the key below each model. The size of the node can be used to compare frequency of responses. For example, node thirteen (i.e. on average getting warmer) is statistically significantly larger on the post survey than the pre survey.

Figure 4.18b also illustrates the nodes for the graphical model that captures student responses justifying their stances regarding anthropogenic climate change. It includes color to identify frequency of each response and easier comparability between each node. The y-axis color gradient of the graphical model indicates frequency of students who gave a specific response. Darker colors and a larger node correlate to more frequent responses. Conversely, lighter colors and smaller nodes correlate to less frequent responses. Note that the number in the middle of each node is matched to the number in the key, which shows the specific student response category.

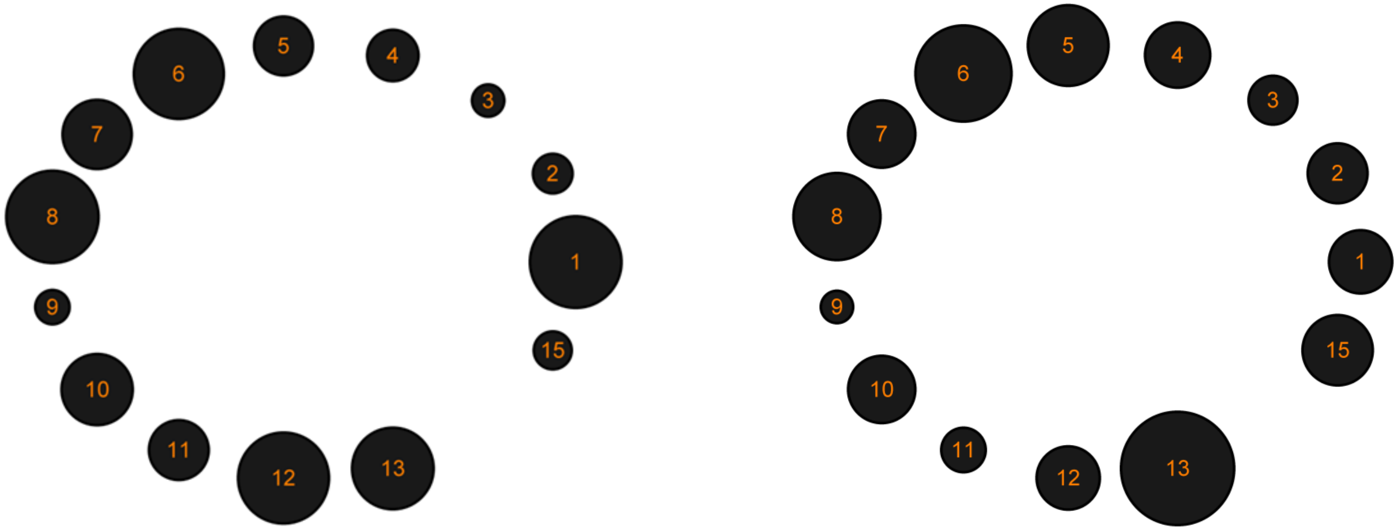


Figure 4.18a. Key to graphical model and nodes by size

1 = Don't know reason(s) for climate change	9= Animals will be negatively impacted
2= Not sure if climate change is happening	10=Natural changes and/or normal seasonal changes
3= Don't care about the topic	11= Alternative concept identified in literature: Ozone depletion
4= Not happening, no data to support climate change	12 = General pollution (e.g., Littering, factories)
5= Impacts (increase in severe storms, droughts, ice melting)	13 = On average getting warmer
6 = Messy middle knowledge (e.g., earth's tilt/rotation, sun getting closer doomsday scenario, plate tectonics, burning fires)	14 =Religious claims made (did not meet threshold→excluded)
7= Human actions (e.g., increased technology us, cutting down trees, increased population)	15= Off topic: Learned in school
8 = Increases in—fossil fuel use, CO_2 emissions, and/or greenhouse effect	

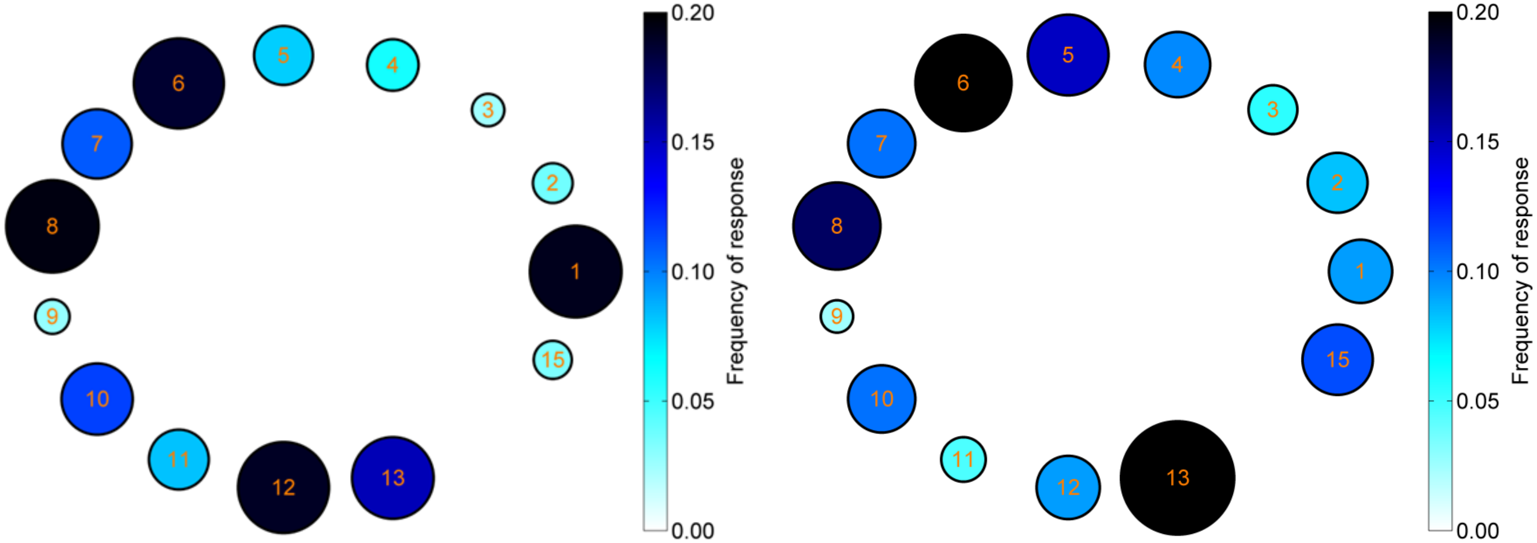


Figure 4.18b. Key to graphical model and nodes by color and size

1 = Don't know reason(s) for climate change
2= Not sure if climate change is happening
3= Don't care about the topic
4= Not happening, no data to support climate change
5= Impacts (increase in severe storms, droughts, ice melting)
6 = Messy middle knowledge (e.g., earth's titlt/rotation , sun getting closer, doomsday scenario, plate tectonics, burning fires,)
7= Human actions (e.g., increased technology us, cutting down trees, increased population)
8 = Increases in—fossil fuel use, CO_2 emissions, and/or greenhouse effect

9= Animals will be negatively impacted
10=Natural changes and/or normal seasonal changes
11= Alternative concept identified in literature: Ozone depletion
12 = General pollution (e.g., Littering, factories)
13 = On average getting warmer
14 =Religious claims made (did not meet threshold→excluded)
15= Off topic: Learned in school

Key to Colors:

- Green=statistically significant increase from pre to post
- Black= stayed the same pre to post
- Red=statistically significant decrease from pre to post

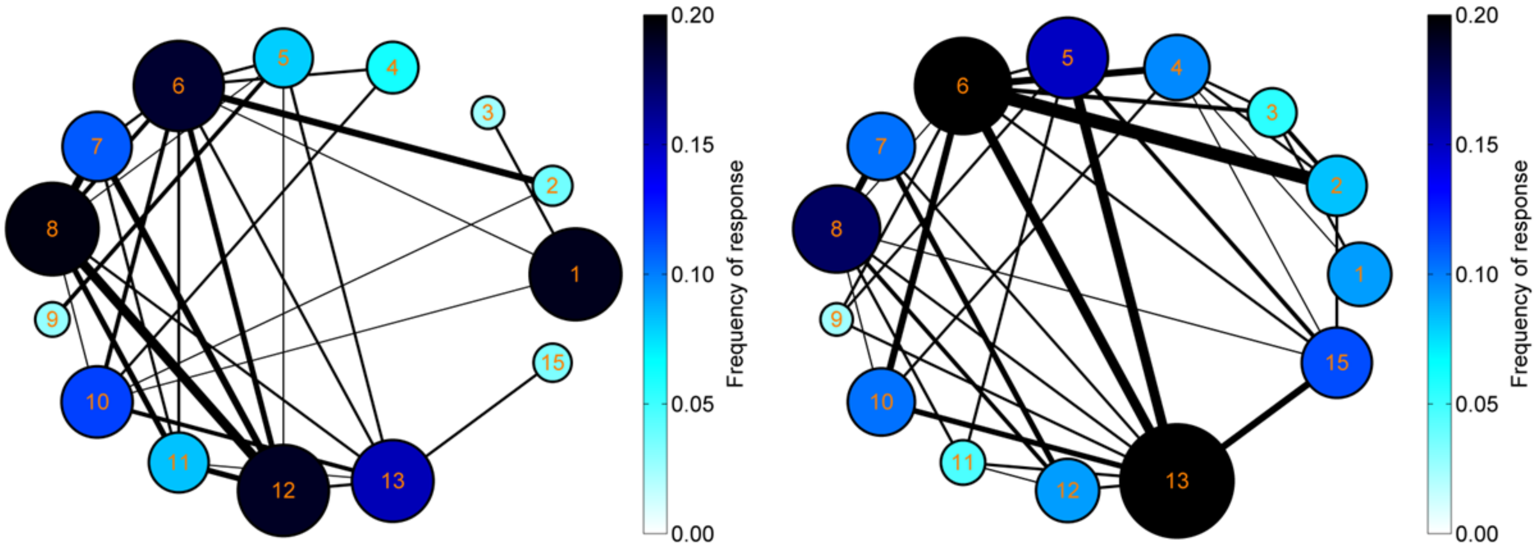


Figure 4.18c. Key to graphical model and nodes by color and size including edges

1 = Don't know reason(s) for climate change	9= Animals will be negatively impacted
2= Not sure if climate change is happening	10=Natural changes and/or normal seasonal changes
3= Don't care about the topic	11= Alternative concept identified in literature: Ozone depletion
4= Not happening, no data to support climate change	12 = General pollution (e.g., Littering, factories)
5= Impacts (increase in severe storms, droughts, ice melting)	13 = On average getting warmer
6 = Messy middle concepts (e.g., earth's tilt/rotation, sun getting closer, doomsday scenario, plate tectonics, burning fires, earth's rotation)	14 =Religious claims made (did not meet threshold→excluded)
7= Human actions (e.g., increased technology us, cutting down trees, increased population)	15= Off topic: Learned in school
8 = Increases in—fossil fuel use, CO_2 emissions, and/or greenhouse effect	

Pre Shared Reasoning	Post Shared Reasoning	
6⇔ 2	**6⇔ 2**	• Green=increase from pre to post
8⇔ 12	**5⇔13**	• Black= stayed the same pre to post
6⇔12	**6⇔13**	• Red=decrease from pre to post
7⇔12	**6⇔10**	
8⇔11	**13⇔ 15**	

On the pre survey the most frequent responses were (1) *I don't know the reason climate change is happening or not happening*, (2*) it is happening because there has been an increase use of fossil fuel/carbon dioxide and/or an increased greenhouse effect* (3) *climate change is happening and the result of general pollution form factories and/or littering,* and (4) *students stated a messy middle concept why climate change is happening (e.g., on average global temperatures are cooling, a doomsday end of the world scenario, earth's tilt changing, and the sun is getting closer*). The messy middle knowledge stated above were separated from alternative concepts already identified in the literature, such as climate change is the result of ozone depletion or general pollution/littering is causing the atmosphere to change. This idea of using a spectrum of correct to incorrect science (e.g., messy middle concepts) to justify climate stances is discussed in more detail in Chapters 6, 7 and 8

To explore if the responses for each node statistically significantly increased or decreased from pre to post surveys, tests for marginal homogeneity were conducted. These tests account for dependence between pre and post responses. The results indicate that there were both significant decreases in some categories from pre to post surveys, as well significant increases in others. In particular, the frequency of students who used the reason *I don't know* ($p < 0.0001$)*, ozone depletion* ($p = 0.0396$)*, and general pollution from littering and factories* ($p = 0.0001$) statistically significantly decreased from the pre to post survey.

The statistically significant increase in responses from pre to post were *on average it is getting warmer* ($p < 0.0001$), *abiotic impacts (increase in severe storms, droughts, and ice melting)*($p = 0.001$)*, an off-topic response: Learned it in school* ($p = 0.001$)*, not sure if climate change is happening* ($p = 0.0112$)*, don't care about the topic* ($p = 0.0412$)*, climate change is not happening/not enough data to support it* ($p = 0.0339$). The frequency of the messy middle response (which included *On average it is getting colder*) increased, but not significantly. This last justification could be associated with the fact that many of the students took the curriculum during the winter months, and moreover, many students struggled with the difference between weather, seasons, and climate. As further evidence of this idea, many students who stated this messy middle justification shared the same reason with students who stated that climate change is the result of natural and/or seasonal changes in the environment. I discuss the conflation of these concepts in Chapters 6, 7, and 8.

Edges and Relationships in the Graphical Model

The graphical models illustrate more than frequency and changes in frequency of open-ended responses in the pre and post surveys. It shows shared relationships and patterns in common student answers. The edges are the number of students who shared the same stance justification. By exploring shared reasons across the sample, it indicates common patterns of thought around the topic.

Figure 4.18c is the graphical model that includes edges as well as nodes by size and color. On the pre survey, students shared the reasons that climate change is due to human activities (e.g., increased technology use) and general pollution. Similarly, the response of *General pollution and littering* is often shared with students who stated more specifically that *Increased fossil fuel use and greenhouse effect* are a main justification for a stance on the existence of anthropogenic climate change.

Not only can the graphs show how many students shared the same reasons, it can illustrate which node has the most connections. For example, node 6 (e.g., messy middle concepts not cited by previous literature) has shared responses with at least ten of the thirteen other nodes. This means, it is both a popular response in terms of frequency and there are many shared connections in the web. I believe this speaks to the complexity of the topic of climate change. While students can hold knowledge that is partially correct some students discuss other aspects of the topic as scientists do, such as general warming trends, and others hold messy middle concepts alongside the ideas of node six, such as climate change is a result of natural variations and/or seasonal changes. Along the same lines, in the pre survey, as discussed above, there was a high frequency of respondents who attribute increased fossil fuel use and/or enhanced greenhouse effect as the cause of climate change. This node has three shared responses with high frequency of overlap of answers (high rate of shared connections). While many students state the importance of fossil fuels and greenhouse effect, at the same time they include ozone depletion or general pollution and littering as their justification for why they think climate change is happening. Again this speaks to the point that students can hold a mixture of correct and incorrect science alongside one another; it is not an either or condition. This is discussed as messy middle knowledge (Gotwals & Songer, 2010) at the end of this chapter and again in Chapters 6, 7, and 8.

Just as the frequencies of responses for the post survey are different, the shared connections between responses also changed. The most shared response is between: (1) *general warming trends and impacts of climate change* (e.g., increased storms, droughts, melting ice), (2) *messy middle concepts* (e.g., on average getting colder) and *not sure if climate change is happening*, (3) *messy middle concepts* (same as above) and *general warming trend*, (4) *messy middle concepts* (same as above) and *natural variations and/or seasonal changes*, and (5) *getting warmer* and *learned it in school*. Like the pre survey, those students who have messy middle conceptions are sharing responses with many other students who justify stances with both with a spectrum of correct and incorrect science. After participating in the curriculum more students stated climate change is happening because they learned it in school and shared the response with an overall warming trend, which was a major component of the curriculum.

I further explored the idea of which students used the justification that climate change is happening because (s)he learned it in school. Is there a difference in responses based on school attended? The response is highly statistically significant ($p = 0.001$) on the post survey by school. Note, there is no dependence of these two variables on the pre-survey. The highest frequency of responses (over 25%) were in North Central MS and Village MS students. While this is not a scientific reason for a student's stance regarding anthropogenic climate change, the idea that students attribute learning it in school for their rationale that climate change is happening is discussed in more detail in Chapters 6 and 7. Table 4.10 is an overview of the findings of the nodes and edges for the model that explores students' stances regarding the existence of climate change.

Table 4.11 illustrates examples of student reasons (nodes in the graphical models) regarding their stances on anthropogenic climate change. The students' responses are from the post survey. Note that the students' answers have not been corrected for spelling, grammar, etc. The sample student quotes are given to illustrate student thinking and rationale in attempts to explain such a complex science phenomena. Student responses are anonymized. The responses illustrate that middle school students in a variety of schools and locations are sharing similar stances and reasons in response to this question and topic.

Table 4.10.
Overview of Findings for Students' Justifications of Stance on the Existence of Anthropogenic Climate Change.

Overview of Findings of Graphical Models		
Graph (Figure 4.18c): Reasonings students gave for the stance that anthropogenic climate change is happening	Statistically significant **Decrease** in Frequency of responses from pre to post	• Don't know reason why climate change is happening • Ozone depletion (alternative concept identified in literature) • Pollution and littering (factories)
	Statistically significant **increase** in Frequency of responses from pre to post responses	• Abiotic impacts of climate change (e.g., severe storms, droughts, ice melting) • On average getting warmer • Off-topic response: Learned in school • Not sure if climate change is happening • Don't care about the topic • Climate change is not happening/not enough data to support it
	Decrease in shared responses (thinner edges) from pre to post	• Increase in fossil fuel use and carbon emissions & Pollution and littering (factories) • Alternative scientific theories for climate change (earth's rotation, plate tectonics, doomsday scenario) & Pollution and littering (factories) • Human actions (increased technology use, cutting down trees, increased population) & Pollution and littering (factories) • Increase in fossil fuel use and carbon emissions & Ozone depletion (alternative concept identified in literature)
	Increase in shared responses (thinner edges) from pre to post	• Impacts of climate change (e.g., severe storms, droughts, ice melting) & On average getting warmer • Alternative scientific theories for climate change (earth's rotation, plate tectonics, doomsday scenario) On average getting warmer • Alternative scientific theories for climate change (earth's rotation, plate tectonics, doomsday scenario) & Result of natural and/or seasonal changes • On average getting warmer and off-topic response: Learned in school

Further Exploring Students' Reasons

Figures 4.19a and 4.19b further explore students' stances and reasons regarding the existence of anthropogenic climate change. Again, the analysis is looking only at post survey responses from the merged data set (n=326). *Figure 4.19a* looks at the justifications given based on if students stated anthropogenic climate change was happening or not. *Figure 4.19b* explores if the reasons given by males and females are different.

Happening vs. not happening. Further analysis was conducted to see if students with different stances regarding climate change (e.g., it is happening or not happening) are using different reasons to justify their climate change stances. Note the frequencies in both *Figures 4.19a and 4.19b* sum to greater than 100% because students could have stated multiple responses because each student open-ended response was coded for up to two answers.

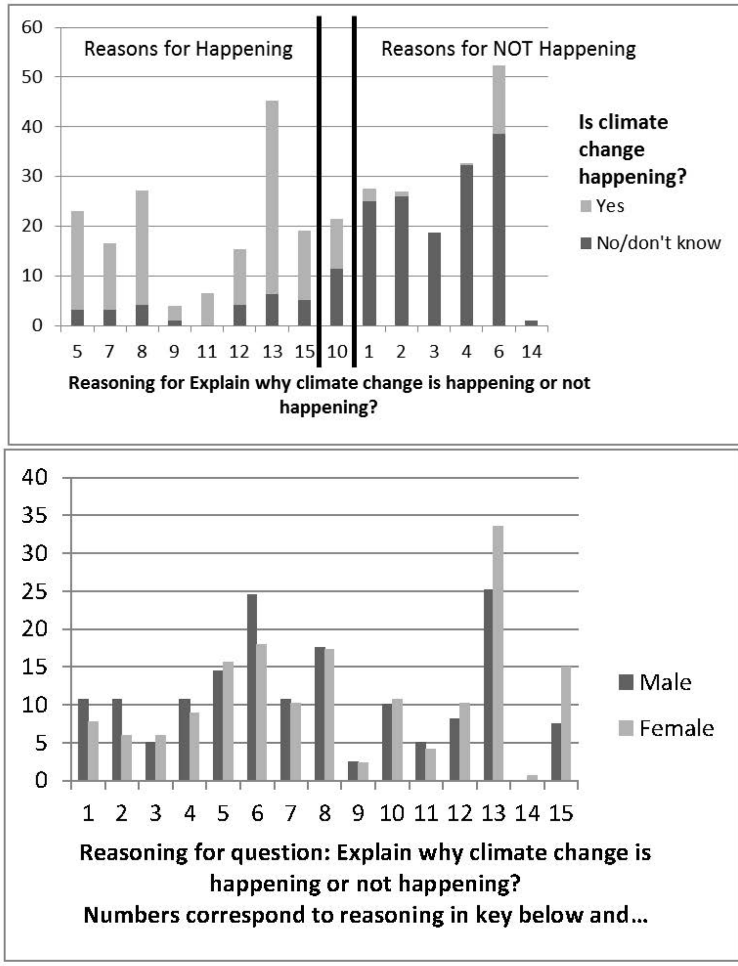
It is clear that students who state that they *Do not know the reason to explain climate change*, *Not sure if climate change is happening*, and/or *Do not care about the topic* have the highest ratio of respondents who say that climate change is *Not happening/do not know*. The highest ratio of respondents who said that climate change is happening used the reasons *On average it is getting warmer*, the *Abiotic impacts of climate change* (e.g., melting ice, increased number of severe storms, droughts, floods), the *Documented alternative concept of ozone depletion,* and/or *Increased fossil fuel use,* CO_2*, and/or greenhouse effect*. The highest ratio and overall percentage of responses to affirm climate change used scientific reasons and evidence, even if the justifications contained messy middle knowledge. However, those students in the sample who used *Messy middle concepts, such doomsday scenario and/or It is on average getting colder* as reasons more often answered that *Climate change was not happening or they Did not know*. Also, those students who explained his/her response with *Natural changes and/or it is a result of normal seasonal changes* were relatively split on their responses if anthropogenic climate change is happening or not.

Table 4.11

Student Post Responses to Justify Stance on the Existence of Climate Change

Post-survey: Justification for stance on the existence of anthropogenic climate change (Part 1 of 2)	
Don't know reason(s)	I really don't know. I don"t discuss climate change with my family or friends" (Female, Circle, 7th grade) . "I don't know, because I don't really pay attention to the news" (Female, South Kernel, 6th grade).
Not sure if climate change is happening	"I don't know if climate change is happening because climate always changes, like weather or temperature. So I'm not sure if global warming in happening"(Female, Circle, 7th grade). People all over the world are arguing rather its happening or not. So I don't know if its happening or not" (Female, South Kernel , 8th grade) i dont know because most days it has been the normal weather for this time of year...yes, there was a few times were the weather patterns were a bit off, but that happens sometimes. It has been happening since the earth was created" (Female, Circle, 7th grade).
Don't care about CC	I don't care about climate change Therefore I dont know about it" (Male, KY Rural, 8th grade). I don't know...whatever happens happens" (Female, South Kernel, 8th grade).
Not happening, no data to support climate change, getting colder	"I dont think it is happening since It seems to be the same temperature or colder than normal" (Male, South Kernel, 8th grade) "Global warming is not happening because its just a myth" (Male, South Kernel, 8th grade). "I do not think it is happening because the person that brought Global Warming up admitted that it he was lying just to get people to think about it. It has also been proven that Global warming is not happening besides right now the temperature is 30 degrees lower than average for this time of year" (Male, King St, 7th grade). "i think its another fad to make us buy new products too "help the environment" when its worse for it" (Male, Circle, 7th grade). "I think Global Warming is not happening because the world goes through warm streaks and cold streaks in a pattern. We are in a warm streak" (Male, Circle, 7th grade).
Increased in impacts (e.g., storms, melt, drought)	I think it is happening because our world is eating up and there are starting to be more storms as a result of the heat"(Male, North Central, 8th grade). "I think that that it is hapining because placed that were cold are warming up more and more. The glaciers are melting and animals like the polar bears are losing there home" (Male, Circle, 7th grade).
Messy middle knowledge not discussed in literature	"Because of the earths rotation" (Male, South Kernel, 8h grade) It is happening because of fosil fuils from cars and everything else because they are burning up the atmispher" (Male, South Kernel, 8th grade) california and all those other countries and states are getting hurricane, earthquake, and tornado" (Male, King St, 7th grade).
Human actions (e.g., increased technology & deforestation)	"i think it is happening because people keap cutting down trees and don't know how to stop so it keeps getting hotter and hotter and people really don't care" (Male, King St, 7th grade). "Climate change is happening because of human activity. Humans have new technology and it has caused pollution and the release of carbon dioxide into the atmosphere combining with other greenhouse gases to cause an increase in the global temperature" (Female, Circle, 7th grade).
Increases in—fossil fuel use, CO_2 emissions, greenhouse effect	"I think global warming is happening because of the increasing use of fossil fuels. When breaking down fossil fuels, there are greenhouse gases being released, which causes them to go into the atmosphere" (Female, Main St., 8th Grade). "Climate change is most likely happening because there are more greenhouse gases in the atmosphere, and the greenhouse gases sometimes catch the infrared photons and the photons are bounced back to the Earth, and it may escape, but it might get caught" (Female, Village, 6th grade) "The carbon output around the world is too high for the carbon sinks to absorb" (Male. King St, 7th grade).

Post-survey: Justification for stance on the existence of anthropogenic climate change (Part 2 of 2)	
Animals will be negatively impacted	"Climate change is happening because the polar bears, ice caps are melting and is killing the polar bears" (Female, South Kernel, 8th grade) "Clamate change is happening because some of the animals are moving from where they live normally for this time andnot staying in there normal spots" (Female, King St, 7th grade).
Natural changes/ normal weather changes	"I think it is but it's not being caused by global warming. But I think the earth heats up and cools off every so often" (Male South Kernel, 8th grade). I believe that our planet just goes through cycles on its own to be honest. I truly think that it is all just people over reacting on something that might be nothing" (Male, South Kernel, 8th grade)
Alternative concept (identified in lit): Ozone depletion or sun getting closer	"It is happening because the greenhouse gases are puting holes in the ozone layer" (Male, Village, 6th grade) "All the pollution is tinning out the earths ozone and causing more direct sunlight. because of the greenhouse gases it is causing the earth to warm up" (Female, Circle, 7th grade). "The ozone is beginning to dissolve because of pollution so everything is heating up. Besides, scientists have proof of it" (Female, South Kernel, 8th grade).
General pollution (e.g., Littering, factories)	"Yes, I do think that global warming is and has been happening. The reason i think that global warming is happening is because of all of the many different types of pollution being created and put into our atmosphere. Some of the things i think that is causing this is Power plants, cars, Factories, Machines, Transportation, ETC. Another reason i think that global warming is happening is that overall the climate in the world has decreased over the years and continues to decrease. Our Climate in Kentucky has dramatically changed" (Female, Circle, 7th grade). "I think it is happening because of littering on the earth. Also because of dirtying of the water" (Female, South Kernel, 8th grade)
Getting warmer	"because its getting hotter every year and proxy data can tell us" (Male, North Central, 8th grade). Yes, because if you look at all the attention its has been getting you can see that the temperature has gone up. Over the years the temperature has gone up 1-2 degrees" (Female, Circle, 7th grade).
Learned in school	"In science we have been learning about it and if you pay attention to the news then they talk about how its getting hotter and hotter" (Female, Circle, 7th grade). "I do think that climate change is happening because the carbon dioxide is increasing and the average weather for each season is changing. I no this from doing lessons and activities during science class" (Female, Circle, 7th grade). .



1 = Don't know reason(s) for climate change
2= Not sure if climate change is happening
3= Don't care about the topic
4= Not happening, no data to support climate change
5= Impacts (increase in severe storms, droughts, ice melting)
6 = Alternative concepts (e.g. doomsday scenario, plate tectonics, burning fires, earth's rotation)
7= Human actions (e.g. increased technology us, cutting down trees, increased population)
8 = Increases in—fossil fuel use, CO_2 emissions, and/or greenhouse effect
9= Animals will be negatively impacted
10=Natural changes and/or normal seasonal changes
11= Ozone depletion (alternative concept)
12 = General pollution (e.g. Littering, factories)
13 = On average getting warmer
14 =Religious claims made
15= Off-topic response:
Learned in school

Figures 4.19. Reasoning for why climate change is happening/not happening. The figure on the top illustrates student reasoning for explain why climate change is happening or not happening? by student responses to the question Is climate change happening? The frequency of responses are arranged in descending order of ratio of responses by students who responded Yes climate change is happening. The figure on the bottom also explores students reasoning for why one believes climate change is happening or not. The reasoning stated is divided by gender to illustrate the difference in responses for males and females in the sample.

Gender differences for reasoning (Males vs. females). Another way to explore differences in responses is by gender. As discussed earlier in the results section, males and females in the sample had different shifts in responses from the pre to post survey to the question: Is anthropogenic climate change happening? *Figure 4.19b* illustrates that males more often than females in the sample responded in the post survey that they *Did not know the reasoning for climate change,* were *Not sure if climate change was happening,* and/or stated a messy middle concept, *such as on average the climate is cooling, a doomsday scenario, and/or the earth's tilt is changing*. Frequency of female responses to the Earth is *On average getting warmer and it is happening* because *I learned it in school* is greater than the frequency for male respondents.

Graphical Model: Why are you Worried or Not Worried about Climate Change?

The step by step graphical models below depict the complexities between frequencies of response and shared responses for student explanations to the question: *Why are you worried or not worried about climate change impacts?* While the multiple choice responses regarding level of worry remained statistically stable, several justifications to why students are worried or not worried changed after participating in the curriculum. The first model **(***Figure 4.20b*) shows the frequency of pre and post survey responses for each category. The number inside the node matches to the numbering in the key below the graph to the category of response. Furthermore, the size of the node correlates to the frequency of response; the larger the node the more frequent the response and visa-versa.

Figure 4.20b (node with color) illustrates the frequency of responses on the pre and post survey, but also includes a color gradient to indicate the actual frequency of responses. Again, the size of the node and color gradient as depicted on the y-axis have been standardized to allow for comparability across graphical models. The most frequent responses on both the pre and post survey are students are: (a) *worried climate change will impact humans* and (b) *not worried because climate change will not impact them and/or it will happen in the distant future*. The only statistically significant increase from pre to post responses for the nodes is *not worried about the* *impacts of climate change.* The frequency of students who are not worried and responded that *Nothing major is happening* statistically significant decreased from the pre to post survey.

Graph Edges for Worry

The graphical model technique goes beyond depicting frequencies of responses and the ability to compare frequencies over a period of time (i.e. pre to post survey). A graphical model can illustrate relationships and a network of interconnections. For this specific model, the edges show shared responses between students. The thicker the line (i.e. edge), the more students said both responses. The illustration of the graph helps to see a more complex, two-dimensional way the students are thinking about and discussing their stance justification. Examples of student responses used in the graphical models for worry can be seen in Table 4.13**.**

When looking at the graphs of pre to post justifications regarding students' worry about the impacts of climate change, one can see that the thickest edge (i.e. most shared response) on the pre is *Not worried* and *Don't know why* (see *Figure 4.20c*). The same responses are highly shared on the post survey, but so is the response *Not worried about it* and *Not worried because it is not impacting me/will happen in the distant future*. A major shared response that appears on both the pre and post survey is that climate change is *Not worried because not happening/myth* and the *Student does not care* about this topic. Moreover, on the pre survey the responses of *Don't care* and *Not worried* are a common shared response. Another shared response that appeared on both the pre and post answers: *The students are not worried because they have not witnessed any major changes* and *Climate change will not impact them/the impacts will happen in the distant future*. Furthermore, on the post survey students who stated that they are worried about the animals shared that response with many students who are also worried about the impacts on humans. On the post survey there were three major shared answers that did not appear on the pre survey (e.g., N*ot worried and Not impacting me/distant future*, *Not impact me and Climate change is not happening, and Worried it will impact humans and worried it will impact animals/the environment*). The only relationship that is strong on the pre survey and decreased on the post is *not worried* and *do not care*. The other edges remained stable from the pre to post survey. The questions raised in this section regarding students' worry and/or lack of worry are discussed in detail at the end of the chapter and again in Chapters 6,7, and 8.

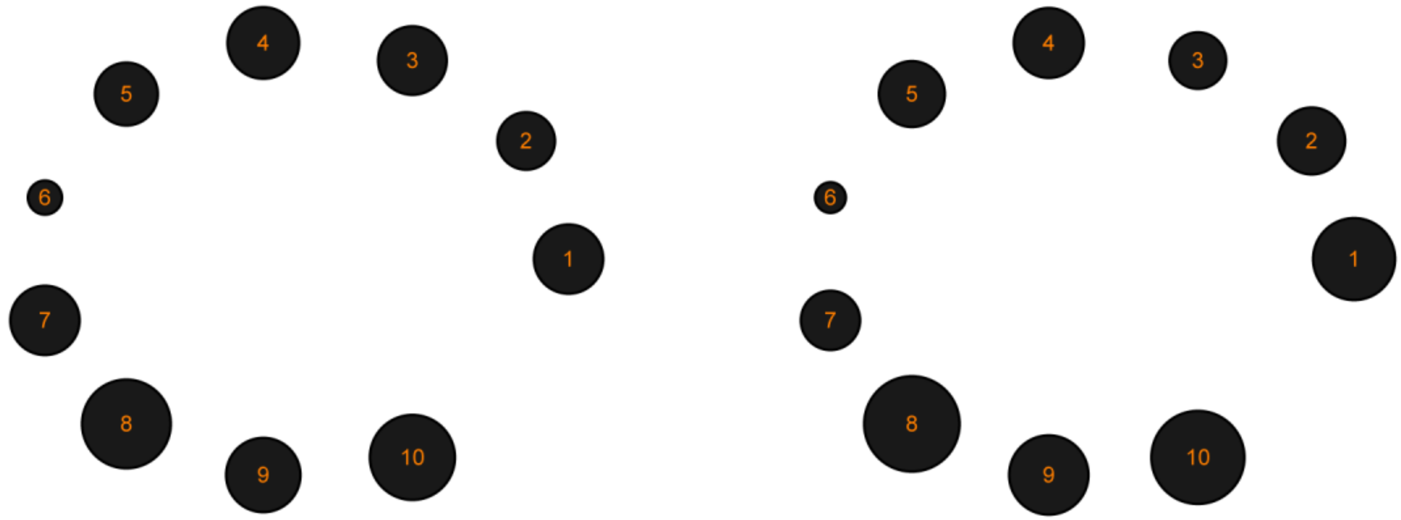


Figure 4.20a. Key to graphical model and nodes by size	
1 = Not worried 2 = Just part of our lives, will adapt or tech will solve problems 3 = Not worried because nothing major happening 4= Messy middle knowledge (doomsday, earth will burn up, sun getting closer) 5 = Climate change not happening (myth, skeptical)	6= Confusion weather vs. climate, natural fluctuations 7= Don't care 8= Worried will impact humans 9= Worried will impact environment and animals 10= Not impacting me/ will happen in distant future

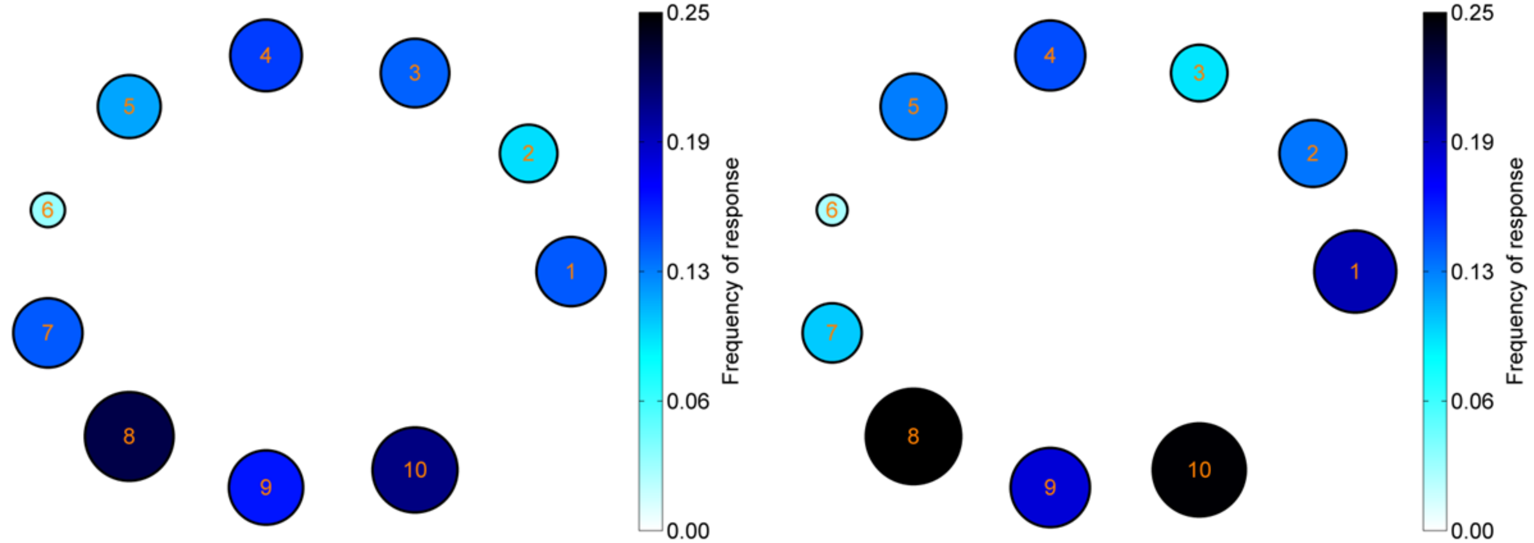


*Figure 4.20b***.** Key to graphical model and nodes by color and size	
1 = Not worried 2 = Just part of our lives, will adapt or tech will solve problems 3 = Not worried because nothing major happening 4= Messy middle knowledge (doomsday, earth will burn up, sun getting closer) 5 = Climate change not happening (myth, skeptical)	6= Confusion weather vs. climate, natural fluctuations 7= Don't care 8= Worried will impact humans 9= Worried will impact environment and animals 10= Not impacting me/ will happen in distant future • Green=statically significant increase from pre to post • Black= stayed the same pre to post • Red= statistically significant decrease from pre to post

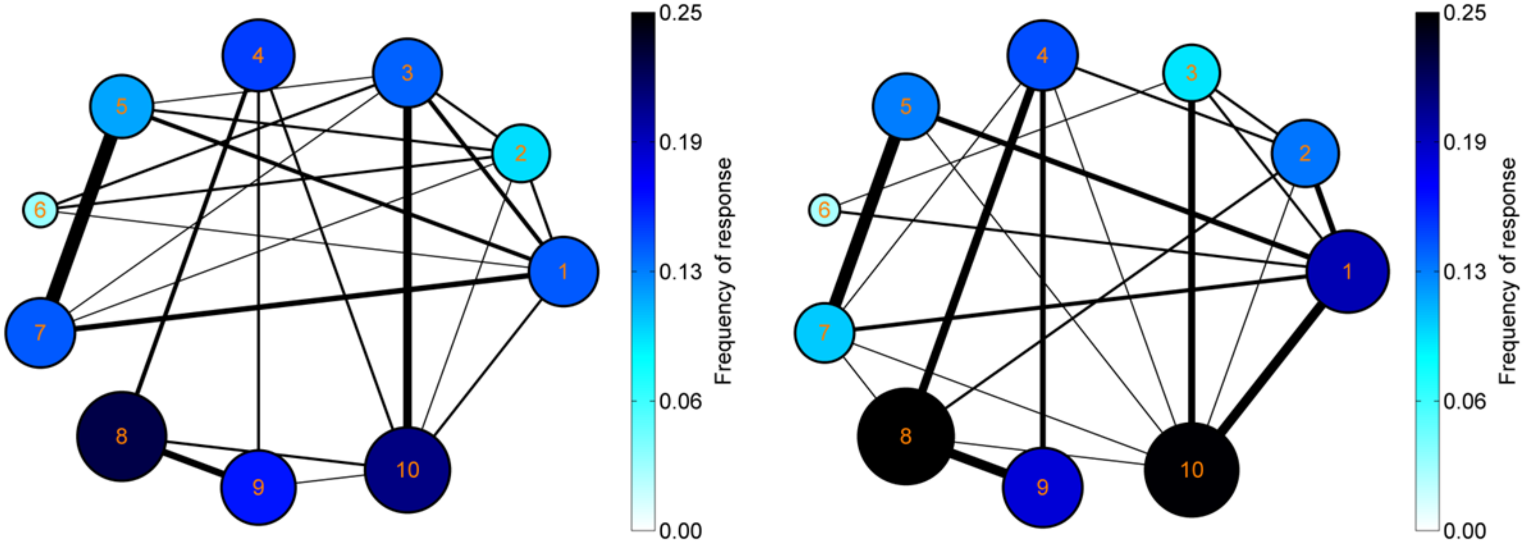


*Figure 4.20c***.** Key to graphical model and nodes by color and size including edges

1 = Not worried 2 = Just part of our lives, will adapt or tech will solve problems 3 = Not worried because nothing major happening 4= Messy middle knowledge (doomsday, earth will burn up, sun getting closer) 5 = Climate change not happening (myth, skeptical)	6= Confusion weather vs. climate, natural fluctuations 7= Don't care 8= Worried will impact humans 9= Worried will impact environment and animals 10= Not impacting me/ will happen in distant future

Pre Shared Reasoning	Post Shared Reasoning	
5⇔7 **8⇔4** **3⇔10** **1⇔7**	**5⇔7** **8⇔4** **3⇔10** **1⇔10** **8⇔9** **1⇔5**	• Green=increase from pre to post • Black= stayed the same pre to post • Red=decrease from pre to post

Table 4.12.
Review of Findings for Graphical Model Exploring Why Students are Worried or Not Worried about Climate Change Impacts.

Overview of Findings of Graphical Models ***Statistically significant at p < *0.05***		
Graph 2 (Figure 4.20c): Reasoning for worry stance	Statistically significant **decrease** in Frequency of responses from pre to post	• Not worried because nothing major happening • Don't care
	Statistically significant **increase** in Frequency of responses from pre to post responses	• *Not worried about the impacts of climate change
	Decrease in shared responses (thinner edges) from pre to post	• Not worried about the impacts & Don't care
	Decrease in shared responses (thinner edges) from pre to post	• Not worried & Not impacting me and/or impacts will happen in the distant future • Not worried & Climate change not happening (myth, skeptical about theory) • Worried will impact humans & Worried will impact animals/environment

Table 4.13.

Student Post Survey Responses Justifying Stance on Worry and/or Lack of Worry Regarding Climate Change Impacts

Not worried (NW)	"I am not worried about climate change because if our world heats up then, since the world is warm, none of our plants or animals will die from the cold" (Female, South Kernel, 7th grade) "Not very worried--Because I have air conditioning" (Male, South Kernel, 8th grade)
NW: Will adapt, tech will solve part of life	"I am not very worried because of the fact that human beings can change if need be" (Male, Circle, 7th grade). "I am not very worried. We are already doing things to help decrease fossil fuels like driving Eco-friendly cars or factories using clean energy" "(Female, Circle, 7th grade). "I'm no to worried because I think scientist will find a way to stop it" (Male, King St, 7th grade).
NW: Nothing happening	"I'm not because the earth Has been the same temperature. Every once in a while it's hotter than the other year. Or it's colder. That's been happening for millions of years" (Female, Main St, 8th grade) "Untill it gets realy bad i will not worry about it" (Male, North Cental, 8th grade)
Messy middle knowledge (doomsday, earth will burn up)	"I'm worried because we might go through the very cold time and we might not survive" (Female, North Central, 8th grade). "I am worried because this mean that the earths crust could be getting thinner and that means the earth could overheat" (Male, Main St, 8th grade). "because the world will end by the global warming that is what i believe" (Female, Circle, 7th grade). "I am worried about climate change becaus if the earth gets to warm it will be like an other Mars; hot and dry.We have to keep the earth healthy becaus there isn't an other earth" (Female, Circle, 7th grade). "i might die and and my kids might also. i dont whant to have my childeren grow up having to breath bad air" (Male, King St, 7th grade)
Climate change not happening	"becase climete cange is not happening at all" (Male, Cincinnati suburb, 7th grade). "its most likely fake" (Male, Cincinnati suburb, 7th grade). "its not proven to be the reason of the earth changing" (Male, NC rural, 8th grade)
Confusion weather vs. climate, natural fluctuations	"I am not because I believe that the weather and temperature are just having a slight swing right now, but it will soon go back to normal like it usually does. And even if I did believe that global warming, the temperature would increase to slowly to effect anyone in my lifetime" (Male, Circle, 7th grade). "I am not worryed. Because I believe that the world is natural releasing heat and can stand a very large amount of heat" (Male, King, 8th grade).
NW: Don't care	"im not worried because i don't really care about it" (Male, King St, 7th grade). "I don't really care about climate change and if something does happen it will be a while from now or after my lifetime" (Male, Circle, 7th grade) "I'm going to be honest. I'm not into this and I'm not worried one bit that is someone elses job" (Female, Cincinnati suburb, 7th grade).
Worried will impact humans	"I am worried about climate change because I dont like hot weather and if it is hot i cant ski. i am also worried that some crops wont be able to grow in a warmer climate so we wont have a larger vsriety of food" (Male, Circle, 7th grade). "I'm worried because when I am older all of our resources maybe scarce" (Male, Circle, 7th grade). "I am slightly worried because so many people don't seem to care when we are just using up the Earth and it may one day, not support us and the habitats" (Male, North Central, 8th grade)
Worried will impact environment/animals	"I like warm weather. Dont really like cold weather. So if the earth were to get warmer, I would be ok with that. But I am concerned for some animals that need the colder areas to survive. So the areas would get warmer and cause animals that live in the cold areas to relocate and move north to colder spots." (Male, Circle, 7th grade). "I am worried because a big climate change might cause a horrific natural disaster" (Female, Main St, 8th grade). "I am a little worried about the climate because of the plants and animals going extinct. (some of those plants could cure cancer)" (Female, Circle, 7th grade)
Happening slowly/not impacting me	"i will be dead by the time any thing bad happens" (Male, North Central, 8th grade). "Because that wouldn't happen for millions of years" (Female, Circle, 7th grade). "Since it seems to be happening so slow that it wont really affect my life" (Male, South Kernel, 8th grade).
Religious	"God said the Earth would never flood again" (Male, South Kernel 8th grade) "I am not worried because I don't believe in in Global Warming besides if the world wants the world to end he will make it end" (Male, King St, 7th grade).

Part V: Generalized Linear Models

The logistic regression (logit) model is a type of generalized linear model to explore statistical relationships between variables in the model while controlling for other factors. In this data set, control variables include, but are not limited to: mother's education level of the student, frequency of type of news read and watched, self-reported grade earned in science, gender, and geographic location. Other variables considered for the model included the multiple choice and open-ended items exploring students' stances on climate change.

Random Effects Logit Model: Worried or Not Worried about the Impacts of Climate Change

Table 4.14 shows the random effects logistic regression model, which provides the jointly significant statistical predictors of students' worry about climate change impacts. In the model, standard errors were clustered by student identification and regressed on a binary worry variable over pre and post time points. The binary worry variable was coded so that a positive value indicated that the student was worried about climate change and a zero value indicated s(he) was not worried about climate change.

Dummy variables were created for all categorical variables in the model and compared versus a base group for each variable. The base categories were purposefully chosen to ensure that the comparison group was a larger category within the dummy variable. Moreover, while the base group can impact which individual categorical variable is statistically significant in the model, it does not impact whether the variable is jointly significant over all categories in the model. All categorical variables were tested for joint significance in the model.

The overall model is significant ($p<0.0001$). A Hausman test was conducted to determine if a fixed effects model was necessary, but it was found to be insignificant ($p=0.69$). Thus, a random effects model was executed. Table 4.14a illustrates the findings of the random effects, joint logistic regression paneled by pre and post survey responses and clustered by student identification number.

This random effects joint logistic regression model shows several major findings. The constant indicates that on average, students in the sample are not worried about climate change. Females are approximately three times more likely to be worried than males. Also, students who stated that they have experienced the effects of climate change are approximately two times more likely to be worried than those students who state that they have not felt the impacts of climate change. Similarly, in comparison to students who do not talk about climate change at all with friends and family, students who discuss climate change is happening but either use a mixture of correct and incorrect science in their discussions or do not consider the scientific aspects of climate change both tend to be more worried. Also, students who attend school Village MS are more than eight times more likely than students in school South Kernel MS to worry about the impacts of climate change. Students who report that climate change is happening are approximately two times more likely to be worried about climate change compared to students who say it is not happening.

Conversely, students who state that climate change is not happening or they do not know the causes of climate change are less likely to be worried than students who think climate change is the result of natural events in the environment. For the majority of dummy variables, compared to completing HS, the students’ father’s education level is a negative predictor of students’ worry.

Post tests for joint significance indicated that the following variables were significant across pre and post variables when holding all else constant: students’ gender ($p < 0.0001$), is anthropogenic climate change happening ($p < 0.001$), the categorical variables exploring what is discussed at home about climate change ($p < 0.0001$), causes of climate change ($p < 0.001$), and school student attends ($p < 0.01$). The student's father's education level was borderline jointly significant, but not statistically significant. Lastly, the news channel a student watches is not significant.

Many of these findings speak to the idea of making the topic more tangible and relevant to students' everyday lives. In Chapter 8, I further explore the idea of creating curricular materials to help students see that climate change is both a global and personal issue that is not just impacting the Polar Regions and animals.

Random Effects, Joint Logistic Regression Model Paneled by Pre and Post and Clustered by Student ID

$$\Pr(Worry)_{i,t} = H\big(\beta_0 + \beta_1(Climate\ Change\ happening)_{i,t} + \beta_2(Experience\ Climate\ Change)_{i,t} + \beta_3(Discuss\ Happening)_{i,t} + \beta_3(Cause\ of\ Climate\ Change)_{i,t} + \beta_4(Female)_i + \beta_5(Science\ Grade)_i + \beta_6(Dad\ Education)_i + \beta_7(School)_i + \beta_8(Often\ Watch\ News)_i\big),$$

$$H(x) = \frac{1}{1+e^{-x}}$$

Table 4.14

Random Effects Joint Logistic Regression Analysis of Exploring Students' Worry about Climate Change Impacts (n=326)

Random Effects Logistic Regression Worried =1 Not Worried = 0	Odds Ratios	(Standard Errors)
Climate Change happening?	2.19**	(0.63)
Experienced Climate Change Impacts?	2.19**	(0.52)
Causes of Climate Change (compared to result of natural changes)		
Climate Change not happening	0.04**	(0.05)
Don't know why	0.37*	(0.16)
Human activities	1.24	(0.41)
Discussion Climate Change with friends/family (compared to Don't Discuss)		
CC happening; correct science reasoning	2.51	(1.52)
CC NOT happening/natural	0.67	(0.33)
Confusion between weather and climate	0.79	(0.41)
CC happening; incorrect science reasoning	1.78	(1.81)
CC happening; mixture correct and incorrect science reasoning	4.50**	(2.37)
CC happening; no discussion of science	3.89***	(1.41)
Female (compared to Males)	3.21***	(0.91)
Current science grade	1.01	(0.12)
Dad Education Level (compared to HS)		
Less than 8th grade	0.24*	(0.17)
Some high school	0.41	(0.22)
Associates Degree	0.44	(0.29)
Some College	1.18	(0.44)
College	0.48*	(0.18)
MA	0.85	(0.36)
MD, PhD, JD	1.79	(1.38)
School Attended (comparison S. Kernel MS)		
Main St. MS	0.63	(0.34)
North Central MS	2.54	(1.40)
King St. MS	1.16	(0.60)
Circle MS	1.87	(0.63)
Village MS	8.48**	(5.55)
Watch news (comparison Rarely)		
1-2x/week	1.30	(0.44)
3-4x/week	1.73	(0.66)
More than 4x/week	1.80*	(0.69)
Constant	0.03***	(0.02)

Number of observations=652, Number of groups =326, clustered by student ID; Wald chi2= 80.67 (p< 0.0001); *p<0.05; **p<0.01; ***p<0.001

Logit Model 2: Is Climate Change Happening (Males)?

In the Pearson chi2 and symmetry models, female students in the sample had a statistically significant positive shift regarding the existence of anthropogenic climate change, while males did not have a statistically significant positive trend, yet positive nonetheless. I further explored this finding by looking at statistical predictors for male and female stance on the existence of anthropogenic climate change. A logistic regression model was constructed. The responses were collapsed into binary categories (1) *Yes* and (2) *No or Don't know* if anthropogenic climate change is happening. Table 4.15 depicts the logit model for male students, but the same model was estimated for female students. Both results are discussed in this section.

A post hoc test for categorical variables was conducted to explore joint significance of the categorical variables while holding all else constant. The categorical variables that were statistically jointly significant in the logistic regression model for male students are dad's education level ($p \leq 0.05$), the school in which the students attend ($p \leq 0.05$), the stated cause of climate change for a closed form multiple choice question ($p \leq 0.001$), and how one states he has experienced climate change is borderline significant at $p=0.06$. The binary variable of if a student identifies as being of European White descent or of non-European white descent (i.e. minority) is not a significant predictor of if a male states that climate change is happening.

The positive, statistically significant predictor of students stating that anthropogenic climate change is happening is the variable of how students feel they have experienced the effects of climate change. While some students conflated the concepts of climate and weather, those students who had this confusion were thirty five times more likely than students who did not to say that climate change is happening. Similarly male students who stated that on average the climate is warming and/or animals and the environment are negatively impacted and that although climate changes was not personally impacting them because it is happening too slowly

$$\Pr(Male\text{: } CC\ Happening)_i = H\left(\beta_0 + \beta_1(Experience\ Climate\ Change)_i + \beta_2(Cause\ of\ Climate\ Change)_i + \beta_3(School)_i + \beta_3\left((Dad\ Education)\right)_i \beta_4\left((Minority)\right)_i\right),\ H(x) = \frac{1}{1+e^{-x}}$$

Table 4.15.

Logistic Regression for Males Regarding the Existence of Climate Change (n=159).

Climate Change Happening Happening =1 Not happening/Don't Know = 0	Odds Ratios	(Standard Errors)
How students have experienced the impacts of climate change:		
Has not experienced	1.65	(1.22)
Not impacting me---happening too slowly/happening in other regions	4.39*	(3.31)
Impacting environment, animals, and on average hotter	4.33*	(3.24)
Not happening, natural changes	0.06*	(0.07)
Confusion weather vs. climate	42.67*	(70.02)
Incorrect science (pollution, get sick more often)	9.61	(14.48)
What would impacts look like?	4.61	(4.61)
General statement—CC impacts not good	3.49	(3.84)
Causes of Climate Change (compared to result of natural changes)		
Climate Change not happening	0.80	(0.79)
Don't know why	0.07**	(0.07)
Human activities	1.44	(1.04)
School (compared to South Kernel)		
Main St. MS	1	(empty)
North Central MS	12.78*	(14.35)
King St. MS	2.61	(2.33)
Circle MS	4.83**	(2.86)
Village MS	1	(empty)
Dad Education Level (compared to HS)		
Less than 8th grade	0.02**	(0.02)
Some high school	0.15	(0.17)
Associates Degree	0.01***	(0.02)
Some College	0.15*	(0.12)
College	0.13*	(0.11)
MA	0.65	(0.60)
MD, PhD, JD	0.05*	(0.07)
Minority (compared to European White)	1.10	(0.77)
Constant	1.61	(1.54)

*p<0.05; **p<0.01; ***p<0.001 LR Chi2 (22)=73.00 (p<0.001)

and/or it is impacting other regions are statistically significantly more likely to state that climate change is happening. Conversely, male students who attended Southern Kernel compared to male students who attended Circle MS are less likely to say that climate change is happening while holding all else constant. Similarly, a father's education level is a negative statistically significant predictor for male students to say that climate change is happening.

When the same variables are used in a model to explore statistical predictors for female students' stance on is climate change happening, none of the variables are jointly significant. There needs to be further work conducted to identify predictors for females' stances regarding anthropogenic climate change.

Table 4.16.
Overview of Findings for Generalized Linear Models in Chapter 4.

Summary of Logit Model Results	
Model	**Findings**
Random Effects Joint Logit Model (Paneled by Pre and Post): Are you worried about the impacts of climate change?	• Discuss with friends and family compared to don't discuss (positive and significant) • Females more worried compared to males (positive and significant) • Experienced the impacts of climate change (positive and significant) • Anthropogenic climate change is happening compared to not happening (positive and significant) • School student attends (significant) o Village compared to South Kernel (positive and significant) • Father's education level (negative, not significant)
Logit Model 2: Is anthropogenic climate change happening (Males)?	• How students feel they have experienced the impacts of climate change (positive and significant) except students who state not happening (negative and significant) • School student attends (negative) • Father's education level (negative and significant)
Logit Model 2: Is Climate Change Happening (Females)?	• None of the variables in the model were significant predictors for females in the sample

Patterns and Recap of Major Findings

In this section, I highlight the major findings from this chapter and provide additional context from which to explain some of those findings. This helps to delineate some of the complexities of climate change stances and their development, which are then further discussed in the next chapters. The major results discussed in this section include (a) the lack of stability of students' stances regarding the existence of anthropogenic climate change; (b) the high frequency of students' responses that there is a lack of scientific consensus regarding climate change; (c) the differences in students' climate change stances across schools; (d) the messy middle knowledge for justifying climate change stances; (e) the students' (lack of) worry regarding impacts; (f) the differences in students' climate change stances across gender; (g) the role of student self-efficacy; and (h), the comparisons of my results to the Yale Group of Climate Change Communication.

Is Anthropogenic Climate Change Happening?

While there is over 95% consensus in the scientific community that anthropogenic climate change is happening, the American public does not showcase the same consensus regarding the matter (Leiserowitz, Maibach, Roser-Renouf, Feinberg, & Howe, 2013). What do middle school students feel and think about the matter? Do they believe it is happening? Moreover, what do they think is causing the current changes in climate? A major goal of the study was to extend beyond identifying students' stances on these topics and to see if climate change stances change after participating in a purposeful evidence-based curriculum.

The results in this chapter indicate that students' stances were not stable regarding the existence of anthropogenic climate change. Their stances significantly changed in a positive direction after participating in the curricular module. This is supported by my results which show that a majority of students who either said climate change is not happening or said they do not know shifted significantly to an affirmative stance that climate change is happening (see *Figure 4.9*). Moreover, over 70% of the post-sample expressed that climate change is happening. Similarly, there was a significant shift towards stating that the current changing climate is the results of human activities. (see *Figures 4.10a and 4.10b*). The positive stance shift regarding the existence of anthropogenic climate change and its causes after interacting with an evidence-based curriculum is the basis for a major hypothesis stated in Chapter 7 based and is discussed in greater detail in Chapter 8 in the curricular suggestions and implications section.

Students State that There is a Lack of Consensus in the Scientific Community

While nearly 70% of students said climate change is human caused (with a similar frequency responding that climate change is happening), only 45% of the students said there is consensus amongst scientists that climate change is happening (see *Figure 4.11*). Why is there a disconnect between what students personally think and what they believe the scientific community's stance on the topic is?

The need for more transparent could be one factor to explain this behavior, which is discussed in Chapter 8. The curriculum presents scientific data, including graphs, figures, and models illustrating the work of the scientific community. However, the curriculum did not explicitly discuss the consensus of scientists and/or the method scientists used to collect the data, and create the figures and models. There was an activity in the curriculum that focused on the Intergovernmental Panel on Climate Change Future prediction models. In the simplified Futures models, students worked with major variables, such as energy use per person, clean energy use, and population growth rates (all variables indicated as high or low) to make predictions about the relationship between carbon dioxide concentration and temperatures in 2100. However, it was not transparent who collected these data, how the model was created, and who supported the models. This is just one example within the curriculum where data collection methods and model construction techniques were not made explicit to the students. A larger discussion of data transparency and modifying the lesson discussed above can be found in Chapter 8.

Differences by School

As mentioned above, the majority of students said that climate change is happening, but the changes and responses differed across the participating schools. Ideally, we could have clustered schools by region to make claims about regional stances. However, since the sample in this study was not a simple random sample, I cannot generalize my results by region. Additionally, the sample size was not large enough to make such claims. Instead, I discuss results and explanations at the school level. I gave characteristics about each school to provide a more robust picture of the students and other factors. Students within each school had many similar shared experiences, which I believe reduces the variance within any one school. For example, students from one school may share similar experiences of personally feeling the impacts of climate change, such as increased frequency and severity of storms, droughts and/or floods. These potential commonalities helped to create groupings. The schools also divided students by potential shared experiences, such as students who attend a school in a rural, agricultural area might have different experiences when compared to students who live in and attended school in a suburban town. Finally, there were commonalities within a classroom, where students shared the same teacher, science activities and curriculum.

As an example, all of the students who attended Main St. MS, which was located in the suburbs of a major urban center in a Midwest state, expressed on the pre-survey that they either believed climate was happening or did not know if climate change is happening. On the post survey, however, over 10% of the students stated that anthropogenic climate change was not happening. One possible explanation is based on discussions from the teacher. The curriculum was stopped after completing just over half because the teacher did not agree with the scientific statement that the curriculum made. She personally did not believe climate change was happening, expressed that sentiment to her class, and stopped the curriculum midway.

The largest cohorts of students who indicated that climate change is not happening attended schools in rural settings in the South and Midwest (see Table 4.7b). One of the teachers in those regions expressed multiple contradictory opinions on whether climate change is happening and another teacher indicated that their town was quite divided on the topic. The school which had the greatest percentage of students expressing that they believe climate change is happening was a small parochial school in a northeast city near a major military base. The teacher articulated that many students began talking about the impacts of climate change after the community was hit hard by Hurricane Sandy. Note that these examples provide anecdotal evidence about the role of the school attended in students' stances. However, due to the reasons stated above and again in a discussion of study limitations in Chapter 8, I cannot generalize these statements to geographic regions nor make causal claims. Nevertheless, the anecdotal evidence provides context for the current results and also indicates that a larger sample study is warranted.

The Messy Middle Knowledge to Justify Climate Change Stances

The majority of students (approximately 70%) agreed that climate change was happening based on responses on the post-survey. Students were asked to explain their stances on the existence of anthropogenic climate change. In the pre survey, a frequent response (20%) was (s)he does not know the reason for anthropogenic climate change. The frequency of *Don't know* responses decreased on the post survey (down to below 10%). However, the messy middle concepts expressed in certain categories remained on the post survey. These included explanations for climate change due to the earth's tilt, the sun getting closer, and approaching doomsday scenarios. However, other messy middle knowledge concepts decreased, such as providing pollution and littering as causes of climate change and associating ozone depletion with a changing atmosphere. Furthermore, there was an increase of shared responses that mixed correct scientific statements as seen by the increased edge thickness in the graphs.

Some of the students illustrate the pattern of moving from a *Don't know* stance to messy middle knowledge. Others move from the *Don't know* stance directly to stances which align with the scientific community. Others had alternative concepts previously identified in the literature, such as the association of ozone depletion with climate change, and still moved to the accepted scientific reasoning. The messy middle knowledge can coexist in parallel with accepted science as students try to reason through the complex science. This is not necessarily a linear path from don't know (or incorrect science) to messy middle concepts to accepted science. *Figure 4.21* illustrates many of the potential paths of students' reasons and justifications for their stances. *Figure 4.21* also demonstrates that messy middle knowledge (c.f. Gotwals & Songer, 2010) is a blend of knowledge concepts and is part of a spectrum of accepted science principles to misunderstandings.

If there was more contact with the content and data and/or more time to grapple with the topic, would students increase correct scientific responses? Would they then transition from the messy middle knowledge to the accepted scientific perspective? Students in this sample clearly show that there is a high difficulty in going from not having a reason for scientific phenomenon to reasoning that exhibits a full science comprehension. I argue that this transition is difficult for the majority of middle school students. Further research needs to be conducted to aid students in making the full (and non-linear) transition. Illustrations of messy middle knowledge are discussed in Chapters 6 and 7, and how to address these concepts is a focus of Chapter 8.

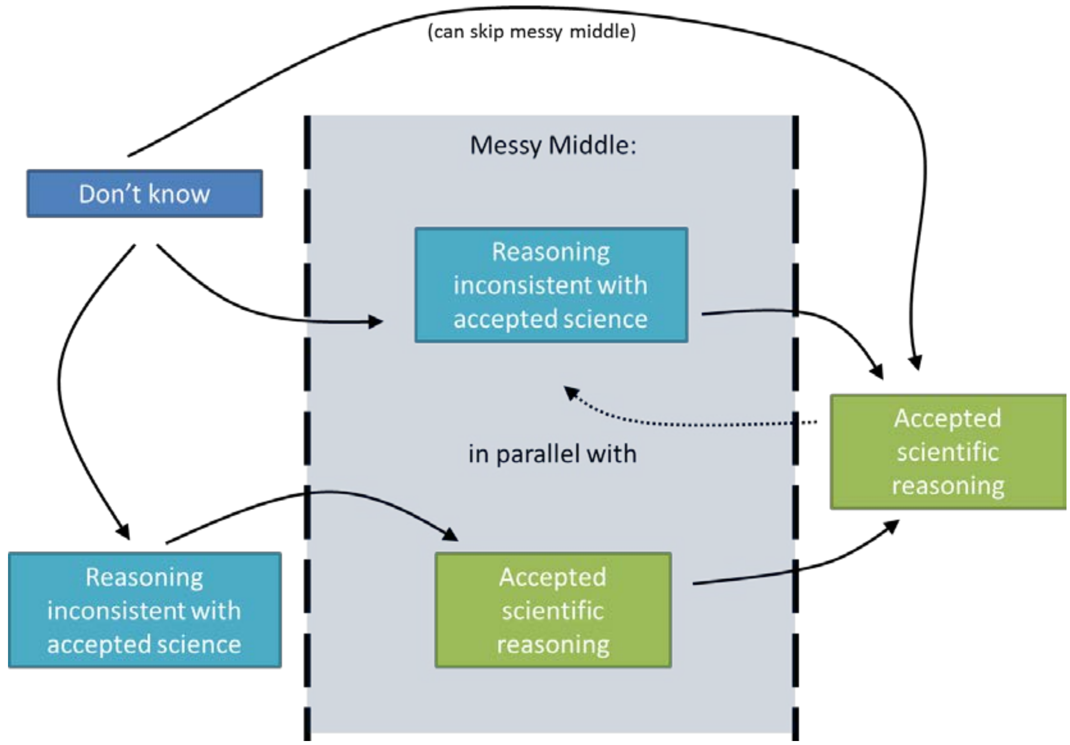


Figure 4.21. Illustration of students' reasoning (don't know, reasoning which is inconsistent with accepted science and accepted science) to explain climate change stances.

Exposure to mixture of scientific theories. Village MS is a parochial school and the students are not required to take standardized state tests. There is more flexibility in the curriculum; the teacher decided to adopt the curriculum with principal and department chair support. There was a parent who objected to the "agenda" of the curriculum. The parent was opposed to the discussion of anthropogenic climate change, specifically with regard to human-enhanced mechanisms that amplify the greenhouse effect, such as increased carbon dioxide and methane emissions. After meeting with the principal and teacher, the parent pulled the student from the study and also demanded that multiple theories of the causes of climate change were presented to the entire class. These included the following theories to explain the changing climate: (a) natural fluctuation and cycles (b) result of a change in the Earth's tilt, (c) solar variability, and (c) changing ocean currents. The parent helped the student prepare presentations to give to his peers in the science class.

Students in this classroom were exposed to multiple explanations and alternative scientific concepts to explain the widely accepted scientific view of anthropogenic climate change. This interaction with multiple explanations and theories could have lead students to confusion on how to explain the mechanisms of climate change. Furthermore, for a socio-scientific topics (e.g., political, cultural, and religious), students might not only struggle with the complexity of the science, but also the social ramifications such as whether their views align with their friends and family's beliefs on climate change. Chapter 7 provides additional discussion of socio-scientific topics as they relate to climate change education.

Complexity of the science and teaching new material. The students from South Kernel MS had stable stances and the lowest frequency of students who stated that anthropogenic climate change is happening. Based on discussions with the teacher throughout the curriculum, the teacher struggled to implement the curriculum. She found the technical component and complexity of the topic to be quite challenging for both herself and her students. When we spoke on the phone, she struggled to explain the causes of climate change as she asked questions about the lessons. While this teacher expressed that climate change is happening, the explanations (the how's and why's) the students heard may have needed clarity. With teacher confusion on the topic and potential mixed climate change stances presented, students could remain confused on the topic. In Chapter 8, I offer suggestions for pre-service and in-service teacher training and professional development opportunities to provide climate change content resources to teachers.

Students Worry and Lack of Worry Regarding Impacts

Climate change in a student's life. The results from the study indicate the importance of how students perceive climate change in their own lives with regards to students' level of worry. Specifically, students are more likely to worry about the impacts of climate change if they feel that they have been personally impacted by climate change, if they discuss the topic with friends and family, and/or if they believe that anthropogenic climate change is happening.

As discussed earlier, there is anecdotal evidence that students from Village MS, who experienced Hurricane Sandy during their curriculum, had high frequencies of affirmative responses to the question regarding the existence of anthropogenic climate change (see the Chi-squared results in Table 4.7b). Moreover, those students who expressed that they felt personal impacts of climate change were more likely to be worried. Although this anecdotal evidence cannot be generalized to say that a severe storm increases one's worry about climate change, it does raise interesting questions about this relationship. In Chapters 7 and 8, I discuss this question as well as related ones, such as how can educators help students recognize personal impacts of climate change in their own communities, and subsequently, how does this recognition translate to action and/or sustainable decision-making?

Student actions to mitigate. Students stated actions that can reduce personal carbon emissions, such as driving less, biking more, and recycling to name a few of the top responses. Similar to the above discussion, how do we as educators and curriculum designers encourage the discussions to go beyond the science classrooms? A bigger question is whether students stated actions actually translate to the actual completion of those actions. Bringing the conversation back to the beginning, if a student perceives that climate change will have an impact on their lives, will discussion of solutions and mitigation techniques lead to true action. Further studies need to be conducted to identify if there is a disconnect between statements and actual actions. This idea is discussed in more detail in Chapter 8 in the future works section.

Gender Differences in Climate Change Stances

Stability of stances by gender. There are gender differences for students' stances on climate change. For example, stances for climate change happening are more stable and less positive for males in the study as compared to females. Furthermore, there are statistically significant predictors based on variables from the survey, for whether males believe anthropogenic climate change is happening or not. The predictors include father's educational level, region where students live, the cause of climate change, and how he perceives he has experienced the effects of climate change. On the other hand, these predictor variables were not statistically significant variables for females. The other major difference is that females were more worried about the effects of global warming compared to males.

Taking into consideration the differences between the stability, predictors, and differences of male and female climate change stances is imperative for curriculum design and educational approaches. More specifically, if designers and educators are more aware that students are thinking about the subject differently, there can be more differentiated instruction to meet the needs and stances of all students in the class.

Self-Efficacy

One of the main goals of the research question was to test stability of student stances, such as climate change stances and science self-efficacy. Self-efficacy beliefs did not significantly change from before and after the curricular intervention. Both the overall efficacy category and individual variables remained stable as illustrated in *Figure 4.8***.** Moreover, there was not a statistically significant difference between male and female self-reported science self-efficacy in this study. The overall science self-efficacy variable did not correlate to self-reported science grades earned. On average, the self-efficacy variables were quite high. Students particularly felt they did well on science projects. Self-efficacy and motivation is discussed in greater detail in Chapter 7 when I look at climate change stance and knowledge development. Moreover, in Chapter 8 I build several curricular activities around the finding that students enjoy doing project-based work in science class.

Comparison to Yale Results

The student responses and the results from the Yale Group on Climate Change Communication show similar climate change stances. One result that requires further exploration and explanation is that both sample populations stated that less than fifty percent of scientists have reached consensus that global warming is happening. While more than 70% of students I sampled stated that climate change is happening, why is there a discrepancy between what students believe about climate change and what both a representative sample of the United States and the students think and what they believe is taking place in the scientific community? I believe one possible explanation for this discrepancy is the lack of knowledge of climate science data and more importantly a lack of strong and clear communication of scientists’ findings and positions with the general public. Communicating complex, sophisticated science to a lay audience is quite difficult.

There were two areas where my results and Yale results had different trends. First, when asked about the causes of global warming, a higher frequency of students (over 70% on post-survey) stated it is human-caused versus approximately 50% in the Yale results. Similarly, a greater frequency of respondents in the Yale study stated global warming is caused by natural changes as compared to students in my work. The discrepancy in frequency of responses became greater after the curricular intervention, but was present before participating in the curriculum. One possible explanation for this divide is the interaction with the topic of anthropogenic climate change in school prior to this curriculum, whereas the population in the Yale surveys was older and may not have been exposed to this topic when they were students. An additional explanation is the time difference in data collection. My data were collected several years after the Yale data were collected and published. In that time, there could have been increased media coverage of climate change issues and/or increased awareness of personally experiencing the impacts of climate change.

Another area for exploration is the relationship between moving from the recognition of human-cause climate change to taking responsibility and creating lifestyle changes. Acknowledging that increased greenhouse gas emissions are due to human actions has potentially large economic and policy implications, such as moving from a carbon-based fuel society to one that relies heavily on renewable resources. This discussion goes beyond the scope of this dissertation work, but is worth noting to explore potential influences on respondents' answers.

The second difference between my study and the Yale studies related to fewer student discussions with friends and family than the sample population in the Yale studies. One possible explanation is the difference in age between the two samples. Global warming and climate science might not be the typical conversation for a middle school student. These students were studying the topics in school, but the frequency of discussion did not change before and after the curriculum, although other stances about climate change had significant changes. In the interviews in Chapter 6, I further explore the topic of who discusses climate change outside of the classroom and what is said.

Conclusion

The results and discussion of Chapter 4 illustrate that students' climate change stances are quite complex. After participating in a purposeful curricular intervention, students' stances were not stable regarding the existence of anthropogenic climate change and its causes. However, students remained not concerned about personal climate change impacts in the near future. The students who felt that they have experienced the impacts of climate change are more worried about the impacts than others in my study. There were differences, in both stability and predictors of climate change stances for males and females in the study. In open-ended responses, students illustrated that they do not always directly transition from not knowing to the accepted scientific responses from pre to post surveys; there is a middle component that includes messy middle concepts regarding the complex topics of climate science. The patterns found in this chapter are discussed across all the results from the three main study instruments in Chapter 7.

Chapter 5: Climate Change Stances and Knowledge (Research Question 2)

Overview of Chapter 5

In this chapter, I report results and offer a discussion relating to the second research question in my dissertation work: *What are the relationships between students' climate change stances and climate change knowledge?* with the sub-question of: *Does knowledge change from before and after the curricular intervention?* The chapter is comprised of two major sections: a) results related to knowledge items only and b) results related to the connections between knowledge and stance items. For the first results section, I begin with an overview of the three main knowledge categories (see next section). I report overall scores on the pre and post assessment for each category and as well as the change in scores. I present a correlation table of all the pre and post knowledge and stance categories and I discuss findings for variables that have the strongest two statistical correlations. Results from factor analysis are then discussed and presented for both the pre and post knowledge and stance categories (*note: factor analysis has been done separately for the pre and post categories). I use the latent variables that emerged from the factor analysis along with control variables in a multivariate linear regression model using simultaneous equations to identify statistical correlations between climate change knowledge and stance variables while controlling for background variables.

In the second results section, I present a conversation about the major findings, specifically the statistical relationship that exists between climate science knowledge and climate change stances. This speaks to the development of climate change stances and knowledge.

Then I include a dialogue that looks at differences between participating schools. In Chapter 7, I use the findings from this chapter and the other results chapters to discuss patterns and findings across the entire data set.

Knowledge Categories on Assessment

There are seven items (several with multiple parts) on the knowledge assessment that I discuss in this chapter. The items from this subsample of the full assessment are divided into three content categories: (a) weather versus climate (5 points), (b) anthropogenic carbon and emissions (6 points), and (c) relationship between greenhouse gases and temperature along with other results of climate change (6 points). The maximum possible points score on the knowledge assessment is 17. The full overview of the assessment instrument can be found in Chapter 3 during the discussion of the knowledge assessment (see Appendix B for the full assessment instrument and coding rubric).

In this section, I provide a discussion of the three categories and the changes in student scores from pre to post. For each category, the number of points achieved by each student are added together to calculate total scores on both the pre and the post knowledge assessment. Each student in the sample has earned a pre and post total knowledge score. Moreover, paired t-tests are conducted to test for significant changes from before and after the curriculum. Changes from pre to post are also called learning gains throughout the discussion. A statistically significant learning gain in a category and/or overall scores indicates that there is a significant change in scores before and after participating in the curricular module.

Category One: Weather versus Climate

In the weather versus climate category, students are asked four questions for five possible points. Three points are associated with an overarching question asking students to construct an explanation to the question: *Has climate changed in Ann Arbor over the last 100 years?* Two points are associated with a single item that asks students: *What is the difference between weather and climate?* As seen on the coding rubric (Appendix B), if students defined both weather and climate correctly but they did not necessarily compare and contrast the concepts, they still received full credit. The weather versus climate category has students constructing definitions and using their working knowledge of what climate is to determine if the climate is changing in a given location.

Figure 5.1a graphs the frequencies of scores for the weather versus climate content category on the pre and posttest (n=237). On the pretest, the mean score was 1.88/5.00 points versus the posttest 2.84/5.00 points. A paired t-test showed that this change from pre to post scores was statistically significant ($p<0.001$). Moreover, when looking at learning gains in this category **(***Figure 5.1b***)**, there was a fat right tail indicating that students had positive learning gains. More than 60% of the students had a positive change (greater than zero) and approximately 25% of students had no change in score from pre to post. The remaining students had a negative shift. To further explore the first content category, I conducted paired t-tests on pre and post responses by gender, by region, and by the binary variable regarding the existence of anthropogenic climate change. Both males (n=114) and females (n=123) in the sample had positive significant changes from pre to post knowledge in the weather versus climate category

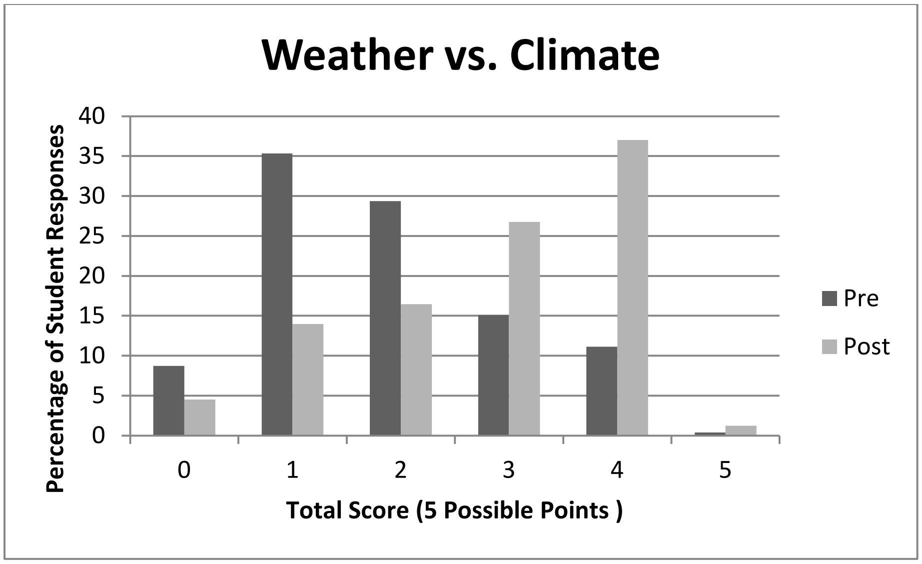


Figure 5.1a. Frequencies of total scores in the weather versus climate category on the pre and post knowledge assessment (n=237).

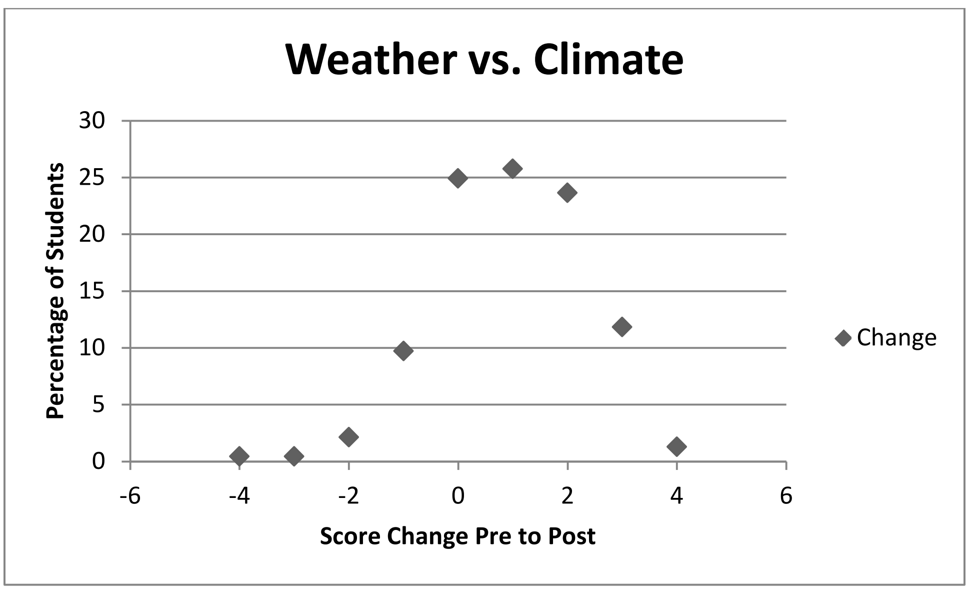


*Figure 5.1b***.** Learning gains from pre to post scores for the weather versus climate category (n=237)

However, when looking at average pre and post scores by school, only students who attended Main St MS. (p<0.001; n=23), Circle MS (p<0.001; n=140), and Village MS (p<0.001; n=20), had statistically significant positive changes in scores. Students who attended North

Central MS and King Street did not have statistically significant changes in scores for the weather versus climate category. On average, students who attended North Central MS and King St. had 0.1 and 0.2 point increases from pre to post, respectively. The students in the South Rural region were not assessed in this test because of a small cell value (n=8).

Category Two: Carbon & Anthropogenic Carbon Emissions

The overarching content category of Carbon and Anthropogenic Carbon Emissions includes topics on carbon sinks and sources and anthropogenic carbon emissions for a total of six possible points. As a reminder from Chapter 3, for two points, students are asked to identify human activities that may contribute to the warming of the Earth's climate. Additionally, for two points, students are asked to list two human activities that would decrease the impact of climate change. The final question in the category has two parts. For one point, students identify the form in which a carbon compound is typically found in the atmosphere. Then, for an additional point, students respond to the question: *Where does the excess carbon produced from cars, factories, and other activities go?*

Figure 5.2a shows students pre and post scores in the category that explores students' knowledge on carbon and anthropogenic carbon emissions. Overall, there was a statistically significant positive shift from pre to post scores in this category. On the pre-test in this category, students scored on average 2.77/6.00 points compared to the average of 4.51/6.00 points on the posttest (paired t-test p<0.001; n=168). *Figure 5.2a* graphs the pre and post scores next to each other. Over 56% of students scored five points or greater on the posttest as compared to approximately 15% on the pre-test. The average score for males and females are not statistically significantly different. Similar to the first category, when dividing the population by school attended, not all schools in the sample had significant positive changes from the pre to post assessment. On average, students who attended King St. MS did not have significant gains and/or changes in this category (n=27; p=0.30). Students who attended: Main St. MS (p <0.001; n=23), North Central MS. (p <0.001; n=19), Circle MS (p <0.001; n=72), and Village MS (p <0.05; n=19) had statistically significant positive shifts in this category. Moreover, students in the South Kernel MS (n=8) were not considered in this analysis due to a small sample size in its cell.

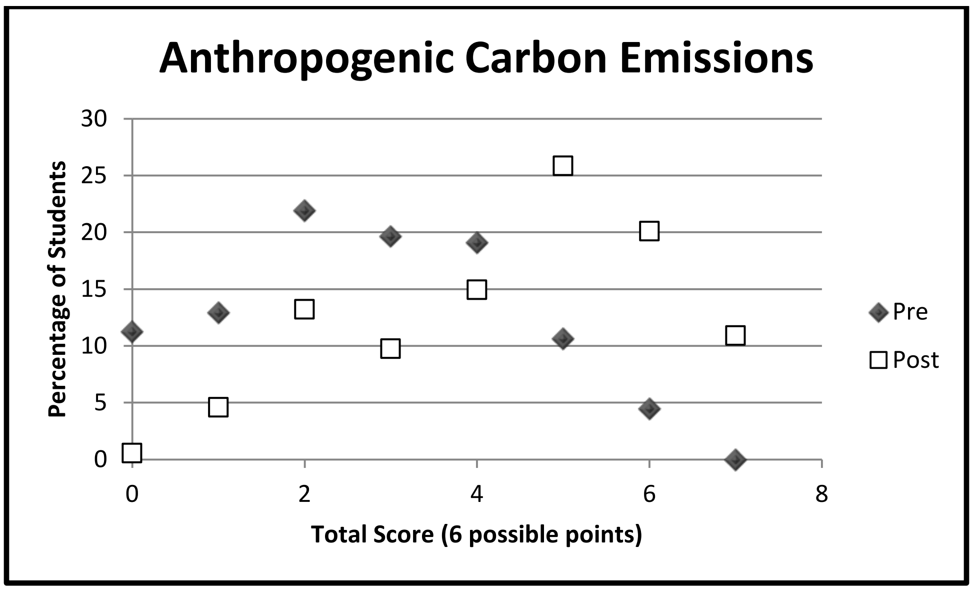


Figure 5.2a. Student pre and post scores for the overarching content category of carbon and anthropogenic carbon emissions (n=168).

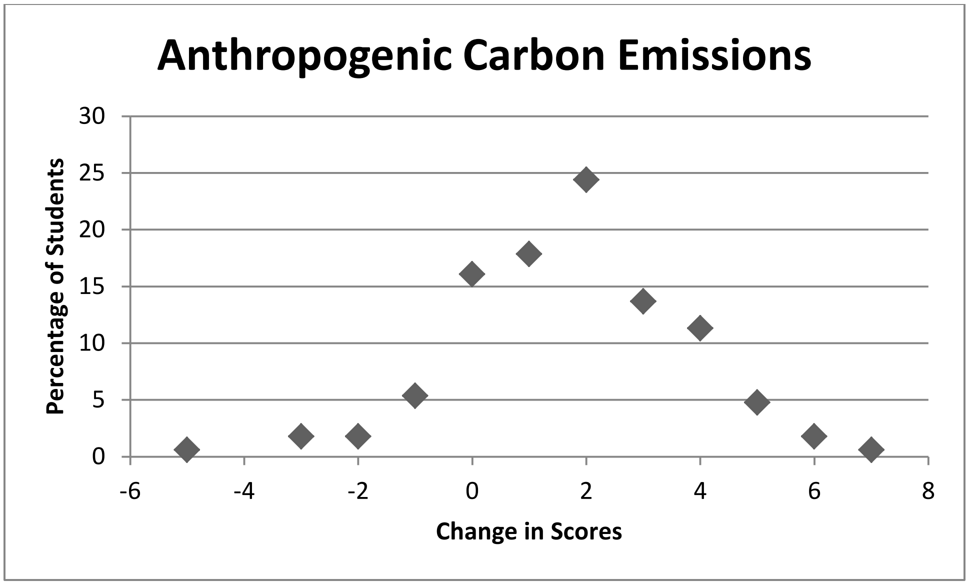


Figure 5.2b. Change in scores from pre to post for the category Carbon and Anthropogenic Carbon Emissions.

Figure 5.2b graphs the frequency of the change in scores from pre to post. It shows a an almost normal Gaussian distribution with a peak at 2 point positive change and a slight right tail indicating that, on average, students had a higher positive change from pre to post scores. Said another way, fewer students (less than 10%) had negative changes and 16% had no change from pre to post scores in this category. There was no statistical difference among the following categories with regard to changes in knowledge from pre to post: gender, whether students believe that climate change is happening, whether students are worried about the effects of global warming, and whether they feel they experienced the impacts. In all categories, there were statistically significant gains from pre to post. Analysis discussed later in this chapter was used to explore the potential relationships and correlations between knowledge and stances.

Category Three: Relationship between Greenhouse Gases and Temperature and the Results of Increasing Greenhouse Gases

The third overarching content category includes questions that explore the results of increased greenhouse gases in the atmosphere and specifically the relationship between greenhouse gases and temperature (6 total possible points). As a reminder, from Chapter 3 (Methods) students are asked the following multiple choice item: *What is predicted to be a result of global warming (1 point)?* The answer options included: (a) Rising ocean level, (b) More severe earthquakes, (c) Larger volcanic eruptions, and (d) Thinning ozone layer. The correct response is rising ocean level and the most popular incorrect answer (alternative concept) was the thinning ozone layer. Students are also asked to calculate the change in temperature in Ann Arbor over a hundred year period (1 point). The final question in this category asks students to construct an explanation using a picture of the greenhouse effect. Students first need to choose the representation that best depicts the greenhouse effect (1 point). Then, using the diagram, they construct an explanation to the question (3 points): *What happens to the earth's temperature when greenhouse gases in the atmosphere increase?*

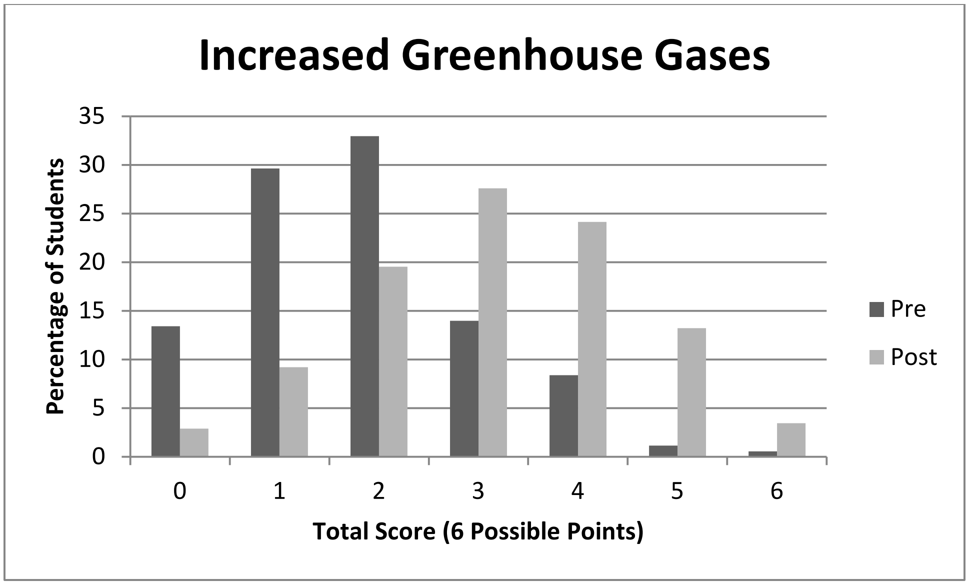


Figure 5.3a. Total score for the category of Results of Increased Greenhouse Gases by percentage of students earning each possible score (n=174).

Figure 5.3a graphs student scores for the category that explores knowledge regarding the results of increased greenhouse gases in the atmosphere. On the pre-test, 76% of the students scored zero to two points as compared to the post-test where 31.61% of the students scored in that range. Over 68% of students earned three or more points. Using a paired t-test, I calculated and compared the means of the pre and post scores. There was a statistically significant difference ($p<0.001$; n=169) in pre and post scores in this category (pre score $\mu=1.83/6$ points; post score $\mu=3.17/6$ points). All schools participating had a significant positive change in this category except students who attended North Central MS. The students from the South Kernel area were once again excluded due to a small cell size.

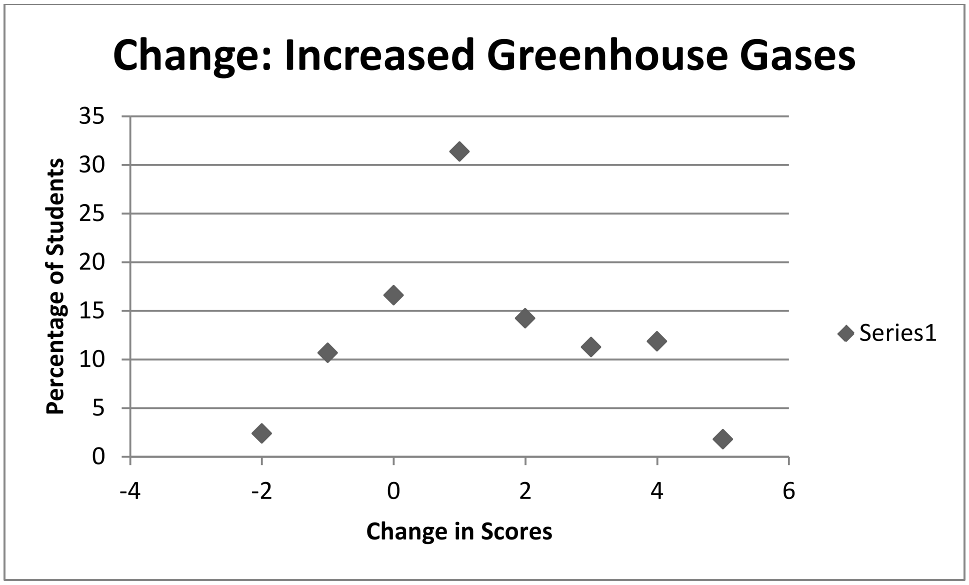


Figure 5.3b. Change in student scores by frequency of students for the category: relationship between greenhouse gases and temperature and other results of increased greenhouse gases in the atmosphere (n=169).

*Figure 5.3b*shows the change in student scores for the category that explores the relationship between greenhouse gases and temperature and other results of increased greenhouse gases in the atmosphere. As indicated in *Figure 5.3b,* 40% of the students had a positive change of at least two or more points from the pre to post assessment. The highest frequency of students increased by 1 point. Moreover, only 13% of the students in the sample decreased in score in this category. There was no statistically significant difference in changes for males and females or by school. Similarly, when exploring changes by climate change stances, such as level of worry and the existence of anthropogenic climate change, there was no statistically significant difference in change in scores based on student responses to the pre and post stance surveys. Table 5.1 gives a summary of the results from this section.

Table 5.1
Summary of Significant Changes in Knowledge Categories by School.

Category	**Schools with Significant Changes**	**Schools with NO significant changes**
Weather vs. Climate	• Main St. • Circle MS • Village MS	• North Central • King St.
Carbon and Anthropogenic Carbon Emissions	• Main St. • Circle MS • Village MS • North Central	• King St.
Results of Increased GHG and Relationship between GHGs and Temperature	• Main St. • Circle MS • Village MS • King St.	• North Central
Overall significant increases out of three knowledge categories: Main St (3/3), Circle MS (3/3), Village (3/3), North Central (2/3), King St. (2/3)		

Section II: Correlations and Factor Analysis

In this section, I present a correlation table illustrating the statistical relationships between variables in order to see patterns in the data between pre and post knowledge and stance variables. I then present the results of a factor analysis that was used as a data reduction technique to reduce variance and to create latent factors to be used in regressions later in the chapter. I present the results of the principal component factor analysis for both the pre and post knowledge and stance variables. The results include scree plots and factors loadings to illustrate how each factor was created. I give an overview of the factors formed, which leads into the third section of this results chapter.

Pairwise Correlations

Prior to conducting factor analysis, I constructed a correlation table (Figure 5.4) of all the variables of knowledge and stances. The correlation table indicates potential relationships between the variables that are used in the factor analysis.

		Pre Knowledge			Post Knowledge			Pre Stances				Post Stances			
		Weather Climate	Carbon	Result GHG	Weather Climate	Carbon	Result GHG	Causes/ Climate Change	CC in Lives	Actions Mitigation	Science Self-Efficacy	Causes/ Climate Change	CC in Lives	Actions Mitigation	Science Self-Efficacy
Pre Knowledge	Weather Climate	1.00													
	Carbon	0.25	1.00												
	Result GHG	0.28	0.38	1.00											
Post Knowledge	Weather Climate	0.29	0.20	0.10	1.00										
	Carbon	0.19	0.32	0.09	0.42	1.00									
	Result GHG	0.14	0.28	0.20	0.50	0.54	1.00								
Pre Stances	Causes/ Climate Change	0.13	-0.05	0.06	0.10	0.12	0.23	1.00							
	CC in Lives	0.03	-0.14	-0.06	0.11	0.00	0.12	0.33	1.00						
	Actions Mitigation	0.16	0.06	0.21	0.19	-0.01	0.16	0.29	0.19	1.00					
	Science Self-Efficacy	0.08	0.08	0.18	0.08	0.02	0.06	0.14	0.19	0.08	1.00				
Post Stances	Causes/ Climate Change	0.14	0.14	0.11	0.12	0.16	0.12	0.36	0.19	0.03	0.09	1.00			
	CC in Lives	0.06	0.04	0.07	0.12	0.04	0.13	0.23	0.62	0.12	0.10	0.30	1.00		
	Actions Mitigation	0.31	0.13	0.18	0.18	0.12	0.13	0.16	0.16	0.16	0.07	0.40	0.26	1.00	
	Science Self-Efficacy	0.16	0.14	0.30	0.11	0.11	0.01	0.15	0.13	0.21	0.57	0.10	0.13	0.17	1.00

Figure 5.4. Two-way correlation table for pre and post knowledge and stance variables.

Figure 5.4 provides the pairwise correlations between pre and post knowledge and stance categories. The highest knowledge correlations existed between post knowledge scores in the following categories: (a) the results of greenhouse gases in the environment and (b) carbon and anthropogenic carbon emissions (rho= 0.54) followed by post knowledge in: (a) weather and climate and (b) results of greenhouse gas emissions (rho=.50), followed by post knowledge scores in: (a) weather and climate and (b) carbon and anthropogenic carbon emissions. Said another way, students who did well in those categories discussed above on the post knowledge assessment generally also did well in the other categories mentioned above. Consistently, there were positive correlations between pre to post knowledge and stance scores within the same category (e.g., stance exploring climate change in students' lives rho=0.62 and knowledge categories carbon and anthropogenic carbon emissions rho= 0.32).

The highest correlation between knowledge and stances existed between pre knowledge in the weather and climate category and post stances in the category actions to mitigate and/or adapt to climate change (rho=0.31) followed by a student's pre stances on (a) is anthropogenic climate change happening and (b) the post knowledge score of results of greenhouse gases in the atmosphere (rho=0.33). The highest positive correlation between climate changes stances occurred between the following two categories: (a) actions to mitigate and/or adapt to climate change and (b) the existence of anthropogenic climate change happening and its causes (rho=0.40) followed by: (a) post stances for the existence of anthropogenic climate change and its causes and (b) climate change in students' lives (rho=0.30), followed by post stances for (a) climate change in students' lives and (b) actions to mitigate and/or adapt to climate change (rho=0.26).

Just as in the knowledge categories, there were higher correlations within stance categories in the post results. Moreover, a student with positive climate change stances (i.e. the stances that align most directly with the majority of the scientific community) on average had more positive stances in the other stance categories. The correlations within and between knowledge and stance categories are explored further in the factor analysis and regression models later in the chapter.

Factor Analysis

As discussed in more detail in the methods section in Chapter 3, exploratory factor analysis was conducted over both the pre and post stance and knowledge variables. Factor analysis is a data reduction technique to reduce several correlated variables into a single unobserved variable (i.e. a factor). Note that all variables were standardized prior to factor analysis in order to have all variables on a comparable scale. A Kaiser-Myer-Olkin (KMO) measure of sampling adequacy over these variables was conducted to explore if I could proceed with factor analysis. The KMO value for the pre knowledge and stance variable was 0.64. Similarly, a KMO value of 0.69 was found for the post knowledge and stance variables. These KMO values are moderate and warranted proceeding with constructing factors.

Factor analysis pre knowledge and pre stances. The results of principal component factor analysis for the pre knowledge and stance variables indicate two potential factors with eigenvalues greater than one (indicating that they were more explanatory than the individual variables). Note that the eigenvalues are proportional to the variance explained by the potential factors. A scree plot in *Figure 5.5a* shows the eigenvalues for the factors**.** The scree plot shows an elbow in the curve indicating diminishing returns (or shallower slope) at around two factors. In *Figure 5.5a*, the elbow/level off point happens below the second factor. Thus, only the first two factors were considered. The factors to the right of the elbow were not strong enough factors to use in further analysis.

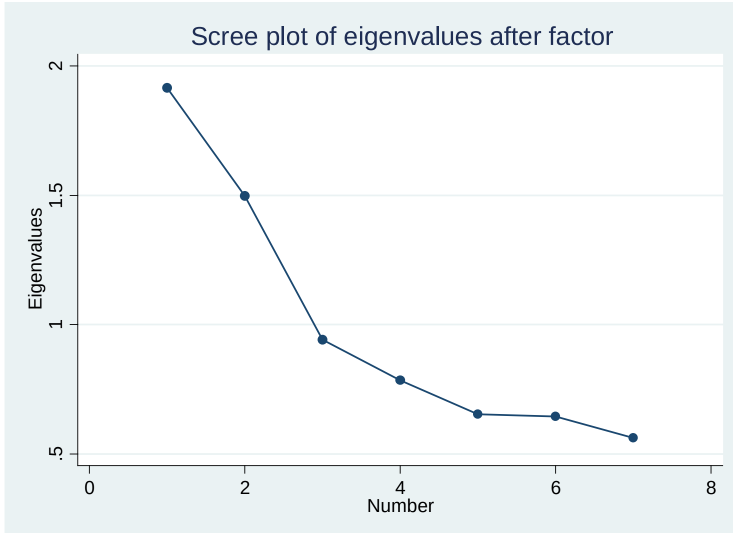


Figure 5.5a. Scree plot of variances of pre knowledge and stances to determine factors.

I performed a promax (oblique) rotation of the factors. The loadings are shown in Table 5.2. Note that in oblique rotations, the factors are no longer orthogonal (i.e., changes in one factor may be correlated with changes in other factors). Generally, factors obtained using oblique rotations have more natural explanations than for orthogonal rotations where the factors cannot be correlated with each other. Table 5.3a shows the loadings of the first two factors as given by principal component analysis. Note that the factors formed were used as the variables in later regressions models. Moreover, it is important to not only look at the loadings quantitatively, but to also qualitatively explain the groupings to ensure that they make sense together. This may lead to latent factors that explain the variance in the data in the statistical models. Note, loadings less than the absolute value of 0.3 are not displayed in Table 5.3a.

Table 5.2

Rotated Factor Loadings for Two Possible Factors from Pre Knowledge and Stance Category Variables.

Variables ***note all variables have been standardized**	**Factor 1**	**Factor 2**
Pre Knowledge Assessment Score:		
Weather and Climate	0.63	-
Carbon Dioxide	0.80	-
Results of climate change/GHG emissions	0.79	-
Pre Stance Survey		
Climate change and causes		0.75
Climate change in students' lives		0.74
Actions and mitigation to reduce CC		0.55
**Note blank cells represent absolute value loadings <0.3*		

The pre knowledge score categories had similar rotated factor loadings, where all categories loaded into a single factor. Thus, the pre climate change knowledge is treated as a single variable in the models moving forward. The three categories of climate change stances had similar factor loading values to one another. The categories of climate change stances and its causes, climate change in students' lives, and actions and mitigation plans to reduce climate change loaded similarly onto the second factor and are treated as a single pre climate change stance variable in models moving forward.

Factor analysis post knowledge and post stances. The results of principal component factor analysis for the post knowledge and stance variables also indicated two potential factors with eigenvalues greater than one. A scree plot shows the eigenvalues for the factors (*Figure 5.5b*).

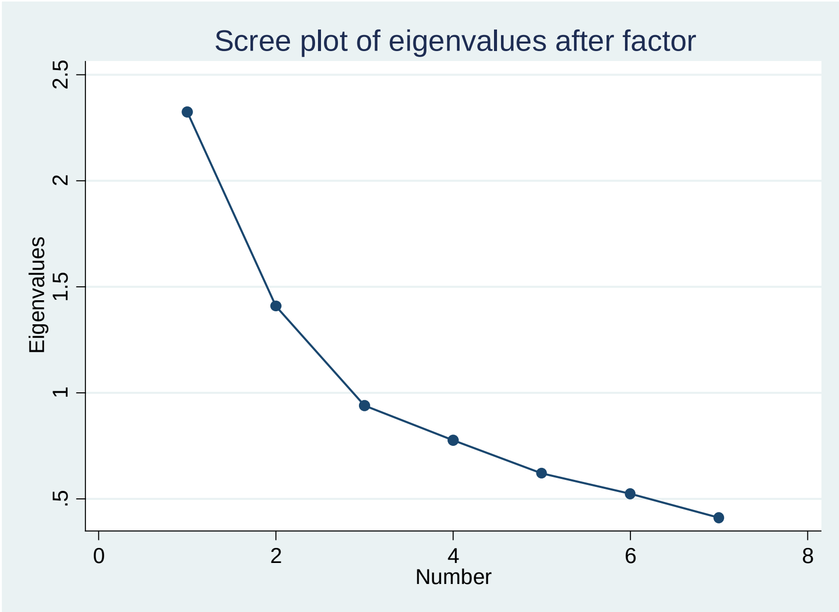


*Figure 5.5b***.** Scree plot of variances of post knowledge and stances to determine factors.

The scree plot shows an elbow in the curve indicating diminishing returns (or shallower slope) at around two factors. Once again, the factors to the right of the elbow were not strong enough factors to use in further analysis.

Table 5.3

Rotated Factor Loadings for Two Possible Factors from Post Knowledge and Stance Category Variables.

Variables *note all variables have been standardized**	**Factor 1**	**Factor 2**
Post Knowledge Assessment Score		
Weather and Climate	0.78	
Carbon Dioxide	0.82	
Results of climate change/GHG emissions	0.86	
Post Stance Survey		
Climate change and causes		0.76
Climate change in students' lives		0.66
Actions and mitigation to reduce CC		0.75

**Note blank cells represent absolute value loadings <0.3*

A promax (oblique) rotation of the factors was performed for the post variables. The loadings are shown in Table 5.3. Similar to the pre stance and knowledge rotated factor analysis, the post knowledge variables: (a) weather and climate, (b) carbon and anthropogenic carbon dioxide emissions, and (c) results of climate change and greenhouse gas emissions had similar factor loadings. The post knowledge variables loaded on a single factor and are treated as a single variable moving forward. The post climate change stance variables also had similar loadings to each other on the second factor. The student post science self-efficacy variable had a smaller loading than the other post stance variables. Moving forward, post climate change stances are treated as a single factor in analysis and post science self-efficacy remains as a stand-alone variable.

Collectively, these factors indicate that there may be some statistical relationships between knowledge and stances, both before and after a curricular intervention. These potential relationships are explored in the regressions later in this chapter, both for purposes of defining the relationships as well determining their statistical significance. In order to use these factors (rotated) in analyses, the following variables were constructed as being explanatory of the variance in the data:

- Pre knowledge score (over the three knowledge categories)
- Post knowledge score (over the three knowledge categories)
- Pre climate change stances score (over the three climate stance categories)
- Post climate change stances score (over the three climate stance categories)

Note that each of the factors discussed above are formed using the variables listed above. Moreover, using these variables reduces the variance in later regressions as compared to using the individual variables, which leads to more interpretable results with less noise. Additionally, the pre and post science self-efficacy variables were used in analysis as individual, standardized variables.

Section III: Multivariate Linear Regression Using Simultaneous Equations

In this section, I present results of a multivariate linear regression using simultaneous equations. The dependent variables in the model are pre and post knowledge factors and pre and post stance factors. The independent variables include control variables such as mother's education level, gender, and science grade. Additionally, to explore the statistical relationships between knowledge and stances, pre stance and knowledge variables were evaluated as independent variables.

The model was constructed as shown in *Figure 5.6*, where the β parameters are jointly estimated across both equations. This model takes into consideration that the standard errors are correlated across the equations. Furthermore, posttests were executed to evaluate changes from pre to post variables, as well as to explore if a covariate has a different statistical effect on the pre and post variable. This analysis allows for comparisons across the equations (e.g., from pre to post changes). While the results cannot be discussed as causal because there was not a control group enacted in this study, I can evaluate and discuss statistical relationships between climate change knowledge and stances before and after participating in the curriculum.

EQ 1:

$$\begin{bmatrix} Pre\ CC\ Stances \\ Pre\ CC\ Knowledge \end{bmatrix} = \begin{bmatrix} \boldsymbol{\beta}_{pre,stances} \\ \boldsymbol{\beta}_{pre,knowledge} \end{bmatrix} \begin{bmatrix} School \\ Gender \\ Gender \times Science\ Grade \\ Science\ Grade \\ Mother's\ Education\ Level \end{bmatrix}$$

EQ 2:

$$\begin{bmatrix} Post\ CC\ Stances \\ Post\ CC\ Knowledge \end{bmatrix} = \begin{bmatrix} \boldsymbol{\beta}_{post,stances} \\ \boldsymbol{\beta}_{post,knowledge} \end{bmatrix} \begin{bmatrix} g(Pre\ CC\ Stances) \\ Pre\ CC\ Knowledge \\ Gender \times Pre\ CC\ Knowledge \\ School \\ Gender \\ Mother's\ Education\ Level \end{bmatrix}$$

$$g(x) = sign(x)x^2$$

Figure 5.6. The figure provides equations (EQ 1) and (EQ 2) used in the multivariate linear regression using simultaneous equations to take into account correlated standard errors. The coefficients of the system of equations are jointly estimated to explore the statistical relationship between climate change knowledge and stances across pre and post time points. Then, post tests are conducted to estimate the significance of changes in responses from pre to post instruments and the statistical impact of covariates on the dependent knowledge and stance variables.

Table 5.4
Multivariate Linear Regression Using a Simultaneous Equation Solution to Explore the Statistical Relationship between Climate Change Knowledge and Stances.

Multivariate Linear Regression Using a Simultaneous Equation Solution

Pre Stance Score (n=168); RMSE=0.87, $\chi 2 = 36.08$ r^2=0.18, p=0.0017
Pre Knowledge Score (n=168); RMSE=0.87, $\chi 2 = 41.07$; r^2=0.19, p=0.0003
Post Stance Score (n=168); RMSE=0.96, $\chi 2 = 75.26$; r^2=0.12; p<0.0001
Post Knowledge Score (n=168); RMSE=1.00, $\chi 2 = 163.54$; r^2=-0.06; p<0.0001

	Coefficient	(Standard Errors)
Pre Stance Score		
School (compared to Circle MS)		
Main Street	-0.0006	(0.22)
North Central	-0.57**	(0.23)
South Kernel	-0.61	(0.35)
King Street	-0.59**	(0.21)
Village MS	0.058	(0.24)
Female (compared to Male)	0.21	(0.29)
Science Grade (reverse coded)	-0.005	(0.08)
Male*Science Grade (reverse coded)	-0.23*	(0.12)
Mom Education (compared to HS)		
Less than 8th Grade	-0.47	(0.43)
Some HS	-0.12	(0.28)
Associates Degree	-0.11	(0.30)
Some College	-0.24	(0.22)
College	0.18	(0.21)
MA	0.31	(0.23)
MD, PhD, JD	-0.67	(0.47)
Constant	0.66*	(0.32)

	Coefficient	(Standard Errors)
Pre Knowledge Score		
School (compared to Circle MS)		
Main Street	-0.66**	(0.22)
North Central	0.39	(0.23)
South Kernel	-0.40*	(0.35)
King Street	0.01	(0.21)
Village MS	0.03	(0.24)
Female (compared to Male)	-0.11	(0.27)
Science Grade (reverse coded)	-0.19*	(0.08)
Male*Science Grade (reverse coded)	0.07	(0.11)
Mom Education (compared to HS)		
Less than 8th Grade	0.14	(0.42)
Some HS	-0.24	(0.28)
Associates Degree	-0.27	(0.30)
Some College	-0.25	(0.22)
College	-0.13	(0.21)
MA	0.26	(0.23)
MD, PhD, JD	0.29	(0.47)
Constant	0.52	(0.26)

Post Climate Change Stance		
School (compared to Circle)		
Main Street	0.05	(0.25)
North Central	-0.19	(0.26)
South Kernel	-0.69	(0.39)
King Street	-0.17	(0.23)
Village MS	0.34	(0.28)
Female	0.32*	(0.15)
Pre Stance Score Squared	0.19***	(0.05)
Pre Knowledge Score	0.91*	(0.41)
Mom Education (compared to HS)		
Less than 8th Grade	-0.42	(0.46)
Some HS	0.58*	(0.30)
Associates Degree	0.62	(0.33)
Some College	0.26	(0.24)
College	0.12	(0.24)
MA	-0.61*	(0.29)
MD, PhD, JD	-0.48	(0.50)
Female*Pre Knowledge Score	-0.35	(0.41)
Constant	-0.18	(0.21)

	Coefficient	(Standard Errors)
Post Knowledge Score		
School (compared to Circle MS)		
Main Street	-0.62**	(0.25)
North Central	-1.28***	(0.25)
South Kernel	-1.07**	(0.38)
King Street	-1.45***	(0.22)
Village MS	-1.01***	(0.27)
Female (compared to Male)	0.13	(0.15)
Pre Stance Score Squared	0.032	(0.04)
Pre Knowledge Score	1.31**	(0.40)
Female * Pre Knowledge Score	-0.47	0.40
Mom Education (compared to HS)		
Less than 8th Grade	-0.03	(0.46)
Some HS	0.20	(0.30)
Associates Degree	-0.05	(0.33)
Some College	0.07	(0.24)
College	0.001	(0.24)
MA	-0.26	(0.29)
MD, PhD, JD	-0.37	(0.50)
Constant	0.59**	(0.21)

$p\leq0.05$, *$p\leq0.001$, ***$p\leq0.0001$

This multivariate linear regression using simultaneous equations was found to be a statistically significant model. The quadratic covariate for pre climate change stances in the post model (EQ 2) indicates that students' with either strong positive or negative pre stances (i.e., the extremes, since a neutral stance was centered around zero) had a significant correlation with students' post climate change stances. In contrast, the quadratic covariate for pre knowledge was found to be insignificant in the post model, and therefore was not included. A linear pre knowledge score covariate was included in the post (EQ 2) model and was found to be a significant positive predictor of both a student's post climate stances and post climate knowledge. However, a student's pre climate change stance was not a significant covariate for the dependent variable post knowledge. Moreover, the school a student attended was a negative coefficient for post knowledge score when compared to students at Circle Middle School, but not a statistical predictor of a student's post stance score. .

Post Tests on Multivariate Regression Model

Post tests on the multivariate regression model were done to explore significant changes from pre to post stance survey and knowledge assessment responses. The school coefficients changed significantly for climate change knowledge score from the pre to post instrument. The school a student attended was a significant variable for all schools compared to Circle MS on the post survey and for two schools on the initial assessment. However, the school coefficient did not change significantly for a student's climate change stance. Pre knowledge was tested to see if it had a statistically significant different effect on post knowledge versus post stances. The test was not significant, which demonstrates that pre knowledge statistically affected post knowledge and post stances in a similar manner.

Finally, I examined if the pre climate change stances quadratic function had a significantly different statistical relationship among post climate change knowledge versus post climate change stances. The test showed a statically significant difference (p=0.0043), suggesting that the effect of pre climate change stances is jointly significant on both post climate change knowledge and post climate change stances. *Figure 5.7* illustrates the overall findings from the multivariate linear regression. All correlations discussed above are conditional on all other control variables in the model.

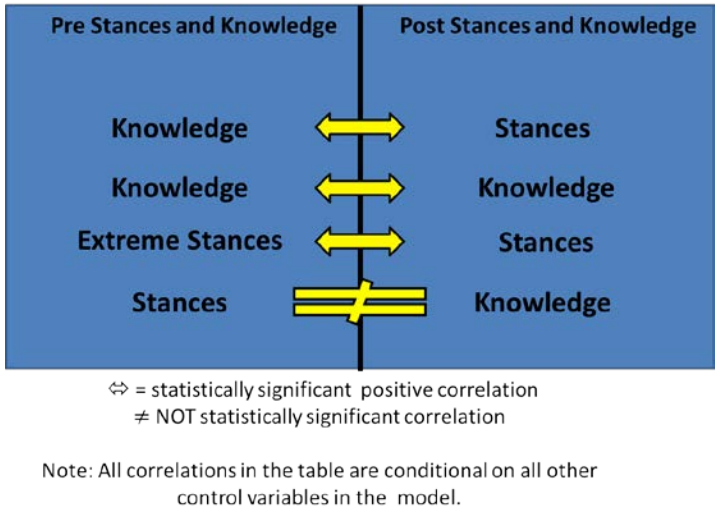


Figure 5.7. Statistically significant positive correlations exist pre knowledge and post stances, and pre knowledge and post knowledge. The pre stances sign squared term is significantly correlated with post stances. There is no significant correlation between pre climate change stances and post climate change knowledge. The double arrows indicate positive statistically significant relationships between the stated variables and the not equal sign indicates that there is no statistically significant relationship.

Patterns and Recap of Major Findings

The research question that I explored in this chapter was "w*hat are the relationships between students' climate change stances and climate change knowledge?*" with the sub-question of "d*oes knowledge change throughout the curriculum?*" In this section, I begin with a dialogue about the relationship between climate change stances and knowledge. Pre knowledge is a statistically significant, positive predictor of a student's post climate change stance. However, pre climate change stances are not significant predictors of a student's post climate change knowledge. Students with the extreme pre climate change stances (e.g., squared sign pre stance score) had significant correlations to post climate change stances. After the discussion of the main findings between climate change knowledge and stances, I enter into a conversation about differences between participating schools in terms of learning gains pre and post curricular intervention and the differences between schools on pre and post climate change knowledge and stances.

Summary of Statistical Relationship between Climate Change Knowledge and Stances

The main overarching goal of the chapter was to explore if a statistical relationship existed between a student's climate change knowledge and stances. Both the results of the pre and post knowledge assessment and pre and post stance survey were used to explore these relationships. The correlations stated below are conditional on all other control variables. The major findings of this chapter are reiterated below:

- Pre knowledge and post knowledge load to one factor each (a pre knowledge and post knowledge factor).
    - Those who do well in one category do well across the three categories on the both the pre and post knowledge assessment, respectively.
- Pre knowledge is a positive predictor of both a student's post knowledge and post climate change stances.
- Pre and Post Climate Change stances load to one factor each (pre climate change stances and post climate change stances).
    - Those who have positive stances in one category have positive stances in all three categories on both the pre and post climate stance surveys, respectively.
- Extreme (positive or negative) Pre Climate Change Stances are a significant predictor for post climate change stances.
- Pre Climate Change Stances are NOT a statistically significant predictor for pre or post climate change knowledge.

To explore the lack of significant correlation between pre climate change stances and post knowledge further, I divided student stances into negative, neutral, and positive categories. Once again, I found no significant coefficients for pre-stances in any stance category in the regression models for pre and post knowledge. On the other hand, in Chapters 6 and 7, I explore student stances through interviews completed months after the curriculum, where evidence of a potential relationship is presented. The claims stated above are not causal, but rather claims about significant correlations between high knowledge and positive climate change stance. The findings speak to the point that one's climate stances can change, and moreover, when they change, they have a relationship to knowledge development.

More work needs to be conducted, specifically a controlled quasi-experimental design, to further explore the above findings. I want to systematically approach the relationship between climate change stances and knowledge to conclusively determine whether one sets the foundation for the other to change and/or develop. This idea is further explored in Chapters 7 and 8.

Differences by School

Throughout the chapter (starting with changes from pre to post knowledge by category and then exploring how the school one attends statistically predicts s a student's pre/post climate change knowledge and stances in regressions), the school one attends was a significant variable in this analysis. As seen in Table 5.1, the majority of schools had significant learning gains from before and after the curricular intervention in the three knowledge categories: (a) weather versus climate, (b) carbon and anthropogenic carbon emission, and (c) results of increased carbon emissions/the greenhouse effect and temperature. However, King Street did not have gains in the first two categories (e.g., A and B) mentioned above and North Central did not have gains in knowledge categories A and C. The reasoning for the gains by the other schools in all three categories, but not by North Central and King Street, can only be speculative. I do not have causal evidence about teaching, learning approaches, and/or how well the curriculum was enacted that could explain these differences.. However, the teacher from North Central emailed me with anecdotal evidence to help explain the findings. She described her school and general feelings about climate change in the following way:

> I teach in a rural part of NC (*Deliverance* was filmed 20 miles south of here, to give you some context J). The students, as young adolescents, parrot a lot of what they hear from mom, dad, and the preacher. When I first asked the students what climate change is, at *least* one kid in each of my 4 classes told us that it doesn't exist. By the end of the unit, I had one kid in the whole grade who still was arguing, and all the other students told him exactly what they thought of that- using IPCC data to support their arguments (Mrs. H, Teacher for North Central Students, 5/30/13).

As Mrs. H describes, there is some sentiment in the community that might be influencing her students to not have stances that align with the majority opinion. Moreover, the teacher from Kansas discussed that she really stuck to the curriculum and did not enter into discussions about stances because she felt there were many dissenting opinions on the matter. Student's climate change stances are discussed in more detail in later chapters, specifically students from King Street in Chapter 6 when presenting the interview data.

Schools in pre stances and knowledge. Before curricular intervention, the school variable was significant for two schools compared to Circle MS (and jointly significant overall). In particular, students from Main Street and South Kernel had overall more negative pre climate change stances as compared to students who attended Circle MS.

Again, based on purely anecdotal evidence, the teachers from Main St. expressed that this was the first time students were exposed to both the climate science topics and practices of constructing explanations. Teachers from the other schools did not comment on how new the material was to their students or their personal teaching practices. Thus, previous experiences may be one possible explanation for lower pre-knowledge scores.

Schools in post knowledge. The school a student attended remained to be a significant predictor of a student's post knowledge score. Compared to Circle MS, all other schools performed less well on the post knowledge assessment. Compiling all the information about the school, teacher, and how well they followed the curriculum, it was evident that the students at Circle MS completed the curriculum in its entirety and the teacher was extremely comfortable with the content and practices in the intervention. Moreover, this teacher was one of two teachers who attended an in-person professional development that we conducted in Kentucky. While I cannot say with certainty that other teachers and students had similar experiences with the curriculum (teaching and learning), the higher post knowledge scores from Circle MS could potentially be explained by the above factors.

Conclusion Chapter 5

There was a positive statistical relationship between climate change knowledge and stances. There was a significant correlation between strong knowledge and consistent, positive stances. Furthermore, there was no statistical correlation between pre stances with post climate change knowledge. The statistical findings from the multivariate linear regression model suggest strong correlations between knowledge and stances, but I cannot make claims about causality as discussed in the limitations section of Chapter 8. Moreover, the quadratic term for pre stances to post stances was significant. This can be interpreted as saying those students with extreme pre stances (positive or negative) had a stronger statistical relationship between his/her pre and post stances. I further explore the relationship between knowledge and stance development in Chapters 6 and 7.

Chapter 6: Student Interviews: Complexities of Stances and Knowledge (Research Question 3)

Overview of Chapter 6

The results I present in chapter 6 investigates the following research question: *How do we characterize the complexities and persistence of students' climate change stances?* I attempt to answer the research question using data and analyses from twenty-five semi-structured interviews from three geographic locations. All students interviewed participated in the curriculum and took both the pre/post knowledge assessments and stance surveys. In the methods chapter (Chapter 3), I specifically outline how the interviews were organized, coded, and analyzed. The full semi-structured interview protocol can be found in Appendix C. As a reminder, the interviews were conducted 4-6 months after students completed the curricular module. The interviews both complement and add to the findings of the quantitative analyses in Chapters 4 and 5. Note, a cross analysis of the findings of the pre/post stance surveys, pre/post knowledge assessment, and interviews is discussed in Chapter 7.

The responses to the student post semi-structured interview and the findings of the Six America's study (Leiserowitz, Maibach, Roser-Renouf, & Smith, 2011) guided the creation of the ordinal stance categories. In this chapter, I focus on creating the stance categories based on student responses, identifying major themes in the interviews, and using student exemplars to highlight the varied stances and findings in the interviews. Student responses informed the design and spread of categories. The categories cover if students believe that anthropogenic climate change is happening and how worried students are about the impacts of climate change.

I present frequency data relative to the ordinal stance categories and student responses to highlight patterns within and across the stance categories.

I focus on student examples as illustrations of student responses from within each stance category. The student exemplars are meant to give an in-depth view of student responses, but cannot be generalized for each category. Finally, I lead a discussion to illustrate differences and similarities across the exemplars and categories. There are general themes that emerged from the student responses that I highlight and discuss in more detail at the end of the chapter.

Choosing Students to Interview: A Reminder from Chapter 3

As a reminder, student post semi-structured interviews were conducted at three locations to complement the information/data collected from over three hundred students who participated in the Climate Change and Its Impacts on Ecosystems curriculum (Songer, et al., 2012). As mentioned in Chapter 3, the students were interviewed in September and October 2013 after completing the curriculum in spring 2013. In an attempt to interview students with diverse knowledge and stances on climate change, students were divided into four categories (see *Figure 6.1*) based quantitative analysis of the students' pre/post survey and knowledge assessment. The students were placed in categories relative to their peers' stances and knowledge. Please note, that high stances are categorized as those opinions/positions that are aligned with the majority of the scientific community. These categories were only used for pre-processing purposes to select students to interview. The details of the protocol of how students were chosen for interviews can be found in Chapter 3.

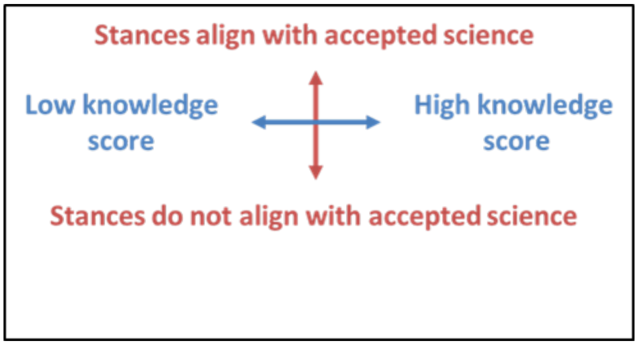


Figure 6.1. Students from each category (e.g., stances align with accepted science with high knowledge or low knowledge, stances do not align with accepted science with high knowledge or low knowledge), were interviewed at three geographic locations to attempt to get a diverse sample of respondents. The four knowledge and stances categories for interview selection were created from responses on pre/post knowledge assessment and stance survey. Students from all four categories were interviewed at each location to attempt to talk to a diverse group of students.

Climate Change Ordinal Stance Categories

I created climate change ordinal stance categories from most positive to most negative stances similar to the Six America's Study (Leiserowitz, Maibach, Roser-Renouf, & Smith, 2011). I used the responses to the following interview questions to construct the climate change stance ordinal categories: (a) is anthropogenic climate change happening? and (b) how worried are you about the impacts of climate change? Note, moving forward the two questions used to create the scale are referred to as the ***stance category items***.

Six America's Study

The Yale Group on Climate Change Communication (YGCC) conducted a representative sample of Americans to capture Americans' beliefs, behaviors, and policy stances on global warming topics. The initial study findings placed the survey participants in six defined categories based on responses to the survey items. The Global Warming's Six America's categories are: Alarmed, Concerned, Cautious, Disengaged, Doubtful, and Dismissive (*Figure 6.2*). The study then tracked members in each group every two years in a longitudinal study to see how beliefs, behaviors, and policy preferences have changed. The study is discussed in greater detail in Chapter 2 during the review of the current literature.

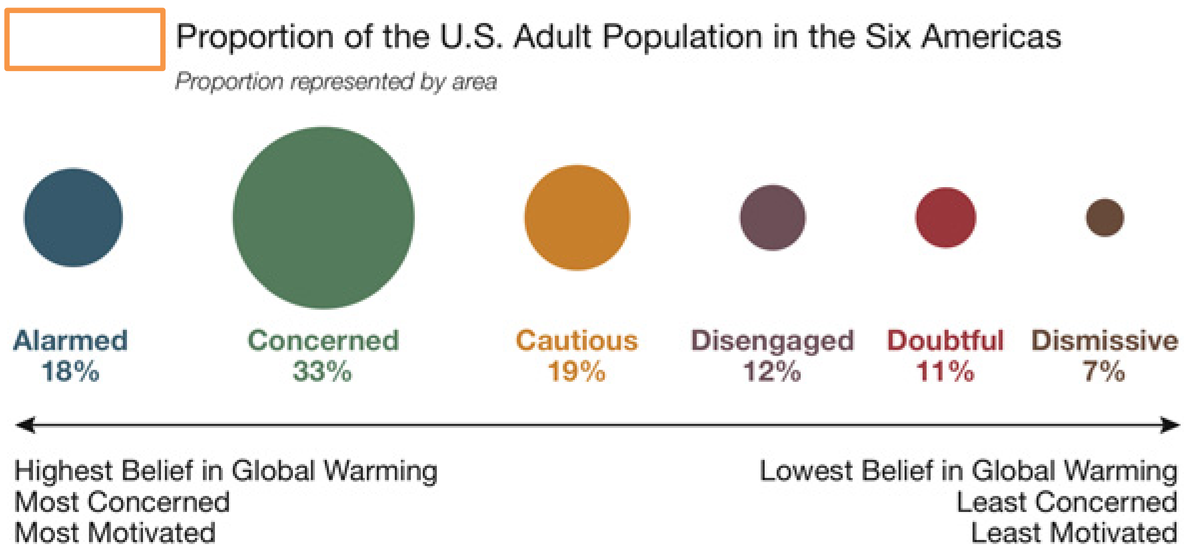


Figure 6.2. Global Warming's Six Americas (Leiserowitz, Maibach, Roser-Renouf, & Hmielowski, 2012) categories on a continuum based on the 2011 representative survey of American adults.

Responses from My Interview to Create the Ordinal Categories

In the post semi-structured interviews, I asked students about their climate change stances and to justify their stances. I used the *stance category items* and the categories from the YGCC to create my climate change stance categories (see *Figure. 6.5*). For the question regarding the existence of anthropogenic climate change, students responded in an open-ended manner. All students answered *Yes* or *No* on the interview except for one student who said he *Does not know* if it is happening. The one student who was initially unsure about his stance changed his answer to *No* as we continued the interview. A student's response to this item is the first step in the ordinal category creation. Students who stated anthropogenic climate change was happening are placed on the left side of the spectrum. Students who stated anthropogenic climate change is not happening are the categories on the right side of the spectrum. For the question regarding worry about the impacts of climate change, during the interview students were asked to place themselves on the spectrum (**Figure 6.3**) based on the YGCC findings.

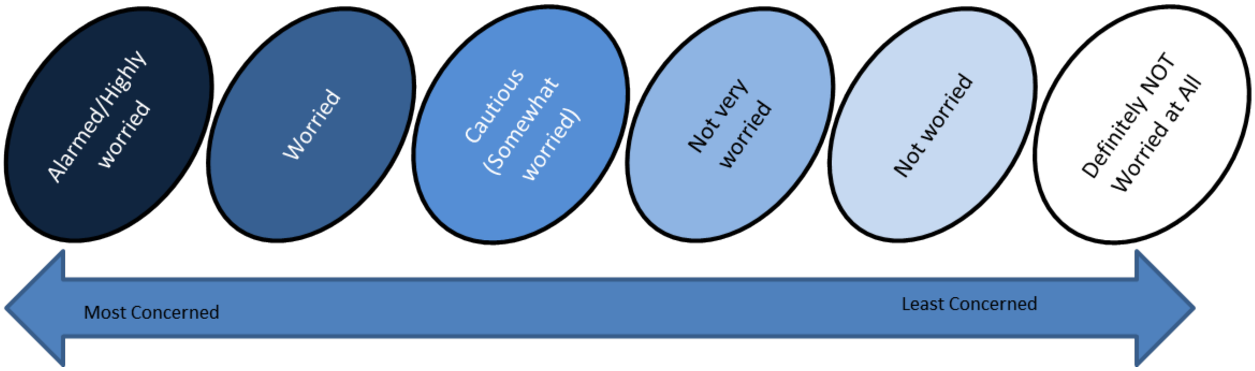


Figure 6.3. Ordinal categories of worry or lack of worry about climate change impacts that students placed themselves on during the post semi-structured interview.

Like the YGCC, the categories read most worried to least worried from left to right. Students placed themselves in the ordinal categories during the interview by pointing to and saying the words in the bubble with which they most associated. In this item, students are given an option of six categories. During analysis, I collapsed the two high concern categories from the Yale studies into a single category because the response rates for students in Alarmed and Worried were low (discussed in more detail below). Even with a single category to capture concern to high concern, the frequency of responses remained lower than the Yale findings.

I created a spectrum with five discrete categories, whereas the Yale findings had six groupings. *Figure 6.5* shows the climate stance ordinal categories. Moreover, the YGCC report groupings is based on three major stance categories (e.g., Belief in Global warming, concern, and motivation) as seen in *Figure 6.2*. However, the categories I created as a result of the interviews is based on the two stances from the ***stance category*** **items;** I did not ask students about motivation.

Student responses to the scale questions identified the categories. The creation of the ordinal categories is illustrated in *Figure 6.4*. First, students were placed in *Yes*, *No*, *or Don't know* if anthropogenic climate change is happening. Then, within those three responses, students were placed according to their level of worry about the impacts. *Figure 6.4* shows the two-way frequency of responses for the *stance category items* used to construct the scale. The cross frequency of students' responses illustrate the correlation of student responses to the two questions used to create the scale. Students who state that anthropogenic climate change is not happening self-divided into two distinct categories: (1) not very worried (75%) or (2) not worried (25%) about the impacts of climate change. This pattern created the right side of the scale (Categories 1 and 2).

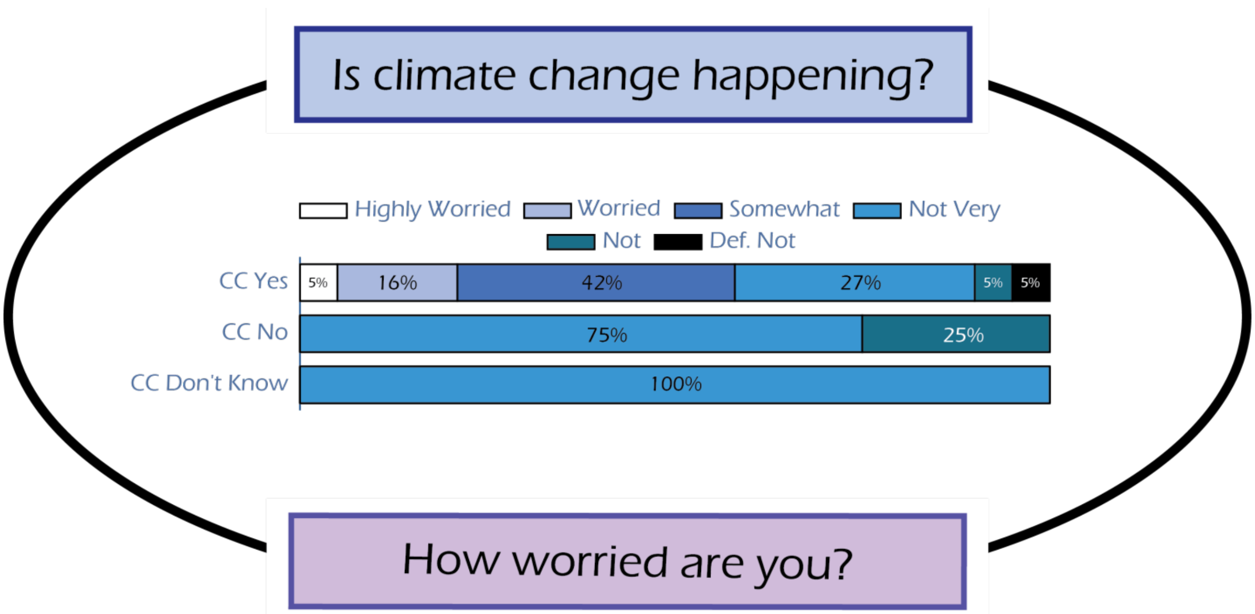


Figure 6.4. Frequency of responses for the two questions: (a) Is anthropogenic climate change happening, and (b) how worried are you? Responses to these two questions were used to generate the ordinal stance categories.

Moreover, the students in the interviews who responded that anthropogenic climate change is happening were heterogeneous in their range of worry. However, 63% of students who responded that anthropogenic climate change is happening expressed some level of concern (i.e. *Somewhat worried* ←→ *Highly worried*). With the low response rate in *Highly worried* and *Worried* it guided my decision to collapse high concern into a single category (e.g., Alarmed). Students who expressed that they were somewhat worried (42%) comprised their own category within the left side. Those students who said climate change is happening and whose worry level was below *Somewhat worried* made up the Happening and not worried category (Category 3) on the stance spectrum.

As seen in *Figure 6.5*, the far right side ordinal scale categories represents students who state that anthropogenic climate change is not happening and demonstrate a lack of concern about the impacts. Students who state that climate change is not happening are divided into two categories of worry: (a) *Not worried* (Dismissive) and (b) *Not very worried* (Doubtful).

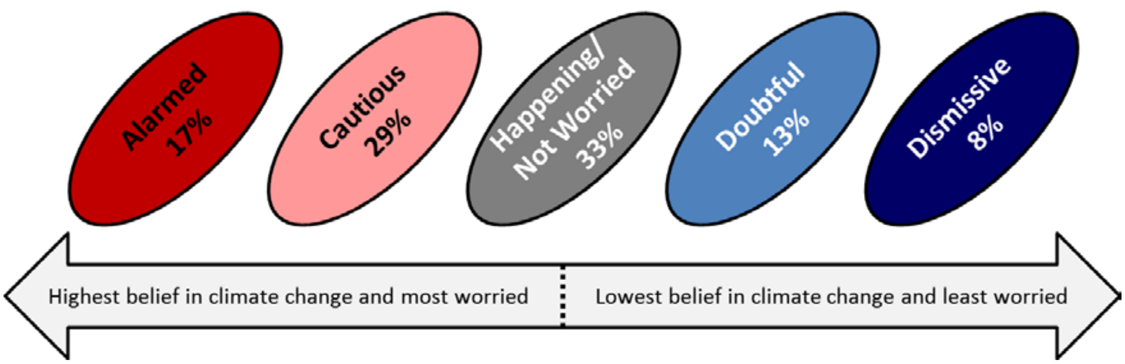


*Figure 6.5***.** Discrete ordinal categories of students' climate change stances with five distinct categories going from most concerned and highest stances to lowest concern and lowest stances (left to right). Frequencies reflect the percentage of interviewed students who were classified in each category.

Differences from the six Americas study. Comparing the frequency of respondents in each category from the dissertation to the Yale group is not a direct comparison because as noted earlier, I collapsed the YGCC Alarmed and Concerned category into a single category indicating concern about the impacts. *Figures 6.2 and 6.5* illustrate the categories and frequencies per stance categories for the Yale results and my discrete categories respectively. The highest frequency of student respondents are in the Happening and not worried category (33%) which correlates to Disengaged on the Yale continuum (12%). A higher frequency of Yale respondents (51%) reported being concerned and alarmed to 17% in my work. Although the two studies are not directly comparable, it appears that the adult population (survey 2012) has higher, more positive overall climate change stances than the middle school population interviewed (2013).

Overview of Each Ordinal Category

The overview of the ordinal categories are constructed from left to right illustrating more positive to less positive climate change stances (*Figure 6.5*). These categories are Alarmed (Category 1), Cautious (Category 2), Happening & Not Worried (Category 3), Doubtful (Category 4), Dismissive (Category 5). All students interviewed were placed in a category. While the categories are distinct, each student's response is nuanced and thus does not always fit cleanly into a single category. However, for analysis purposes all students interviewed were placed within a category based on their responses. Below are the descriptions of the categories (from left to right):

- The **Alarmed (1)** category indicates students who believe anthropogenic climate change happening is happening and they are worried about the impacts. Seventeen percent of the students interviewed are Alarmed. Like the Cautious, and happening but not worried category, the Alarmed students had unwavering stances that anthropogenic climate change is happening. However, unlike the other groups, these students expressed a high level of worry/concern about the impacts of climate change. The concerns expressed could be current and/or future worries regarding climate change impacts.

- The **Cautious (2)** category has the highest frequency of students interviewed (33%). Cautious means that students believe that anthropogenic climate change is happening and have some concern about the impacts. They differ from the students to the left on the spectrum (Happening, and worried) because students in the cautious category have expressed some concern about the impacts of climate change, but are not overly worried.
- Students in the **Happening, and Not worried (3)** category have expressed that anthropogenic climate change is happening, but they are not worried about the impacts of climate change. Some students express that climate change is nothing to worry about because it is not impacting them, happening somewhere else, not going to be that bad/we can adapt and/or going to happen in the distant future. There are 29% of the students interviewed who were in the Happening, and Not worried category.
- Students in the **Doubtful (4)** category are doubtful that climate change is happening. If they state that it is happening, then it is due to natural changes and/or cycles rather than the result of anthropogenic actions. They could have said climate change is not happening, but expressed that there is evidence that it could be happening. The students in this category are not extremely worried about the potential impacts of a changing climate. Of the students interviewed, 13% of the students fall within the Doubtful category.
- The **Dismissive (5)** category includes students that say that anthropogenic climate change is not happening. They are not worried about the potential impacts of climate change. Eight percent of the students in the interviews fell into the Dismissive category.

Patterns of Results from Interviews Based on Stance Categories

I coded additional interview questions, but they were not included in the construction of the stance ordinal categories**.** An additional five responses from the interviews were coded and used in analysis as indicated in the methods section (Chapter 3). The responses give additional insights into how students are discussing climate change. *Figures 6.7a, 6.8a, 6.8b, 6.9, 6.10a, and 6.10b* illustrate student responses to these interview items relative to the stance categories. Moreover, student interview quotes are included in this section as illustrative examples for the additional interview items.

Figures and Results for Additional Interview Items

The color of the bubble below the responses (responses in *Figures 6.7-6.10b* are in diamonds) correlates to an ordinal stance category. See *Figure 6.6* for the key to the color codes for each category. The size of the bubble below the response indicates the relative frequency of the response for that given category.

Figure 6.6. Key for stance categories by color and number of the category.

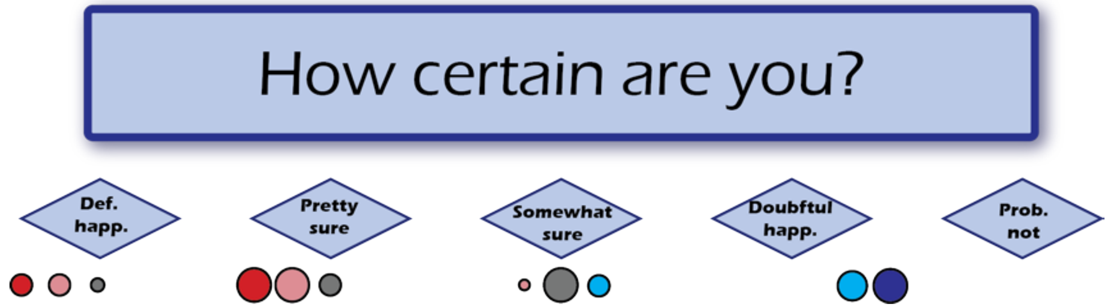


Figure 6.7. Relative frequency of respondents by climate stance category for follow-up to the question: How certain are you that climate change is happening or not? Students in red categories show certainty that climate change is happening. Conversely, students in blue categories show certainty that climate change is not happening.

The patterns from *Figure 6.7* illustrate those students on the left and right extremes of the stance categories answer with certainty (yes or no) happening. However, students in the third category (Happening and Not worried) have more varied responses regarding certainty if climate change is happening or not. *Figure 6.8* explores student justifications for why they believe anthropogenic climate change is happening or not.

Table 6.1.
Major Findings by Relative Frequency of Responses by Stance Categories for Certainty of Existence of Climate Change

Questions	Categories	Patterns
How certain are you that anthropogenic climate change is happening?	Alarmed (1) & Cautious (2)	• All students chose either "definitely happening" or "pretty sure happening"
	Happening, and not worried (3)	• Student responses spread across many certainty categories. • All responses were confirmatory that climate change is happening.
How certain are you that anthropogenic climate change is not happening?	Doubtful (4) & Dismissive (5)	• Confirmed stance categories • No student chose "probably not happening" on the certainty scale even though all students in this category stated that climate change is not happening

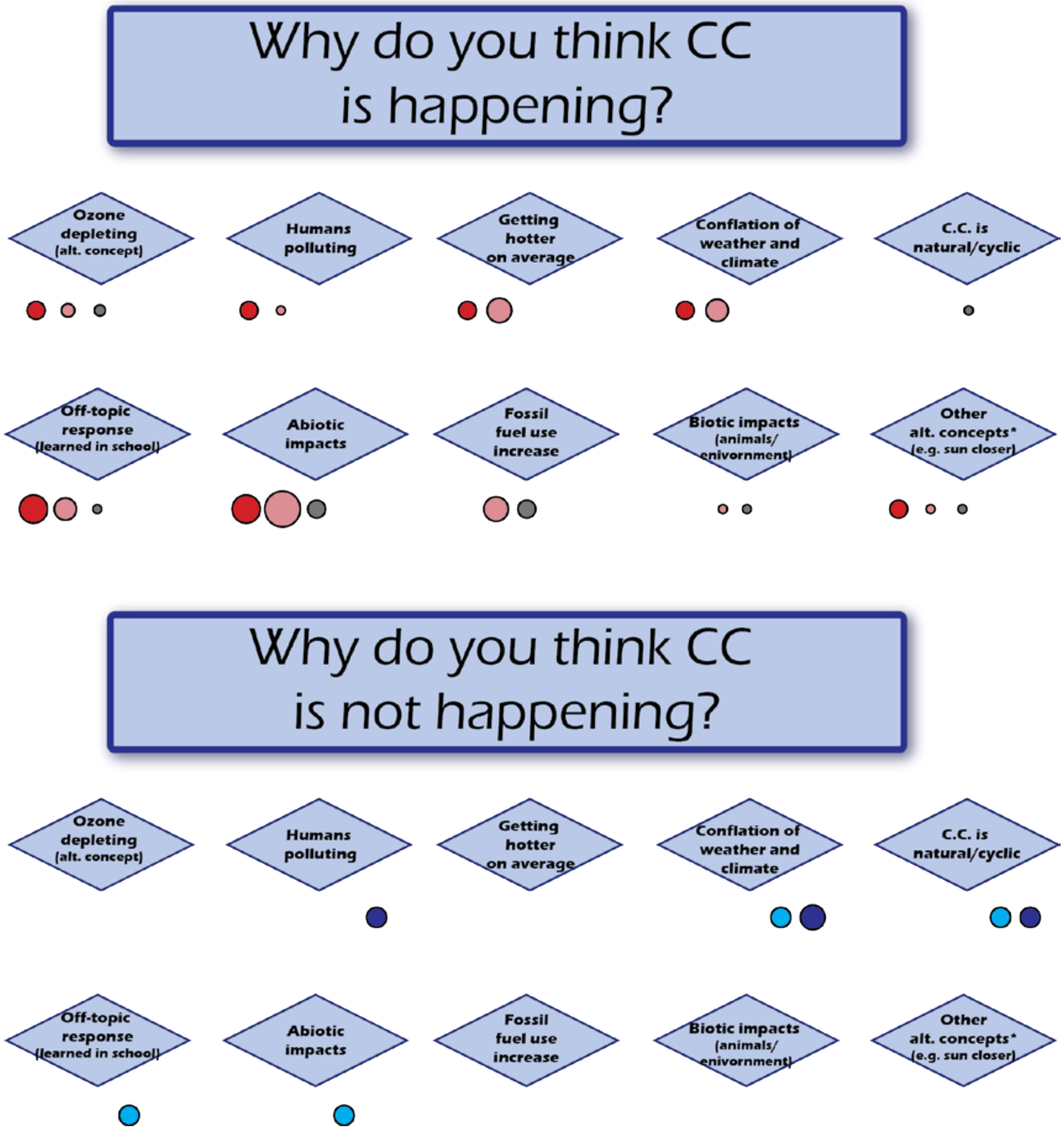


Figure 6.8. Relative frequency of respondents by climate stance category for the question: Why do you think climate change is happening or not? Students' responses represented by the red and gray stance categories have varied responses, included biotic and abiotic impacts. Student responses represented by blue stance category are more concentrated in categories including alternative scientific theories regarding climate change. Students in all categories conflate weather and climate concepts. *Other alternative concepts regarding climate change include the sun is getting closer, people breathing, and cigarette smoke.

There are several patterns that emerge from *Figure 6.8*. Students across all stance categories conflate the concepts of weather and climate to justify their stances regarding the existence of anthropogenic climate change. Students on both extremes of the ordinal stance categories discussed the role of humans polluting (e.g., a general environmental term to describe climate change mechanisms). Moreover, students who have responded that climate change is not happening have less spread in the type of responses stated. When a rationale is given, students in categories 4 and 5 stated alternative scientific theories to anthropogenic climate change and/or their justifications (e.g., result of natural climate cycles and/or the result of the Earth's tilt changing) given were not grounded in science principles. On the other hand, students in categories 1 and 2 gave more varied reasons for their stances. Students representing categories 1 and 2 provided examples of abiotic impacts of climate change, such as sea ice melting more frequently than students in the other three categories.

Table 6.2.
Major Findings by Relative Frequency of Responses by Stance Categories for Stance on Existence of Climate Change.

Question	Categories	Patterns *note: The patterns listed in the table are a discussion of Figure 6.8.
Explain why you think that anthropogenic climate change is happening?	Alarmed (1) & Cautious (2)	• More conversant (higher frequency of responses across response categories) and responses attempted to use scientific principles • Did NOT state multiple alternative scientific theories of climate change • Stated common alternative concepts –e.g., ozone • High proportion stated abiotic impacts (e.g., ice melting, increased propensity of storms and droughts) as reasoning
Explain why you think that anthropogenic climate change is not happening?	Dismissive (5) & Doubtful (4)	• Less conversant about explanations (appears as smaller frequencies across response categories) • When students gave reasoning, they did not employ scientific principles. • Discussed multiple alternative scientific theories, such as natural cycles and the change in the earth's tilt to discuss a changing climate

Students used messy middle knowledge (e.g., a blend of knowledge) to justify why they believed anthropogenic climate change is happening or not. There was an interchangeable use of environmental terms (e.g., ozone depletion and pollution) with climate change topics. Moreover, conflation of weather and climate occurred across all stance categories. To illustrate how students are using these terms (e.g., ozone, pollution, littering, weather, and climate), I have included specific student quotes from the interviews as illustrative examples. The first part Table 6.3 shows student interview responses to how they are discussing environmental issues and climate issues interchangeably (e.g., pollution/littering, recycling, and ozone depletion). The second part of Table 6.3 illustrates the conflation of weather and climate and that students use the idea of weather (e.g., temperature changes) as reasons to state either anthropogenic climate change is happening or not.

Table 6.3

Illustrations of Mixture of Correct and Incorrect Science for Environmental Issues versus Climate Change Topics and Conflation of Weather and Climate From Interview Responses.

Mixture of Correct and Incorrect Science *Illustrative Examples from the Student Interviews* (Part 1 of 3)	
Categories of Responses	Student Interview Responses
Environmental Issues versus Climate Change Topics:	
Pollution and littering associated with the greenhouse effect	*Dialogue from Interview with Richard Circle MS 9/4/13* Richard: I think it's happening because humans have been polluting all the water and it's causing pollution -- all the chemicals to go up in the air so when the light hits all the greenhouse materials, the chemicals, it's making the climate change. Michelle: What kind of pollution do you think? Richard: Like cuz -- where they put all the toxic, like chemicals, they don't have anywhere to put it. So some put it in the ground and some put it in the water. And there are oil spills and everything from humans. Michelle: Have there been any experiences -- your personal experiences that have influenced how you thought about this? Richard: Um, when I was out with my friends the one time, we saw this -- and I forget what it was -- but it had stuff all over the leg from -- It was stuck in like an ocean or water. It had, like, the can rings on it and I didn't like that cuz it's just horrible how it is.

Mixture of Correct and Incorrect Science *Illustrative Examples from the Student Interviews* (Table 6.3 Continued: Part 2 of 3)	
Categories of Responses	Student Interview Responses
Environmental Issues versus Climate Change Topics:	
Recycling associated with reduction of carbon emissions	Because we are not -- like burning them; we're reusing them. We're not allowing them to float on Earth and maybe cause hurt to animals or anything else like that". (*Kelly, King St. MS 10/14/13)* *Dialogue from Interview with Brian King St. MS 10/14/13* Michelle: Looking at this diagram please pick the oval that best answers the question. How worried are you about climate change impacts in your lifetime? Brian: Not very worried because I don't -- I recycle and stuff [9:01] Michelle: What would recycling do? Brian: It protects from like trash and everything and causing [PAUSE] I don't know. It is just bad on the environment.
Ozone depletion associated with climate change and/or the greenhouse effect	*Dialogue from Interview with Ryan King St. MS 10/15/13* Ryan: "Yeah, humans, we pollute a lot. I just think it is burning a hole in the ozone layer like it started a while back but it is just -- It is getting worse. We're trying but [PAUSE] -- We're still having a hard time giving up some of the aerosols and stuff" (10/15/14). Michelle: Where did you hear about ozone layer and climate change? "{Teacher's Name} said that the ozone is the layer that keeps our -- It keeps all our oxygen in and stuff. And it like it blocks out some of the sun's rays and bounces it back. Some can get in but with the hole in the ozone, it is just the sun gets in more and it will heat up. It will heat up our Earth more." *Dialogue from Interview with Matthew Village MS 9/27/14* Michelle: Why do you say that? Matthew: Because probably the stuff we're putting into the atmosphere. The carbon dioxide and everything is causing -- Some people say the ice caps are melting. The ozone layer is being destroyed and everything. Looking through the research we've done with this, I've come to believe that it is happening. Michelle: You mentioned the ozone thinning. Matthew: Yes. Michelle: Where have you heard that? Matthew: Last year, we talked about it in science class. We went a little further on your Website and we went through it and we talked about how all the smoke that we put -- the carbon dioxide, the methane, and all that going up destroys the ozone layer and it is putting us in the harmful way with the sun rays and everything.

Mixture of Correct and Incorrect Science *Illustrative Examples from the Student Interviews* (Table 6.3 Continued: Part 3 of 3)	
Categories of Responses	Student Interview Responses
Conflation of Weather and Climate	
Interchangeable use of the terms weather and climate	*Dialogue from Interview with Stephanie Circle MS 9/4/13* Michelle: How certain are you that climate change is happening or not happening? Stephanie: I'm pretty sure it's happening. I mean because you don't really have it being 60 degrees in winter usually and that's what's been happening now. Michelle: So you said pretty sure. What would you need to get to the "definitely" bubble? Stephanie: Well cuz you know, I don't really know. I don't know for sure what's happening. Sometimes it's really warm and then it'll go cold again. And so it could be getting better or it could be getting worse. *Dialogue from Interview with Max Circle MS 9/4/13* Max: Anthropogenic climate change is happening? Why or why not? Um, yes because, we've been having lots of storms here lately and the weather is really hot, so. Michelle: Who do you think has been the greatest influence on your thinking about climate change? Max: News. Michelle: What does the news tell you? Max: It talks about the weather and how storms appear and stuff like that. Michelle: Have you experienced anything that influences your decision? Max: Well a few days ago, it's actually been getting really, really dark and the trees are like blowing everywhere.
Discussing weather anomalies as evidence for a changing climate	"To be certain that climate change was happening, it would need to be 100 degrees Farenheit in January or something like that" *(Graham King St. 10/15/13)*
Discussing the changing temperature as evidence against a changing climate	"I don't think it's happening because [SIGHS] -- I haven't seen much temperature change. I haven't seen a difference in the temperature. Over the summer the temperature was basically the same the whole summer. Like it didn't change like cold and like it didn't get really hot; it was basically on the same level the whole time… Like right now, the temperatures are staying all the same. Well not exactly the same but close to each other so they're not like getting -- like one is super cold and one is superhot. It's like just the same" (*Henry, Village MS 9/25/13*). *Dialogue from Interview with Herbert King St. MS 10/14/13* Herbert: Maybe my dad because when he hears stuff about that, he says what he thinks. I don't know; it's kind of -- I go by that because he's a smart guy. Michelle: What does your dad say about it? Herbert: He doesn't really think any of that is happening like global warming and what they talk about. It's not like our fault; it is not really something that humans really are doing. It is more of just like [PAUSE] I don't know like weather thing.

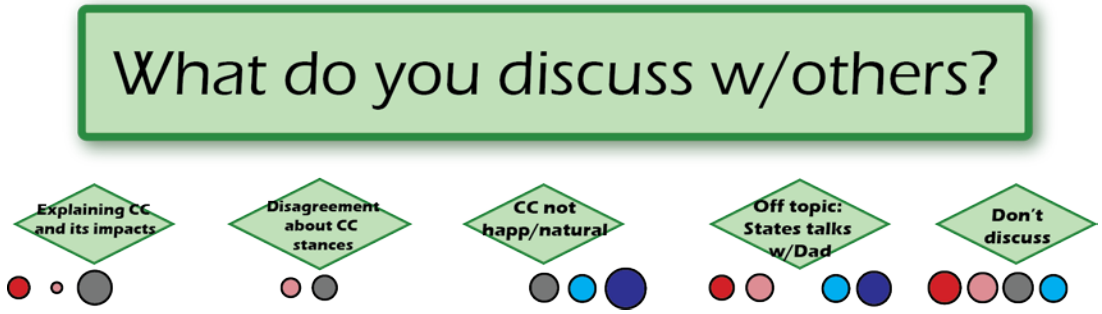


Figure 6.9. Relative frequency of respondents by climate stance category for follow up questions to the question: Do you discuss climate change with friends and/or family and if the response is yes, what do you discuss with friends and/or family?

Figure 6.9 illustrates if students report discussing climate change with friends and family and if it is discussed, what is said about it. When looking at relative frequency of if students discuss climate change with friends and family, the response of *Do not discuss* spans all stance categories, except for Dismissive (5). Those who responded in the interview that climate change is happening are less likely to discuss climate change with friends and family (42% of those students discuss with friends/family) than those who do not think climate change is happening (75% of these students discuss with friends/family). For students in the latter category, the highest frequency of discussion points are that climate change is not happening and/or the climate is changing as a result of natural cycles.

Figure 6.10 illustrates patterns regarding why students are worried or not worried about the impacts of climate change. The figure shows that students in all the stances responded that the impacts of climate change would not be felt until the distant future. There is agreement amongst the students interviewed that climate change impacts are not an imminent threat. Moreover, the highest frequency of responses for students who are not worried about climate change included the beliefs that nothing major is happening and that scientists will find a solution to stop the impacts of climate change. Students in categories 1 and 2 (Cautious and

Alarmed) stated with high frequency that they are worried about both the biotic and abiotic impacts of climate change.

Table 6.4.
Major Findings by Relative Frequency of Responses by Stance Categories for Discussions with Friends and Family about Climate Change.

Questions	Categories	Patterns *Note: The patterns listed in the table are a discussion of Figure 6.9.
What do you discuss with friends and family about climate change?	Happening and not worried (3)	• Express that the family is not aware of climate issues when discussed and/or they disagree with what was expressed in the curriculum
	Dismissive (5) & Doubtful (4)	• Discuss that anthropogenic climate change is not happening and/or it is a natural cycle. • Students in these categories more frequently discuss with friend/family.

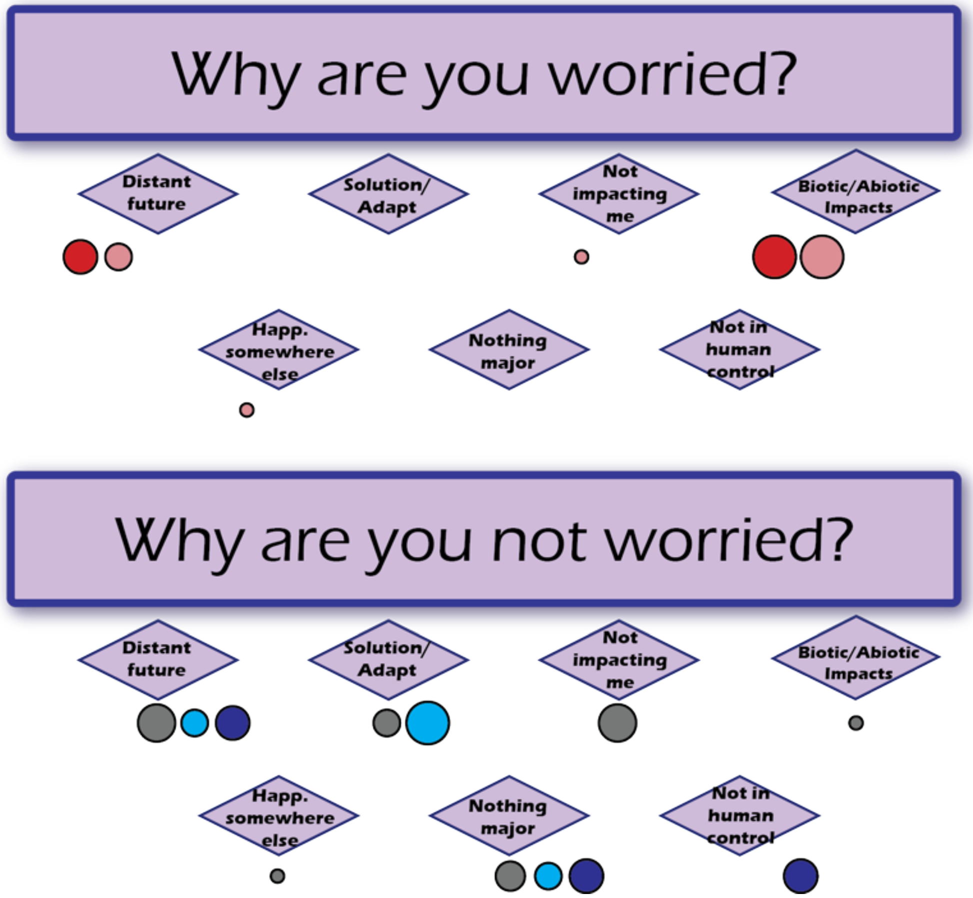


Figure 6.10. Relative frequency of respondents by climate stance category to the question: Why are you worried or not worried about climate change impacts?

Table 6.5a.

Major Findings by Relative Frequency of Responses by Stance Categories Regarding Justifications for Level of Worry.

Questions	Categories	Patterns
Why are you worried about climate change impacts?	Alarmist (1) & Cautious (2)	• Worried: Greatest frequency in discussions of abiotic and biotic impacts of climate change • No students responded that nothing major was happening
Why are you not worried about climate change impacts?	Happening and not worried (3) & Doubtful (4)	• Not worried: students respond that we will adapt and/or scientists will have a solution to stop the impacts
	Doubtful (4) & Dismissive (5)	• Not worried: students respond that nothing major is happening

The students' reasons that they stated for their lack of worry can be grouped into three categories related to detachment from the issue (e.g., it is not currently impacting me). These three categories are (a) impacts will be experienced in the distant future, (b) a solution will be found and/or humans will adapt, and (c) impacts are or will be experienced somewhere else. Table 6.5b shows student responses from the interviews on how students are discussing their lack of worry regarding climate change impacts.

Table 6.5b
Quotes from Interviews Illustrating Students' Lack of Worry for Climate Change Impacts.

Lack of Worry about Climate Change Impacts *Illustrative Examples from the Student Interviews* (Part 1 of 2)		
Reasons Students are Not Worried About Impacts	Student Interview Response	
Not impacting me, impacts will be felt in the distant future	*Dialogue from Interview with John Circle MS 9/4/13*	
	John:	I'd say not very worried because it's not affecting me yet.
	Michelle:	When do you think it might affect you?
	John:	Maybe in a few -- like maybe 60 years or something like that.
	Michelle:	What kinds of impacts might you feel?
	John:	Maybe rise of water level and um, the deserts and forest places will get hotter so endless participation will happen and so they'll start forest fires and everything.
	Michelle:	Do you think some people around the world right now are experiencing impacts of climate change?
	John:	Maybe a few, not many though.
Humans will find a solution/adapt in the future	*Dialogue from Interview with Jason Circle MS 9/4/13*	
	Jason:	Even if it is by natural causes, we'd probably find a way to cool down the earth without thinking.
	Michelle:	When do you think we'll start experiencing the impacts even if it's a natural cause?
	Jason:	Hundreds upon hundreds upon hundreds [LAUGHS] of years --

Lack of Worry about Climate Change Impacts *Illustrative Examples from the Student Interviews* (Table 6.5b Continued: Part 2 of 2)		
Reasons Students are Not Worried About Impacts	Student Interview Response	
Impacts of climate change experienced somewhere else	*Dialogue from Interview with Rebecca King St. MS 10/14/13*	
	Rebecca:	I'm pretty sure it is happening because it is all over the place. Not just in one place but all over. Especially where factories and nuclear power plants are and stuff.
	Michelle:	And why would factories or nuclear power plants matter?
	Rebecca:	Because of the carbon dioxide that would probably be the main cause of the temperature rising. Because it is -- I can't remember what it does. It is like a warmer kind of gas and once it goes up there it stays up there. If you keep putting more and more it just gets -- it starts interfering with the atmosphere.
	Michelle:	When do you think we'll start feeling these impacts or have we started feeling these impacts?
	Rebecca:	Well we started to feel these impacts very slightly. I feel that in the near future we'll probably be starting to notice those changes.
	Michelle:	You refer to a few of the changes. What kind of changes might you feel here?
	Rebecca:	Um, temperature differences, how bright the sun is and how hot the sun can get -- the sun gets now. And uh, some -- it can probably get windier like more wind or less wind. How fast storms develop and stuff like that.
	Michelle:	Have you seen an impact in your community here?
	Rebecca:	Not as much -- not a lot but I've seen it happening near bigger cities like Kansas City or most likely something in New York or one of the major cities.

Finally, religion was a topic that was discussed across many questions in several of the interviews but it did not code neatly into a single category. Religion was discussed by 13% of the students interviewed. In Table 6.6, I show student interview quotes to illustrate how students discuss climate change and religion. The student quotes discuss the lack of control humans have and more specifically that God is in control of the climate and weather systems and the end of the world.

Table 6.6.

Student Responses from the Interviews that Illustrate Discussion of Religion and Climate Change.

Religion in the Climate Change Discussion *Illustrative Examples from the Student Interviews*	
“Because I’m a Christian so I kind of believe God can take care of that and when the world ends; it ends.” (*Brian, King St MS 10/15/13)*	
Dialogue from Interview with Harriet Village MS 9/25/13 “It’s our world and it could be destroyed any second and we could get hurt [WHISPERS] burn to death”. When do you think this might happen? “I’m not trying to change to a different topic but I don’t have an idea because it’s in God’s hands pretty much. He’ll tell us when it’s going to happen.”	
Dialogue from Interview with Heather King St MS 10/15/13	
Heather:	Probably not just me.
Michelle:	Not just you? Okay. How about the whole family or the whole school?
Heather:	No because Mother Nature does it.
Michelle:	Mother Nature controls what?
Heather:	Like how hot it is going to be or how cold it is going to be and what the winters are going to be like.
Michelle:	Was it you that mentioned that some of the summers have been hotter and some of the winters colder?
Heather:	Yeah.
Michelle:	Who controls that? What controls that?
Heather:	Well, Mother Nature, I guess.
Michelle:	How would you describe Mother Nature?
Heather:	[PAUSE] -- Weird [LAUGHTER].
Heather:	It is just like -- just like what the weather wants to do I guess. What God wants the weather to do, I guess. I don’t know how to put it.
Michelle:	That’s fine. Do you think God has control of the bigger weather or climate system?
Heather:	Yeah.
Michelle:	Do you want to explain a little bit what you mean by that?
Heather:	Like I believe that God controls everything in the world. So I believe that he controls that too.

Section II: Student Exemplars of Ordinal Stance Categories

I first briefly outline the criterion that must be met for a student to be chosen as a stance category exemplar. Then, I highlight major themes for each student exemplar by stance categories. There are six student exemplars representing the five ordinal categories. I discuss each student exemplar in detail with specific examples and quotes from the post semi-structure interview. Major themes for each student are highlighted as well as how the exemplar represents the stance category. Finally, I highlight similarities and differences between and across the exemplars in a summary section.

Choosing Representative Students for Each Stance Category

Each student that I discuss below represents a stance category. I discuss the exemplars from left to right on the scale (Dismissive ←→Alarmed). The students chosen are not necessarily representative of all students within that category. For example, a student representing the Cautious category might exhibit a certain messy middle concept and/or have specific conversations with friends and/or family that others in the category did not articulate. Those aspects of the student responses cannot and should not be generalized. Rather, the students chosen for the exemplars exemplify the views of the category defined by the stance category. As a reminder from the methods chapter, below are the criteria that must be met for all students chosen as exemplars:

- There must be at least one student from each of the defined five categories on the scale (Dismissive to Alarmed),
- Each student exemplar needs to be conversant. A student that is conversant is necessary as those students who are less conversant do not easily or fully provide evidence of their views or justifications for their stances.
- The student exemplars must draw at least one student from every school visited. At least one student from King St, Village MS, and Circle MS are used as exemplars from each category.
  Note there are two student exemplars to represent the Dismissive category.

There were only two students interviewed who coded into the Dismissive category. Although the end results (e.g., anthropogenic climate change is not happening and they are not worried) are the same for both students, the reasons given to explain their stances are quite different. Thus, I believe each of their perspectives was important to illustrate. Please see Table 6.7 for an overview of the student exemplars for each stance category and major points from each exemplar.

Table 6.7

Summary of Student Exemplars for Each Stance Category Including Major Points in Each Exemplar.

Summary of Student Exemplars for Each Stance Category		
Stance Category	Student Exemplar	Major Points
Category 1: Alarmed	Travis (Circle MS)	• Influenced by teacher and curriculum on climate change • Uses ideas of graphs and content from curriculum to articulate views • Mixture of correct and incorrect science→Conflation of weather and climate concepts (storms) • Worried about impacts→ flooding
Category 2: Cautious	Molly (Circle MS)	• Influenced by teacher and curriculum on climate change • Moves to action to make environmental changes • Mixture of correct and incorrect science→Conflates environment issues (air pollution and littering) with climate issues • Worried about impacts→ animals

Category 3: Happening, Not worried	Robert (Village MS)	• Attempt to use scientific terminology/reasoning
		    o Discussion of "theories"
		• Climate change discussions use of "propaganda" and "scare tactics"
		• Mechanisms of climate change
		    o Alternative scientific theories to explain a changing climate/Multiple theories on climate change
		    o Mixture of correct and incorrect science→ Ozone depletion, conflation of weather and climate, environmental issues vs. climate change topics
		• Temperature change not drastic/Scale issue and time-frame issue

Category 4: Doubtful	Timothy (Village MS)	• Sees both sides of climate change debate
		    o Father says climate change not happening
		        ▪ Electric cars not environmentally friendly
		    o Curriculum shows evidence that it is happening
		• Not impacting him
		• Temperature change not drastic/Scale issue and time-frame issue

Category 5: Dismissive	Brian (King St. MS)	• Outside of school influence
		    o Religion
		    o Family
		• Does not use scientific reasoning/terminology to explain reasoning for most responses
		• Incorrect science→Conflates environment issues (Recycling) with climate issues

Category 5: Dismissive	Hailey (King St. MS)	• Father major influence • Does not use scientific reasoning/terminology to explain reasoning for most responses • Incorrect science→Conflation of weather and climate concepts (Drought water issue not related to climate)

Exemplar 1: Travis Represents the Alarmed Category

Travis is the student exemplar for the Concerned category. Travis stated that anthropogenic climate change is happening and expressed a high level of worry about the impacts of climate change. Travis appears to draw on information that he learned in the climate change curriculum (Songer et al., 2012) at school to explain his stances. He uses scientific terminology and grounds his positions almost solely from curricular examples. However, he conflates the concepts of weather and climate. For example, he uses changing seasons as a rationale for why he thinks climate change is happening, but then brings into the discussion the ideas of single extreme weather events or anomalous cold or hot stretches.

School and curriculum influences his positions. To justify his stance that anthropogenic climate change is happening, Travis draws on two main sources: (a) the information his teacher has presented in the curriculum (graphs, experiments, etc.), and (b) his perceptions of what the weather and seasons have been like in the last few years; specifically, he feels like it is getting hotter. Travis recounts the positive relationship between carbon dioxide and temperature. He also discusses that there has been a 1 degree Celsius average increase. However, he briefly mentions the sun and does not finish his thought (it is unclear how he would fit the sun into his discussion).

Dialogue below is from interview on 9/4/13 at Circle MS

Travis: I think it is kind of happening because it is getting hotter. We didn't have like a really big winter. Well we had a winter but we didn't have a spring, I guess. I don't know. But um, like the winter wasn't as bad but then it got bad in spring. Which is kind of weird because we usually -- We usually have spring and we didn't; we just had winter.

Michelle: Okay. What do you think have been the greatest influences on your thinking about anthropogenic climate change?

Travis: I think seeing what's been happening, how the weather has been off ever since the past few years. It's sort of gotten hotter, I think and sometimes, I don't know. The seasons are kind of weird, I guess.

Travis: I know Ms. Hansel went through that stuff. I know she's been showing us a lot of -- She used to show us a lot of graphs of how the temperature has changed throughout the past thousand years.

Michelle: How has it changed?

Travis: Isn't it like one degree Celsius or something?....

Travis: Like since the -- I think it is the CO2 emission thing since they're getting higher, the temperature is getting changed. And like the sun -- it is like…

Travis then continues to say why he is pretty sure that climate change is happening. In this response, he draws more on the idea of evidence through graphs, but does not give specific examples of graphs that he saw in the curriculum to help justify his claim.

Dialogue below is from interview on 9/4/13 at Circle MS

Travis: I think -- pretty sure it is happening because as I said I've been seeing a lot of graphs that the temperature has been getting higher over the past century and stuff. And um, the seasons now are starting to get really weird like we're having winter in the spring which is kind of weird, and so, yeah.

Michelle: What would you need to move from pretty sure happening to definitely happening?

Travis: Um, I think it would just. I think if it got more, uh, what's the word? Like sort of more occurring like if we had a really bad winter and -- Well we had no winter in winter but we had a really bad winter in the spring. I think if that was more occurring.

During the interview, Travis continually tried to draw on the ideas from the curriculum. I frequently reminded him that it was not a school test, but he approached the topic by stating scientific ideas and trying to remember information from graphs. In his responses, he sometimes did not finish a complete thought (e.g., the sun) or ended a response with a question (e.g., trying to state the specific average increase in temperature over the semester). Travis does not discuss climate change with his friends or family. It appears that it is just a topic/discussion that occurred within his 7th grade science classroom.

Weather vs. climate When drawing on the curriculum, he stated the idea of time-frame as important for showing a changing climate over the century. However, when talking about personal experience of a “weird” season, the importance of time-frame to distinguish changing weather and climate did not enter the discussion.

Climate change impacting Travis. Moreover, Travis said he was “worried” about climate change. Travis’s concerns about climate change centered around the impact of flooding in coastal areas. He had very specific concerns, but again like other students interviewed, he did not feel like the impacts were happening now. In the excerpt below, Travis discusses why he is worried about the impacts of climate change.

Dialogue below is from interview on 9/4/13 at Circle MS

Travis:	Um, I’m probably worried because I saw that when -- if climate change gets higher, the coastal areas can become flooded and some islands will be flooded too and so they’ll be gone. So we’ll have to move somewhere else and it is kind of scary.
Michelle:	You don’t live on an island?
Travis:	Yeah but close to the coast, we’re like a couple states away.
Michelle:	When do you think you might start experiencing the effects of climate change?
Travis:	Well I know people are trying to start using [*inaudible 10:50*] instead of oil and all that stuff so probably in about, uh, seventy or eighty years I think.

Travis did not elaborate further on his fears, but when questioned about the fear of coastal flooding, he did not express concern for those on the coast, but rather he felt that his state was close enough to the coast that he could be impacted. Readers should note that Travis lives in a land-locked state that is more than 500 miles from the coast. In this response, he discussed the time-frame of switching from an oil-based/fossil-fuel dependent economy to something else and how that will influence when the impacts of climate change will be experienced. Travis is thinking about solutions and how non-fossil fuel based energy sources might alter the current projections of climate change impacts.

Summary. Although Travis lives in a land-locked state, he is concerned about flooding as a result of sea level rise. He has also expressed that changing fuel sources will also change the time-line of impacts; he is thinking about solutions to the issues. While his discussion of the science is not fully comprehensive, he draws on his experiences and evidence presented in the classroom to form his current position and rationale.

Exemplar 2: Molly Represents the Cautious Category

Molly is the student exemplar for the Cautious category. Molly stated that anthropogenic climate change is happening, and she is concerned about the impacts. She credited her teacher and the curriculum for being the greatest influence on her thinking about climate change. Molly expressed that the climate change topic was difficult for her. Alongside several messy middle concepts, specifically the ideas of air pollution (e.g., cigarette smoke) in regard to climate change; she also discusses the general role of cars and gasoline as things humans do to change the environment. Molly expresses a desire to make changes in her lifestyle to help mitigate climate change impacts.

Stances on climate change. Molly states that anthropogenic climate change is happening. She provides a list of reasons as seen below in the following transcript. Moreover, she indicates that her teacher spent extra time with her reviewing the concepts from the curriculum to help clarify concepts.

Dialogue below is from interview on 9/4/13 at Circle MS

Molly: Yes because we do most of -- most of the reason that we have climate change is probably because of humans and stuff that we make and stuff that we do. Like, not recycling [PAUSE] cars, gasoline, coal mine and stuff like that.

Michelle: Who do you think has been the greatest influence on your thinking about this topic?

Molly: Probably {Teacher's name}.

Michelle: Why do you say that?

Molly: Because I never really thought about it until I had her class. She's a really great teacher and she helps me understand things better. Sometimes she'd stay after school and help me things I didn't understand.

Michelle: That's great. Have you experienced anything that you think has influenced your opinion on this topic?

Molly : Oh yeah, since I started {Teacher's Name} class, I [LAUGHS] made my mom buy a recycling bin.

Molly: Every time someone smokes -- if I see someone smoking in a car, I have the habit of saying, Kill the world; why don't you. [LAUGHTER] -- My mom laughs at me all the time.

Discussions in the classroom and working with the climate change curriculum seem to be Molly's first exposures to the topic. She cites that her teacher was a great influence on her thinking and understanding of the climate change topics. She recounts that in class they learned "that it is like seven degrees more" and glaciers are melting and animals are going to die. With these responses, it appears that the curriculum has influenced her thinking because of the focus on animals and ice melt, along with the idea, although slightly confused, about the average increasing global temperatures. These were foci of several of the abiotic lessons in the curriculum. Moreover, Molly, like other student exemplars, discusses issues of scale in terms of how much temperature change there has been. In the curriculum, there are activities focused on a 1 degree Celsius increase on average, but Molly recalls it as 7 degrees, which would be considered a drastic increase.

Environmental versus climate change topics. To illustrate why she thinks anthropogenic climate change is happening, Molly lists things that humans do to contribute to the issue. The list includes not recycling, cars, gasoline, and coal mines. Furthermore, at the end of that piece of dialogue she equates people smoking in the car to killing the world. In the discussion of the "stuff" that humans do, Molly has articulated activities that require fossil fuels and contribute to the greenhouse effect. However, she then conflates general air pollution (e.g., from people smoking) to contributing to anthropogenic climate change.

Also, as a result of curricular and teacher influences, she "made" her mom buy a recycling bin. She expressed frustration that her family does not use the recycling bin. She thinks it is because they are too lazy to go out to the garage to recycle rather than throwing the material in the trash. When probed why it is important to recycle, Molly states, "because it will help." Again, it is unclear how Molly thinks recycling mitigates global climate change.

Molly also said that climate change is sometimes discussed at the church that she and her family attend. The conversation around the topic is limited, but she said, "We just do stuff to help make the world better. Sometimes, we clean-up, pick-up stuff and simple stuff like that" (Molly, 9/4/13). Again, there is conflation with the idea of general pollution/litter and what can change and/or have impacts on the climate system.

More concerned if affecting me. Molly expresses a concern about the impacts of climate change. She states that she is cautious to somewhat worried. Her main concern is about the animals and trees. She feels that she has not personally felt any effects, but that it might happen in the future. Molly's future time-frame is shorter than others; she states that impacts might be felt in five years or so. Below is the discussion where Molly justifies why she is cautious to somewhat worried and what would make her more worried about the impacts of climate change.

Dialogue below is from interview on 9/4/13 at Circle MS

Molly:	Um because -- I don't know. Like I care about; I think about it sometimes because animals die and that's kind of sad. And I think about um [PAUSE] yeah like, mostly just the animals and trees and stuff like that.
Michelle:	What would make you alarmed or highly worried about it?
Molly:	Uh, I don't know if it was affecting me more. Mostly, it's not affecting us yet until like later. It's not really affecting us right now so it's kind of like not worrying. But I feel with the next generation of people, it's probably going to have a bigger effect.
Michelle:	Your timeframe like when it will happen -- give me the years-ish?
Molly:	[LAUGHS] like five
Michelle:	In about five years it'll start.
Molly:	I think it's already happening. It just doesn't have most of the impact on us yet.
Michelle:	What kind of impacts will we feel?
Molly:	Uh, just like shorter winters, like warm winters, um, like things just being not like -- just different. You could tell if it's happening. The news would be blowing up with stuff. And they keep having the website that pop-up with: Save a Polar Bear or something like that.

Molly feels that humans have not yet experienced the impacts of climate change. She believes that when humans feel the impacts, they will become more worried about the situation. Currently, animals are being most affected by climate change. Moreover, Molly mentions concern about the polar bear. The polar bear was not a focal species in the curriculum. However, Moly is not the only student who associates the plight of the polar bear with climate change and fear about its impacts. I discuss this further in Chapter 7.

Molly also expressed that when they were studying the topic in class, she and her friends would talk about climate change. She said that most of the time she and her friends agreed, but she said, "There'd probably be one odd person that would be saying unreasonable stuff." When probed about what that "one odd person" would say, Molly stated, "Who cares if the panda bears die or the glaciers melt; it's not affecting us" (9/4/13). In this excerpt, Molly demonstrates that there are abiotic impacts of climate change although she confuses the panda and polar bears. More importantly, this statement shares the sentiment that a peer does not think humans care about the impacts on animals; it is not affecting humans.

Summary. Molly expressed a desire and commitment to mitigate anthropogenic climate change. Her plans were a mix between reducing greenhouse gas emissions and general environmental clean-up, such as recycling, cleaning up with her church group, and decreasing cigarette smoke. While she used vocabulary and concepts from the curriculum to articulate her stances, she seemed to struggle articulating the scale of change and how the change was occurring. She credits her teacher as the person who had the greatest influence on her thinking about this topic. In this example, Molly exhibits that even without a full grasp of the complex science she can form a stance that anthropogenic climate change is happening and it is important for humans to take action to address the impacts.

Exemplar 3: Robert Represents the Happening and Not Worried Category

Robert is the student exemplar to represent the category that anthropogenic climate change is happening, but he is not worried about the impacts. In this category, student responses were the most varied (as seen in **Figures 6.6-6.8**) from the overall results of the interviews. Robert's interview focuses on doubt about the severity of impacts including time-frame of impacts, and multiple theories/mechanism of climate change discussed in his science class. Unlike the exemplars above, Robert discussed climate change topics a great deal with friends, but he expressed that his family was really too busy to talk about it.

"Propaganda." Robert stated that anthropogenic climate change is happening, but he thinks that there is no need to worry about it. He expresses that he believes the information he hears about climate change impacts is over exaggerated. He does not think climate change and/or its impacts is "as bad as people are saying" (9/25/13). He uses the word "propaganda" to make the point that people are trying to get attention on the matter, but do not have the evidence to prove it is something to worry about at this point. Robert also discusses the scale issue of what he believes constitutes a major temperature shift. The on average 1 degree Celsius increase over 150 years seemed like a relatively slow progression to Robert. He felt like the impacts would be felt in many years from now.

Dialogue below is from interview on 9/25/13 at Village. MS

Robert: I think it is happening. I think that we are one of the main sources. Mainly because, we use a lot of carbon and that can go to CO2. I think there is something. I'm kind of an in-between person. I believe it is happening but I don't believe it is as worse as people are saying. Now, I know since we did a lot of studies in it with {teacher's name}, it's been increasing over the past 50 - 150 years or around there by one degree. Now it seems like nothing but we did an experiment that proved that it is a lot. We also proved that it can overlap over time. I just don't -- I believe it is happening but I don't believe it is as bad as people say. A lot of people use propaganda to get their minds thinking about it. And a lot of people just try to make it so their point is actually recognized so they, um, amplify it. Exaggerate, that's the word I'm reaching for.

Michelle: What kind of propaganda have you seen?

Robert: Well I didn't -- When I say propaganda I mean like when people say, "The world is increasing. This is going to happen and this is going to happen now quite soon. Like sooner or later the coasts of all the states are going to be flooded with water because global warming is happening and it's melting the icebergs [GASP]. I didn't mean propaganda in the way it is usually used. I meant in a way of trying to exaggerate it just to make someone's point notable.

Robert acknowledges that his use of the word propaganda is not used in the traditional sense. However, he told me that he is purposefully using it to make a point. He thinks the information that is portrayed in the public is purposefully trying to sway people to think a certain way and to worry. Therefore, he refers to climate change information that discusses severe impacts in the near-future as propaganda.

Scale and time-frame. Robert does not express any worry in his lifetime about the impacts of climate change and he believes that 1 degree Celsius increase over 100-150 years is relatively slow. Robert expresses that there would need to be a much greater increase in temperature (e.g., 10 degrees Celsius) in his lifetime for him to have true concerns. Robert's response to how worried he is about the impacts of climate change and what would make him more worried can be seen in the following excerpt:

Dialogue below is from interview on 9/25/13 at Village. MS

Robert: My lifetime, I'm not worried. I'm definitely not worried at all really. I mean if it takes 150 or 50 years to increase one percent -- one degree Celsius. I'm planning to live for maybe a 100 years and that's going to be two degrees Celsius on my lifetime -- not so worried but for future lifetime, more worried but not as worried. One degree Celsius does a lot but at the moment, at the same time, it's not that bad.

Michelle: Is there anything that would make you feel very worried about in your lifetime?

Robert: Yes, if we got one of those charts or written down hard solid proof that, um, that indicated that it was increasing rapidly or even more rapid than it is now. Then I would be a little more worried. But unless it truly increased like 10 degrees Celsius or higher then I'd be way-way worried like alarmed or highly worried because a lot of primates and animals will have to move to colder areas. So pretty much if this continues increasing we have to go like this [WHOOP] pretty much to the Poles and sooner or later it would be too hot for life if we let this increase.

To Robert, the change in average temperature is happening slowly. He expresses that in the curriculum they did a lab to show a one degree shift is a major change, but he is not convinced that a one degree change is a major difference. To him a 10 degree increase would increase worry about the impacts. To have a ten degree shift in temperature would have catastrophic results, but from Robert's perspective that would be a reasonable shift to create concern. Moreover, in the discussion of worry Robert did not feel like (a) he was experiencing the impacts of climate change and (b) the impacts are mainly focused on increasing temperatures and that the animals would be the ones that are impacted; there was not a concern about how humans might be affected.

What is a theory? Robert discussed the idea of what a scientific theory is. He wonders who creates these theories. Then, he talked about multiple theories of climate change introduced and taught in his science class during the curriculum.

Dialogue below is from interview on 9/25/13 at Village. MS

Robert: I think that I've got. I'm not going to say it is definite. I'm going to say it is pretty sure happening and in the middle of somewhat sure and pretty sure.

Michelle: What would you need to see to make it definite in your mind?

Robert: True data. One thing that {name of teacher} exaggerated a lot was a theory. Now a theory is great but we're humans we can create that. I mean we can have mess ups. I would need true, thick data like data that was taken by some mechanical instrument that was in many other ways proved to be rightly placed. Then, I would more go to definitely happening because there -- as my friend, {name of friend}, has done a project on -- there are many other things people are thinking of. Maybe they're going through a cycle. There are many other things that are happening. I think that are happening so it may not be this. But there is data showing it is increasing, we just don't know if it is part of a cycle, or if it is just increasing due to what we're doing or what….

Michelle: You mentioned that you talked about a couple of theories in class, what are those theories?

Robert: I don't know their names.

Michelle: Just the general ideas.

Robert: One of the theories is that, the global warming. Then there was the greenhouse gas theory. And the other theory was talking about the Earth's axis. The other theory is the Earth is going through a cycle. I'm trying to remember. There was another theory, um, about the clouds but I couldn't remember it. Because clouds can sometimes be used to reflect light -- I mean infrared light. Sometimes, it can be used to reflect infrared light and sometimes it can be kept to go back. So there was something to do with clouds and how much moisture is going in the air and I couldn't remember that exactly.

In this dialogue about what Robert would need to see to be certain in his response that anthropogenic climate change is happening, he revealed an insight into all the different theories regarding the mechanisms of climate change that were expressed in his science classroom (e.g., greenhouse gas theory, natural cycles, changes in the Earth's tilt, and cloud albedo). The discussion above continued with Robert expressing the importance of evidence and proof to confirm the idea of anthropogenic climate change.

Summary. Robert expressed that anthropogenic climate change is happening, but it is evident that he is not worried about the impacts of climate change. The idea of a global one degree Celsius temperature increase in his mind does not warrant concern. Moreover, he feels that there has been a scare tactic employed to get others talking about climate change. Robert's responses during the interview gave insights into sources of his and others ideas about ozone depletion as well as multiple theories that were discussed in his class about climate change. The idea of messy middle concepts and multiple theories is discussed in more detail during cross discussion of interview and survey data in Chapter 7.

Exemplar 4: Timothy Represents the Doubtful Category

Timothy is the exemplar for the Doubtful category. Timothy is doubtful that climate change is happening, but waivers back and forth between why it might be happening or not. He has been influenced by both the curriculum and his dad's views on the topic, which has left him unsure if it is happening.

Stances on climate change. Timothy expresses that there are multiple sides to this issue. He cites that the Michigan site (i.e. the climate change and its impacts curriculum created by the ChangeThinking research team) showed the students evidence that the climate has changed by 1 degree Celsius, but on the other hand his father states that climate change is not happening at all and he recounts his father's explanation. In the dialogue below, Timothy expressed that there are multiple viewpoints. He also states who and what have influenced his perspectives on the topic.

Dialogue below is from interview on 9/25/13 at Village. MS

Timothy: It's possible that it's happening. You know I haven't been seeing all this data so I don't know for sure or for not. You know some things may be adding to it and some things may be not. There are always some people who think one thing is happening and it could be the direct opposite. You don't know until you look at it.

Michelle: You mentioned you've seen data. What is the data telling you?

Timothy: The data I've really only been seeing was last year off of the Michigan site. It showed a few changes in the temperature just going up by a degree or so over time and that's not too much but if it keeps on going then it's going to become a problem.

Timothy: I know my dad for one thinks that climate change probably isn't happening at all because you know it's probably -- It's warmer one year warmer and one year it's colder. That's what his basic opinion is and that's what I've been mainly hearing all these years about it.

Michelle: Who has been your greatest influences on your thinking on this topic?

Timothy: Greatest influences, that's definitely a challenge between the Website and some of my dad's opinions. We don't talk too much about climate change at all at my house but on those times we do, he thinks about you know some of the things that people call Earth friendly like the electric car -- I know one time we were having a conversation about it, he pointed out to me that the electricity comes from a factory that puts pollutants in the air from the factory. Even though it is getting better and better over the years. And that the battery ends up in a landfill. The car ends up in a landfill and all that.

Timothy pauses and continues…

Timothy: "Um, I think that's what got me going -- him going on about the temperature rising, about the electric car. He says it's probably not happening and that people change it to climate change instead of global warming because the climate is changing and so they can say it's getting colder and change it from it is getting warmer"

In this dialogue above, there are three major themes that need to be noted and discussed in more detail: (a) Influences on stances, (b) conflation of weather and climate, and (c) scale—what is a major change in temperature.

Influences on stances. Timothy acknowledges that the curriculum learned in school contradicts what he hears from his dad. When asked what other information he would like to see to try to make the decision about is climate change happening or not, Timothy states, “Probably some temperature recordings from over 100 years. Because if you look at that, it’s basically going to tell you almost everything you need to know.” When asked he had ever seen such graphs? Timothy said he did see these types of graphs throughout the curriculum, but remains skeptical. Moreover, he recounts that his father thinks that scientists have changed the terms from global warming to climate change. The terminology change was done to allow scientists the leeway to say there was an issue whether it was getting warmer or colder. The skepticism expressed to Timothy by his father is also discussed regarding the environmental friendliness of the electric car. Throughout the discussion of the electric car, Timothy uses the term pollution, but does not articulate that electricity and/or factories emit greenhouse gases.

Weather and climate. In Timothy’s conflict about whether climate change is happening, he conflates the idea of weather and climate. The skepticism from his father is expressed because it gets both warmer and colder from year to year; the temperature is changing. Short-term temperature shifts are descriptions of weather changes. Moreover, the interview with Timothy illustrates a complex scientific idea around climate change that on average some regions are colder as a result of a changing climate. A colder region does not negate the efficacy of anthropogenic climate change.

Scale. Timothy cites that the climate change curriculum he did in school shows a degree Celsius increase in temperature. He discounts this average increase in temperature as not being that much. The context that a degree shift matters is illustrated in the curriculum through a melting point lab. The scale and perspective of what constitutes a major change in average temperature is a difficult concept to illustrate and fully grasp.

Not worried, not impacting me. Timothy is not very worried about the impacts of climate change. He expresses the idea that if the temperature essentially stays the same and he does not see and/or experience any differences, then he will continue to not be worried. Moreover, his concern is low because he feels that if something were to happen scientists can solve the problem:

> "Um, I'm not too, too worried. You know we have scientists all over the world that are monitoring any sort of climate changed then they can say this is happening so this solution is probably going to end up being best so we can either stop this or slow it down enough that we can stop it in the near future" (Timothy, 9/25/13).

Humans have reduced carbon emissions. Timothy continues on the topic of reducing human impacts on the environment with the following dialogue that illustrates he believes that humans have reduced their carbon dioxide emissions over the years:

Dialogue below is from interview on 9/25/13 at Village. MS

> "It could be humans or could just be like natural with cows and stuff. I know people have been going on about in the 1900s how we kept using steam engines. We would have

> factories and how all that could have impacted it; and it could have because we were releasing all these greenhouses gases. But over the years, we've gotten better at containing it so I don't think humans are impacting it too much anymore.
>
> We have reduced the human impact over the years because I think there are cleaners in smokestacks to help get rid of harmful gases that have been released in the past so it is definitely reducing the impacts."

Summary. Overall, Timothy does not have high concerns about climate change despite the fact that he acknowledged that there has been an increase in average global temperature and other evidence that supports the existence of anthropogenic climate change. He personally has not experienced the impacts. Moreover, he has expressed that scientists could come up with a solution to stop "it." However, Timothy does not believe he needs to take personal responsibility to alleviate the situation. Timothy states that humans are emitting less carbon into the atmosphere as compared to the time when the steam engine was invented. He believes the human role in climate change is currently being reduced.

The use of some of the scientific jargon is employed to create doubt in the discussion (e.g., it used to be called global warming and now climate change in order for scientists to say anything changing—hotter or colder—plays into what they want the public to think). Moreover, the discussion of the electric car is mainly introduced by his dad and is used to show that it is a way to stimulate the economy. In his discussions with his dad, it appears that the electric car is not actually better for the environment. Timothy seems to be greatly influenced by his father on the discussion of anthropogenic climate change. Although he specifically cites aspects of the curriculum, such as there has been an average increase in temperature (1 degree Celsius) over the last decade, the outside the classroom influences appear to influence on Timothy's stances. He remains doubtful about the existence of anthropogenic climate change, even though he acknowledges the scientific evidence supporting it.

Exemplar 5: Hailey and Brian Represent the Dismissive Category

Hailey and Brian are the student exemplars to represent the Dismissive category. They both state that anthropogenic climate change is not happening and they are not worried about potential impacts. However, they are both discussed as exemplars because their reasons and justifications for their stances are quite different.

Hailey. Hailey expressed that discussions with her father have helped her form her position about climate change. Her responses to interview questions are vague and she does not employ scientific rationale to justify her stances. When she recounts her dad's views on the topic as well as why she is not worried, she demonstrates a conflation of weather and climate concepts. Moreover, she mentions pollution, but then disagrees with her initial thoughts saying that could not really change the climate. When she uses the term pollution, it is difficult to discern if she is referring to greenhouse gases or general air pollution. Air pollution is an environmental issue, which is not necessarily equivalent to climate change. She does not see how humans could have such a huge influence on something as grand as the climate.

Dialogue below is from interview on 10/14/13 at King St. MS

Hailey: [PAUSE] -- Well maybe like a little bit because people like polluting and that might kind of have a problem with it like stuff in the air. I don't know.
Michelle: In your original answer you said no.
Hailey: Well and [PAUSE] because I don't really see how something like that could change the climate because everything - I don't know. I don't see how that could happen that much.

Outside influences. Hailey was asked who or what has been the greatest influence on her thinking about climate change topics? Her response to this question can be seen below:

Dialogue below is from interview on 10/14/13 at King St. MS

Hailey:	Maybe my dad because when he hears stuff about that, he says what he thinks. I don't know; it's kind of -- I go by that because he's a smart guy.
Michelle:	What does your dad say about it?
Hailey:	He doesn't really think any of that is happening like global warming and what they talk about. It's not like our fault; it is not really something that humans really are doing. It is more of just like [PAUSE] I don't know like weather thing.

When I asked Hailey her stance on anthropogenic climate change, she expressed a similar sentiment to what she said her father has told her about the topic. This is the idea that if there is a change it is not because of human actions. She adds a component when discussing what her father says. She brings in complex ideas of weather versus climate. If there is change, it is a "weather thing."

Weather vs. climate. Just as I reported on with Travis and Timothy, there is a conflation of weather and climate. The idea of what can be seen as a weather or climate event appears in Hailey's interview again, beyond what her father expresses on the topic. Hailey tells me that she is not worried about the impacts of climate change. She says, "I don't think it is going to happen." I continued by asking her if the climate were to change what might some of the impacts be? She discusses that the crops that her family grows might get ruined. Hailey continues by recounting that the animals she studied in the curriculum last year would have trouble adapting and her crops might experience a similar plight. Finally, when I asked if she has seen any differences with her family crops over the last few years, Hailey responded:

> "Yeah. Well there wasn't really a change with the chickens, they were the same. But I think it was last summer when we had it really dry; it never rained. Some of our stuff didn't grow right and died off. But I don't know if that was just -- it wasn't really climate. It was more like water -- not getting green and stuff like that but no, it hasn't really" (Hailey, 10/14.13).

In this response, Hailey begins to question if a drought they experienced is a climate event. She dismisses that thought, and conveys that she thinks that the drought had something to do with water and not climate. She raises the difficult concept that a single event, such as a drought cannot be attributed to a changing climate, but increased occurrence and length of droughts are associated with a changing climate.

Hailey uses the terms weather and climate in her interview, which is a focal point in the curriculum. She concludes that the events she has witnessed are weather-related and not climate-related. However, Hailey does not use scientific reasoning to justify her position. She does not express the conceptual difference between weather and climate. Rather she just states that an event, such as the drought is not related to climate. Moreover, she is vague and often uses the phrase "I don't know" in the middle of explanations.

Brian. Brian also does not believe that anthropogenic climate change is happening. However, he is dismissive more on the grounds of his religion. He reports that his family stated that global warming has been dismissed according to a report they heard on the radio. Although Brian is not worried about the impacts of climate change, he recycles. Brian stated that he recycles because he wants to reduce the impacts on soil health. His responses are short, and he does not employ scientific reasoning to justify and explain his stance.

Brian begins the interview with hesitant responses about his views on anthropogenic climate change. He appears to want to give the "right answer." His waffling between options can be seen in the following dialogue:

Dialogue below is from interview on 10/15/13 at King St. MS

Brian:	Um, it may be happening. I guess like sometimes it is warmer than others and like today it is cold. And so I don't really think it is too big of a deal right now.
Michelle:	Is there a difference between the climate changing and the weather changing day-to-day?
Brian:	Um, well climate is like over time and everything so. This recent year, it has been a lot cooler than it was last year. I guess that could be an outlier or something. I don't specifically believe in the climate change.

While leading to his conclusion that he does not believe in climate change, he conflates the ideas of weather and climate. He discusses going between hot and cold days, and experiencing a cold winter. The change in temperature (i.e. weather) is how he initially dismisses climate change.

Religion. I continued the conversation with Brian, and asked him specifically why he does not believe in climate change?

Dialogue below is from interview on 10/15/13 at King St. MS

Brian:	Because I'm a Christian so I kind of believe God can take care of that and when the world ends; it ends.
Michelle:	You mentioned that as a Christian that has influenced your thinking on the topic. Has anything else influenced your thinking on the topic?
Brian:	Um kind of what I hear from my parents. They said that several days ago that it is actually global warming. Well they heard it on the radio that global warming was a lot like was happening ten years ago and since then it has kind of gone down a little, I guess.

As the discussion continued, Brian said another major influence on his thinking is the bible. He said, "Revelations—where it talks about the world ending." He continued:

Brian: This anthropogenic or whatever where it says that we're the cause of it -- the Lord did leave us to take care of the world so I do think we have a responsibility to kind of take care of it.

Brian grounded in stance in his beliefs as a Christian. In his interview, he illustrated that he believes that God has the ultimate control regarding the end of the world; it is out human control. However, he continues that humans do have the responsibility to take care of the world. These are relatively conflicting statements. Moreover, the discussion is much broader than the scientific discussion of climate change.

In the same part of the interview, he expresses that his parents have also influenced his thinking on the topic. Based on what his parents heard on the radio, they have dismissed global warming. Brian disclosed that he did not hear this report on the radio. He said that he did see evidence from data (graphs) from the curriculum to contradict what his family has said on the topic. He also expresses that he should pay more attention to growing seasons and differences to see if something is changing. He is influenced by both his religious convictions and discussions with his parents, but there is acknowledgement that there is evidence that contradicts his current position. However, his stance remains stable that anthropogenic climate change is not happening.

Recycling. Although Brian does not believe climate change is happening and he is not worried about the impacts, when asked what he does, if anything, to reduce his carbon emissions, he states that he recycles. When asked why he recycles, Brian states:

> Probably the trash and trying to keep the soil healthy. It protects from like trash and everything and causing [PAUSE] I don't know. It is just bad on the environment (Brian, 10/15/13).

In our conversation that is specifically on climate change and impacts, Brian discusses general environmental problems like trash and soil health. Reducing trash by recycling and reducing climate change impacts appear to be interchangeable to Brian. It appears that he thinks recycling is the way to take care of the environment.

Contradictory evidence seen in school. The interview with Brian illustrates that parents and religion can influence a middle school students' view on climate change. However, when Brian was asked what he thought about the graphs and evidence he saw in the curriculum he said, "Uh, this is evidence like maybe this is really happening but I'm not so sure." Although, he temporarily waivered, Brian then expressed skepticism about the graphs and data and that that he personally does not believe that climate change is happening. I then asked him if he expressed his view in class. He said he did not because he is quiet (both in class and at home) and that no one else in class said a different perspective from the curriculum.

Brian's stances are based mostly in his religious convictions. He does not try to explain why climate change is not happening through scientific theories or rationale, such as the changes are due to natural cycles. His word choice and discussion stay vague and he does not use scientific terminology.

Summary. Both Hailey and Brian are influenced by outside factors beyond the classroom, such as discussions with parents and religion convictions. During the interviews, they both discuss ideas of weather to dismiss an idea of a changing climate. Moreover, they use terms, such as pollution and trash, which are vague, general environmental terms and not directly aligned with the climate change discussion. Finally, both Brian and Hailey used the phrase "I don't know" throughout the interviews. It appears that when they could not explain their positions, they resorted to “I don’t know.” They did not use scientific explanations or terminology (those used in the curriculum, for example) to give rationale for their stances.

Patterns of Findings from Student Interviews

The findings from the interviews illustrate additional themes and patterns that spanned students’ climate change stances and knowledge. The major discussion points in this section include (a) influences on students’ stances, (b) mixture of correct and incorrect science to justify climate change stances (e.g., messy middle knowledge concepts), and (c) lack of worry about the impacts of climate change. In Chapter 7, I discuss these patterns within and across the stance categories, compare the findings to literature in the field, and bring in findings from Chapters 4 and 5 to draw conclusions across the entire data set.

Student Attributed Influences on Their Climate Change Stances

In the interviews, students who hold positive stances draw information from school, their teacher, the curriculum, and/or scientific evidence. Conversely, students with more negative climate change stances are more influenced by conversation with parents and religious beliefs. The students that exemplify the Dismissive (5) and Doubtful (4) categories appear to be greatly influenced by interactions and conversations with parents. In the three exemplars within those categories – Hailey (Category 5), Brian (Category 5), and Timothy (Category 4) – the parent perspective contradicted the stance of the curriculum. For these students, the discussions that occurred outside of school centered around the ideas that (a) humans could not have such an influence on something as big as the climate; it is something happening with the weather, (b) climate change has been dismissed and God has control of these issues, and (c) scientific terms were switched (i.e. climate change to global warming) to support claims made by the scientific community.

To build on the idea of influence on a student's stances on climate change, the three student exemplars who agreed that anthropogenic climate change is happening – Robert (Category 3), Molly (Category 2) and Travis (Category 1) – all cited the strong influence of their teachers and/or different aspects of the curriculum. The conversations that occurred within the curriculum were cited and expressed more than discussions outside of classroom.

Mixture of Correct and Incorrect Science

When scientific rationale and terminology were employed in the interviews, it was most often used to make the claim that anthropogenic climate change is happening. However, students across all categories used messy middle knowledge to justify their stances. This mixture of science knowledge is specifically seen in the interviews within the context of conflation of weather and climate, confusion of general environmental issues with climate change specific topics and mechanisms and lack of comprehension of scale and timeframe. This speaks to the messy middle knowledge discussion, which I discuss in great depth in Chapter 7 and have defined in Chapter 2.

Conflation of weather and climate and confusion between environmental issues and climate change topics. Students in all the stance categories conflated the concepts of weather and climate, general pollution, littering, and ozone depletion with causes of climate change. Students use weather, not climate, across the spectrum to justify their stances on anthropogenic climate change. Students discussed weather events, specifically hot extremes in winter, as evidence of a changing climate. Conversely, students cite lack of experience with extreme weather and/or experience with colder temperatures as reasons for why climate change is not happening. The concept of climate being a longer trend than a single weather event appears to be difficult. I discuss this idea further in Chapter 7 where I illustrate that students can define the terms of weather and climate, but have difficulty using the scientific definitions in defending personal stances. Moreover, some terms are used vaguely, such as pollution, and at times it is difficult to determine if a student is referring to air pollution or enhanced greenhouse gas emissions. I discuss distinction further in Chapter 7 with the use of cross analysis of the results chapters.

Scale and rate of change. Scale in science is a difficult concept because of its abstract nature. Indeed, lack of comprehension of scale is one of the obstacles in differentiating between weather and climate. As an example, the student exemplars illustrated that the impact of a small variation in climate are expressed by the students to be equivalent to small fluctuations in day-to-day temperature (i.e. weather). The scientific community discusses a 1 degree Celsius increase on average as climate change and 3 degree Celsius increase as drastic climate change (IPCC, 2013). However, student exemplars said a 7 and 10 degree increase (did not specify Celsius or Fahrenheit) would warrant concern and would show proof of a changing climate.

Moreover, the current rapid change in climate is also not recognized by the students as a dramatic, fast shift. A change over 100-150 years is considered to be unprecedented on a geological scale, but students regarded this timeframe as being rather slow. In the student exemplars, Robert (category 3) expressed that a change in a 100-150 year timeframe was very sluggish and uses this as proof that there is no need for current concern about the impacts.

The conflation of these topics speaks to the point that climate change is an extremely complex scientific concept. It is difficult to reason through a socio-scientific topic such as climate change without full comprehension of the science. Educators need to alleviate the confusion of weather and climate, the grouping of general environmental issues with climate change, and confusion with scale and timeframe in regards to a changing climate. These disconnects need to be addressed in curricular development to aid students in grasping the severity of small changes in climate. This is discussed further in Chapter 8.

Students Not Worried about Impacts of Climate Change

The students across the worry spectrum shared several major commonalities. First, students in all categories were not concerned about the imminent threat of climate change impacts (even those students who expressed concern). It was something that was going to be experienced (if at all) decades from the present. Second, the impacts that inspired concern were in relation to animals and/or impacts that are most likely experienced by people in other regions (e.g., the coast). The concerns were not grounded in local issues that might actually impact the student personally. *Figure 6.11* illustrates reasons students stated of why there were not worried about the impacts and consequences of climate change. The clouds show the general categories for lack of worry that the students expressed in the interviews.

Figure 6.11. General categories based on student interview responses of why students are not worried about the impacts of climate change.

In Chapter 7, the lack of worry is discussed across the entire study. Moreover, connections to literature are made in Chapter 7 to illustrate the similarities and differences in my findings to others in the field.

Conclusion

The student interviews afforded the opportunity to illustrate the spread of student stances and the range of influences and justifications for particular viewpoints. Specifically, the interviews helped identify themes that were present across all stances and which ideas were inherent in specific categories. There were big picture patterns that emerged from the interviews that built on the ideas from the stance categories. These patterns include: (a) using general environmental terms/issues, such as pollution, littering, and trash, and subsequently equating them to climate change issues, (b) conflating the ideas of weather and climate, (c) misusing scale—e.g.,, an average change in a single degree Celsius is not considered to be a major issue, (d) indicating lack of concern/care about climate change impacts, specifically not being worried about (personal) impacts in the near future, and (e) having influences both inside and outside of the classroom. Student exemplars for each category highlight both the spread of stances as well as the big topics that emerged from the interview data.

Science knowledge varied across all stance categories. In all five categories, students conflated the ideas general environmental terms and specific climate change topics and the concepts of weather and climate. Weather concepts were used as evidence by students to state that anthropogenic climate change was happening or not happening. The use of knowledge differed across stance categories. Students in the Dismissive (5) and Doubtful (4) categories used less scientific explanations or terminology, as seen in the curriculum, to give rationale for their stances. Students on the left side of the scale, more often cited the curriculum, such as graphs and activities, to articulate climate change stances.

Additionally, from the student interviews, it appears that students who say that anthropogenic climate change is not happening more often have conversations with friends and/or family on the topic. The student exemplars on the right side of the spectrum cite school, scientist data, evidence, and information, and teacher influences on a positive anthropogenic climate change stance.

Although stances differ across the interview and entire sample population, the interviews revealed that there are common themes and discussions for students across the stance spectrum. Students, even those that expressed current concern about impacts on animals, are not worried because in their view, humans are not currently experiencing the impacts of climate change. Moreover, as students discussed their rationale for stances it became evident that there was conflation of ideas regarding weather versus climate, environmental issues and specific climate topics, and the complexity of scale.

Chapter 7: Discussions across Knowledge and Stance Chapters

Overview of Chapter 7

In this chapter, I present a brief overview of the major findings in Chapters 4, 5 and 6 to discuss the results and findings across the chapters and to illustrate the key contributions of my dissertation. As a reminder, the pre/post surveys and pre/post knowledge assessment were conducted just prior to and just after completing the curricular intervention. The post semi-structured interviews were conducted 4-5 months after completing the curricular unit. As mentioned earlier, all student and school names that appear in this chapter are pseudonyms.

In each section, I give an overview of specific findings and then analyze the findings relative to literature in the field. I begin by exploring the stability of students' knowledge and stances both for the entire sample population, as well as when divided by gender. Subsequently, I provide an in-depth examination of students' stances associated with their lack of worry about climate change and its implications.

I discuss climate change as a socio-scientific issue with connections between my results and the literature. This includes discussions of the role of religion and political ideologies, and outside-of-school factors. I also examine the importance of students' funds of knowledge, use of science vocabulary, and exposure to informal and scientific evidence, as they relate to stance and knowledge development.

Next, I examine the common presentations of messy middle knowledge (Songer & Gotwals, 2012; Gotwals & Songer, 2010) as showcased in the interviews and open-ended survey responses. As a reminder to the reader from Chapter 2, messy middle knowledge is "where students may have some pieces of knowledge and ability to respond to complex science tasks but not all of the pieces" (Gotwals & Songer, 2010, p. 277). It is a blend of accepted science and misunderstandings. I give specific examples of the messy middle knowledge, including use of general environmental terms to explain climate change topics, as well as conflation of weather and climate. Additionally, I discuss the relationships between the current literature and the messy middle knowledge as exhibited in my study. This leads to a justification of the alignment of my study with the p-prim perspective for how knowledge is held in small, contextualized pieces (diSessa, 1988).

Next, I elaborate on the relationship between stance and knowledge development as evidenced by my study and compared to the literature. I provide evidence from both my quantitative and qualitative results. Subsequently, I compare my findings to the literature, including hot conceptual change (Pintrich, Marx, & Boyle, 1993; Eccles et al., 1983).

Finally, I conclude with a summary of the overarching results. From these results, I provide hypotheses, which are addressed in the implications and suggestions section of Chapter 8.

Summary of Findings and Discussion across Chapters

Table 7.1 shows a summary of the big picture findings across Chapter 4 (nature and stability of climate change stances), Chapter 5 (statistical relationship between climate change stances and knowledge), and Chapter 6 (complexities of stances and knowledge based on post semi-structured interview data). Table 7.1 shows themes that presented across all analyses including gender, reasons for student worry (or lack thereof) about climate change, the relationship between knowledge and stances, sources for stated messy middle knowledge, a spectrum of incorrect concepts about climate change held in parallel with accepted scientific theories (i.e. the messy middle) (Songer & Gotwals, 2012), and specific messy middle topics that are exhibited by students.

The topics and themes on the left side of Table 7.1 correlate to headers and sub-headers throughout Chapter 7 and are organized in the table in the order in which they appear in the chapter. Although the grain sizes of the topics are varied, the themes highlight the discussion points that are the focus of this chapter and which lead to the implications and future work that are discussed in Chapter 8.

Table 7.1
Summary of Major Findings Across the Results Chapters.

Topic/theme	**Finding (Part 1/2)**
Overall stability of knowledge and stances	• Positive knowledge change in all three categories. • Positive stance change for the existence and causes of climate change • Stable stances for worry and self-efficacy.

Differences in Stability of Climate Change Stances and Knowledge by Gender in my sample	• In my results, there were gender differences for male and female participants relative to their climate change stances.
	  o Females: Statistically significant positive shift from pre to post survey stating that anthropogenic climate change is happening
	  o Males: Stance on anthropogenic climate change is stable before and after intervention as indicated on the pre/post stance survey
	  o Males: Statistical significant predictors (e.g., father's education level, school attended, and if he feels like he has experienced the impacts of climate change) of statement if anthropogenic climate change is happening (results from the pre and post stance surveys)
	• There are no statistical differences between male and females' climate change knowledge scores on pre or post knowledge assessment instruments

Students' Lack of Worry about Climate Change Impacts	• In pre/post surveys and post interviews, approximately half of the students show did not show any worry about the impacts of climate change
	  o Students attribute their lack of worry to the following reasons (from open-ended responses and interviews):
	    ▪ Not impacting me personally
	    ▪ Impacts happening in the distant future
	    ▪ Impacts will happen somewhere else

A Mixture of Correct and Incorrect Science: Sources for messy middle concepts stated in the interviews	• Despite the interviews being conducted 4-5 months after the conclusion of the curricular unit, students from all stance groups(e.g., Alarmed, Cautious, Happening and Not Worried, Doubtful, and Dismissive), attribute their messy middle concepts to being learned in school, such as from their teacher and/or previous years of school, but do not attribute it directly to the curriculum • Alternative concepts identified in the literature, such as ozone depletion were present in higher frequencies in the interviews (conducted 4-months after curriculum completion) as compared to the pre and post survey data collected o Discussion of ozone decreased from pre to post survey (10% decreased to 5% after the curriculum), but increased to 17% in the interviews (4-5 months after curricular completion)

Topic/theme	Findings (Part 2/2)
A Mixture of Correct and Incorrect Science: Alternative concepts held in parallel with accepted scientific theories (Messy Middle)	• Across all stance groups in the interviews (conducted 4-5 months after completing the curriculum), students discuss incorrect science and a blend of accepted science with incorrect science to explain their rationale for stances. o e.g., chemicals/pollution increases ozone depletion which causes warming because more sun rays are trapped • On post survey responses, students demonstrated a higher frequency of messy middle knowledge (Songer & Gotwals, 2012; Gotwals & Songer, 2010) such as climate change happening because of earth's changing tilt/rotation and/or the sun is getting closer. Response of "don't know the reason for climate change" decreased (20% to 8% on the post survey). These frequencies in responses represent the limbo between incorrect and fully correct knowledge (e.g., the messy middle).

Specific Messy Middle Topics: General environmental issues vs. Climate change specifics	• Across all stance groups in the post semi-structured interviews, and in open ended pre/post survey responses students use the term pollution in multiple contexts
	  o Pollution is used as a synonym for greenhouse gases
	  o Pollution used as a general term (like littering) to describe issues such as water and air pollution
	• Recycling mentioned in surveys and interviews. In interviews students discussed recycling as way to mitigate climate change impacts, but students unsure how/why recycling "helps"
	• On pre to post surveys decrease in student responses regarding general pollution (approximately 20% to 10% on post survey).

Specific Messy Middle Topics: Conflation of weather and climate	• On pre/post knowledge assessment students had significant learning gains on weather and climate questions.
	  o The assessment asked students to define the terms weather and climate, to read a graph that illustrated a climate trend, and to construct an explanation that sought to differentiate between the concepts of weather and climate.
	• Across all stance groups in the post semi-structured interviews, when justifying personal stances, students conflated weather and climate concepts
	  o Individual extreme weather events/heat anomalies are used as evidence for anthropogenic climate change
	• Individual temperature staying the same/no extremes is used as evidence that anthropogenic climate change is NOT happening

Climate Change Stance and Knowledge Development	Quantitative findings (pre/post climate stance survey and knowledge assessment)
	  • Positive statistical correlation between pre knowledge and post stances
	
	Qualitative Findings (post semi-structured interview conducted 4-5 months after curriculum completed)
	  • Negative stances correlate with weak knowledge development from pre to posttest time points and post interview data
	  • Positive stances correlates with both weak and strong knowledge development
	• The results align with hot conceptual change literature; beliefs precede knowledge development (Eccles & Wigfield, 2000;Pintrich, Marx & Boyle, 1993)

Stability of Climate Stances and Knowledge

Chapters 4 and 5 provided multiple results regarding the stability of climate stances and knowledge. This section begins with a discussion of the stability of climate change stances and knowledge over the entire sample population. Then, I focus on the gender similarities and differences regarding the stability of climate change stances and knowledge. Finally, I compare the results regarding stability and gender to literature in the field.

Overall Stability of Knowledge and Stances

Across all students, my results indicate that on average climate change knowledge significantly increased from the pre to post assessment. Moreover, the climate change stance regarding the existence of anthropogenic climate change and its causes had a statistically significant positive shift, although other stances such as worry and self-efficacy remained stable. Table 7.2 shows the stability of stances and knowledge categories before and after the curricular intervention. It can be seen that there were no significant negative shifts in either stance or knowledge categories. Moreover, Table 7.2 shows which schools had significant changes in each knowledge category.

Table 7.2.
Overview of Stability of Stance and Knowledge Categories from Pre/Post Instruments.

Type of shift	**Stances (n=326)**	**Knowledge (n=237)**
Significant Positive Shift	• Anthropogenic climate change is happening (n=326) • Cause: Human actions	• Weather versus climate (Main St, Circle MS, Village MS) • Anthropogenic carbon emissions (Main St, Circle MS, Village MS, North Central MS) • Relationship between carbon dioxide and temperature (Main St, Circle MS, Village MS, King St)
Significant Negative Shift	None	None
No Significant Shift	• Climate change in students' lives (e.g., worry about impacts, experiencing the impacts, and discussing climate change with friends or family) (n=326) • Actions/solutions to mitigate and/or adapt to climate change (n=326) • Self-efficacy (n=326)	• Weather and climate (North Central, King St) • Anthropogenic carbon emissions (King St.) • Relationship between carbon dioxide and temperature (North Central)

Gender Similarities and Differences in Climate Stances and Knowledge

There were more gender differences found for students' climate change stances than climate change knowledge. Gender was found to be a significant predictor of the stability of climate stances. On the other hand, gender was not a predictor for stability of knowledge development.

Stability of climate stances by gender. In Chapter 4, males and females were found to differ in terms of their stability of climate change stances. Specifically, females had a significant positive shift from pre to posttest time points when asked if anthropogenic climate change is happening. On the other hand, the responses from males did not have a significant shift either way (i.e., they were stable) over the same time period.

A gender difference was also found regarding the significant predictors of the logistic regressions that explored the: (a) existence of anthropogenic climate and (b) worry. Specifically, the school in which a student attends, the father's education level, and the self-report of experiencing the impacts of climate change were all significant predictors for males, but not females, in the logistic regression for the existence of anthropogenic climate change.

McCright and Dunlop (2011a) sampled the adult population in the United States and found that there was a difference between male and female climate change stances (McCright & Dunlop, 2011a). Their results suggest that well-educated white males are more likely than females to state that climate change is not happening. My results partially align with the findings of McCright and Dunlop (2011a). In my sample, male stances did not have a significant positive shift towards stating climate change was happening. Males were more likely than females to say that climate change was not happening. However, my convenience sample used a self-selected middle school population as compared to an adult male population in the McCright and Dunlap (2011a) study. Moreover, I cannot speak to education level differences.

The logistic regression for being worried about climate change impacts suggests that females were significantly more worried than males in both the pre and post surveys. Similar results were found in the Six America's study, where a higher frequency of females were placed into the categories that were characterized as being more concerned about the impacts (Leiserowitz, Maibach, Roser-Renouf, & Smith, 2011). Moreover, based on eight years of Gallup data, McCright (2010) also found that adult women were more concerned than men about climate change. My findings align with the literature that females on average are more concerned about the impacts of climate change.

Stability of scientific knowledge by gender. In Chapter 5, I found that there were no significant stability differences among the knowledge categories between males and females. Similarly, gender was not a significant predictor of the knowledge categories, except when interacted with the student's science grade. In my work, knowledge development was not significantly different between males and females. Also, students' science self-efficacy was not significantly different by males and females (Chapter 4). The literature indicates that males have higher interests in the sciences (e.g.,, Baram-Tsabari & Yarden, 2011). Higher interest and efficacy regarding science can lead to higher achievement (e.g., higher scores) for secondary school students (Bandura, 1997; 2001). On the other hand, McCright (2010) found that adult females in the overall U.S. population had greater climate knowledge than men. In this study, middle school students did not exhibit statistically different climate knowledge as measured by the pre and post knowledge assessments. My findings suggest that within my sample of middle school students, knowledge development about climate change topics does not depend on a students' gender. Moreover, there was not a significant self-efficacy difference between males and females in my study, suggesting that there would not be a science achievement difference (Bandura, 1997; 2001), which also aligns with my findings. When middle school males and females have similar science self-efficacy and are exposed to the same climate change curriculum, climate change knowledge development appears to be similar.

Students' Lack of Worry about Climate Change Impacts

In the pre/post surveys and post interviews (Chapters 4 and 6), the majority of students in all stance groups and both genders were not worried about the impacts of climate change in the near future. In the first part of this section, I recap the major findings regarding students' worry and/or lack of worry regarding climate change impacts. I then discuss these findings in terms of student detachment from the issues (e.g., climate change is not impacting me, the impacts will be experienced in the distant future, and/or the impacts are felt/will be felt somewhere else). Throughout this section, I compare my findings and ground the discussion in literature in the field.

Worry Results from Chapters 4 and 6

The surveys and interviews identified that the majority of students (over 50%) were not worried about the impacts of climate change. On the post survey, although the overwhelming majority of students stated that anthropogenic climate change is happening (over 70%), 55% of all students expressed that they were either *Not very worried* or *Not at all worried* about the impacts of climate change.

The survey data in Chapter 4 demonstrated that a student was significantly more likely to be worried if (s)he feels that (s)he has experienced the impacts of climate change. This finding was consistent with the chi square and logistic models presented in Chapter 4. If students expressed that they had experienced the impacts of climate change, they were significantly more likely to be worried than students who did not feel like they have been impacted by climate change. Similarly, students who stated that anthropogenic climate change was happening were more likely to be worried than students who did not believe in the existence of human-caused climate change.

In the post semi-structured interviews, students also exhibited a lack of concern or worry regarding climate change and its impacts. In the interviews, half of the students expressed concern in some form (worried (17%) or somewhat worried (33%)), while the remainder expressed little or no concern about climate change impacts. Moreover, of those students who expressed worry, many (over 40%) stated they were worried because of the concern of future impacts.

The interviews highlighted why students did not express concern about the impacts of climate change. The students' reasons that they gave for their lack of concern can be grouped into three major categories: (a) climate change is not impacting me, (b) the impacts are going to happen in the distant future, and (c) the impacts are happening somewhere else. It should be noted that across all study instruments the majority of students remained not worried about climate change and did not think it would impact them. The lack of concern is similar to studies of secondary students (Pruneau et al., 2001) and adults in the United States (Leiserowitz, Maibach, Rosen-Renouf, Feinberg, & Howe, 2012). Collectively, these results suggest that the United States population is not worried about current climate change impacts.

Student Detachment from Climate Change Impacts

In this discussion of worry, I highlight two main categories that illustrate student detachment from climate change impacts: (a) climate change is not impacting me, and (b) the impacts are happening somewhere else. I compare my findings to existing literature in the field**.** My work supports the existing literature that Americans, on average, are not overly concerned about the impacts of climate change. I characterize this lack of concern as a detachment issue.

Climate change is not impacting me. The survey and interview data show a correlation between students who feel the impacts of climate change (e.g., increased number and intensity of storms and/or droughts) and students who indicate they are worried. Conversely, those who express being detached (i.e., climate change is not impacting them or is happening in the future/somewhere else) are correlated with less worry. The results are consistent with the existing literature. For example, Pruneau et al. (2001) found that teenagers and adults in their study lacked concern about climate change. Their participants stated that climate change would probably not have an impact on their personal lives.

Additionally, my study findings align with the results of Climate Change in the American Mind April 2014 (Leiserowitz, Maibach, Roser-Renouf, Feinberg & Rosenthal, 2014). In this study, only one in three Americans stated that they believe climate change is impacting Americans right now. Adults and middle school students alike did not believe that Americans are currently and/or personally being impacted by climate change. Furthermore, the American perceived climate risk was found on average to be moderate (Leisorowitz, 2005), where a moderate risk perception was defined as believing that climate change will impact distant people and geographies in varying timeframes. Similarly, in my study students who articulated that the impacts were being experienced also said that the impacts were either outside of their personal geographic location or will be experienced in the future.

Happening somewhere else. Students in my study were less concerned about impacts in their region. One student articulated in the interview that she will have more protection from climate impacts than those in New York City, for example, because there are less factories and people and more diversity of plants where they live. This sentiment articulated by the student is an example where messy middle knowledge is interacting with a negative stance. The student justified her lack of worry with an incorrect reason regarding the mixing of the atmosphere. She believed that the excess greenhouse emissions in one area would not impact her and/or the global circulation patterns. This example also illustrates a misunderstanding that general pollution causes climate change. This student's interaction between stances and knowledge may make it difficult for her to see that climate change will impact her in a rural setting. Others in the survey expressed that climate change will impact the Artic or the polar bear (e.g.,, far away from where they are living and/or not impact humans). In the Six America's study (2011), participants were asked how serious a threat is global warming to… "people in you and your family, people in the community, people in the U.S., people in other countries, and plants and animals". Similar to the students in my study, the participants responded that the greatest threat (across all six categories) is to plants and animals followed by a threat to people in other countries. The lowest concern was expressed for their families and their local community (Leiserowitz, Maibach, Roser-Renouf, & Smith, 2011). In both populations (my study of middle school students and a representative sample of US adults), there was a sentiment that we personally are not threatened about the impacts of climate change.

In the literature, skepticism and the “naysayer attitude” (i.e. lack of worry and perception of risk) have increased since 2008, which plays an influential role in perceived risk of global warming (Smith and Leiserowitz, 2012). Smith and Leiserowitz report that “naysayer associations were more significant predictors of global warming risk perceptions than cultural worldviews or socio-demographic variables, including political party and ideology” (p. 1021). Their study discusses the importance of imagery, which is associated with mental models and cognitive representation. It illustrates the importance of personal cognitive models of climate change and less about one’s political ideologies. Moreover, Leiserowitz (2005) indicated that alarmists and climate naysayers had divergent perspectives on climate change impacts and risks. I did not specifically probe students’ perceived risk associated with the impacts of climate change. However, those students who dismissed anthropogenic climate change did not express that they believed there was risk associated with its impacts. Both the middle school and adult populations were not overly concerned about climate change impacts. My findings align with the results discussed above where my students cite similar reasons for their lack of worry regarding climate change impacts.

Climate Change as a Socio-scientific Issue

Topics, such as climate change and evolution, are termed socio-scientific issues, because they are inseparable from societal issues in terms of decision-making, consequences, and level of interest (Sadler, 2004). In this section, I build on the discussion of students’ lack of worry about climate change impacts, and I discuss how my findings regarding climate change stances and statistical predictors of stances compare to the literature and existing findings. There are both internal and external factors that act on students’ beliefs. Below I discuss specific variables that are associated with a person’s views on socio-scientific issues.

Walsh (2012) found that students' climate change views were more grounded in political orientation than religious convictions. I did not probe specifically for political or cultural ideologies in either the surveys or interviews. In these data, political parties and ideologies were not mentioned in any of the student interviews. However, religion was discussed in a minority of the survey responses and students interviewed. Less than 5% of the student responses for open-ended items on the surveys included religious view to justify a stance. Moreover, 13% of students interviewed stated religious beliefs when discussing climate change. For those who mentioned religion, it appeared to be correlated with particular stances. Like the reasoning for lack of worry, religion is correlated with detachment of the human role in climate change. In particular, a theme emerged wherein students discussed that God was in control of climate and/or weather or the doomsday scenarios (e.g., the end of the Earth).

The interview and survey results showed similarities to the research on learning about evolution. In evolution-related studies, students' understanding of evolution was found to be correlated to social and religious views (Hokayem & BouJaoude, 2008; Sinatra, Southerland, McConaughy & Demastes, 2003). To help foster teaching of evolution where beliefs are guided by religion, a teacher and the curriculum must not ignore these perspectives (Smith, 10a); they must be part of the lesson to foster a comprehension of the scientific principles of evolution (Smith 2010a). As a more general statement, research findings regarding stances and decisions on socio-scientific issues stress the importance of personal experiences (Bell & Lederman, 2003), such as familial interactions, political stances, and religious ideologies. Students in my Dismissive and Doubtful categories in the interviews aligned with this research, by exhibiting strong familial and religious factors that were used to justify their socio-scientific climate change stances.

Furthermore, the Six America's study (Leiserowitz, Maibach, Roser-Renouf, & Smith, 2011) found that people in their Alarmed category answered scientific questions correctly more often than their peers in other categories. On the other side of the spectrum, in the Six America's Study people in the Dismissive category had the lowest climate change concept scores. Additionally, the Dismissive group discounted the ability of excess greenhouse gases to change the Earth's temperature. Students in my study exhibited a similar trend. Students in the Alarmed and Cautious categories more often tried to use scientific terminology and evidence to justify stances as compared to the Dismissive category. This is further explored later in the chapter when discussing the correlation between strong knowledge and positive climate change stances.

Previous literature showed mixed findings on whether outside factors were correlated to science knowledge development for socio-scientific issues. Tytler (2001) found that personal local experiences are significant for knowledge development, specifically regarding local issues for study participants, whereas Sadler, Chambers and Zeidler (2004) found that personal experiences were not important in regards to science knowledge development for more global issues. The funds of knowledge literature speaks to the importance of outside factors in student learning, specifically connecting curricula to students' lives and culture in a school curriculum to more effectively engage students. Funds of knowledge refer to "the historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being" (Moll, Amanti, Neff & Gonzalex, 2001, p. 133). Moreover, Moje and colleagues (2004) discuss that students' funds of knowledge shape students' literacy and what they learn in school. Gee (1996) discusses that this interaction between aspects of literacy acquisition, students' funds of knowledge, and students learning in school is called Discourse. In Moje and colleagues' (2004) observations of science classrooms, students did not bring in their everyday Discourse into the science discussions. In interviews, when students were prompted to discuss personal experiences regarding the science, they were quite conversant relating their personal lives to the topics. Students either could not or chose not to relate to the science topics because, for example, it was not their local river that they were studying and they did not relate to or engage with the contexts or community spaces being offered as examples in their science classrooms. This speaks to the need for multiple contexts being offered to personally engage as many students as possible in the science topics.

My findings align with the works that speak to the importance of connecting students' experiences to the content. Specifically, students who felt that they have personally experienced the impacts of climate change were statistically significantly more likely to be worried about the impacts. Students' funds of knowledge are revisited in Chapter 8 in the discussion of making science curriculum more relevant to students' lives. This can potentially address the issue of detachment from climate change impacts (e.g., increase students' level of worry).

Furthermore, Fleming (1986) examined the importance of school in introducing science vocabulary when discussing controversial socio-scientific issues. Fleming states:

> Adolescents' knowledge of the physical world appeared to be restricted to a few words heard in science class. Knowledge of the physical world is rarely, if ever, used when analyzing and discussing socio-scientific issues. School science is the source of the colloquial expressions. It is not, from students' perspectives, a source of useful information for analyzing socio-scientific issues (p. 698).

My findings show that students also use scientific terminology superficially and within a mixture of correct and incorrect science to justify their stances. On the other hand, students who stated in the interviews that school and/or the curriculum were greatest influence on their climate change stances attempted to use scientific terminology and concepts more consistently in their reasons and rationales for stances.

Also, in contrast to Fleming, my findings illustrate the importance of school and a curriculum to help students go beyond just the colloquial expressions to describe socio-scientific issues. 32 % of students in my interviews explicitly credited school for introducing them to the topic of climate change. Several students in the interview stated that what they learned in school and/or from their teacher about climate change had the greatest impact on their climate change views. Moreover, students with a high knowledge score were statistically significantly (p=0.022) more likely to credit their stance that climate change was happening because (s)he learned it in school. School and interactions with the curriculum appears to be positively correlated with stance development.

Additionally, Fleming (1986) explored how students use content knowledge understanding to analyze socio-scientific issues. When assessing use of understanding, the author divided scientific responses into two categories: (a) those students who used only scientific vocabulary without demonstrated comprehension of the terms used; and (b) those students who applied the vocabulary that showed complete comprehension of the scientific knowledge. It was found that 91% of the students merely used scientific terms in the interviews and the remaining 9% articulated scientific knowledge to justify their positions. The vast majority of students relied on social knowledge (aka informal reasoning) to state views on the socio-scientific issues. Informal reasoning and Discourse are part of students' science justifications. As educators, we need to be able to distinguish when social knowledge and informal reasoning are being used to articulate comprehension of a science topic or masking conflation of an idea and/or articulating a messy middle concept. In Chapter 8, I discuss the role of vocabulary and the curriculum to developing science knowledge.

To build on this idea, Sadler (2004) argues that there is a difference between informal evidence and scientific evidence as a foundation for argumentation. As discussed in Chapter 2, Deanna Kuhn and colleagues (2000) discuss that knowledge theory is developed through the coordination of objective and subjective dimensions. Informal evidence includes circumstantial evidence, common sense, and personal experience. Scientific evidence, like science knowledge is developed in a methodological manner and is accepted by the majority of the scientific community (e.g., normal science (Kuhn, 1962). Like students in the study, Tytler, Duggan, and Gott (2001) found that in regards to environmental issues, the general public relies more on informal evidence than scientific evidence to form an argument. Students in my work used both scientific and informal evidence to justify their stances as seen in the open-ended responses and the interviews. The use of informal reasoning and evidence in my work does not equate to incorrect science. Rather, informal reasoning incorporates the importance of personal and prior experiences and students' Discourse. Students across all knowledge levels used both informal reasoning and scientific evidence to justify their stances; through their justifications they exhibited a spectrum of the full comprehension of the science through messy middle knowledge. The importance of the use of informal reasoning and personal experiences is discussed in curricular suggestions in Chapter 8.

Messy Middle Knowledge Concepts

In this section, I first give an overview of the findings regarding students' use of messy middle knowledge concepts to justify their stances. Specifically, I discuss the conflation of environmental issues and climate change specific topics (e.g., pollution, factories and littering, recycling, and ozone depletion, which students use as evidence and/or causes of climate change). I then compare my findings to literature in the field. In the final piece of this section, I give a brief overview of findings that illustrate students' conflation of weather and climate concepts and discuss these results relative to other literature.

Overview of Findings from Chapters 4 and 6

The interviews, pre/post knowledge assessments, and surveys allowed for triangulation of the data to explore the idea of the messy middle knowledge. As a reminder to the reader from Chapter 2, Gotwals and Songer (2010) discussed the messy middle, which is also known as middle knowledge, as "where students may have some pieces of knowledge and ability to respond to complex science tasks but not all of the pieces" (p.277). The messy middle knowledge is a step toward the sophisticated knowledge development. As discussed in Chapter 4 and by Gotwals and Songer (2010), the path to sophisticated, correct knowledge is not necessarily linear and/or the same for each student.

The interviews both built on (e.g., new and expanded findings) and confirmed several themes that were discussed in Chapters 4, 5, and 6 that illustrated students' blend of correct and incorrect science to justify climate stances (e.g., the messy middle knowledge). In Chapter 4, the idea that students do not necessarily transition from not knowing the information to grasping the fully correct science was identified. On the open-ended responses on the surveys, the frequency of *Don't know* responses decreased on the post surveys in comparison to the pre surveys. However, the frequency of responses, such as climate change is the result of the sun getting closer, the Earth's tilt changing, and/or approaching doomsday, increased on the post surveys. Furthermore, the interviews illustrated a similar trend where many students are using a mixture of correct and incorrect science to justify stances.

Messy middle concepts can exist in parallel with accepted scientific principles and they may persist (Smith, DiSessa, & Roschelle, 1993/1994; Driver, Guesne, & Tiberghien, 1985). The science topics where the messy middle knowledge occurred are identified below, including (a) confusion between general environmental issues (e.g., pollution, recycling, and ozone depletion) and climate change topics/mechanisms and (b) conflation of weather and climate.

Environmental Issues versus Climate Change Specifics

In this section, I show specific categories where students have shown messy middle knowledge in their explanations and justifications across the results chapters. I briefly discuss and give major findings for the following categories that confuse environmental issues with climate change specific topics: (a) pollution, factories and littering, (b) recycling, and (c) ozone depletion.

Pollution, factories, and littering. After analyzing the responses in the open-ended surveys, I was left with several questions about students' use of the words pollution and litter: (a) are students using the term pollution as if it were synonymous with excess greenhouse gases in the atmosphere? (b) is it a messy middle concept or just an over generalization of a mechanism of climate change? Moreover, (c) if a student mentions littering, how does that fit into his/her idea of the climate change discussion? In open-ended responses, approximately 20% of the students on the pre survey and 10% on the post survey discussed general pollution (e.g., factories) and littering as a cause of climate change. The interviews showed similar trends to the surveys in term of the use of the words pollution and/or litter when discussing climate change.

Recycling. Along the same lines of discussing pollution, littering, and chemicals students discuss the idea of recycling with a vague connection to climate change. It was mentioned as a way to reduce the impacts of climate change. On the surveys, when students were asked to list two activities that they could do to reduce your personal carbon emissions, approximately 18% and 25% from male and female respondents, respectively, gave recycling as a solution on the post survey. However, recycling was never discussed in the curriculum and is less clearly connected to the reduction of carbon emissions. The interviews revealed that when asked what recycling does to benefit the environment, the responses were often vague. Students had difficulty describing how and why recycling is associated with climate change. Climate change and other environmental science topics, such as recycling are being treated as synonymous to each other. Moreover, regardless of whether students believed that anthropogenic climate change is occurring or not, students discussed that they recycle to reduce waste. Students knew they should recycle, but could not articulate how recycling impacts the environment and more specifically how it reduces carbon emissions.

It appears that students are discussing recycling as an environmentally friendly act, which has no direct connection to carbon reduction. Students did not distinguish between general acts to reduce waste with actions directed towards climate change mechanisms. Although recycling is a successful environmental campaign (e.g., The Reduce, Reuse, Recycle triangle (http://www2.epa.gov/recycle), it appears that students may have difficulty in discussing what will actually mitigate personal carbon emissions and what is generally good for the environment. In the Nature of Science discussion, it is said that ideas have to be made explicit in order for the learner to engage in the topic and pick up the nuances of the concepts (c.f. Lederman & Lederman, 2014). Just doing the science does not translate to student learning. Rather, there needs to be explicit discussions and enough talking time to truly highlight the topics and practices that are targeted (c.f. Lederman et al., 2002). We have failed to explain the nuances in the differences regarding recycling as an environmentally friendly act and carbon reduction to reduce climate change. In Chapter 8, I discuss in more detail the importance of specific vocabulary and repeated exposures in different contexts to help students differentiate between reducing our overall global environmental impact and specifically actions to reduce climate change.

Ozone depletion. The pre and post survey results from the open-ended questions indicate that approximately 10% of the students in the pre survey and 5% students in the post survey cited ozone depletion as the cause of anthropogenic climate change. For context, the term ozone did not appear on the surveys. Moreover, the curriculum does not mention ozone and/or atmospheric stratification in any of the activities. In the interviews, ozone was mentioned in 17% of the responses regarding the causes of anthropogenic climate change, which is almost as often as fossil fuels and/or the greenhouse effect (21%). The frequency of discussing ozone decreased from pre to post survey (10% to 5%,) but increased to 17% several months after completing the curriculum

Students had difficulty distinguishing between the result of a hole in the ozone and an enhanced greenhouse effect as a result of increased greenhouse gases. Other researchers found similar findings regarding ozone as a common alternative when discuss climate change and global warming (Rye, Rubba, & Wiesenmayer, 1997; Bostrom, Morgan, Fischhoff, & Read, 1994). Their work indicates that students and adults incorrectly discussed ozone depletion as both a result of a changing climate as well as being synonymous with an enhanced greenhouse effect.

Additional Literature Regarding Environmental Issues versus Climate Change Topics

Scientifically vague terms such as pollution, recycling and ozone depletion are not synonymous with increased greenhouse effect and reduction in carbon emissions. Yet, students used these terms interchangeably to describe both climate issues and general environmental topics. The Six America's study (Leiserowitz, Maibach, Roser-Renouf, & Smith, 2011) identified scientific principles that were expressed by their participants that were not accepted as sources of climate change. Like students in my study, these participants discussed waste (pollution) and ozone depletion as sources of climate change. Similarly, there was conflation of general environmental issues with climate concepts. Across both my ordinal stance categories and the Yale spectrum, all categories exhibited a mixture of correct and incorrect science. However, those that exhibited a tendency towards using more correct than incorrect science were correlated with more positive climate change stances.

In a literature review of students' alternative concepts regarding climate science and climate change from 1993-2005, Choi, Niyogi, Shepardson, and Charusmbat (2010), there was no discernable pattern in change of student alternative concepts nor was there a pattern of alternative concepts by worldwide geographic location. Work in the field has identified that K-12 students, as well as educators, have difficulty explaining the greenhouse effect (Rye, Rubbas, & Weisenmayer, 2007; Andersson & Wallin, 2000; Boyes & Stanisstreet, 1993). Specifically, there is the conflation of the idea of ozone depletion and the mechanisms causing the enhanced greenhouse effect. For example, Rye, Rubbas, and Weisenmayer (2007) found that when they asked 24 middle school students, "When you think about global warming what comes to mind?", the majority of students brought up the ozone layer or ultraviolet radiation in their interview responses. Similarly Boyes and Stanisstreet (1993) found that 60% of students in their study discussed that the ozone layer is responsible and/or the cause of increased average global temperatures. While my results indicated patterns of conflation of ozone layer and depletion with the greenhouse effect, the frequency of responses were not as high as in previous work in the field. I contend that interacting with an evidence-based curriculum may aid in the reduction of stated messy middle concepts.

Similarly, it is not uncommon for students to state that climate change is caused by general pollution (Rye, Rubbas, & Weisenmayer, 2007; Gowda, Fox, & Magelky 1997; Pruneau, Moncton, Liboiron, & Vrain, 2003; Kouladis & Christidou, 1999) and/or the result of littering (Boyes & Stanisstreet, 1993; Gowda, Fox, & Magelky, 1997). Pruneau et al. (2001) found that the majority of students in their study stated that climate change can be caused by any kind of pollution (e.g., air, water, littering). Similarly, 40% of students studied equated greenhouse gases with general air pollutants (Kouladis & Christidou, 1999). Choi et al. (2010) concluded that, "Students' concepts of pollution are often not sophisticated enough to differentiate between the disparate effect of traditional air pollutants, such as soot and other particulates and greenhouse gas pollutants" (p. 895). The studies mentioned above all illustrate the similar trend that students are not distinguishing between general air pollutants and enhanced greenhouse gases.

It has been found that pre-service science teachers also attribute air pollution to a climate change mechanism (Papdimitriou, 2004). Moreover, Boyes and Stanisstreet (1993) found that, "children are aware of a range of environmentally 'friendly' and 'unfriendly' actions, and cognizant of a range of environmental problems, but that they do not link particular causes with particular consequences" (p. 531). Rather, children appeared to think in a general way that all environmentally friendly actions help all problems (Boyes & Stanisstreet, 1993). Along the same lines, Fortner (2001) found that both students and teachers think that environmentally friendly action or behavior can impact all issues. This speaks to the idea that students in my study discussed recycling as an environmentally friendly action that was not linked to a specific mechanism of climate change. Thus, when students state recycling or reduce pollution as a means to reduce carbon emissions, it cannot be assumed that they are distinguishing between doing something that is generally environmentally friendly or attempting to mitigate climate change.

Conflation of Weather and Climate

A main lesson of the curriculum focuses on the distinction between weather and climate. The lesson has students work with data to help see the difference in timeframe and scale between the concepts of weather and climate. Three out of the five schools (two out of three of the locations interviewed) (see Table 7.2) had statistically significant positive learning gains on the weather and climate category on the knowledge assessment (Chapter 5). While students did well on the knowledge component of this category, the interviews revealed that months after completing the curriculum students still conflated the concepts of weather and climate. The students used the terms interchangeably. Students also used the changing weather as both evidence for and evidence against anthropogenic climate change.

Weather versus climate comparison to literature. Although, the knowledge assessment indicated a positive significant learning gain for the category weather versus climate, the interviews illustrate that months after completing the curricular module, students conflated the complex topics of weather and climate. It is difficult to grasp the idea that a small average change, over a longer period of time indicates climate change, while a single extreme event constitutes a weather event.

For a middle school student, the concept of a single event (e.g., extreme hot day, tornado) appeared in their discussions about why climate change is or is not happening. From the interviews, students used a single extreme hot weather event as evidence for climate change, while others used cold weather as evidence against climate change. This speaks to both the conflation of weather and climate, as well as confusion that climate change must be associated with warming globally. Moreover, the results across my study illustrate the abstract and complex nature of scale. Specifically, students articulated issues with the concepts of timeframe (i.e. climate is over an extended period of time rather than a single weather event) and the magnitude of temperature change that is necessary to constitute a changing climate (e.g., an average shift of half a degree Celsius).

Other literature also found that students conflated the ideas of weather and climate (Gowda, Fox, & Magelky, 1997; Pruneau et al., 2003). In these studies, students discussed the idea that warmer temperatures and weather are evidence of climate change. Gowda, Fox, and Magelky (1997) also found that students thought the average temperature change was associated with global warming/climate change and would be much greater than 1-3 degrees Celsius. Students in their study reported that currently (study conducted in 1997) there has been a 7 degree Fahrenheit increase and by 2050 there would be an 18.4 degree Fahrenheit increase. In our curriculum, there was an activity dedicated to the drastic impact on the environment of a single degree Celsius shift (e.g., melting point lab), which was the final section of the lesson that focused on weather and climate concepts. The findings from the other cited literature align with the interview respondents who overestimated the average temperature change that occurs with climate change. As indicated in interview responses, a 1 degree Celsius shift did not seem like a big change for several of the interview exemplars.

Alternative Concepts and Messy Middle Knowledge

As discussed in Chapter 2, connections between p-prims in multiple contexts must be made in order to learn the metacognitive process that enables a student to build on prior knowledge and then contextualize that knowledge. P-prims can be both incoherent and abstract in nature. When asked a question, students make connections to different p-prim structures from past knowledge construction and experiences. They can connect ideas that are both consistent and inconsistent with expert knowledge (Hammer, 1996; diSessa, 1988). Thus, there needs to be an active process between the learner and the knowledgeable other (e.g., the teacher the curriculum, and/or other tools (Vygotsky, 1978)). However, in this study, conflation of climate and weather concepts as well as environmental issues with climate change topics occurred frequently throughout the data collection. Messy middle knowledge is part of the learning process (Carey, 2000). Carey (2000) states that,

> "Misconceptions are inevitable. Not having the target concepts is not an undesirable stage in students, but an absolutely necessary one. Indeed, students *will* construct intermediate steps and misconceptions that do not with the views of developed science, and educators should recognize when these steps constitute progress, not problems" (p.18).

Students illustrated these messy middle concepts in my findings. They should be identified by educators in order to build productively on these knowledge and belief systems. The messy middle concepts are not inhibitors to learning, but rather steps and paths along the way to progress.

Minstrell (2001) illustrates that students can reorganize and identify scientifically correct facets if they are given the opportunity to work through multiple activities. As a reminder from Chapter 2, a facet of student knowledge is the spectrum of ideas and reasons students give, which include incorrect ideas, messy middle knowledge, to full comprehension of the science topics. Students reason through a situation based on previous experiences and learning and draw on different facets of knowledge. Through multiple activities and contexts, students can begin to integrate the new knowledge into the existing structures and continually build towards the more expert knowledge. The goal is to build productively on the existing p-prims towards expert knowledge, but one does not have to eliminate these contextualized ideas in the process of the learner creating knowledge (Hammer, 1996). In Chapter 8, I suggest modifications to the curriculum to address the specific alternative concepts and messy middle topics discussed above.

Evidence for Alignment with P-prim Perspective

My findings indicate that knowledge is held in smaller pieces that are associated with prior knowledge and contexts (diSessa, 1988; Minstrell, 1992). Climate stances and knowledge appear to be held in pieces, as shown by students who discuss the impacts of increased carbon dioxide in the atmosphere and, yet, also state that anthropogenic climate change is not happening. The response of ozone depletion as the stated cause of climate change reduced in frequency on the post survey. It appears that the initial messy middle concepts did not inhibit knowledge construction as was theorized by diSessa (2006) and Smith et al. (1994). In the context of the post-survey, students were able to use other p-prims to respond to the items regarding climate change mechanisms. Ozone depletion had not been mentioned in the formal curriculum (Songer et al., 2012) that was given to the students and teachers. However, the response of ozone depletion reappeared in higher frequency in the student interview responses. It never disappeared and remains in parallel with a student's cognition to the material learned in the curriculum (Smith, diSessa, & Roschelle, 1994).

Sometimes the p-prims were not connected when discussing climate science in the varied contexts within the curriculum and data instruments. For example, some students drew on the ozone depletion p-prim and connected it to climate change causes more often in the interviews, which were a different context in comparison to the curriculum and written assessments. Moreover, when students were asked where they heard about ozone depletion and climate change, students discussed hearing about it in science class over multiple grades. This speaks to the idea that students retain prior experiences and previously constructed p-prims from prior learning moments.

The curriculum did not specifically address ozone depletion; in fact, we purposefully did not design lessons around atmospheric layers in attempts to avoid confusion of ozone depletion with the mechanisms of climate change. However, as shown in this study, students' prior learning experiences need to be considered with regards to messy middle concepts, such as ozone depletion and/or general pollution and climate change.

For some students, the messy middle concepts appeared in the interview responses months after completing the curriculum. The messy middle knowledge is not replaced, but constructively built by connections to other experiences and knowledge. Moreover, students may not have exhibited the incorrect knowledge concept on the post assessment, because they are savvy at "doing school" and were experienced test takers within the curricular module. On the other hand, the interview was a separate context where students made connections to other existing knowledge and prior experiences. Moreover, knowledge that was acquired in the curriculum may have deteriorated given the time lapse of the interviews.

Knowledge and Stance Development

Knowledge and stances are complex constructs that have a great deal of overlap. As discussed in Chapter 2, both climate change stances and knowledge development are potentially mediated by inside and outside of school factors. Knowledge is influenced by the culture, norms, and people in power at the time (T. Kuhn, 1962), and the creativity of the scientist (Lederman et al., 2002). Although scientists try to make the knowledge unbiased and objective it ultimately has a human bias. It can be difficult to tease apart students' science knowledge and stances. Carey (2000) discusses the relationship between belief systems and cognitive change. Through examples, she demonstrates that students' belief systems differ from adults. A child's beliefs change as they are exposed to and understand the scientific world around them. The beliefs are contextualized within the given concept (Carey, 2000). Additional connection between belief systems must be connected to encourage change. As discussed above, students' messy middle knowledge is part of the learning process and should not be seen as an inhibitor for knowledge development.

My findings suggest a positive correlation between students' climate change stances and knowledge, conditioned on all other control variables in the models. In this section, I take into consideration my study's findings and also the conceptual change literature to discuss the relationship between climate change knowledge and stances. The stability of students' stances and knowledge, the statistical relationship between climate change stances and knowledge, and the qualitative findings from the post semi-structured interviews lead to a discussion of which acts as a foundation for development, stances or knowledge?

The results from Chapters 5 and 6 indicate that there is a positive correlation between knowledge and stance development. My quantitative results indicate a significant, positive correlation between knowledge scores and climate change stances. A positive climate change stance can exist without strong knowledge existing. My interview results indicate that a student with a weak knowledge score can have a positive or negative stance. However, a student with negative stances was less likely to demonstrate strong knowledge construction. In Chapter 8, I suggest future studies and data that need to be collected in order to fully define the relationship between stance and knowledge development.

Evidence for the Statistical Relationship between Strong Knowledge and Consistent, Positive Stances

In Chapter 5, pre knowledge is both a significant predictor of a student's post knowledge and post stance score. Pre knowledge has a positive statistical relationship to a student's post climate change stance. A student's pre stance is only a predictor for a student's post stance score, but not pre or post knowledge. The quadratic sign function indicates that student with extreme pre stances had a statistical correlation to his/her post stance.

There is additional evidence to suggest that strong knowledge is statistically related to positive stances when looking at the statistical relationship between knowledge and the student's stance regarding the existence of climate change. In particular, students were separated into two groups based on their pre knowledge scores (e.g., high knowledge score—above 10 points or above and low knowledge score--below 10 points). Then a Fisher's exact test was conducted to test for a difference between post responses to the question regarding the existence of anthropogenic climate change among the two knowledge groups (e.g., high and low). Students with a high pre knowledge score (10 or more points out of a possible 16) were statistically significantly (p=0.015) more likely to say that climate change is happening after the curriculum. Every student in the higher knowledge category stated that anthropogenic climate change is happening, except a single individual who stated that he did not know.

A similar finding was exhibited on the open-ended post survey question regarding the reasoning why the student stated anthropogenic climate change was happening or not. Responses differed significantly between the high and low knowledge score students. Students with a high pre knowledge were more likely than students with low pre knowledge scores to have responded that climate change is the result of human actions ($p = 0.01$). The human actions response included answers regarding increased use of technology, increased energy use, population growth, and deforestation, all of which indicate comprehension of different aspects of human contributions to a changing climate.

Evidence from Interviews between Stances and Knowledge

In Chapter 6, I presented results from the post semi-structured interviews. Students in the Dismissive and Doubtful categories exhibited negative climate change stances. Moreover, the knowledge to justify the stances was vague and did not align with accepted scientific principles. The students consistently discussed incorrect science in their explanation and evidence regarding the mechanisms of climate change. Students in the more positive stance categories (e.g., Happening and not worried, Cautious, and Alarmed) presented a mixture of strong and weak knowledge. Positive stances did not consistently equate to weak or strong knowledge. Said another way, a student with a positive climate change stance could lie anywhere on the spectrum of strong to weak knowledge. This speaks to the idea that students exhibited messy middle knowledge as they progressed to complete knowledge development of the complex science. It is not necessarily a linear or direct path to go from incorrect scientific knowledge to expert (see *Figure 4.21*). Many students need to go through messy middle stages before fully articulating the complex concepts. When I discuss curriculum design approaches in Chapter 8, I offer different methods that can be used to help students work through the messy middle knowledge.

Knowledge and Stance Development Literature

Eccles and Wigfield (2002) argue that beliefs (e.g., self-efficacy) need to change first before there is a change in outcomes and expectations (Bandura, 1997, Pintrich, et al., 1993). As discussed in Chapter 2, self-efficacy is not synonymous with climate change stances. However, there are parallels between these beliefs and stances. Outside of school factors might impact both of these stances, and self-efficacy, just like many other climate change stances is often stable (Bandura, 1994). Connell and Wellborn (1991) also cite belief control and change occurs before certain psychological needs, such as competence. Although the works of these authors are not directly analogous to the relationship between socio-scientific stances and knowledge, they suggest that beliefs are the first to change. Fleming (1986), Tytler, (2001), and Hogan (2002) suggest a need for scientific knowledge to serve as a base for socio-scientific decisions and positions, such as climate change stances. Thus, the knowledge change would precede stance change. My results cannot speak conclusively to the order of change, but they align with findings from the Six America’s study discussed in Chapter 6, where there was a correlation between strong climate science content knowledge and positive stances.

Cold and hot conceptual change. As discussed in the conceptual framework in Chapter 2, cold conceptual change focuses only on cognition and knowledge. Hot conceptual change accounts for the role of students’ motivation and classroom contextual factors as potential mediators for conceptual change (Pintrich, Marx and Boyle, 1993). Hot conceptual change as discussed by Pintrich, Marx, and Boyle (1993) incorporates students’ motivational beliefs (e.g., goals, values, self-efficacy, and control) and how students’ role as a learner contributes and/or inhibits conceptual change.

The literature in hot conceptual change work points to belief change leading to knowledge change. To change knowledge, stances first have to change. For example, Expectancy-value theory states that “individuals’ choice, persistence, and performance can be explained by their beliefs about how well they will do the activity and to what extent to which they value the activity” (Wigfield and Eccles, 2000, p.68). Productive oriented views, stances, and beliefs exist before creating productive knowledge. Hot conceptual change takes into account the motivation and belief structures that correlate to change.

My work aligns with the knowledge in pieces literature regarding the contextualized nature of small knowledge structures. Moreover, my work takes into account the role of stances and context in regards to knowledge development, particularly when considering a student’s prior knowledge and experiences to develop knowledge. I hypothesize that my interview findings align with aspects of the hot conceptual change literature where stances and knowledge development is at least partially mediated by factors, such as motivation, context, and environment/cultures of learning.

While my work explores only one motivational construct (i.e. self-efficacy), the other stance categories regarding climate change draw parallels to the hot conceptual change work of Pintrich et al. (1993). They are both complex constructs with many potential inside and outside of school factors that help to develop a student’s stance. Moreover, stances can be different by gender and are stable in certain categories (Bandura, 1994). Similar to hot conceptual change studies, this work suggests that students’ climate change stances, just like self-efficacy, can be a part of a students’ knowledge development, specifically regarding climate change knowledge. Moreover, the self-perception of the learner in their own learning can possibly hinder or help conceptual change. For example, in the interview, Brian said he did not think anthropogenic climate change was happening and cited his religious beliefs to justify his stance. When probed on the issue, Brian said he did not express his views in class. He discussed that he knew others did not agree with him, so he just kept it to himself and stayed strong in his position. Unlike messy middle knowledge, which is a step toward knowledge development that aligns with accepted science, a student's stance (negative or positive) could possibly be a factor in helping or hindering knowledge development.

Climate Change Stances as the Foundation for Knowledge Development?

The hot conceptual change literature indicates that productive beliefs set the foundation for productive knowledge development. My data provide mixed results about the relationship between stances and knowledge articulation. In the surveys and interviews, students with weak stances (e.g., anthropogenic climate change is not happening) exhibited weak and/or vague climate change knowledge, as illustrated in *Figure 7.1*. This is also confirmed by the results in Chapter 5, where weak pre knowledge is significantly correlated with negative post stances. *Figure 7.2* illustrates that positive stances in the interviews do not consistently correlate with strong knowledge. I hypothesize that positive stances should be considered as a possible factor to help students work through the messy middle toward strong knowledge development. Evidence for this pathway of knowledge development is given in the interviews conducted months after the curriculum, where students with positive stances exhibited both strong and weak knowledge, while students with negative stances only displayed weak knowledge.

The timeline of data collection needs to be considered in drawing conclusions about stance and knowledge development. In Chapter 5, during or shortly after the curriculum, I showed that knowledge development was not differentiated by pre climate stances (e.g., stances did not statistically correlate to the type of knowledge developed). However, months later when the interviews were conducted, negative stances were found to be associated with weaker knowledge. Therefore, one hypothesis to explain these results is that negative stances might limit complex knowledge development or, said another way, these data suggest the hypothesis that negative stances might make it more difficult for students to develop complex knowledge. This speaks to the idea that repeated exposure to climate science evidence may be needed for consistent, positive knowledge development. This idea is further discussed in Chapter 8.

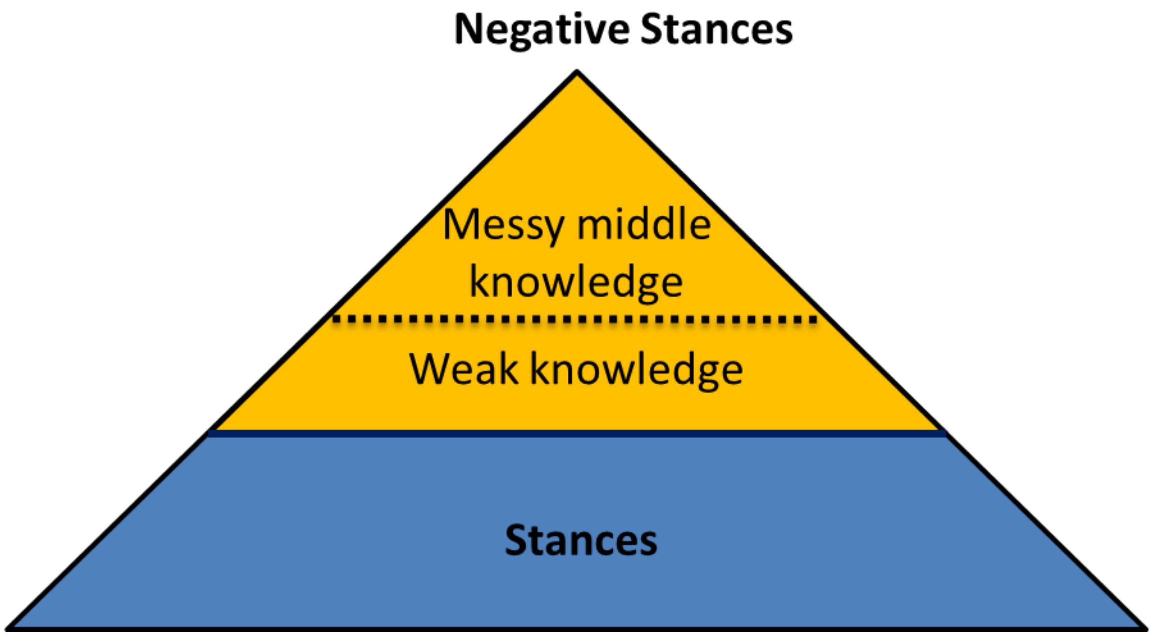


Figure 7.1. In the post interviews, negative stances are associated with weak knowledge statements. Additionally, the quantitative data shows a correlation between weak pre knowledge and negative post stances. The findings speak to the hot conceptual change literature regarding beliefs preceding knowledge development.

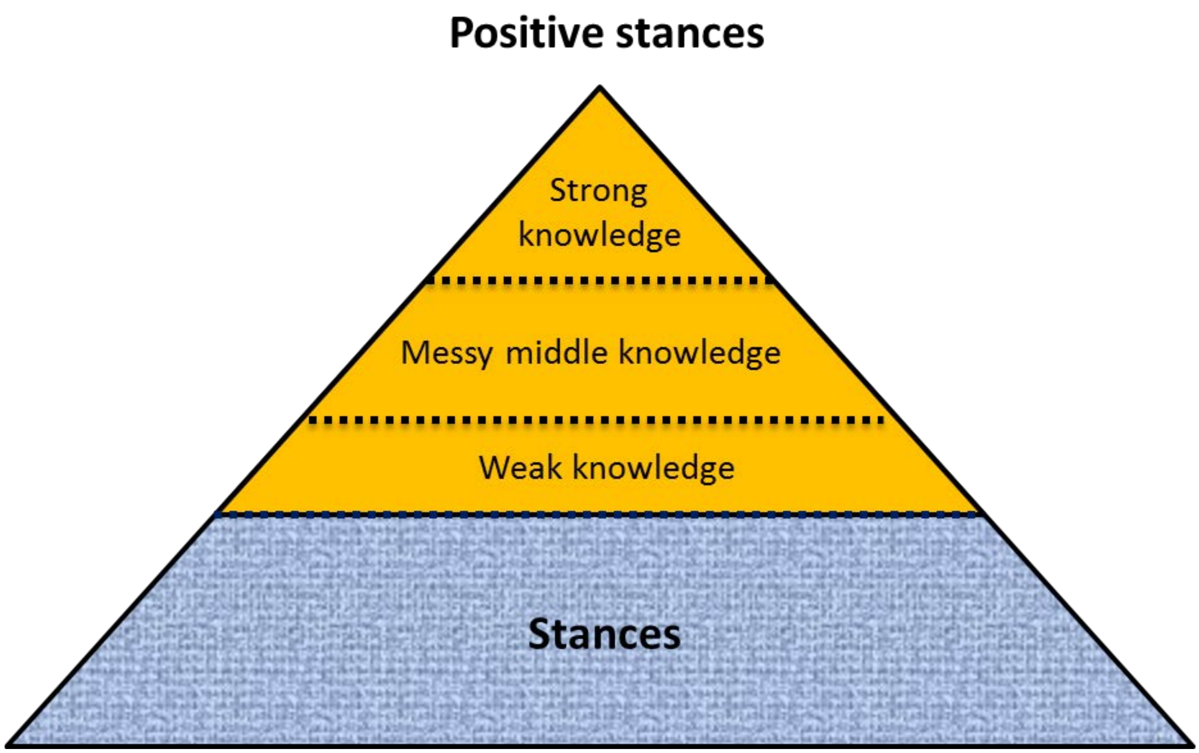


Figure 7.2. In the post semi-structured interviews students with positive stances exhibited both strong and weak knowledge. The findings from the interviews suggest positive stances might provide the foundation for strong knowledge development where those students illustrating weak/messy middle knowledge and not as far along in their development of strong knowledge. However, the interview results are inconclusive.

Conclusions

My study indicates that there is a positive, significant relationship between pre knowledge and post stances (e.g., higher knowledge on average correlates with more positive stances). Moreover, post interview data suggests that negative stances are associated with weak climate change knowledge. Negative stances might make it more difficult for students to develop complex knowledge, as indicated by the interview results. A mixture of correct and incorrect science has less consistent correlation with stances. The messy middle knowledge was exhibited for students with both positive and negative stances. Figures 7.1 and 7.2 illustrate these patterns of stance and knowledge development for students with negative stances and positive stances in the interviews, respectively.

Another major finding in my work is the students' lack of worry regarding climate change impacts. The reasonings students gave for their lack of worry regarding climate change impacts included: (a) it is not impacting them, (b) the results/impacts will be felt in the distant future, (c) the results/impacts are happening somewhere else (a different geographic location), and (d) the results/impacts will are affecting animals but will not be felt by humans. The lack of worry is discussed in Chapter 8 with regards to curricular suggestions.

Table 7.3 lists the major findings from my dissertation work, which are addressed in Chapter 8 in my implications and limitations sections. The first statements address findings in regards to the relationship between stances and knowledge. I discuss the results from two time-points: (a) during the curricula intervention time-frame (e.g., pre and post stance and knowledge) and (b) post intervention at 4-5 months after completing the curriculum (e.g., post semi-structured interviews). For the first time point, the results I discuss are based on quantitative analysis of the pre and post stance and knowledge instruments. For the post time-frame, I offer findings from the interviews. The other statements reference the stability and/or statistical predictors of students' climate change stances from the stance surveys. Finally, I provide hypotheses based on my results, which leads into the discussion in Chapter 8.

Table 7.3

Summary Statements and Hypotheses Based on Dissertation Findings

Summary Statements and Hypotheses Based on Dissertation Findings
Relationship Between Stances and Knowledge 1. High pre and post knowledge correlates to positive post stances. If a student earns a high score of his pre and/or post knowledge assessment, he is more likely to consistently have a positive climate change stance immediately after completing the curricular module. 2. In the interview data (4-5 months after completing the curriculum), there is no clear pattern between positive stances and high knowledge. Students who had positive stances in the interview exhibited both high and weak/messy middle knowledge to explain their climate stances. a. Note: Given the time-frame of the interviews, I would like to acknowledge that knowledge may have deteriorated over the 4-5 months, which is natural process when students are not continually exposed to the material and is an expected result. 3. Weak stances on the pre surveys have no correlation with strong or weak knowledge on the post assessment. The evidence is inconclusive and does not negate the possibility that weak stances can interfere with complex knowledge development. a. Overall pre stances do not correlate with strong or weak knowledge. This speaks to students across categories exhibiting messy middle knowledge in this complex science. 4. In the interview data (4-5 months after completing the curriculum), there is evidence that students with weak stances had weak knowledge. a. Again, this finding speaks partially to knowledge deterioration, which is natural given the time lag between the interview and completing the curriculum. This result potentially speaks to negative stances can interfere with complex knowledge development and/or be a component of knowledge confusion for students. **Stability of Stances** 5. For the stance category that encompassed the existence of anthropogenic climate change and its causes, on average students had a positive and statistical significant change from pre to post survey. In other words, significantly more students on the posttest stated that climate is happening and that it is caused by human actions. a. There is a correlation between participating in an evidence-based climate change curriculum and the positive stance change in this category. **Statistical Predictors of Climate Change Stances** 6. In general, students' level of worry remained statistically stable from before to after the curriculum. a. In the interviews, students attributed their lack of worry regarding climate change impacts to the feeling that it was not impacting them personally. 7. Students who reported that he experienced the effects of climate change, (even if the experience was a stated conflation of weather and climate), students were statistically more likely to be worried about climate change impacts in both the pre and post logistic regression model examining statistical predictors of students' worry.

Hypotheses:

1. Since a significant predictor of students' worry is whether a student feels that s/he has experienced the impacts of climate change, we can make climate change curriculum more relevant to a student's life by highlighting the local, personal and human impacts of climate change.

2. If a positive stance shift is correlated to participating in an evidence-based curriculum, more focus should be placed on curricular interventions that expand the use of transparent data and evidence to foster stance and knowledge development.

3. Messy middle knowledge can be exhibited across all levels of stances and knowledge. We can create curricular activities with more exposures in multiple contexts that are continually promoting more complex and sophisticated knowledge development.

4. Consistent with other studies investigating the relationship to beliefs and knowledge development, there is some evidence in this study to suggest that stance development precedes knowledge development. If this hypothesis were true, a student with a positive stance would have an increased likelihood of developing complex, strong knowledge. However, before curricular suggestions can be made, more data needs to be collected and analyzed to further explore the relationship between climate change stances and knowledge.

The findings from my dissertation work reaffirm and illustrate new aspects of the complexity of the correlations between climate science knowledge and climate change stances and the many variables statistically related to climate change stances. While this is not an exhaustive study (limitations of the work are discussed in Chapter 8), the work can help guide curriculum development to build on students' prior knowledge, messy middle concepts, and stances regarding climate change. After identifying the statistically significant relationship between knowledge and stances, more emphasis needs to be placed on climate change curriculum, teacher professional development and training in this complex science, as well as shaping policies/funding to encourage climate change to be taught in all classrooms. Our middle school students are our future decision-makers. My work illustrates the inherent need for a sound climate education to foster knowledge and stance development. Suggestions based on my findings are discussed in greater detail in Chapter 8.

Chapter 8: Suggestions, Limitations, and Future Work

Overview of Chapter 8

In this chapter, I discuss the suggestions and implications of this work, the limitations, and future work. The findings and results discussed throughout my study confirm the complexity of students' climate change stances and knowledge. My findings suggest that climate change knowledge and stances are not always stable and they can change after a curricular intervention. Also, climate change knowledge and stances are highly correlated. Moreover, the timeline of my findings (e.g., statistical findings based on pre and post instruments and post semi-structured interviews months after the curriculum) must be taken into account when making suggestions. As a reminder, Table 7.3 shows the major findings from my work and my hypotheses based on my results.

In this chapter, I discuss implications of the findings and suggestions based on my results. My implications and suggestions are focused on three main areas: (a) curriculum development and activities, (b) teacher training and professional development, and (c) educational policy. The suggestions for curriculum designs emphasize creating curricular activities that are relevant to students' lives, expanding the exposure to transparent, evidence-based curricula, and addressing how to deal with messy middle knowledge. Suggestions are made for both pre-service and professional development programs in order to prepare educators to teach and address the complexities and socio-scientific considerations of climate science. Finally, suggestions are given for educational policy to make climate science a focus of middle school science learning. I conclude the chapter with a discussion of limitations of the study and data set and suggestions for future work.

Curricular Suggestions

To address the findings from my study, the curriculum intervention and activities should specifically address (a) students' lack of worry about climate change impacts by making the impacts relevant to their lives and being explicit about local and personal effects that they might experience, (b) continue to allow students to interact with a curriculum that explores data and evidence for the existence of anthropogenic climate change and its causes, and (c) build on the current activities to address students' messy middle knowledge, specifically targeting the separation of general environmental issues from climate change topics, and the conflation of weather and climate concepts. The curricular suggestions should continually attempt to surface students' climate change stances and knowledge to attend to students' prior knowledge.

As seen through the interview discussions and responses to the open-ended questions on the survey, the students' stance structures are quite complex where parents, religion, personal views, and personal experiences enter the climate change discussion. The curriculum should aim to present the information through representations that depict the accepted scientific perspective. The goal of the curriculum is for students to learn the content and practices encompassed by the climate science field as outlined in the NGSS. The curricular suggestions below also target students' knowledge regarding the existence of climate change and its causes and highlight personal relevance to the subject, which might in turn change their stances on worrying about climate change impacts. While teaching stances and knowledge, the curriculum needs to be sensitive and aware of the spectrum of climate change stances that students hold.

Climate change stances are very personal and often based in cultural, societal, and personal experiences and contexts. I do not think it is appropriate nor the place of an educator to target specific stances, but student stances and knowledge should be identified in order to construct curricular that attends to students' prior stances and knowledge. For example, it should not be the agenda of a curriculum to try to change the mind of a student who believes that anthropogenic climate change is not happening, but it should be known that this is the students' position on the matter. Taking the modern day constructivist perspective, I think that prior knowledge should be surfaced and identified, which acts as a learning mechanism, but should not be the agenda of the lesson to change a students' mind. Rather, as I hypothesize, interacting with the data might ultimately change a stance, but a student with a more negative stance should not be the target of an activity. However, as Bell (2004) suggests, science educators should not shy away from socio-scientific issues in the classroom, but welcome them and design curricular activities and teachable moments around them. A curriculum should allow students to interact with the evidence and as seen by my results, this may in turn encourage positive stance development. Additionally, creating curricular materials that are more relevant to students' lives helps to engage students and again might alter one's perspective, specifically regarding worry about climate change impacts. A goal of the curricular activities is to aid students in learning the complex, intricate science of climate change and to become informed global thinkers.

A Curriculum to Address Worry—Making Activities and Learning Relevant to Students' Lives

Hypotheses:

1. Since a significant predictor of students' worry is whether a student feels that s/he has experienced the impacts of climate change, we can make climate change curriculum more relevant to a student's life by highlighting the local, personal and human impacts of climate change.

My results indicate that students are not worried about the impacts of climate change. When discussing worry about climate change impacts, students exhibited a detachment from the issue and impacts (e.g., climate change is happening somewhere else, it is not impacting me personally, and/or the impacts will be experienced in the future). However, in the logistic regression models in Chapter 4, students who stated that they have experienced the impacts of climate change are statistically more likely to be worried about the impacts. I hypothesize that if we can create a curriculum that is more relevant to students' lives that takes into account students' personal experiences, students' detachment from the issue might diminish. A curriculum can be designed to address aspects of detachment, specifically to guide students in activities that highlight threats and current impacts in their local geographies. Before discussing specific curricular activities, I offer literature to ground my suggestions.

Studies find that there are psychological impacts associated with experiencing the results of climate change. Doherty & Clayton (2011) discuss three types of psychological impacts: (a) direct, e.g., traumatic effects of extreme weather; (b) indirect, e.g., emotional response to seeing the impacts and/or perception of fear because of unknown risk in the future; and (c) psychosocial, e.g., impacts a community experiences, such as conflict resulting from climate change impacts or adjusting after an extreme event. A curriculum should be designed to encourage students to have a psychological connection to climate change impacts, particularly through indirect and/or psychosocial associations.

Direct (or traumatic) associations should not be the goal of the curricular intervention. Indeed, fear is not enough to encourage engagement (O'Neill & Nicholson-Cole, 2009). O'Neill and Nicholson-Cole indicate that representations of fear will cause people to have momentary attraction to the issue, but not encourage personal, long-term engagement. Rather, "nonthreatening imagery and icons that link to individuals' everyday emotions and concerns in the context of this macro-environmental issue tend to be the most engaging" (O'Neill & Nicholson-Cole, 2009, p. 355). Ungar (2000) argues that the ozone hole issue engaged the general public with the use of popular culture metaphors. The public became engaged in the ozone issues because there was immediate concrete risk and people were able to understand and perceive the everyday risk. Ungar also argues that climate change has failed to engender this science literacy and concern, because of the lack of a concrete connection between everyday risk with climate change issues.

Moreover, Maibach, Roser-Renouf, Akerlof, and Leiserowitz (2012) studied the relationship between perceived personal experience of global warming and certainty that it is happening. In the longitudinal study, they found that the relationship went both ways. Those who feel they have experienced global warming have high belief certainty. Also, those who have higher certainty (those who are engaged in the issue) are more likely to state perceptions of experiencing global warming.

The curriculum needs to have a greater focus on the timeframe and risks associated with climate change impacts, as well as how impacts of climate change might be experienced in local geographies in order to play to students' everyday emotions and concerns and heighten their engagement. We need to address the global impacts of climate change, which include mixing of the atmosphere (i.e., greenhouse gasses emitted in one location become a global threat) and the increased severity and propensity of storms. Moreover, students should be exposed to the concepts that there are impacts of climate change that go beyond solely affecting animals. Finally, a greater stress needs to be placed on current communities distressed by climate change (e.g., coastal cities and island nations). More specific curricular activities are discussed at the end of this section.

Probing students' prior knowledge and personal experiences. There are several components to making climate change topics and experiences relevant to the students' lives. To make it relevant, we must first probe what students know and are thinking about the topics. Students' prior knowledge is always important in creating educational strategies. I would argue that with topics such as climate change that can be greatly influenced by factors outside the classroom, it is imperative to gather students' prior knowledge and experiences on the topics. Before starting the lessons, there can be an open dialogue that asks students to share about what they have heard on this topic. The questions should be open-ended enough that students do not feel pressure to identify who and where they heard these ideas and/or if they personally align with these stances. For example, the continuums I used in the interviews can be a tool used to quickly identify a student's stance without asking the students to elaborate on his/her position. Similarly, having conversations and making a dialogue with students rather than purely lecturing to them on the topic, a teacher can identify stances, messy middle knowledge, and different knowledge entry points. Moreover, as seen in the interview results, students with negative stances had weak knowledge. Strategies need to be in place to respect a student's stances, while giving structured and guided opportunities to work through and grasp the complex science. If these ideas are identified earlier, then the teacher can be both sensitive to these ideas and help students work through knowledge constructs that might not fully align with their existing stance structures.

By identifying prior experiences, stances, and knowledge about climate change, educators can begin to see where there might be disagreement in the material presented and what is already in a student's head. This information can help structure lessons to build in the appropriate amount of time to allow students to work through multiple exposures and contexts in the curriculum. Each student starts at a different position. Some might be highly knowledgeable about the science, while others might have strong stances on the topic without the knowledge base to reason through the science. Identifying prior knowledge and stances can begin the process of constructively and productively building students' knowledge and stances.

Relevance to students' lives. To connect climate change issues to students' lives, it is extremely important to have students begin to see that these issues go well beyond the walls of the science classroom. Climate change is an issue that is and will impact the global community. If projects in the curriculum are made relevant to the students' own backyard, I contend more students will be invested in the issue. Also, more students expressed that they feel that they do better on science projects than science tests. Bandura (1994) discusses that when a student has a positive self-efficacy in a subject matter, students are typically more invested in the work and do better academically. Engaging in topics and issues that are relevant to students lends itself to project based work that incorporates science practices outlined in the NGSS, such as data collection, analysis, construction of explanations, and design-based projects.

Moreover, the funds of knowledge literature speaks to the importance of making the projects and activities relevant to the students' lives from a cultural perspective, specifically acknowledging a students' prior experiences from home and cultural contexts (c.f. Moll et al., 1992). As educators, it becomes our role to learn about the students, their family, and their everyday life activities. I believe this becomes even more important when teaching socio-scientific issues, such as climate change. Is climate change discussed at home based on religious convictions, political ideologies, science principles, job/livelihood security, and/or economic/policy decisions? What activities do students do outside of school? Are they community and civic minded activities where a student advocates for change? Is a student not tuned into climate issues and they just hear these discussions and see this information in school? This information becomes an educational resource in the classroom. By identify students' prior knowledge and experiences from discussions, activities, and experiences, we can create curricula that are meaningful and align with their prior experiences and contexts outside of the classroom. Also, with climate change issues, we can be sensitive to all stances and why students might hold these convictions. In the next section, I offer specific project examples of how curriculum developers and teachers can incorporate students' funds of knowledge in climate change topics.

When teachers and curricula developers take into account students' funds of knowledge, the curriculum incorporates practices and language that students use in attempts to comprehend the material in school. Moje and colleagues (2004) speak to the importance of creating multiple contexts and references that employ students' funds of knowledge. The driving question of the science lesson they studied used a local river to engage the students. However, many of the students did not know the river mentioned in the lesson and did not personally identify with this community landmark. Learning about what is culturally and personally important to the students and their families can help curriculum designers create units that encourage students to use their outside-of-school experiences and knowledge in the classroom. These actions help to engage the students in the topics.

Projects and activities relevant to students' lives. Students in my study that stated they have experienced the impacts of climate change, even if the effect stated was a conflation of weather and climate, were on average more worried about climate change impacts. Based on this idea, I propose two specific curricular additions that can incorporate students' funds of knowledge and make the issue more relevant to students' lives.

The first project involves a community focus on the current changes experienced by the local area, including and not limited to tracking differences in intensity and number of storms, droughts, rising sea levels for coastal communities, and/or changing growing seasons. The curriculum would include resources for the teacher and students to access and gather local data. Resources, such as NOAA, EPA, and Weather Underground are easily accessible websites that allow students to gather data in their local geographies. Once students have focused on an impact topic, the groups can make emergency plans for their communities regarding their topic. For example, plans could include evacuation routes and/or shelter plans for an intense storm. Or if students are in a coastal area and are studying rising sea-levels, how does the coastline deal with beach erosion and flooding? How will it affect local businesses? Finally, after studying carbon footprints (lesson discussed in more detail in the next section), students can offer solutions, such as local green energy projects, actions that can be done in their schools and homes to reduce greenhouse gas emissions, and offer sustainability ideas for their towns. These projects can be presented to local city council and businesses in presentations and/or poster fairs in local malls to both educate the community and encourage the students to share their findings. This project encourages flexibility to allow students to focus on a topic of interest. Moreover, their findings and suggestions regarding creation of emergency plans and reduction of carbon emissions can benefit the students personally and help the community.

Students in my study expressed a lack of worry about climate change impacts. In the interviews and open-ended responses, they attributed their lack of worry to the belief that the effects of climate change were happening in the future, happening elsewhere or were solely affecting animals. The second project incorporates the concepts that climate change is currently impacting humans around the world. The activity illustrates that greenhouse gases are part of global circulation patterns. While one country may emit more greenhouse gases than another (e.g., United States versus Uganda), students would begin to recognize that all countries are still vulnerable to the impacts of climate change. The second focus area is on current human impacts to expand beyond impacts experienced by just animals. To introduce these concepts, I propose that students view the movie Climate Refugees (Nash & Hogan, 2010) to introduce the idea that whole populations are currently being displaced as a result of the changing climate. From the curriculum design perspective, we need to modify the carbon lesson to illustrate the global mixture of greenhouse gases. One challenge here is to properly simplify the models and keep the integrity of the science. Then, we can create climate impact maps across the globe that show the current climate change effects in each locality (e.g., on average getting warmer or colder, sea level rise, longer or shorter growing season, etc.). This can help students see that the effects are and will continue to effect humans and more specifically are not just happening in the Polar Regions and to animals.

Evidence-Based Curriculum to Address Existence of Anthropogenic Climate Change and Its Causes

Hypotheses:

2. If a positive stance shift is correlated to participating in an evidence-based curriculum, more focus should be placed on curricular interventions that expand the use of transparent data and evidence to foster stance and knowledge development.

After participating in the current climate change curriculum, on average students' stances changed regarding the existence and causes of climate change. While the goal of the curriculum was not to target student stances, I contend that interacting with this data correlated to the stance shift. Indeed, there was a statistically positive shift to say climate change is happening and it is the result of human actions. The curriculum had students work with climate change data, such as average temperatures in the Northern Hemisphere in recent and deep time, as well as simplified IPCC Future scenarios.

Moreover, I think the curriculum can be modified to continue to help students work through evidence regarding the existence and causes of climate change. Part of the modifications would include being more transparent about how the data is collected and how the models are constructed. By providing transparency of the data collection and model construction methods, we give context to the data in which students are working. Presenting data without transparency may lead to difficulties for students who enter the classroom with a skeptical perspective on the topic, particularly when the data (or conclusions) do not align with the stance that is discussed at home or elsewhere. Taking the time to expose a scientific method and to question where and how the data was gathered is important for giving context to the existing knowledge and stances.

Specifically, in the current curriculum, we show students a graph of the average temperature in the Northern Hemisphere over the last 150 years. Before seeing this graph, I think there needs to be a discussion on how the data was collected, who collected it, and if others have similar data. Moreover, we can direct students to different data sources so they can see that the trend lines are reproducible and this one graph that we are showing them is not an anomaly. Moreover, rather than merely telling them that we are providing data from a reputable source, we can use this as a teachable moment on how to distinguish reputable scientific sources from sources and information that should be questioned. For example, we can create scenarios, based on data and sources found online where students work with their peers to discern if the data can be trusted or not. This can lead into a class discussion. We should be explicit on where the data in the curriculum is from and how it was collected, specifically referencing the scientific methodology behind it.

Similarly, the simplified IPCC Futures activity can be expanded to show how the models are constructed. We can create an activity where students learn about the IPCC review process. Again this can be simplified to make a user-friendly learning environment. The models can be made more transparent to the students by discussing the variables used to create the models. Moreover, we can discuss the level of certainty in the collected data (e.g., with 99% certainty scientist think that anthropogenic climate change is happening), as well as how conclusions were drawn. This lesson can also tie back to the idea of relevance and worry. The IPCC scenarios offer predicted impacts beyond the carbon dioxide emissions and temperatures. Each student group can do a mini project exploring a climate change impact that is offered by the most recent IPCC report. Based on the impacts maps discussed in the previous section, then students can choose a specific climate change impact and area of the world to study. Or they can do a project to further explore the variables that are used to create the IPCC Future scenarios, such as proportion of clean energy, carbon emissions, and population growth. They can look at the variable locally and then globally to see if it is possible to change these variables currently or in the future to alter the predicted futures. Looking at the variables in greater depth can help students to see how these scenarios are created and more importantly potentially changed with global actions.

To continue to have students interact with the causes of climate change and once again have them personally connect to the issue, I would suggest doing a personal carbon footprint calculation and world carbon footprint lab. A carbon counter activity is included in the high school version of the Climate Change and Its Impacts curriculum (Songer et al., 2012) and can be modified for the middle school audience. If middle school students have the opportunity to calculate a personal carbon footprint, they can build on their knowledge of greenhouse gas emissions and identify personal activities that add to the enhanced greenhouse effect. Then, as a class, they can look at carbon footprints of different countries and/or industries to further identify mechanisms and causes of climate change.

These suggestions have students work with scientific evidence and transparent data collection mechanisms to support the existence of climate change and causes of the enhanced greenhouse effect. Moreover, students in the stance survey did not think there was consensus amongst scientists that anthropogenic climate change is happening. This stance was stable from before and after participating in the curriculum. The evidence-based curriculum correlated with a positive shift in stances regarding the existing of anthropogenic climate change in my study. Similarly, I believe that these activities and projects discussed above will continue to build positive shifts in student stances including the existence and causes of climate change as well as acknowledged consensus in the scientific community.

Addressing Messy Middle Knowledge in the Evidence-Based Curriculum

Hypotheses:

3. Messy middle knowledge can be exhibited across all levels of stances and knowledge. We can create curricular activities with more exposures in multiple contexts that are continually promoting more complex and sophisticated knowledge development.

Students across all stance categories in the interviews and in the open-ended questions on the surveys exhibited messy middle knowledge to justify their climate change stances, specifically the mechanisms of climate change and evidence to support anthropogenic climate change. These messy middle concepts need to be addressed in a curricular intervention, especially because of the complexity and interdisciplinary nature of climate science. In this section and sub-sections, I offer a short discussion of literature that addresses messy middle knowledge. Then, I make specific suggestions regarding curricular activities and design to address the messy middle knowledge for the conflation of weather and climate and the use of general environmental terms versus climate change specific topics.

Songer and Gotwals (2010) discuss the messy middle in terms of complex fused knowledge development where reasoning is difficult. While the blend of knowledge that aligns and does not align with the accepted science to justify a climate stance is not synonymous with fused knowledge development, such as constructing an explanation, they are both complex, higher order skills that require continual time, purposeful guidance and repeated exposures (Songer, Kelcey, Gotwals, 2009). For such a complex and interdisciplinary science, such as climate science, students may not fully comprehend the topic in the first or second exposure.

As Songer, Kelcey, and Gotwals (2009) and Windschitl and Adre (1998) suggest, I believe time, guidance and repeated exposure of continually more complex science can serve as guidelines to deal with messy middle knowledge. Additionally, the repeated exposures should be in the form of multiple contexts and activities. As the conceptual change literature suggest, exposures with multiple contexts helps to build connections between the knowledge pieces. Since climate change is a charged socio-scientific issue, curricular activities and contexts need to be designed with the awareness that each student's prior knowledge and experiences are different.

Furthermore, when students are exposed to new situations, the new information needs to be integrated into the existing knowledge and stance p-prims rather than replacing them. Integration of knowledge and stances into the existing framework is a process that requires time as well as acknowledgement and incorporation of students' prior knowledge and experiences that may include motivation and stances. Each piece of knowledge is contextualized (Hammer, 1996) and each p-prim is encoded, abstract and connected to situations. Moreover, building complex knowledge that engages higher order thinking skills (e.g., explaining one's rationale) requires repeated exposures that are continually more sophisticated (Atkins & Karplus, 1962; Bruner, 1997; Songer, Kelcey, Gotwals, 2009).

In addition to involving purposeful learning progressions to address messy middle concepts, Walsh and Tsurusaki (2014) discuss that "The literature demonstrates that explicitly addressing learners' social and community experiences, values and knowledge supports understandings of and increased concern about climate change. Science learning environments that situate climate change in its social context can support conceptual understandings, and shift attitudes" (p.299). With time, guidance, and repeated exposure through multiple contexts, while also taking into consideration students' community experiences (c.f. Moll et al., 1992), students can begin to move from the messy middle knowledge to the complex climate science knowledge that aligns with the current accepted scientific principles.

Specifically based on my findings and the discussion of the above literature, I suggest frequent check-ins to probe students' prior knowledge and understanding throughout the curriculum to identify messy middle knowledge. Before the curriculum, teachers can informally probe students' knowledge and stances through discussions that introduce the topics. This can include students playing word association and explaining why they think of that word or concept when discussing climate change and its causes. Moreover, the class can read a news article together to introduce the topic and prompt open-dialogue. An activity can be focused on a classic climate change image, such as the carbon dioxide curve created from Mauna Loa data and have students identify features of the graph and discuss what they think it means. Then, the discussion can continue by asking students to talk about what they have heard or know about the topics of climate change and carbon dioxide.

As Minstrell (2001) suggests, teachers can use these discussions to catalogue students' spectrum of knowledge facets, including messy middle knowledge. These provide markers for topics that may need to be revisited later in the curriculum. Throughout the curriculum, formative assessments can also be used as a tool to identify areas where students need more support and/or activities and contexts to support knowledge development. The purpose of the formative assessment is to alter teaching and learning strategies within a unit rather than for the purpose of grading and evaluating students (Black & Wiliam, 1998). Continual feedback based on student responses to the formative assessment can be used in order for students to see and acknowledge their struggles and successes and for teachers to alter instructional strategies to guide learning. Indeed, continual feedback has been shown to be a positive factor in student growth and learning (Black & Wiliam, 1998).

In this context, formative assessments can include student explanations that are already embedded in the curriculum. However, I argue that students need more opportunities to work with these messy middle knowledge topics (specific curricular activities are discussed below by topic). The formative assessments can be embedded in the majority of the activity structures to provide check-ins. The results from the formative assessments allow purposeful revisitation of specific topics that enable teachers to give multiple contexts for students to connect current learning goals to their previous experiences and prior knowledge.

Curriculum to address general environmental terms and climate change topics. My findings indicate that middle school students use general environmental terms to describe climate change specific topics. For example, students discuss pollution as a mechanism of climate change. In the interviews and survey responses, some students use pollution to describe general air pollution, while others use the term pollution in attempts to describe excess greenhouse gases. Others suggest that we should recycle more to mitigate climate change, without drawing a direction connection to carbon reduction. To alleviate this issue, it is imperative to use purposeful and specific science vocabulary throughout the curriculum. In conceptual change literature, it is suggested to use analogies that help to give context to the terms and concepts used in order to allow the student to be actively involved in the learning process (Duit & Treagust, 2003). In the discussion of Nature of Science, Lederman and Lederman (2014) suggest explicit discussions to engage the students in the nuances of the topics we are addressing. Being explicit includes using vocabulary and taking the time in discussions to engage learners and encourage them to take part in the act of learning. This should aid students in distinguishing between and making connections with different concepts (e.g., environmental issues and climate change mechanisms).

When specific vocabulary is introduced in the curriculum with contextual markers and analogies, it becomes more evident when students are describing specific climate change topics and mechanisms. Moreover, the students' everyday discourse should be used as much as possible in building science understanding and vocabulary as well as identifying students' funds of knowledge (Gomez, 2007). In a study of how 6th graders use multiple science discourses in a science fair project, Gomez (2007) suggests:

> "that classroom teachers should recognize and incorporate students' everyday science talk as a useful tool in instilling basic scientific concepts. Teachers should also help students develop awareness of the value and appropriateness of drawing on life circumstances in talking about science and the benefit of knowing and talking about scientific phenomena along a continuum of science understanding" (p. 41).

Just as in alternative concept literature and messy middle knowledge discussions, even if the student discourse is not exactly consistent with the scientific community's expert language, it should be incorporated and used constructively to build science discourse in the classroom. Osborne and Frayberg (1985) discuss that students develop ways of describing scientific phenomenon using non-scientific language (e.g., colloquial terms and descriptors) that is logical to the students. If the teacher and curriculum encourage use of everyday language, teachers can begin to identify if the vocabulary being used by the student indicates comprehension, messy middle knowledge (Gomez, 2007).

Rather than merely telling students that there is a difference between general environmental issues and climate change, one should take the suggestion of Minstrell (2001) and give students multiple opportunities to contextualize the information and learn the metacognitive process to continually construct more scientifically complex and correct knowledge. Thus, students should be exposed to scenarios that illustrate the differences between climate change issues and its mechanisms as compared to other topics such as water/air pollution, littering, and ozone depletion. Finally, it should be stressed how recycling can help reduce the impacts of climate change through lessening carbon emissions and decreasing the need for new production. However, educators should be aware that recycling can be used by students to describe general waste reduction with little scientific connection back to climate issues.

Curriculum to address conflation of weather and climate. Climate science is both complex and abstract. I hypothesize that students are struggling to use weather and climate as evidence in their justifications for their climate stances because of the abstract nature of scale and climate timeframe. It is difficult for a middle school student (ages 11-14) to have the perspective of the climate timeframe (on the order of decades and centuries) to fully grasp the difference between weather and climate. The differences between single events and average change should be addressed with multiple exposures in curricular activities. Calculations need to be done in several contexts to help students identify what constitutes climate change and what constitutes weather variations.

A single exposure that differentiates an extreme from average change, particularly when done in a mathematical setting, may not be sufficient to help students apply this concept in different contexts. For example, students in this study did well in defining the difference in climate change and weather on the knowledge assessment (e.g., significant positive change from pre to post). Moreover, they were able to analyze and interpret graphical data to justify whether climate change is happening or not. However, in later contexts such as the interview setting, the students continued to conflate weather and climate to justify their personal stances. They could state the definitional difference, but students used a single weather phenomenon and directly linked it to changing or stable climate.

Students used weather phenomena as a way to justify all climate stances. Specifically, they used hot or cold events to state climate change is happening or not happening, respectively. The idea of an average shift of a full degree versus a heat wave for a week (i.e. the scale and time-frame issue with weather versus climate) appears to be difficult and abstract for students. Like Songer, Kelcey, and Gotwals (2006) suggest, I think students need repeated exposures, with guidance, over a longer period of time. Within these exposures, educators need to take the time to explicitly guide students through multiple contexts that make the learning objective tangible and explicit and also relevant to the students and community. This helps to make the complex science less abstract in nature and gives students the opportunity to bring in their everyday discourse and language into the science context (Moje et al., 2004; Gee, 1996). To go beyond the messy middle knowledge (Gotwals & Songer, 2010) and develop sophisticated knowledge, students should be guided and tested throughout as check-ins to see how students are differentiating between weather and climate. High level thinking questions, such as constructing explanations, should be used to push students to justify claims about weather and climate concepts with scientific evidence and reasoning. These types of questions help to reveal where there are gaps in understanding and/or if students continue to conflate the concepts.

As discussed above, students should be given multiple opportunities to calculate climate averages. Before starting the calculations, curriculum designers need to create exemplars of weather data and climate data to help students differentiate between the concepts. Simplified scenarios can be presented to the class so students can first apply the definitions that they learned before introducing calculations and numbers into the concepts. For example, students can work with the following scenarios and determine if they are describing weather or climate: (a) if you read in the newspaper that it is going to rain over the next two days, (b) if you read in the newspaper that over the last 30 years, the United States has experienced a warming trend, (c) this past winter we received a record amount of snow, (d) a strong hurricane is about to make landfall on the east coast of the United States, and (e) there has been an increase in the intensity and number of tornadoes in the Midwest in the last 10 years. The scenarios can be done as a class, in small groups, or individually. The class should come back together and discuss each scenario and why it is describing weather or climate. These are just a few exemplars, but they show a progression of exemplars getting increasingly more complex and abstract to help students reason through the differences between weather and climate concepts.

After working through different weather and climate scenarios in different contexts, we can apply the concepts through calculating weather and climate events. Similar to the suggestions regarding the use of transparent data, for the concepts of weather and climate students can build to the complex task of gathering their own data (e.g., using online resources) to calculate climate differences in specific geographic locations over a 100-150 year period. After doing multiple calculations that illustrate these concepts, such as a single extreme event and/or a warm or cold season cannot change the average global temperature, have students write their own scenarios to illustrate the differences between weather and climate. They can write a scenario for each concept. Students would need to apply the concepts of weather and climate and include calculations to justify their exemplars. To complete the task successfully students would need to grapple with the ideas of: (a) what could cause a change in climate?, (b) timeframe differences between labeling something as weather or climate, and (c) realistic scales for a changing climate. The scenarios would be drawn and presented to the class. Each group would have to justify their position. Peers would give suggestions and each group would have an opportunity to modify their weather and climate exemplar designs. If the teacher has time, an optional extension can be a mini unit on severe storms and the changing intensity and number of storms with a changing climate.

This curricular suggestion begins with the core concepts of weather and climate. It starts with multiple simplified scenarios that students can relate to (e.g., storms, rain, everyday weather, reading an article in the newspaper about the changing climate). Then, adding in numbers and calculations revisits the topic and adds complexity to the concepts. Finally, having the students design their own scenario where they present and justify their ideas to their class continues to help build on their comprehension of the topics and differentiate between the complexities of weather and climate.

Stance Development as a Precursor for Knowledge Development

Hypotheses:

4. Consistent with other studies investigating the relationship to beliefs and knowledge development, there is some evidence in this study to suggest that stance development precedes knowledge development. If this hypothesis were true, a student with a positive stance would have an increased likelihood of developing complex, strong knowledge. However, before curricular suggestions can be made, more data needs to be collected and analyzed to further explore the relationship between climate change stances and knowledge.

While I hypothesize that stance development precedes knowledge development, I do not provide specific suggestions for curricular changes at this point. Researchers need to first conclusively confirm that stance development is a foundation for climate change knowledge development. At that point, curriculum designs can be altered and tested for learning and stance changes. I discuss the topic in greater depth in the future work section later in the chapter.

The Importance of the Teacher

To teach this complex, interdisciplinary subject, a teacher needs the proper guidance and educational opportunities to be able to support student learning. While the focus of my work is on student climate change knowledge and stances relative to a purposeful curricular intervention for middle school students, the important role of the teacher needs to be noted. The results indicate that knowledge is not stable; there is a significant positive change from pre to post exposure to the material. Moreover, knowledge and stances are positively and significantly correlated. Teachers are an integral part of these findings. Teachers can help develop productive, complex knowledge. Also, as seen in the interview responses, teachers can also be the source of messy middle concepts. Indeed, within conversations I had with the teachers in the study, this blend of correct and incorrect science was expressed. For example, several teachers expressed that ozone depletion and/or chlorofluorocarbon (CFCs) were the main mechanism of climate change. Also, three of the teachers in discussions and emails used general environmental terms, such as pollution as the cause of climate change. Additionally, one teacher had difficulty differentiating between what causes climate change and the mechanisms for seasonal variations.

Additionally, the complex nature of climate science seemed new to some of the teachers and there was an explicit need to provide additional supports in terms of content and navigation of socio-scientific issues. One teacher said to me that she did not have exposure to atmospheric mixing and she struggled with the discussion of climate change as a global issue rather than just regions that emit the greatest greenhouse gases. There cannot be an expectation that educators should self-teach climate science to be prepared to guide students in developing climate science knowledge. There needs to be a focus on climate science in professional development workshops and teacher education programs.

Climate change is a relatively new topic to be included in secondary science classrooms. As discussed in Chapter 1, climate change has a presence in the middle and high school performance expectations in the Next Generation Science Standards (NGSS Lead States, 2013).

One can argue that the NGSS are the most robust standards thus far. The standards call for all students to engage in sophisticated science and practices. Depending on the state, some middle school teachers are only required to have elementary certification without needing to major in a science and/or become certified in a science subject in order to teach middle school science. It is difficult to teach yourself such sophisticated disciplinary core ideas and practices. I would argue that without formal exposure to the topics and practices, a teacher is put at a disadvantage for teaching climate change topics and practices.

Pre-Service Teacher Education Programs

In a university setting, if a pre-service teacher majors in a science discipline, such as Biology, Chemistry, Physics, and/or Geology, (s)he might have courses that reference climate change, but there is rarely a focus on the topic to complete the major. Currently, there are elective and/or upper level courses that provide in-depth coverage on climate change in specific science disciplines. However, further research needs to be conducted to see the breadth and depth of climate science topics that pre-service teachers typically experience in a university setting.

To prepare pre-service teachers to effectively support climate change learning, I suggest that there needs to be a module in their methods course to address teaching climate change. The module can include an overview of the science, specifically the mechanisms of climate change, weather versus climate, carbon cycle and anthropogenic carbon emissions, and green energy and sustainable practices. Additionally, it is imperative that we give resources to the pre-service that can be used as refreshers when they begin their teaching careers. These include and are not limited to reputable web-based resources that are both knowledge refreshers and resources for students and curricular activities that have already been created for specific climate science topics.

In addition to exposing pre-service teachers to the topics, it is imperative that they are tasked with using the content and practices in order to create lesson plans and activities regarding climate science knowledge and practices. Moreover, in the activity development, pre-service teachers should be tasked with addressing issues that may arise in the classroom surrounding climate change. This can include issues such as when a parent does not want anthropogenic climate change taught or when a student exhibits a specific messy middle topic (e.g., conflation of weather and climate). Students can share their activities with the peers to build more resources to use when they start teaching. Moreover, the instructor can facilitate discussions surrounding the difficulties of tackling messy middle knowledge and also how to successfully introduce and navigate teaching socio-scientific topics in a middle school classroom.

Professional Development Opportunities

A single interaction with climate change topics may not be sufficient to effectively and creatively teach climate science in a middle school classroom. Moreover, while climate change courses are currently offered at the university setting, it was not necessarily the case ten, twenty, or more years ago when many of our current classroom teachers received their training. Professional development opportunities need to be offered to continue the learning and to provide support. There should be arenas where teachers can post issues that they are having when teaching these topics. This could provide opportunities for colleagues to offer advice on how these problems and/or concerns were addressed in their classroom/community. Moreover, there needs to be professional development that is focused on climate change topics, specifically those that are addressed in the Next Generation Science Standards. Over the summers, mini courses can be offered by faculty from universities to expose teachers to the topics and to participate in labs that can be modified to use in the middle school setting.

Curriculum designers need to provide additional resources for teachers both before a lesson is taught and also embedded within and after the lesson. Initially, references and sources should be provided to the teacher as a refresher on the topic and at a high level that goes beyond the expectations for their students. Subsequently, additional material should be provided that can be used as lesson extensions. For example, in a carbon cycle activity, teachers should initially be given resources that review the carbon cycle at a high level, which would include descriptions of carbon exchange between sinks and sources. Additionally, links and activities beyond the scope of the current lesson can be provided when the teacher or students would like to delve deeper into the topic. For the carbon cycle, this may include interruptions in the natural cycle throughout history as well as additional labs.

Finally, there needs to be a variety of learning environments and opportunities for in-service teachers to learn about climate science and approaches to effectively engage their students. This variety allows teachers to choose what works best for their learning styles and needs. At the same time, this encourages the topics to be taught in school.

Implications for Policymakers

Climate reports issued in May 2014 indicate that scientists are concluding more than ever before that anthropogenic climate change is happening and the impacts (e.g., severe storms and droughts and sea level rise) are already being experienced across the country and world. With these findings, the importance to fund climate science education is now more important than ever. Citizens need to begin to prioritize climate change policies in order to prepare to adapt to the inevitable changes. Knowledge of the topic is highly correlated to one's stances on the matter. More emphasis needs to be placed on curriculum development to aid in knowledge and stance development. What students are exposed to as middle school students, can impact how we as a nation respond to the threat of climate change. They are the next generation of decision and policy-makers. It is imperative that they are knowledgeable citizens who can justify their climate change stances in science.

There needs to be changes at the policy level in order to enable educators to make the material relevant to students' lives, make the data more transparent, identify students' prior knowledge, focus on transitioning students out of the messy middle knowledge, and develop the knowledge and skills to effectively teach climate change. There has been a start with the inclusion of climate science and human impacts topics in the Next Generation Science performance expectations (NGSS Lead States, 2013). However, several important questions leave ambiguity in implementation of these performance expectations. Since climate change is such an interdisciplinary topic, in which science discipline and/or year of MS are the climate science topics expected to be taught? Will climate science topics be tested on the assessments? Climate science and climate change needs to become a recognized science discipline in secondary school science and to be included in important state-wide and national assessments.

Climate science as a core secondary school topic and test item. Biology, physics, chemistry, and earth science are the core science disciplines outlined in the NGSS (NGSS Lead States, 2013). Climate science, such as weather versus climate and human impacts on the environment can be incorporated in the earth science discipline, but this is not enough. First, it is such an interdisciplinary topic that it does not fit neatly within the earth science discipline. It incorporates chemistry, biology and physics. Second, since it is such a complex and interdisciplinary topic, climate science topics and activities, as discussed above, need to have the time allotted for multiple exposures that are needed to continually build more sophisticated and complex knowledge. It should be its own discipline.

The topics in the climate science performance expectations can be expanded and incorporated more often throughout the NGSS learning progressions. In order for this to occur, policy makers need to become involved in making climate science a science topic at the forefront of secondary school science. With my study results indicating a strong positive correlation between knowledge and stances, it speaks to the need to expose students to the climate science topics. Students with positive stances have both weak and strong knowledge. I hypothesize that science curriculum focused on climate topics throughout second school can aid students in moving from the messy middle concepts to have positive stances that are supported by strong knowledge. This is extremely important because decisions, such as voting on climate policies and/or energy protocols, are informed by one's stances and knowledge.

Given the current high-stakes test environment, climate science performance expectations need to be on large-scale assessments. Educators have to cover many topics throughout the year and a greater focus is placed on those disciplinary core ideas, practices, and cross-cutting concepts that may appear on the test. As assessment designers are creating tests to align with the NGSS, it is imperative that the climate science performance expectations are tested. I believe this incentivizes teachers, local school boards, and states to create a curriculum that takes the time to expose students to the climate topics.

Summary of Implications and Suggestions

There are several implications and suggestions that I have discussed based on the findings from my study. Curricular interventions and activities need to be designed to specifically address students' lack of worry regarding climate change through exposing them to the science of climate change impacts. Additional evidence-based activities, particularly with transparent data and models, should be included in future curriculum design. Additionally, curricula should be constructed to help students move from the messy middle knowledge to fully correct, scientific knowledge. The other important stakeholders in the discussion, beyond the middle school students, are the teachers and policy makers. Teachers need supports in place to help them be strong and effective educators when implementing climate change topics and activities in their classrooms. Finally, policy makers need to make climate science and human impacts a greater focus of secondary education. Table 8.1 includes a summary of the suggestions based on my study results.

Table 8.1
Summary of Suggestions and Implications Based on Study Results

Topics Addressed in Implications and Suggestions Section	**Suggestions Based on Findings**

Curriculum to address lack of worry regarding climate change impacts	• Address issues of detachment from impacts and consequences (e.g., climate change is happening somewhere else, it is not impacting me personally, and/or the impacts will be experienced in the future)
	  o Develop healthy psychological connection to impacts
	• Design projects and activities relevant to students' lives and communities
	• Highlight timeframe of impacts
	  o Illustrate current impacts on humans (not just animals and melting ice)
	• Show global circulation patterns→actions in one part of the world impacts everyone

Evidence-based curriculum design	• Give students additional opportunities and resources to engage with climate science data and models • Make data collection and construction of models transparent • Engage students in collection of data and construction of models • Analyze if data and/or resources are reputable and reproducible
Curriculum to address: Messy Middle knowledge parallel to accepted science	• Time, guidance, and repeated exposures (Songer, Kelcey, & Gotwal, 2009) • Give students opportunities for exposure to accepted science in multiple contexts with multiple pieces of evidence. • Build on prior knowledge and stances (do not attempt to eliminate knowledge and stances that are not consistent with expert knowledge)
Curriculum to address specific Messy Middle Topics regarding climate change and its causes General environmental issues vs. Climate change specifics	• Push students to use specific science terminology to determine if discussing general environmental issues or climate change specific topics/mechanisms • Expose students to difference between environmental and climate issues • Model climate change activities based on successful recycling campaigns • Emphasize specific vocabulary to help students differentiate between general environmental issues and climate change topics
Curriculum to address specific Messy Middle Topics regarding evidence for climate change: Conflation of weather and climate	• Scale and time-frame issue complex and abstract issue so have students work with scenarios that illustrate both weather and climate concepts. Discuss differences between examples • Multiple opportunities to calculate averages to identify weather vs. climate • Ask more questions that push students to explain rationales using complex science of weather and climate
Teacher Education and Professional Development	• Teacher education programs and professional development to give teachers access to the material and opportunities to ask questions and develop content and practice knowledge. • Create supports in the curriculum and in outside resources so teachers do not have to self-teach the material
Policy Makers	• Make climate science its own disciplinary field • Expand climate science and climate change topics in the NGSS performance expectations • Provide funds to support teacher PD and expansion of climate topics in secondary education • Have climate science and human impacts topics on large-scale high stakes assessments

Limitations

The study findings give a great deal of insights into the stability of students' climate change stances and knowledge as well as the relationship between climate change stances and knowledge. However, there are limitations that stem from the way in which data was collected as well as the data itself.

Mode of Data Collection

In an ideal study, the sample would be a representative simple random sample of the middle school population in the United States. All students in the sample would have completed the curriculum in standardized manner and would have all taken the pre and post stance and knowledge instruments. This sampling technique allows for generalizability regarding the population.

My sample was a convenience sample based on voluntarily participation in the Climate Change and Its Impacts on Ecosystems Middle School Curriculum. While it included students from different schools and multiple geographies, I could not make overall statements about findings in those specific locations. Nor could I generalize that my findings regarding climate change stances and knowledge can be applied to the entire middle school population.

Moreover, I collected data quantitatively at two time points and qualitatively at an additional time point. Ideally, I would have collected both quantitative and qualitative data at all time-points, and potentially during the curricular intervention as well. This would have allowed for time-series analysis to determine when changes occurred. Also, it would speak to the directionality of stance and knowledge development. Without a control group, it is difficult to make causal claims, particularly with regard to knowledge and stance development. Additional steps and data are needed to effectively establish causality and the directional relationship between stance and knowledge development.

Data Collected

My data included a pre and post stance survey, questions from within a larger pre/post knowledge assessment, and post semi-structured interview data from three different schools in varied geographies. I only worked with merged data sets to be able to draw conclusions about stability (i.e. changes from before and after participating in the curriculum) for the same student population across the study. The merged survey data set was over 300 students and the survey data merged with the pre and post knowledge assessment included over 200 students. The numbers allowed for analysis techniques that included descriptive statistics, linear regressions, generalized linear models, displays of graphs, multivariate linear regressions, factor analysis for data reduction to reduce variance, and tests to determine correlations and stabilities.

A larger data set would have allowed for different and potentially more powerful tests to be conducted. This could include multilevel models that explore interactions with more highly specific groups. For example, I divided my groups into males and females, where each group had sufficiently large members to satisfy the normal distribution assumptions. However, a larger overall sample size would have allowed for more interactions between the variables in my dataset. Similarly, more panel data analysis could have been used in order to account for heterogeneous groups within the data. A larger sample size would have also decreased the size of confidence intervals on the estimated regression coefficients. This may have led to the finding additional statistically significant dependencies. Due to the smaller nature of the sample size in this study, I cannot overgeneralize my findings. A larger sample could also be used to confirm the results of my work.

Future Work

My findings yield partial insights into some questions in my study and have also created new questions that I hope to explore. In this section, I offer ideas for my future work that stem from the results of my dissertation. I want to build on my findings regarding the relationship between climate change stances and knowledge. As addressed in the limitations discussion, I think a modified study design and increased data sample size can better characterize the stance and knowledge relationship. In the first part of this section, I discuss a new large-scale study design. Moreover, I propose a smaller more in-depth case study of a class studying climate change to continue to unpack the complex relationship between climate stances and knowledge. Then, I discuss a new area that I think is a natural progression from my current work: What motivates students to act in a sustainable manner? Does knowing and having a positive stance translate to actions that mitigate and/or adapt to climate change? Finally, although teachers were mentioned throughout my study, teaching practices, professional development, and the general role of the teacher were not explicitly studied. To fully characterize such a complex topic, I would want to conduct a study that explores teachers' stances, knowledge, action, and approach to teaching climate change.

Further Exploring the Relationship between Climate Stances and Knowledge

In future work, I intend to build on the findings that have identified the stability of climate change stances and knowledge, recognized statistically significant predictors (e.g., inside and outside of school variables, stance categories, and knowledge groups) of students' climate change knowledge and stances, surfaced statistical relationships between climate change stances and knowledge, and identified complexities between and within climate change stances and knowledge. Future studies will be designed to further identify relationships (i.e. causality) between students' climate change stances and knowledge.

To determine causality, a new study design needs to be considered, which would include a control group. As suggested previously in this chapter, changes to the curriculum need to be incorporated into the existing activity structures and learning progressions of the Climate Change and Its Impacts on Ecosystems middle school curriculum. Moreover, a new study design would include a larger sample. Ideally, the study would be conducted using a simple random sample that is representative of the middle school population in the United States. This approach is not realistic if all students are participating in a voluntary curricular intervention. However, a great emphasis can be placed on recruiting a larger number of students with a greater variety in geographic locations and student diversity. With greater widespread adoption of the NGSS, more states and classrooms will be looking for middle school climate science curricula that can be adopted. Study instruments, such as the pre/post stance surveys, the pre/post knowledge assessment, and the post semi-structured interview, would be modified to continually better capture students' climate change knowledge and stances. Additional data from within the curriculum (e.g., student answers and quizzes) and additional interview time points could also be added. These modifications would allow for a greater depth of data to be collected and analyzed.

Drawing on the findings of the new study, I can make curricular suggestions regarding how to address knowledge and stance development more effectively. This could include providing more general curricular redesigns that specifically targets the foundational stances and knowledge as identified by the larger scale study. Additionally, with these modified data collection instruments, I can continue to identify messy middle knowledge, just as diSessa (1993) catalogued students' alternative concepts in physics. Building on this idea, I can explore if climate change stance p-prims exist and can also be compiled. Moreover, teacher development could also benefit by focusing on the specific issues that ground stance and knowledge development.

Case study of a single classroom. Another option moving forward is to do careful and purposeful observation of a single classroom implementing a climate change curriculum that aligns with the NGSS. The observations could include protocols to collect data on students' pre stances and knowledge, messy middle concepts, knowledge and stance change throughout the curriculum, teacher presentation and articulation of the material, and student post knowledge and stances right after completing the curriculum and then again several months later. Careful observations of a single case study classroom could reveal other insights into students' climate change stances and knowledge. While this approach cannot be generalized to a greater population, it can help inform specific areas of curriculum design by better unpacking student and teacher confusion on disciplinary core ideas, practices, and activities.

Studying Sustainable Actions: Moving from knowledge and stances to actions?

For climate change education, I believe an ultimate goal should be to go beyond knowing the science and having positive stances; we want students to change their actions in order to personally adapt and/or mitigate climate change and to encourage sustainable actions in their communities and beyond. To build on the idea of this study, I would like to go beyond identifying students' climate change stances and knowledge, including stability and relationships, by exploring how knowledge and stances correlate with sustainable actions. There is current work in the field of social psychology that explores why people do and do not take action against climate change. Frantz and Mayer (2009) build their work on why people do and do not act in an emergency situation and apply their findings to climate change issues. They discuss that people first need to identify climate change as an emergency before taking actions. They also offer barriers for why people do not take responsibility for climate change. Would factors that inhibit or encourage adults to take action be the same for the middle school population?

As mentioned in the introduction, we want to help our students become informed global citizens. To be a global citizen, one must take actions to better the society. In the knowledge assessments and stance surveys, students were asked questions regarding actions to reduce greenhouse gas emissions. It now needs to be taken a step further and see what actions are done to personally reduce their carbon footprint? Do positive stances and/or strong knowledge transfer into actions? What motivates a student to take action? Is there a disconnect between knowing and doing? Another study could explore sustainability and student actions relative to their stances and knowledge.

The Role of the Teacher

Finally, as mentioned earlier, the focus of my work was on student climate change stances and knowledge. However, teachers are an integral component to student learning and engagement. I would like to extend my work to identify teachers' climate change stances and knowledge. Identification of messy middle knowledge and personal stances, might aid in designing teacher preparation and professional development opportunities for climate science topics and practices.

Conclusion

Climate change stances and knowledge are extremely complex. Not only is the science complex, but climate change is a socio-scientific issue that has personal factors, such as religious and political views, that further complicate discussions and the implementation of curricular units in public schools. My study adds to the secondary school climate change literature by studying both students' knowledge and stances. My multi-instrument and multi-timepoint study in a variety of schools contributes to the work in this field by adding depth and breadth to exploring the stability of stances and knowledge, identifying the messy middle knowledge regarding climate change science, investigating the relationship between stances and knowledge, and probing how students reason through and justify climate change stances.

My findings suggest the importance of continued curriculum design in climate science. This includes making curriculum personally relevant to students, which was shown to increase levels of worry regarding climate impacts, extending evidence-based activities which was correlated with positive shifts in climate stances, and developing lessons and repeated exposures to target messy middle knowledge. Additionally, more studies need to be conducted to further study the relationship between socio-scientific stances and knowledge. As educators, we can then continue to develop more purposeful curricular interventions that address students' prior knowledge and build activities to support sustainable decision-making based on positive stances and strong knowledge.

Furthermore, in the introduction, I speculated that climate change is like the anti-smoking campaign in terms of stance stability and action change. With the anti-smoking campaign as more facts were learned and there was an overwhelming consensus in the scientific community that smoking was harmful to one's health, the number of people who smoke decreased. Peoples' stances shifted and then they took action. In this study, there is a correlation to exposure to climate change evidence and positive stance shift in regards to existence and causes of climate change. With continued exposure and an overwhelming consensus in the climate science community, will middle school students begin to take more actions towards mitigating and/or adapting to climate change? Again, this idea will be explored in future studies.

Climate change and its impacts are a global threat. It is imperative as researchers and educators that we afford students the opportunities to engage in these topics and practices. Similarly, curricular activities need to be presented to encourage engagement and to build on students' prior knowledge and stances from both inside and outside of the classroom. By continuing to study the complexities and relationships between climate change knowledge and stances, we can better engage students in fruitful curricular interventions and activities in both formal and informal settings. Middle school students are the decision and policy-makers of energy and climate reforms in the near future. We are obligated to help secondary students engage in this critical socio-scientific issue.

Appendices

Appendix A: Pre and Post Stance Survey & Construction of Stance Categories

Climate Change Survey

UNIVERSITY OF MICHIGAN

CLIMATE CHANGE QUESTIONNAIRE

Survey | Contact

Climate Change Questionnaire

Please read the following questions and answer them as fully and as honestly as possible. There are no correct or incorrect answers. For the open-ended responses, please write in complete sentences. Please make sure to press the submit button, at the bottom, when you are done. Thank you!

* Required

Name *

Gender *

- Male
- Female

Age *

Teacher's Name *

Please write your state and zip code of where you live *

(Example: Michigan, 48109)

What is your current letter grade in science?

(Example B+)

What letter grade did you earn in science last year?

(Example B)

1a. How often do you watch the news on TV and/or on the internet? *

- Rarely
- 1-2 times per week

http://www-personal.umich.edu/~reicher/survey.html[5/23/2013 3:54:31 PM]

- 3-4 times per week
- More than 4 times per week

1b. Name the news shows that you most often watch online or on TV:

2a. How often do you read a newspaper or magazine online and/or offline? *

- Rarely
- 1-2 times per week
- 3-4 times per week
- More than 4 times per week

2b. Name the newspapers or magazines that you most often read on the internet or in printed form:

3. What media source do you most often go to for news? Check the two boxes that most apply. *

- The New York Times
- Fox News
- Blogs
- Youtube
- CNN
- The Daily Show/Colbert Report
- Google Search or other search engines
- Nightly news shows
- Government web pages (ex: EPA, NOAA)
- Huffington Post
- Other:

4. What is the highest level of education that your mother has completed *

Less than 8th grade

5. What is the highest level of education that your father has completed *

Less than 8th grade

6a. Recently, you may have noticed that global warming has been getting some attention in the news. Global warming refers to the idea that the world's average temperature has been increasing over the past 150 years, may be increasing more in the future, and that the world's climate may change as a result. What do you think? Do you think that global warming is happening? *

- ○ Yes
- ○ No
- ○ Don't know

6b. In one to two sentences, explain why you think climate change is happening, not happening or you do not know? *

7a. How worried are you about climate change? *

- ○ Not at all worried
- ○ Not very worred
- ○ Somewhat worried
- ○ Very worried

7b. Explain why you are worried OR not worried about climate change. *

8. Assuming global warming is happening, do you think it is... *

- ○ Caused by human activities
- ○ Caused mostly by natural changes in the environment
- ○ None of the above because global warming isn't happening
- ○ Other:

9a. How often do you discuss global warming with your family and friends? *

- ○ Never
- ○ Rarely
- ○ Occasionally
- ○ Very often

9b. When you discuss climate change with your family and friends, what is said about climate change? *

10a. Do you think climate change is happening? *

- ○ No
- ○ Yes
- ○ Don't know

10b. In one to two sentences, please give reasons for your answer for the question: Do you think climate change is happening? *

11. Which comes closest to your own view? *

- ○ Most scientists think global warming is happening
- ○ Most scientists think global warming is not happening
- ○ There is a lot of disagreement among scientists about whether or not global warming is happening
- ○ Don't know enough to say

12a. The actions of a single individual won't make any difference in climate change. *

- ○ Strongly agree
- ○ Somewhat agree
- ○ Somewhat disagree
- ○ Strongly disagree

12b. Name two actions that you can do to reduce your personal carbon emissions:

13. What do you think is causing climate change? *

- Climate change is not happening
- It is caused by natural changes in the environment
- It is caused mostly by human activities
- I don't know why it is happening

14a. I have personally experienced the effects of global warming. *

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

14b If you have experienced the effects of global warming. describe how you have experienced them. Otherwise, if you have not experienced the effects of global warming, explain why you feel this way.

15. New technologies can solve climate change, without individuals having to make big changes in their lives *

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

16. Which of the following statements comes closest to your view? *

- Humans can reduce climate change, and we are going to do it successfully
- Humans can't reduce climate change, even if it is happening
- Humans could reduce climate change, but it's unclear at this point whether we will do what is needed

○ Humans could reduce climate change, but people aren't willing to change their behavior, so we're not going to
○ Climate change isn't happening

17. I do well on tests in my science classes *

○ Strongly disagree
○ Disagree
○ Agree
○ Strongly agree

18. In comparison to the rest of my science class, I consider myself a strong science student. *

○ Strong disagree
○ Disagree
○ Agree
○ Strongly agree

19. If I get stuck on a problem on my science homework tonight, there is no chance I will figure it out on my own. *

○ Strongly agree
○ Agree
○ Disagree
○ Strongly disagree

20. I do well on projects in my science class. *

○ Strongly agree
○ Agree
○ Disagree
○ Strongly disagree

Construction of Stance Categories

Creating Categories from the Survey Items	
Is climate change happening and its causes.	6a, 6b reasons, 8, 10a, 10b, 11, 13
Climate the students' lives (worry, discussion, and impacts)	7a, 7b, 9, 9b, 14a, 14b-
Solutions/Actions to mediate climate change	12a, 12b, 15, 16 12a, 15, and 16
Self-Efficacy	Sum scores from items 17-20 to get a total self-efficacy score

Appendix B: Pre and Post Knowledge Assessment and Scoring Rubric

Created by Sania Zaidi and Nancy Songer

Modified for the questions used in this study

Total Number of items= 10

Total Potential Points=16

NGSS Science and Engineering Practices addressed in the assessment

- **Item 4a:**
    - **Practice 5:** Using Mathematics and Computational Thinking
        - 5. 3 Apply concepts of ratio, rate, percent, **basic operations**, and simple algebra to scientific and engineering questions and problems.
- **Item 4b:**
    - **Practice 5**: Using Mathematics and Computational Thinking
        - 5.4: Use mathematical arguments to describe and support scientific conclusions and design solutions.
    - Practice 7: Engaging in Argument from Evidence
        - 7.1: **Construct,** use, and present oral and **written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon** or a solution to a problem.
- **Item 6b**
    - **Practice 7:** Engaging in Argument from Evidence

7.1: Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon or a solution to a problem.

Item	**Type** **(Content/Fused)**	**Scoring Rubric** *Points are in ( )*
2. What is predicted to be a result of global warming? **a.** Rising ocean level **b.** More severe earthquakes **c.** Larger volcanic eruptions **d.** Thinning ozone layer	Content **National %** 30-USA 67-Best 33-Avg **Grade Level**- 8 *NOTE: Score "6" stands for capturing the thinning ozone response.*	**Released Item # 58 (TIMSS)** **Total Possible Points (1)** Correct Response: (a) **Scoring** (1): a (0): b, c (6): d (9): no response

3a. Some scientists think that the Earth's climate is getting warmer. The Earth's climate may be getting warmer because of some things that people do human activities that may contribute to warming of the Earth's climate.	Content **National %** 21.3% **Grade Level**-8 ***Note***: *Coding Rubric is from NAEP, This rubric will <u>NOT</u> be revised*	**Released Item # 102(NAEP, 2005)** **Total Possible Points (2)** Correct Response: Human Activities • Using automobiles • Using factories • Deforestation • Using fossil fuels • Using electricity • Too many landfills OR landfills Possible Incorrect Responses (Code 0) • Pollution (code 6) **Complete (2)** Student lists two human activities that are thought to contribute to global warming. **Partial (1)** Student lists one activity that may contribute to global warming.

		Unsatisfactory/Incorrect (0) Student response does not indicate an understanding of the relationship of humans to global warming. **(9):** no response --- **Sample of Correct Student Response**
3b. List two human activities that can **decrease** the impact of climate change.	Content ***Note for Coders****:* please add to the list of correct responses	**Total Possible Points (2)** Correct Response • Using alternative forms of transport • Using clean energy • Planting trees • Drive Less/Carpool • Recycling • More efficient fuel use **Scoring**

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<td></td>
<td>(2): Correctly lists two human activities
(1) Correctly lists one human activity
(0): Incorrect
(9): no response</td>
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<td></td>
<td></td>
<td>Sample of Correct Student Response</td>
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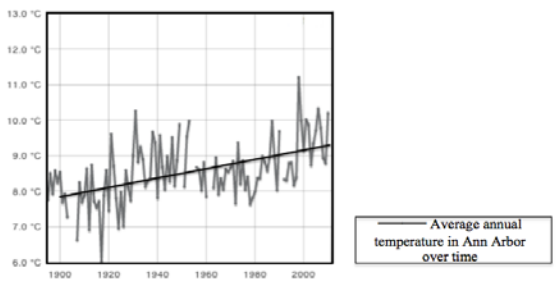
<td>4. The graph below shows the average annual temperature from 1900 until 2010 for the town of Ann Arbor, Michigan, USA.

4a. The change in average annual temperature from 1900 to 2000 in Ann Arbor is_________________.</td>
<td>Fused

NGSS Sci &Eng Practice
5. 3 Apply concepts of ratio, rate, percent, basic operations, and simple algebra to scientific and engineering questions and problems.

Note for data analysts:
When analyzing correct/incorrect, Correct response =’1’ + ‘6’</td>
<td>Total Possible Points (1)
Correct Response:
Any number between 1-1.4 C
Scoring
(1): temperature between 1-1.4 C
(0): incorrect
(6): correct temperature, missing units
(9): no response</td>
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4b. Use information from the graph above to construct an explanation to answer the question: **Has climate changed in Ann Arbor over the last 100 years?** **My explanation:**	Fused **NGSS Sci & Eng Practice** • 5.4: Use mathematical arguments to describe and support scientific conclusions and design solutions. • 7.1: **Construct,** use, and present oral and **written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon** or a solution to a problem. **Note to Coders**: Score explanation in three parts 4b.1-claim 4b.2-reasoning 4b.3-evidence	**Total Possible Points (3)** (1) 4b.1- refers to Claim (Note: A claim is a complete sentence) (1) 4b.2-refers to Reasoning (1) 4b.3-refers to Evidence <u>Correct Response</u> **4b.1 Claim:** should state that climate has changed in Ann Arbor over the last 100 years. **(Note:** Score it as (1) if there is a complete sentence with claim and continues on with reasoning or evidence, even if the latter part of the sentence is incorrect.) **4b.2 Reasoning**: should include what is meant by climate OR climate change. **Climate**: The set of weather conditions that prevail in a particular place or region over a long period of time. OR Climate is determined by averaging a set of weather observations collected over a long time period. **Climate Change:** a long-term change in the characteristics of climate over time, particularly in the properties that define the climate, such as temperature, *precipitation, etc.* **4b.3 Evidence**: needs to be provided from the graph by reading temperatures at 1900 and 2000 and calculating the change OR Interpreting the rising slope of the trend line. Examples for Evidence: • The graph shows that the climate has risen by ~1-1.4C in the last 100 years. • The slope of the trend line in the graph, from 1900-2000 is increasing, thereby showing that

		climate has changed in the last 100 years. **Scoring for <u>each part</u> (4b.1, 4b.2, 4b.3)** **4b.1: Claim:** (1) Correct claim (0) Incorrect claim (9) No response **4b.2: Reasoning** (1) Correct reasoning (0) Incorrect reasoning (9) No response **4b.3: Evidence:** (1) 1 piece of correct evidence (0) Incorrect evidence (9) No response
		Sample of Correct Student Response **4b.3**: the average annual temperature has gone up 0.1C every 20 years and has not declined.

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5. What is the difference between weather and climate?

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<td>Content</td>
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Total possible points (2)

<u>Correct Response</u>

- Weather is atmospheric conditions (OR temperature, precipitation) over short periods of time such as days or months while climate is the average atmospheric conditions (OR temperature, precipitation) over a longer period of time such as a decade.
- Weather is at the exact moment and climate is all year round

Scoring

(2): Should include correct descriptions of both weather and climate.

(1): Correct description of weather or climate. Other can be blank or incorrect

(0): Incorrect description of both weather and climate.

(9): no response

Sample of Correct Student Response

1. Weather is if it is hot or cold outside or if it is rain, snowing or hail and stuff like that. Climate is the average weather year round.

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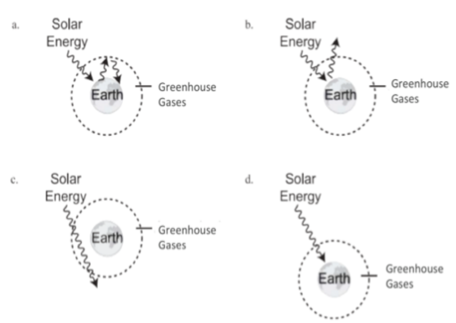
6a. Circle the picture that best represents the **greenhouse effect**.



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Content

No comparative Stats available for this item

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Adapted from Released test item (CT, 2009)

Total Possible Points (1)

Correct Response: a.

Scoring:

(1): a

(0): b, c, d

(9): no response

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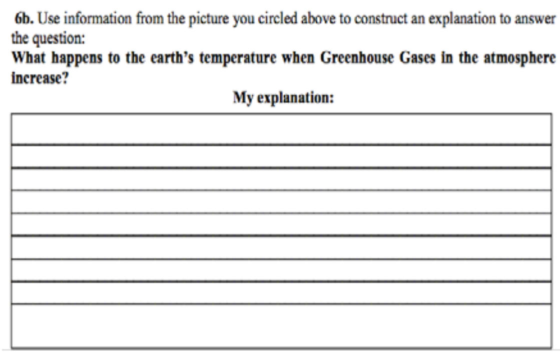
</tr>
</table>

 **6b.** Use information from the picture you circled above to construct an explanation to answer the question: **What happens to the earth's temperature when Greenhouse Gases in the atmosphere increase?** **My explanation:**	Fused **NGSS Sci & Eng Practice** 7.1: **Construct,** use, and present oral and **written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon** or a solution to a problem. **Note to Coders**: Score explanation in three parts 6b.1-claim 6b.2-reasoning and evidence	**Total Possible Points (3)** (1) 6b.1- refers to Claim (2) 6b.2- refers to reasoning and evidence <u>Correct Response</u> **Claim:** The Earth's temperature increases when greenhouse gases in the atmosphere increase. (**Note:** score it as (1) if there is a complete sentence with claim and continues on with reasoning or evidence, even if the latter part of the sentence is incorrect.) **Reasoning and Evidence** (Note: Give full credit if two reasoning statements are present) • Any information from the picture or the phenomenon • As greenhouse gas concentrations increase, more heat is retained in the atmosphere and earth's temperature increases. The picture shows that greenhouse gases trap solar energy The picture shows how the greenhouse gases in the atmosphere increase. **Scoring <u>for each part</u> (6b.1, 6b.2)** **6b.1: Claim:** (1) Correct claim (0) Incorrect claim (9) No response **6b.2: Reasoning and Evidence** (2) Two of the above 4 responses (1) One of the above 4 responses (0) Incorrect response , (9) No response

7a. Carbon in the atmosphere is most often found as which of the following compounds? **a.** ozone **b.** fossil fuel **c.** carbon monoxide **d.** carbon dioxide	Content No comparative Stats available for this item	**Adapted from Released item # 132 (California St. Test, 2006)** **Total Possible Points (1)** Correct Response: (d) **Scoring:** (1): d (6): a (0): b, c (9): no response
7b. Where does the **excess carbon** produced from cars, factories and other activities go? ____________________ ____________________ ____________________	Content	**Total Possible Points (1)** Correct Response: Most of the carbon goes into the atmosphere. Some portions of it gets absorbed, into water bodies and soils **Scoring:** (1): mentions atmosphere (OR air, sky) OR water bodies/soil. (6) mention of ozone (0): other response (9): no response **Sample of Correct Student Response**

Appendix C: Pre-Processing for Interview & Post Semi-Structured In Depth Interview Protocol

ID	Post_Teach	Pre Teach	Positive P	Positive P	Negative P	Negative P	Change Positive (Want P	Change Negative (Want N		Knowledge Pre	Knowledge P	Knowledge Chan
CT12030101	Rowlands	Rowlands	7	4	7	11	-3	4		5	5	0
CT12030105	Rowlands	Rowlands	7	12	7	1	5	-4		7	8	1
CT12030106	Rowlands	Rowlands	7	13	8	2	6	-6		9	12	3
CT12030115	Rowlands	Rowlands	8	10	5	5	2	0		7	6	-1
CT12030111	Rowlands	Rowlands	8	10	5	5	2	0		6	10	4
CT12030108	Rowlands	Rowlands	9	12	6	3	3	-3		6	8	2
CT12030117	Rowlands	Rowlands	9	9	6	6	0	0		10	12	2
CT12030120	Rowlands	Rowlands	9	10	4	5	1	1		3	12	9
CT12030119	Rowlands	Rowlands	10	13	5	2	3	-3		5	11	6
CT12030114	Rowlands	Rowlands	10	13	4	1	3	-3		4	11	7
CT12030118	Rowlands	Rowlands	10	11	5	4	1	-1		5	12	7
CT12030102	Rowlands	Rowlands	12	14	2	[illegible]	2	-1		11	8	-3
CT12030110	Rowlands	Rowlands	12	9	3	6	-3	3		11	11	0
CT12030104	Rowlands	Rowlands	12	10	3	5	-2	2		10	12	2
CT12030103	Rowlands	Rowlands	12	11	3	4	-1	1		3	12	9
CT12030107	Rowlands	Rowlands	12	[illegible]	3	[illegible]	2	-2		8	13	5
CT12030116	Rowlands	Rowlands	13	11	2	4	-2	2		7	11	4
CT12030109	Rowlands	Rowlands	[illegible]	[illegible]	[illegible]	[illegible]	-1	1		11	9	-2
CT12030121	Rowlands	Rowlands	13	11	3	2	-2	2		7	11	4

ID	Post_Teach	Pre Teach	Positive P	Positive P	Negative P	Negative P	Change Positive (Want P	Change Negative (Want N		Knowledge Pre	Knowledge P	Knowledge Chan
CT12100102	McKinney	McKinney	4	12	9	3	8	-6		4	7	3
CT12100110	McKinney	McKinney	4	10	11	5	6	-6		10	12	-4
CT12100212	McKinney	McKinney	5	6	9	8	1	-1		1	5	4
CT12100216	McKinney	McKinney	5	8	10	7	3	-3		4	5	1
CT12100106	McKinney	McKinney	6	5	8	8	-1	0		2	4	2
CT12100101	McKinney	McKinney	6	10	7	5	4	-2		10	4	-6
CT12100217	McKinney	McKinney	8	4	5	11	-4	6		4	6	2
CT12100115	McKinney	McKinney	8	10	4	4	2	0		2	6	4
CT12100105	McKinney	McKinney	8	11	6	4	3	-2		4	6	2
CT12100203	McKinney	McKinney	8	13	7	2	5	-5		3	6	3
CT12100117	McKinney	McKinney	8	11	5	4	3	-1		5	10	5
CT12100204	McKinney	McKinney	8	8	7	6	0	-1		8	11	3
CT12100209	McKinney	McKinney	9	11	5	4	2	-1		13	3	-10
CT12100202	McKinney	McKinney	9	8	6	5	-1	-1		8	6	-2
CT12100111	McKinney	McKinney	9	10	5	4	1	-1		4	7	3
CT12100214	McKinney	McKinney	9	7	6	8	-2	2		5	9	4
CT12100205	McKinney	McKinney	9	11	6	4	2	-2		10	11	1
CT12100107	McKinney	McKinney	9	7	6	7	-2	1		9	14	5
CT12100201	McKinney	McKinney	10	11	5	4	1	-1		2	4	2
CT12100218	McKinney	McKinney	11	9	3	5	-2	2		5	5	0
CT12100213	McKinney	McKinney	11	11	3	4	0	1		6	6	0
CT12100114	McKinney	McKinney	11	9	4	6	-2	2		7	7	0
CT12100210	McKinney	McKinney	11	13	4	2	2	-2		10	9	-1
CT12100206	McKinney	McKinney	11	12	3	3	1	0		12	11	-1
CT12100108	McKinney	McKinney	11	14	4	[illegible]	3	-3		7	11	4
CT12100104	McKinney	McKinney	11	7	4	8	-4	4		8	14	6

ID	Post_Teach	Pre Teach	Positive P	Positive P	Negative P	Negative P	Change Positive (Want P	Change Negative (Want N		Knowledge Pre	Knowledge P	Knowledge Chan
CT12080118	Hansel	Hansel	[illegible]	8	10	7	5	-3		1	16	15
CT12080412	Hansel	Hansel	6	5	8	10	-1	2		2	10	8
CT12080324	Hansel	Hansel	6	5	7	8	-1	1		6	13	7
CT12080102	Hansel	Hansel	6	10	8	4	4	-4		8	13	5
CT12080313	Hansel	Hansel	6	8	7	5	2	-2		7	15	8
CT12080125	Hansel	Hansel	6	9	9	6	3	-3		6	15	9
CT12080103	Hansel	Hansel	7	10	8	5	3	-3		6	8	2
CT12080402	Hansel	Hansel	7	5	8	10	-2	2		5	10	5
CT12080221	Hansel	Hansel	7	9	7	6	2	-1		7	11	4
CT12080428	Hansel	Hansel	7	10	6	4	3	-2		7	12	5
CT12080117	Hansel	Hansel	7	6	8	9	-1	1		7	13	6
CT12080319	Hansel	Hansel	7	9	7	6	2	-1		9	13	4
CT12080216	Hansel	Hansel	7	10	7	5	3	-2		6	14	8
CT12080312	Hansel	Hansel	7	12	7	3	5	-4		9	14	5
CT12080114	Hansel	Hansel	7	8	5	5	1	0		3	15	12
CT12080120	Hansel	Hansel	7	9	8	6	2	-2		11	16	5
CT12080123	Hansel	Hansel	7	10	6	5	3	-1		8	16	8
CT12080224	Hansel	Hansel	7	11	8	4	4	-4		5	16	11
CT12080222	Hansel	Hansel	8	10	5	4	2	-1		8	11	3
CT12080206	Hansel	Hansel	8	9	7	6	1	-1		4	12	8
CT12080315	Hansel	Hansel	8	11	7	4	3	-3		8	13	5
CT12080426	Hansel	Hansel	8	9	7	6	1	-1		6	17	11
CT12080230	Hansel	Hansel	9	9	5	6	0	1		2	9	7
CT12080420	Hansel	Hansel	9	11	5	3	2	-2		9	9	0
CT12080106	Hansel	Hansel	9	7	5	6	-2	1		10	11	1
CT12080213	Hansel	Hansel	9	13	6	2	4	-4		4	11	7
CT12080422	Hansel	Hansel	9	10	5	5	1	0		3	12	9
CT12080322	Hansel	Hansel	9	11	4	4	2	0		4	12	8
CT12080417	Hansel	Hansel	9	5	5	10	-4	5		9	13	4
CT12080407	Hansel	Hansel	9	7	4	7	-2	3		4	13	9
CT12080418	Hansel	Hansel	9	13	5	2	4	-3		5	13	8
CT12080304	Hansel	Hansel	9	9	5	5	0	0		4	15	11
CT12080217	Hansel	Hansel	9	13	5	2	4	-3		4	15	11
CT12080401	Hansel	Hansel	10	11	5	4	1	-1		4	8	4
CT12080421	Hansel	Hansel	10	12	5	3	2	-2		5	8	3
CT12080330	Hansel	Hansel	10	9	3	6	-1	3		6	10	4
CT12080427	Hansel	Hansel	10	11	4	4	1	0		8	12	4
CT12080317	Hansel	Hansel	10	12	5	3	2	-2		9	13	4
CT12080419	Hansel	Hansel	10	12	5	3	2	-2		8	13	5
CT12080214	Hansel	Hansel	10	10	5	5	0	0		8	14	6
CT12080413	Hansel	Hansel	10	11	5	4	1	-1		8	14	6
CT12080212	Hansel	Hansel	10	9	4	6	-1	2		9	15	6
CT12080220	Hansel	Hansel	10	12	5	3	2	-2		6	15	9
CT12080113	Hansel	Hansel	11	9	4	5	-2	1		9	9	0
CT12080416	Hansel	Hansel	11	12	4	3	1	-1		7	11	4
CT12080126	Hansel	Hansel	11	9	4	6	-2	2		4	12	8
CT12080414	Hansel	Hansel	11	11	4	4	0	0		8	12	4
CT12080209	Hansel	Hansel	11	10	3	4	-1	1		7	13	6
CT12080232	Hansel	Hansel	11	12	4	3	1	-1		7	13	6
CT12080107	Hansel	Hansel	11	10	4	5	-1	1		6	14	8
CT12080409	Hansel	Hansel	11	10	4	5	-1	1		4	14	10
CT12080105	Hansel	Hansel	11	9	4	6	-2	2		6	15	9
CT12080205	Hansel	Hansel	11	13	4	2	2	-2		11	16	5
CT12080423	Hansel	Hansel	12	10	3	5	-2	2		7	9	2
CT12080405	Hansel	Hansel	12	10	3	5	-2	2		10	11	1
CT12080303	Hansel	Hansel	12	12	3	3	0	0		8	11	3
CT12080108	Hansel	Hansel	12	12	3	3	0	0		4	12	8
CT12080112	Hansel	Hansel	12	7	3	8	-5	5		5	14	9
CT12080225	Hansel	Hansel	12	9	3	5	-3	2		8	14	6
CT12080203	Hansel	Hansel	12	11	3	4	-1	1		11	14	3
CT12080320	Hansel	Hansel	12	13	3	2	1	-1		6	15	9
CT12080403	Hansel	Hansel	12	12	3	3	0	0		8	16	8
CT12080411	Hansel	Hansel	12	14	3	1	2	-2		7	17	10
CT12080301	Hansel	Hansel	12	12	3	3	0	0		6	18	12
CT12080408	Hansel	Hansel	13	11	2	4	-2	2		3	7	4
CT12080231	Hansel	Hansel	13	13	2	2	0	0		3	11	8
CT12080211	Hansel	Hansel	13	14	2	1	1	-1		5	12	7
CT12080124	Hansel	Hansel	13	10	2	5	-3	3		9	14	5
CT12080210	Hansel	Hansel	13	12	2	3	-1	1		10	14	4
CT12080207	Hansel	Hansel	13	12	2	3	-1	1		5	15	10
CT12080208	Hansel	Hansel	13	11	2	4	-2	2		9	16	7

Introduction:

Interview: Hi, my name is Michelle Reicher. I am a graduate student at the University of Michigan. Thank you so much for agreeing to talk to me today. I am going to ask you a few questions about climate change. Do you remember in your science class last year, you worked on climate change and its impacts on biodiversity?

Possible Follow-up questions:

- *What do you remember most about the unit, if anything?*
- *What was the most interesting?*
- *Most disturbing?*
- *Most fun?*

Today we are just going to talk about some of the topics and ideas from last year. Your responses are extremely important and I want you to know that there are no right and wrong answer. I'm simply interested in hearing what you have to say in response to my questions. Your answers will help other students, as well as teachers and researchers better understand how students your age are thinking about these important issues.

I promise I will not take more than 30 minutes of your time. Some of the questions might look familiar because they are similar to questions you and your classmates worked on last year in science. I want to say it again, there are no correct or incorrect answers. This is not a test. I just want you to tell me what you honestly think and believe. It will be like a conversation between us. Please feel free to talk freely. Your answers will remain anonymous so no one will know what you said and I will not share your responses with your teacher or classmates. You will NOT be graded on your responses. At any point if you do not want to answer a question, you can just ask move to the next question.

There are a few different types of questions that I will ask you. Before we begin the interview, I will model how I might approach answering the different types of questions. The other questions are just like we are having a conversation. Then, you will have a chance to talk through sample questions. Please feel free to ask me any questions that you might have.

Would you be ok if I recorded our discussion? Ok are you ready to begin?

Let me first model how I would answer the different questions and then you will have a chance to do the same. Notice how I am constantly thinking out loud and saying what I am thinking. I read the whole question and all the options given.

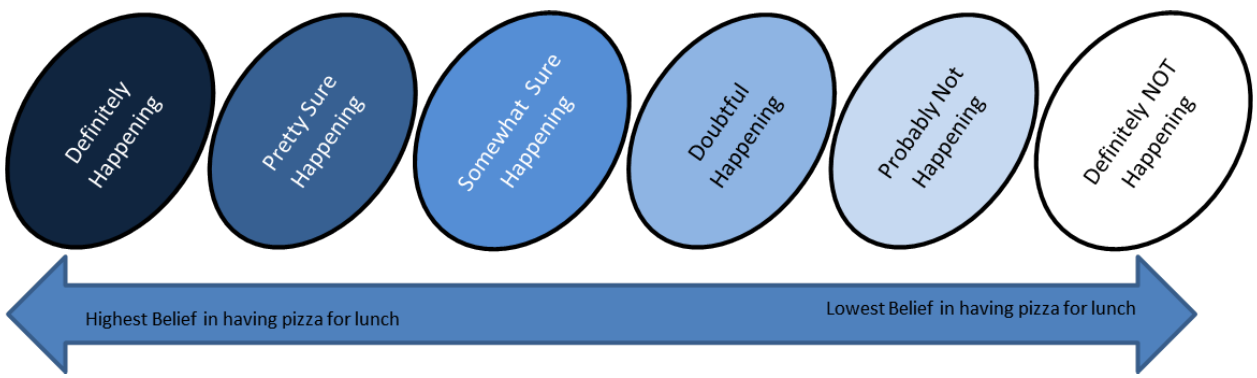
Name: ____________________ **Date___________**

School:____________________

Interviewer Protocol

There are several different types of questions in the interview. As the interviewer, I will first model several different types of questions that are similar to those in the interview, but on a different topic. When, I work through the questions notice how I think out loud and say everything that is on my mind. If you have any questions, please ask!! Ok, I am going to start.

1. Looking at this diagram please pick the oval that best answers the question: How certain are you that you will have pizza for lunch today?



Interviewer will follow-up with several questions.

2. Which statement do you believe in? and Why?

Statement 1: "I have the most fun after school when I am watching TV with my friends"

Statement 2: "I have the most fun after school when I am playing sports or being active with my friends"

Interviewer will follow-up with several questions:

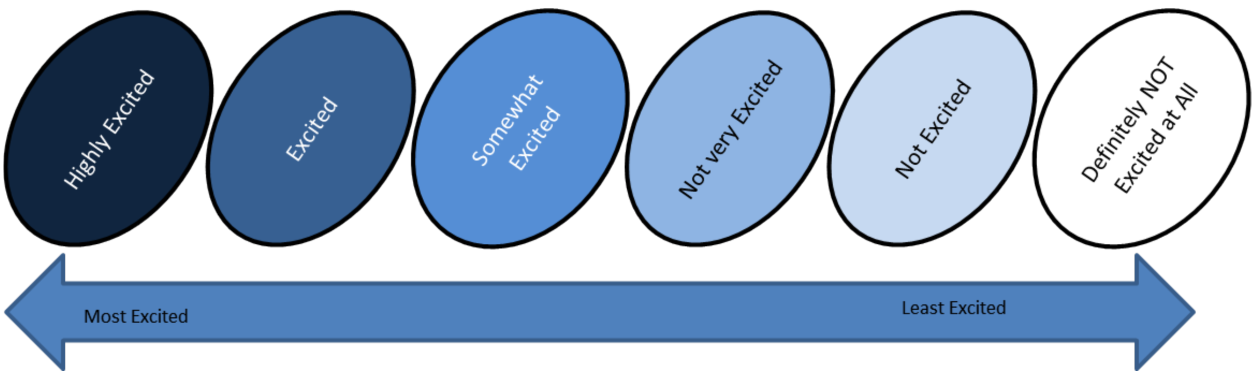
Why do you think someone else might choose the other statement?

Do you have any questions? Are you ready to try a few sample questions on your own?

For Interviewer: Read each question out loud and remember to encourage you to think out loud so this is a good time to practice.

Sample Student Questions

Looking at this diagram please pick the oval that best answers the question: How excited are you about going to high school soon?



Interviewer will follow-up with several questions.

Some of your peers might have a different response to you on the continuum. If you are excited about going why do you think others might not be as excited? If you are not excited about going to high school, why do you think some people might be excited about it?

Your principal has asked you to start an educational program about exercising after school. What are some of the health benefits of exercising? Can you discuss why some of your friends might not like this program?

Do you have any questions? Are you ready to begin?

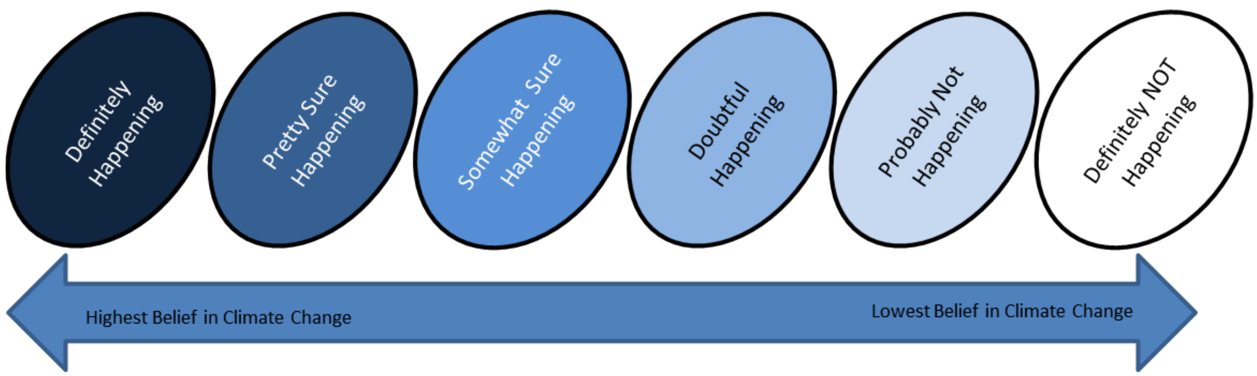
Beginning of the Interview Protocol

Persistence Questions

b) (6a on Survey) Recently, you may have noticed that climate change has been getting some attention in the news. Anthropogenic (human caused) climate change refers to the idea that the world's average temperature has been increasing over the past 150 years, may be increasing more in the future, and that the world's climate may change as a result. What do you think? Do you think that anthropogenic climate change is happening? Why or why not?

- **Who have been the greatest influences on your thinking on this topic?**
- **What experiences have been the greatest influences on your thinking on this topic?**

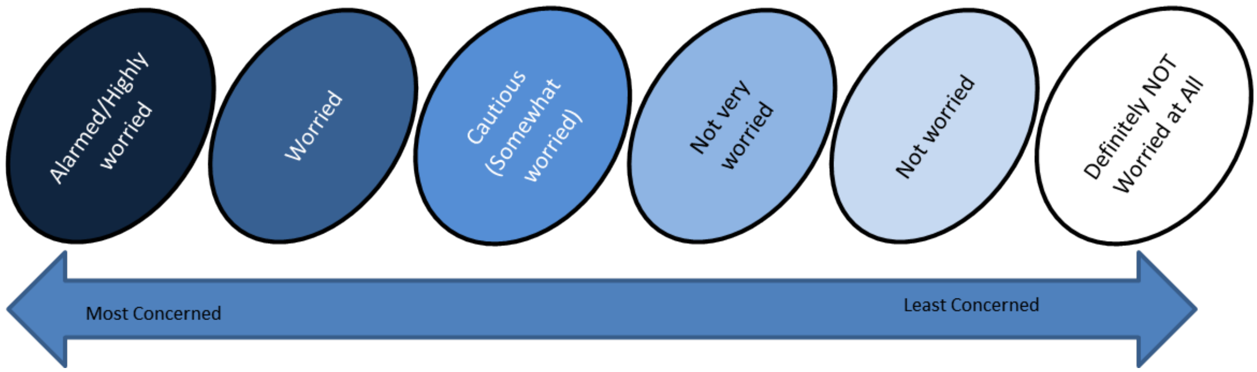
c) Looking at this diagram please pick the oval that best answers the question: How certain are you that climate change is happening or not happening?



Interviewer will follow-up with several questions. IF response disagrees with responses given during pre and post can probe further.

- **Who have been the greatest influences on your thinking on this topic?**
- **What experiences have been the greatest influences on your thinking on this topic?**

d) 3. Looking at this diagram please pick the oval that best answers the question: How worried are you about climate change impacts in your lifetime?



Interviewer will follow-up with several questions.

(I) IF response disagrees with responses given during pre and post can probe further. Will probe further about why the student is worried or not (impacts?)

.

Section 2: Complexity Questions

Probe 3 main topics of influence beyond family and friends (politics, media, and religion, and leave room for other influences).

Influences on Climate Change

*In this section, the interviewer will use the vignettes and responses to prompt students. The students will hear the questions and not write responses. This will be a conversation.

Reiterate to student that if they want to skip a question at any point because they do not feel comfortable just to say so.

1. Do your friends and family discuss climate change? If so, what is said?

(**In interviewer protocol)** Several possible follow-up prompts (students will not see, prompts and discussion questions for interviewer):

- When climate change is mentioned, do your friends and family often discuss politics? If so what is said? OR Is climate change, discussed when you are talking about religion? Or when and if you are talking about jobs?
- If you don't talk about climate change, why do you think you do not talk about it?
- If climate change is not discussed, why do you think your friends and family do not talk about it?

- What do you typically talk about around the dinner table or when you are together in the car/places where you spend time together?

- Does your family have similar views as you about climate change happening or not happening?
  - How are they the same or different?
  - Why do you think they are the same or different

- Do you discuss actions to reduce your impact, what does your family do? (for example do they help you/encourage you, do they not think climate change is happening, do they think that one person/family cannot make a difference so it is not worth it?
  -

2. If you watch the news? what is said about climate change (who is causing it?, does it matter?)
3. Where else do you discuss climate change with other people (if you do discuss it)? Religious institution (if yes, can follow up if student is comfortable discussing religious affiliation and background), related to science, political discussions?

Section 3: Student Questions

Wrap-Up Final Questions

What questions do you have about climate science?

- Are there questions that pop into your head at school or at home, that you have not asked?
- What confuses you about climate science?
- Is there something you have seen or experienced about climate change since you have finished the curriculum that you have questions about?

  Student specific question from the survey and assessment…

-

Thank you for your time, honesty, and help! We are all done unless you have anything else that you would like to add?

Appendix D: Coding Rubric for Pre/Post Survey and Sample Responses from Open Ended Survey Questions

Gender * Male Female	1= Male 2= Female	
Gender * Male Female	1= Male 2= Female	
Age *	1	11 years old
	2	12 years old
	3	13 years old
	4	14 years old
	5	15 years old
Teacher's Name *	1	Mrs. BMI
	2	Mrs. BoMI
	3	Mrs. CNC
	4	Mr. CKY
	5	Mrs. EKY
	6	Mrs. HOH
	7	Mrs. MKS
	8	Mrs. RVA
	9	Mr. WHO
	10	Mrs. WMI
Zip Code	1	Ohio
	2	Michigan
	3	KY

	4	NC
	5	VA
	6	KS
Current Grade?	1	A
	2	B
	3	C
	4	D
	5	F
	9	Other
Grade last year?	1	A
	2	B
	3	C
	4	D
	5	F
	9	Other
1a. How often do you access the internet?	1	Rarely
	2	1-2 per week
	3	3-4 times per week
	4	More than 4 times per week
1b. News watched	1	Conservative
	2	Moderate
	3	Liberal
	4	Comedy
	5	Pop culture
	6	Local Station
	7	Does not watch the news
	8	Unknown
	99	Missing
	1	NBC
	2	Fox

	3	Local News Channel
	4	CNN
	5	ABC
	6	Pop Culture channels/shows
	7	Does not watch the news
	8	unknown
	9	Religious channel
	99	Missing
2a. How often do you read a newspaper/magazine?	1	Rarely
	2	1-2 per week
	3	3-4 times per week
	4	More than 4 times per week
2b. What newspaper/magazine?	1	Conservative
	2	Moderate
	3	Liberal
	4	Comedy
	5	Pop culture
	7	do not read
	9	Missing
3. What media source?	1	Conservative
	2	Moderate
	3	Liberal
	4	Comedy
	5	Pop culture
	6	Local Station
	7	Does not watch the news
	8	Uknown
	99	Missing
	1	NBC
	2	Fox

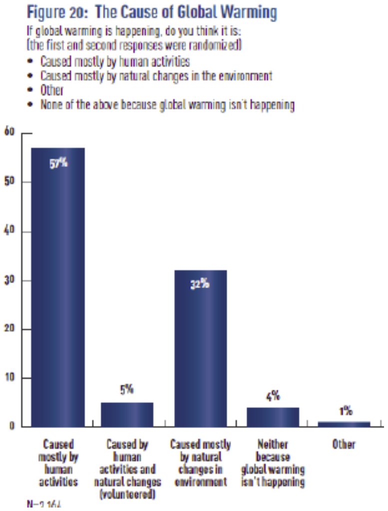
	3	Local News Channel
	4	CNN
	5	ABC
	6	Pop Culture channels/shows
	7	Does not watch the news
	8	unknown
	9	Religious channel
	99	Missing
4. Mom education level	1	Less 8th Grade
	2	Some HS
	3	HS
	4	Associates Degree
	5	Some College
	6	College
	7	MA
	8	MD, PhD, JD
5. Dad education level	1	Less 8th Grade
	2	Some HS
	3	HS
	4	Associates Degree
	5	Some College
	6	College
	7	MA
	8	MD, PhD, JD
Race Post Survey	1	White
	2	African American
	3	Hispanic
	4	Mixed Race
	5	Asian
	6	Other

6a. Anthro CC happening?	1	No
	2	Don't Know
	3	Yes
6b. Reasoning for 6a	1	Don't Know reason
	2	Don't Care
	3	Getting warmer (less snow)
	4	Sun getting closer
	5	Pollution/Littering/General Discussion of Factories
	6	Seasons Changing
	7	Ozone Depletion/increased UV rays
	8	Greenhouse Effect
	9	Religious
	10	Natural Changes
	11	Carbon Dioxide increases/increased greenhouse gases
	12	Getting colder
	13	Human Activity/Increase Technology Use
	14	Ice Melting/increasing sea level
	15	Animals Dying
	16	Cutting down trees
	17	Fossil fuel use
	18	It's not happening
	19	Floods, droughts, and other natural disasters
	20	Increased Population
	21	Burning Fires
	22	Changing weather/rapid changes (hot to cold to hot)
	23	don't pay attention/not worried
	24	Learned about it in school or media
	25	No data to support climate change/no sig increase
	26	Mention of plate tectonics (volcanoes, earthquakes)
	27	Different climate all over the world
	28	Misc wrong science

	29	Don't know if happening/skeptical
	30	doomsday/humans all die
		Correct or incorrect science
	0	wrong science
	1	correct science
	2	mixture of correct and incorrect
	3	don't care, don't know, no mention of science
		Codes/categories to combine in stata
	1	Don't know reason (1)
	2	Not sure happening (29)
	3	Don't care (23, 2)
	4	Not happening, no data, no sig change (25,18)
	5	Impacts (increased storms, ice melt) (19,14)
	6	Misc alternative concepts (28, 30, 27, 26, 21)
	7	Human Actions (13, 16, 20)
	8	Fossil fuels, increased CO2, greenhouse effect (8,11,17)
	9	Animals (15)
	10	Natural changes/seasons, normal weather (6,10,22)
	11	Ozone depletion, sun getting closer (4,7)
	12	Littering, factories (5)
	13	Getting warmer (3)
	14	Relgious (9)
	15	Learned in school (24)
7a. How worried are you?	1	Not at all worried
	2	Not very worried
	3	Somewhat Worried
	4	Very Worried
7b. Reasoning for 7a.	1	Not worried
	2	Not a big deal; nothing bad will happen or nothing bad is happening

	3	not impacting me/Nothing to do with me; won't impact me (ie ice caps melting far away)
	4	It's natural; natural cycles, cycle of cold and hot
	5	Change in Distant Future; long time away/happening slowly
	6	Worried-animal extinction/migration; general impact nature
	7	Worried-will be hot
	8	worried-general impact on humans; will impact lifestyle; general scientists tell us to worry worried-general world ending/uninhabitable;
	9	Worried-earth will burn up, sun closer, earth overheat, all going to die
	10	pollution in air, general science alternative concept
	11	I don't care
	12	lie, myth, conspiracy
	13	Just part of our lives and humans will adapt
	14	Worried-Food production
	15	Religious
	16	If it happens it happens, just changing climate, nothing we can do about it
	17	I don't know about it
	18	Not worried--weather colder than last year
	19	not worried-weather constantly changing
	20	not worried--everything seems normal; regular temps; nothing to worry about
	21	worried-polar ice caps melting
	22	worried-causes human health issues (correct or incorrect science)
	23	Likes the warmer temperatures
	24	Increase flooding, natural disasters, droughts
	25	Global warming/cc not happening, not real
	26	Not worried--Technology will solve problem/we can stop it or fix it
	27	skeptical if happening
		collapsed worry reasoning variable for stata
	1	not worried (1)
	2	just part of lives--will adapt-tech will solve, like warmer temps (13, 16, 23, 26)
	3	Not worried nothing major happening, colder than before (2,18 20)

<table>
<tr><td></td><td>4 alternative concept to why worried (9,10, 22)
5 cc not happening, myth, skeptical (11, 12, 25, 27)
6 confusion weather vs climate, natural fluctuations (4, 19)
7 Don't know, don't care (11,17,
8 worried--impact humans (7,8, 14,)
9 worried impact environment (6, 21, 24
10 not impacting me, distant future (3, 5
11 religious (15)</td></tr>
<tr><td>8. Causes of global warming</td><td>1 GWNot Happening
2 Natural Changes
3 Combo
4 Human activities
5 Don't know/alternative idea
Compare to Yale Study results



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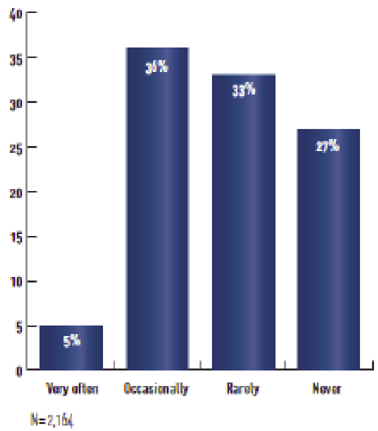
9a. How often do you discuss with friends and family?	1 Never 2 Rarely 3 Occasionally 4 Very Often Figure 31: Frequency of Discussion How often do you discuss global warming with your family and friends? 

9b. When you discuss, what do you discuss?	1	Don't talk about it
	2	Not discussed because boring/don't care
	3	Religious discussion
	4	Political discussion
	5	Getting hotter, no more snow
	6	It does not impact us, not worried about it
	7	Just hear in class and/or media
	8	Human actions to blame; humans caused it
	9	Controversy, Argument about Happening or not
	10	Climate change not happening; not real (myth)
	11	Impact--Severe storms and weather (tornadoes, drought, hurricanes, crops)
	12	General bad things happening in envt and people general causes
	13	impact animals
	14	ice melt, sea level rise
	15	joke around, don't take it seriously
	16	humans need to find solution/prevention, need to do something about it
	17	natural cycles
	18	talk about the weather, not the climate
	19	serious issue, high worry/concern
	20	need to alter lifestyle bc of it (eg move), what will happen in the future
	21	humans choose not to change behavior
	22	Humans need to reduce ghg emissions
	23	talk about it (did not elaborate what is said)
	24	alternative energies not a solution (actually worse than ff); waste of money
		discussion---general happening?
	0	combined category 1 and 2 --don't talk about it
	1	Pro CC (correct science)
	2	Not happening, natural, won't impact us

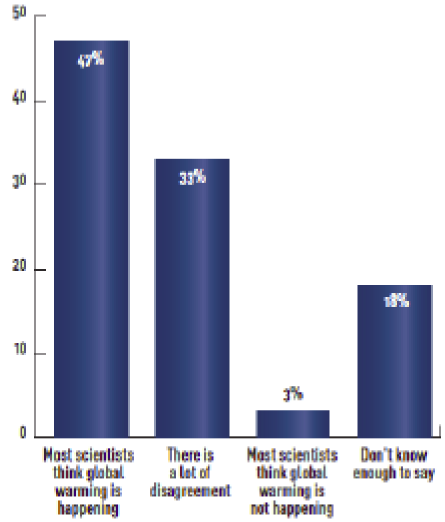
	3	confusion of weather and climate
	4	Pro CC (incorrect science)
	5	Pro CC (partial correct and incorrect)
	6	Pro happening, no science discussed
		collapsed categories for stata for discuss
	1	not discussed (1)
	2	boring, joke about it, will not impact us (2, 6, 15)
	3	discussion about solutions, changes in lifestyle (16, 20, 24)
	4	not happening, natural (10,17,
	5	discuss impacts on humans, general impacts not good (12, 19,
	6	impacts on animals, environment (5,11, 13 14
	7	weather discussed not climate (18)
	8	only hear about in class (7)
	9	blame (8, 21, 22)
	10	religious, political discussions (3,4)
	11	argument if happening (9)
	12	discuss don't know what is said (23)
10a. Do you think CC is happening?	1	No
	2	Don't Know
	3	Yes
	Compare responses to 6a	
10b. Reasoning for 10a	1	Don't Know reason
	2	Don't Care
	3	Getting warmer (less snow)
	4	Sun getting closer, Earth's tilt, axis
	5	Pollution/Littering/General Discussion of Factories, toxins
	6	Seasons Changing
	7	Ozone Depletion/increased UV rays
	8	Greenhouse Effect
	9	Religious, govt conspiracy

	10 Natural Changes, cycles 11 Carbon Dioxide increases/increased greenhouse gases 12 Getting colder 13 Human Activity/Increase Technology Use, humans not changing behaviors 14 Ice Melting/increasing sea level 15 Animals dying or migrating/plants dying 16 Cutting down trees 17 Fossil fuel use 18 It's not happening 19 Floods, droughts, and other natural disasters, changing crop cycles 20 Increased Population 21 Burning Fires 22 Changing weather/rapid changes (hot to cold to hot), changing all the time 23 don't pay attention/not worried/haven't learned about it yet 24 Learned about it in school or media, evidence and/or data presented by scientist 25 No data to support climate change/no sig increase/when it happens it happens 26 Mention of plate tectonics (volcanoes, earthquakes) 27 Different climate all over the world 28 Misc wrong science 29 Don't know if happening/skeptical 30 doomsday/humans all die 31 General yes happening 32 weather not changing; all the same, pretty normal, nothing drastic happening or happening too slowly to notice 33 Timing of seasons changing; other generally correct pieces of evidence
11. What do scientists think is happening with GW?	**Science attitude** 1 Most scientists think global warming is not happening 2 There is a lot of disagreement 3 Don't know enough to say 4 Most scientists think happening **Compare to Yale Study results**

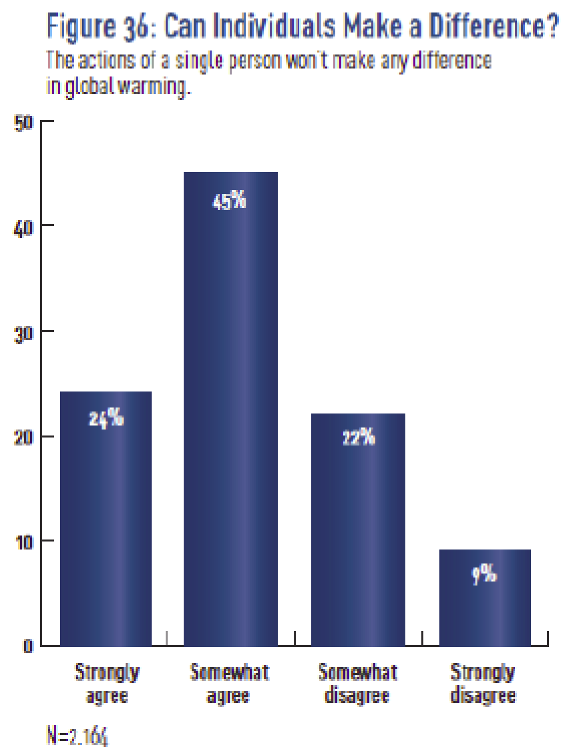
Figure 19:
Perceptions of Scientific Consensus

Which comes closer to your own view?
(the first and second responses were randomized)

- Most scientists think global warming is happening
- Most scientists think global warming is not happening
- There is a lot of disagreement among scientists about whether or not global warming is happening
- Don't know enough to say



N=2,164

12a. Actions of individual can make impact	1 Strongly Agree 2 Somewhat Agree 3 Somewhat Disagree 4 Strongly Disagree **Not directly comparable** 

12b. Name 2 actions	1	Recycle
	2	Drive less/carpool/take bus
	3	Ride bike/walk (something instead of driving)
	4	Use clean energy (wind, solar, alternative energies)
	5	stop polluting
	6	Stop littering, less trash
	7	Use less energy/electricity (less heat, less AC, energy efficient bulbs, use less tech, shorter showers
	8	Turn off lights/unplug appliances
	9	Alternative transportation (electric cars, smart cars, hybrids)
	10	Less waste/consume less/Reuse
	11	Less fossil fuel use (emit less CO2), reduce greenhouse gases
	12	Use less plastic, burn less plastic
	13	Plant trees, don't cutdown trees
	14	Buy green products
	15	Don't know, have not learned about it yet
	16	General wrong answer
	17	Hold breath, no farting
	18	General take care of envt, clean things
	19	Less factories,
	20	don't care
	21	don't need to do anything, nothing going on
	22	Not use aerosols
		collapsed categories
	1	recycle (1)
	2	don't know, have not learned (15)
	3	don't care (20)
	4	Nothing going on (21)
	5	Incorrect science (16,17,22)
	6	drive less/walk and ride bike (2,3)
	7	don't pollute litter (specific incorrect sci) (5,6)

	8 Lower CO2 (9,11,4) 9 green actions (13,14,18,19) 10 less energy use (7,8, 10,12)
13. What do you think is causing CC?	**Attitudes** 1 Climate Change Not Happening 2 Natural Changes 3 Don't Know why 4 Human activities **Compare to answers in Q11**
14a. Experienced CC?	1 Strongly Disagree 2 Somewhat Disagree 3 Somewhat Agree 4 Strongly Agree **Compare to Yale Study**

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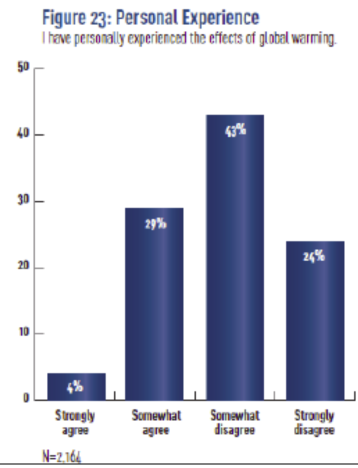

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<td>14b. Reasoning for 14a.</td>
<td>1 Not experienced it (general)
2 Experienced extreme hot or cold event
3 Weather/temp always changing
4 Saw pollution or littering
5 nothing has happened; temp feels the same (have not experienced it), no effects
6 Don't care, don't pay attention
7 Does not impact me/doesn't effect me
8 On average warmer; getting hotter, less snow
9 Severe weather event/condition (flood, drought, storms)
10 get sick (even if alternative concept)
11 not experiencing b/c getting colder/not hot
12 impacting animals</td>
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</table>

	13	happening so slowly
	14	happening in other regions, not in my geography, happening somewhere
	15	general--impact is not good
	16	just get attention to scare people
	17	don't know; don't know what impacts would be, don't know how you would experience it
	18	getting colder (on average)
	19	not hapenning/can't do anything about it
	20	rising sea levels, melting ice
	21	natural , seasons always changing
	0	not experienced; don't know; don't care
	1	actual potential impact of climate change
	2	not a predicted impact of cliamte change
		collapsed variable for stata how experienced
	1	general does not experience it (1)
	2	not impacting me (slowly, other regions, not big change) (5,7,13, 14)
	3	Correct science (melting, average hotter (8,9,12,18, 20)
	4	natural, not happening, just to scare (11, 16, 19, 21)
	5	confusion weather vs climate (2,3)

	6	Don’t care and alternative concepts (4,6,10)
	7	Don't know what it would like like (17)
15. New technology can solve climate change?	1	Strongly Disagree
	2	Somewhat Disagree
	3	Somewhat Agree
	4	Strongly Agree
16. Humans can reduce CC?	1	Climate Change Not Happening
	2	Cant reduce it
	3	won't change behavior
	4	unclear if can reduce it
	5	reduce successfully
17. I do well on tests?	1	Strongly Disagree
	2	Disagree
	3	Agree
	4	Strongly Agree
18. I do well in science?	1	Strongly Disagree
	2	Disagree
	3	Agree
	4	Strongly Agree
19. Figure out problems on science homework?	1	Strongly Agree
	2	Somewhat Agree
	3	Somewhat Disagree
	4	Strongly Disagree
20. I do well on projects?	1	Strongly Disagree
	2	Somewhat Disagree
	3	Somewhat Agree
	4	Strongly Agree

Example Responses from Post Survey on Open-Ended Questions

When you discuss climate change with your family and friends, what is said about climate change?	
Category of Response	**Sample Student Responses**
Don't discuss it	"Only in class NEVER with family or friends its a boring subject and in class it very little time spent on it" (Male, Circle, 7th grade). "We never say "Oh I should stop using carbon dioxide." I don't think anybody says that and we just want to care about something else than the environment and plus we hear enough of that environment from Obama" (Female, Circle, 7th grade).
Climate change is happening—correct science discussed	"The greenhouse effect, the melting ice caps, and animals" (Male, South Kernel, 8th grade). "If we do talk about climate change, it is mostly about alternative energy or severe storms and weather" (Female, Circle, 7th grade). "How 1 C can change the world in so many different ways" (Male, Circle, 7th grade). "When I talk about climate change with my family or friends, we talk about how the Earth is getting warmer and the temperature is rising" (Female, Village, 6th grade).
Climate change is happening—incorrect science discussed	"When climate change is dicussed in my family, we think that it is caused by natural resources on the earth. Recycling can produce heat on the earth which could be make climate change happen along with other resources on the earth" (Female, Village, 6th grade). "the world might go into the ocean" (Female, Main St, 6th grade). "just about the liter and trash" (Female, Circle,7th grade).
Climate change is happening—mixture of correct and incorrect science discussed	"Me and my family, friends, etc. don't talk about climate change that much but when we do, it is about human activities. We all believe that humans have caused the climate changes. We talk about how our factories and transportation vehicles are putting out so much pollution" (Male, Circle, 7th grade). "like how we should make people stop smoking & like stop all the awful gases that are put in the air" (Female, Circle, 7th grade).
Climate change is happening—No science discussed	"It's away to say that it's almost time for the world to end" (Female, Circle, 7th grade). "ho awful it is and how we can never stop it" (Female, Circle, 7th grade). "i do it b/c i want them to be aware of it happening" (Male, Circle, 7th grade). "about how bad its getting and about the money invold" (Male, King St 7th grade).
Climate change not happening--Natural	"That the government is just telling us that" (Male, Circle, 7th grade). "That it is natural but is also being boosted by our fires we reuse" (Male, South Kernel, 8th grade). "That it is a huge waste amount of money and attention that could be used towards something better" (Male, South Kernel, 8th grade). "Most of my family think that global warming is a bunch of bologna" (Male, Circle, 7th grade). "I will speak about it if we have in class or if I have been thinking about it but i hardly comes up in conversations. All that is said is what my family thinks but they don't believe in climate change or global warming" (Female, Circle, 7th grade).
Confusion between weather and climate	"Just how hot or how cold it's gonna be that day" (Male, North Central, 8th grade). "Uhhh. How it will be sunny and hot than about 2 minutes later cold, windy, rainy" (Female, South Kernel 8th grade).

	“We barley do,but when it probably about how quickly the weather changes” (Female, Main St, 8th grade). “We rarely talk about climate change with my family, but when we do its always just how the weather was today and how it was 3 days ago” (Female, Circle, 7th grade).
Other	“When I rarely discuss climate change with my family, we think about things that people claim are friendly to the environment. We think about the electric car and where the electricity comes from, how the car was made and where it will go when it breaks down for good” (Male, Village, 6th grade). “i beleive that our world will end by the sun will get to close to the earth and we will all die and the earth will be reborn with all the good people and try to keep out all the bad people” (Female, Circle, 7th grade). “I hardly ever discuss climate change with friends or family. What is said about climate change is stuff like "The new biofuel is more expensive than normal gasoline." Or, "The spiral lightbulbs are slightly cheaper and are more energy efficient”” (Female, Circle, 7th grade). “We never talk about global warming... if something is said, it is always said as a joke” (Male, King St, 7th grade).

If you have experienced the effects of global warming. describe how you have experienced them. Otherwise, if you have not experienced the effects of global warming, explain why you feel this way.	
Category of Response	**Example student responses**
Not experiencing the impacts	“why i dont think that i have experinced global warming is because my parents have never said anything about global warming to where i would know about it” (Female, King St, 7th grade) “I have never felt the effects of global warming. I feel this way because I havent felt a huge temperature change or less heat in the environment” (Male, Circle, 7th grade). “the reason i say i have not experienced global warming is beacuse it hasent gotten hotter” (Female, Circle, 7th grade).
Not impacting me—happening too slowly or happening in other regions	“See you can't feel global warming, you can see the change happening but it doesn't make me feel different.If you go visit the arctic you can see the change,if your asking how would I see the change well you would see glaciers melting away” (Male, Circle, 7th grade). “I don't live in the arctic so I have never experienced global warming” (Male, Circle, 7th grade). “I have not really personally experienced the effects of global warming, it may be because I am not paying to much attention to climate change or it isnt effecting my area or daily activities” (Female, Circle, 7th grade).
Feeling the heat and/or seeing the melting ice, more severe storms, earlier spring, less snow	“I have somewhat experienced the effects of global warming because over the years the temperatures risen and could feel a difference in the winter and summer” (Female, Village, 6th grade) “I've lived in the Cincinnati area all of my life. When I was younger and a kid (mid 2000's) I recall the temperature on average get up to only 85 degrees Fahrenheit. Now, the temperature's can generally be 88, 89, and the humidity is A LOT higher then it was back then” (Male, Circle, 7th grade). “I play baseball for a team in kenton county kentucky and in the past couple years we have been able to start outside practice much quicker because of the fact there is not much snaw and if there is it melts fairly quick” (Male, South Kernel, 8th grade). “It has gotten warmer in the summer flowers bloom earlier and the birds fly south later” (Female, King St, 7th grade) “One way i've experinced them is because there has been more hurricanes because if the temperutare get hotter the

	oceans get hotter and creat hurricanes. Another reason is that there has been more snowstorms" (Male, Village, 6th grade).
Not happening/just a scare tactic/getting colder	"i feel this way because its useless global warming is fake" (Male, Circle, 7th grade). "Nothing has happened to prove that it is happening" (Male, KY rural, 8th grade). "I feel that i have never experienced Global Warming, because it's not real" (Female, Circle, 7th grade) "ther is no gloal warming so i dont feel its effects" (Male, Circle, 7th grade). "The temperature has been the same. We had 6 months of winter this year and we usually have 4 months the temperature is not increasing" (Female, Main St, 8th grade)
Confusion weather vs. climate, seasons	"I have had a day when the temperature was 105 degrees F" (Male, Village, 6th grade) "in Ky. weve been ex[eincing weird weather, as in it'll be hot one day, then frezzing the next" (Female, Circle, 7th grade). I know that the weather is getting warmer but around i do not think anything is happening. We still have all 4 seasons" (Male, Circle, 7th grade). "Because I don't see the difference in the weather changing. I mean it just has been acting up" (Female, South Kernel, 8th grade).
Don't know what it would be like to experience GW	"Because I really dont know what it would feel like and I dont know if it is happening in Kentucky" (Female, South Kernel, 7th grade). "i feel that i have not experinced climate change before because i never know when its happening" (Female, Circle, 7th grade) "I have not experienced global warming iand I feel this way because i do not know how you can experience clobal warming" (Female, Village, 6th grade). "I don't know how it feel or what I should feel" (Female, Main St, 8th grade).
General—impact felt is not good	"I feel that i somewhat have because of the hurricane in november....that is not normal...we got the after rain/storm, but other than that i dont feel anything different has happened" (Female, Circle, 7th grade)/ "i feel that climate change is not that good because they have to find out what's going to happen" (Female, North Central, 8th grade).

	Post-survey-Explain why you think climate change is happening or not happening?
Don't know reason(s) for climate change	I really don't know. I don"t discuss climate change with my family or friends" (Female, Circle, 7th grade) . "I don't know, because I don't really pay attention to the news" (Female, South Kernel, 6th grade).
Not sure if climate change is happening	"At the moment it doesn't seem that climate change is happening so my answer is not sure" (Female, Main St, 8th grade). "I don't know if climate change is happening because climate always changes, like weather or temperature. So I'm not sure if global warming in happening"(Female, Circle, 7th grade). People all over the world are arguing rather its happening or not. So I don't know if its happening or not" (Female, South Kernel , 8th grade) I don't know because there is evidence to support both theroys but I don't want to say one way or the other because I want to study it more" (Female, South Kernel, 8th grade). i dont know because most days it has been the normal weather for this time of year...yes, there was a few times were the weather patterns were a bit off, but that happens sometimes. It has been happening since the earth was created" (Female, Circle, 7th grade).
Don't care	I don't care about climate change Therefore I dont know about it" (Male, South Kernel 8th grade).

about the topic	I don't know...whatever happens happens" (Female, South Kernel, 8th grade).
Not happening, no data to support climate change, getting colder	"I dont think it is happening since It seems to be the same temperature or colder than normal" (Male, South Kernel, 8th grade) "Global warming is not happening because its just a myth" (Male, South Kernel, 8th grade). "I don't think it is happening becuase there isn't any discussion about it. It has been proven that it isn't happening" (Male, King St, 7th grade). "I havent seen any difference in the years ive been alive" (Male, King St. 7th grade). "I do not think it is happening because the person that brought Global Warming up admitted that it he was lying just to get people to think about it. It has also been proven that Global warming is not happening besides right now the temperature is 30 degrees lower than average for this time of year" (Male, King St, 7th grade). "i think its another fad to make us buy new products too "help the environment" when its worse for it" (Male, Circle, 7th grade). "I think Global Warming is not happening because the world goes through warm streaks and cold streaks in a pattern. We are in a warm streak" (Male, Circle, 7th grade). "I say it is not happening. For example Arkansas lost over half it's crops due to frost. The temperature has not increased. Every year my aunt loses her plants due to frost. In my opinion the earths climate has not warmed" (Female, Main St, 8th grade)
Impacts (increase in severe storms, droughts, ice melting)	I think it is happening because our world is eating up and there are starting to be more storms as a result of the heat"(Male, North Central, 8th grade). "I think that that it is hapining because placed that were cold are warming up more and more. The glaciers are melting and animals like the polar bears are losing there home" (Male, Circle, 7th grade). "One reason is that ice caps are melting. The second reason is sea level is rising" (Female, Circle, 7th grade)..
Messy middle concepts (e.g., atmosphere burning up, earth's rotation)	"Because of the earths rotation" (Male, South Kernel, 8h grade) It is happening because of fosil fuils from cars and everything else because they are burning up the atmispher" (Male, South Kernel, 8th grade) california and all those other countries and states are getting hurricane, earthquake, and tornado" (Male, King St, 7th grade).
Human actions (e.g., increased technology us, cutting down trees, increased population)	"i think it is happening because people keap cutting down trees and don't know how to stop so it keeps getting hotter and hotter and people really don't care" (Male, King St, 7th grade). "I think that climate change is happening, humans have increased in activites that raise temperature. "We use way more electricity, driving cars, and burn a large amount of fossil fuels" (Female, Circle, 7th grade). "Climate change is happening because of human activity. Humans have new technology and it has caused pollution and the release of carbon dioxide into the atmosphere combining with other greenhouse gases to cause an increase in the global temperature" (Female, Circle, 7th grade).
Increases in—fossil fuel use, CO_2 emissions, and/or greenhouse effect	"I think global warming is happening because of the increasing use of fossil fuels. When breaking down fossil fuels, there are greenhouse gases being released, which causes them to go into the atmosphere" (Female, Main St, 8th Grade). "Climate change is most likely happening because there are more greenhouse gases in the atmosphere, and the greenhouse gases sometimes catch the infrared photons and the photons are bounced back to the Earth, and it may escape, but it might get caught" (Female, Village, 6th grade) "The carbon output around the world is too high for the carbon sinks to absorb" (Male. King St 7th grade).
Animals will be negatively impacted	"we can see climate change with in the polar ice caps, wich are slowly melting. we can also see decraeses in wildlife with in certain regions due to climate change" (Male, Circle, 7th grade). "Climate change is happening because the polar bears, ice caps are melting and is killing the polar bears" (Female, South Kernel8th grade)

	"Clamate change is happening because some of the animals are moving from where they live normally for this time andnot staying in there normal spots" (Female, King St, 7th grade).
Natural changes and/or normal seasonal and weather changes	"I think it is but it's not being caused by global warming. But I think the earth heats up and cools off every so often" (Male South Kernel, 8th grade). I believe that our planet just goes through cycles on its own to be honest. I truly think that it is all just people over reacting on something that might be nothing" (Male, South Kernel, 8th grade) It is happening because it will be in the middle of winter in 20 degree weather and the next day be 60 degrees
Ozone depletion and/or sun getting closer	"It is happening because the greenhouse gases are puting holes in the ozone layer" (Male, Village, 6th grade) "All the pollution is tinning out the earths ozone and causing more direct sunlight. because of the greenhouse gases it is causing the earth to warm up" (Female, Circle, 7th grade). "The ozone is beginning to dissolve because of pollution so everything is heating up. Besides, scientists have proof of it" (Female, South Kernel, 8th grade).
General pollution (e.g., Littering, factories)	"Yes, I do think that global warming is and has been happening. The reason i think that global warming is happening is because of all of the many different types of pollution being created and put into our atmosphere. Some of the things i think that is causing this is Power plants, cars, Factories, Machines, Transportation, ETC. Another reason i think that global warming is happening is that overall the climate in the world has decreased over the years and continues to decrease. Our Climate in Kentucky has dramatically changed" (Female, Circle, 7th grade). "I think it is happening because of littering on the earth. Also because of dirtying of the water" (Female, South Kernel, 8th grade)
Getting warmer	"because its getting hotter every year and proxy data can tell us" (Male, North Central, 8th grade). Yes, because if you look at all the attention its has been getting you can see that the temperature has gone up. Over the years the temperature has gone up 1-2 degrees" (Female, Circle, 7th grade). "The summers are getting hotter and winter is getting warmer as well and artica melted ice" (Female, South Kernel, 8th grade) "Because the winters have had less snow and have had warmer days. And the summers are very hot. And so I think that the temperature is getting warmer on earth. So I believe global warming is happening" (Male, Circle, 7th grade).
Learned in school	"In science we have been learning about it and if you pay attention to the news then they talk about how its getting hotter and hotter" (Female, Circle, 7th grade). "I do think that climate change is happening because the carbon dioxide is increasing and the average weather for each season is changing. I no this from doing lessons and activities during science class" (Female, Circle, 7th grade). .

	Post survey responses—Why are you worried or not worried about climate change?
Not worried	"Not very worried- Because some things can adapt but some things can't and they will die" (Female, South Kernel 8th grade) "I am not worried about climate change because if our world heats up then, since the world is warm, none of our plants or animals will die from the cold" (Female, King St, 7th grade) "Not very worried--Because I have air conditioning" (Male, South Kernel, 8th grade) "Not worried--beacuse i have clearly lived 13 years with it" (Female, Circle, 7th grade).
Just part of our lives, will adapt or tech will solve problems	"I am not very worried because of the fact that human beings can change if need be" (Male, Circle, 7th grade). "I am not very worried. We are already doing things to help decrease fossil fuels like driving Eco-friendly cars or factories using clean energy" "(Female, Circle, 7th grade). "I'm no to worried because I think scientist will find a way to stop it" (Male, King St, 7th grade). "I ain't worried because I can adapt to pretty much any kind of climate" (Male, South Kernel, 8th grade). "Well the reason that im not that worried is that we could use less resources we could save the planted.If the planted is saved then we can live

	here for a long time" (Male, Circle, 7th grade).
Not worried because nothing major happening	"Im not worried because its not a big deal" (Male, King St, 7th grade). "I'm not because the earth Has been the same temperature. Every once in a while it's hotter than the other year. Or it's colder. That's been happening for millions of years" (Female, Main St, 8th grade) "Untill it gets realy bad i will not worry about it" (Male, North Central, 8th grade) "I'm not very worried about global warming because I can't see it happening" (Female, Circle, 7th grade).
Messy middle concepts (doomsday, earth will burn up, too cold, sun getting closer)	"I'm worried because we might go through the very cold time and we might not survive" (Female, North Central, 8th grade). "I am worried because this mean that the earths crust could be getting thinner and that means the earth could overheat" (Male, Main St, 8th grade). "because the world will end by the global warming that is what i believe" (Female, Circle, 7th grade). "I am worried about climate change becaus if the earth gets to warm it will be like an other Mars; hot and dry.We have to keep the earth healthy becaus there isn't an other earth" (Female, Circle, 7th grade). "because i dont want to be fried from the sun" (Male, Circle, 7th grade). "Unhealthy air is obviously dangerous, and I'm going to be one affected by due to the fact that I'm still considerably young. In 70 years I'm expecting I, my peers, and young relatives to still be alive (unless killed due to an accident, murder, or suicide) and low amounts of Oxygen means we would probably have to buy Oxygen Tanks to live. It also harms our plants, and water, which would cause a fight for essential resources" (Male, Circle, 7th grade). "I am worried because climate change can be an apocolyptic situation" (Female, South Kernel, 8th grade) "i might die and and my kids might also. i dont whant to have my childeren grow up having to breath bad air" (Male, King St, 7th grade) "Because if climate change is happening then more animals are going to have to move and some are not fast enough so they could die. It might get too hot so we could burn and die" (Male, Village, 6th grade)
Climate change not happening	"becase climete cange is not happening at all" (Male, Circle, 7th grade). "its most likely fake" (Male, Circle, 7th grade). "its not proven to be the reason of the earth changing" (Male, North Central, 8th grade)
Confusion weather vs. climate, natural fluctuations	"I am not because I believe that the weather and temperature are just having a slight swing right now, but it will soon go back to normal like it usually does. And even if I did believe that global warming, the temperature would increase to slowly to effect anyone in my lifetime" (Male, Circle, 7th grade). "there are lots of changes and patterns in the weather" (Female, Circle, 7th grade).. "it's always hot or cold so thats fine by me" (Female, South Kernel, 8th grade) "I am not worryed. Because I believe that the world is natural releasing heat and can stand a very large amount of heat" (Male, South Kernel, 8th grade).
Don't care	"im not worried because i don't really care about it" (Male, King St 7th grade). "I'm not worried because I don't care about the climate change" (Male, South Kernel 8th grade). "I don't really care about climate change and if something does happen it will be a while from now or after my lifetime" (Male, Circle, 7th grade) "I'm going to be honest. I'm not into this and I'm not worried one bit that is someone elses job" (Female, Circle, 7th grade).
Worried will impact humans	"I am worried about climate change because I dont like hot weather and if it is hot i cant ski. i am also worried that some crops wont be able to grow in a warmer climate so we wont have a larger vsriety of food" (Male, Circle, 7th grade). "I'm worried because when I am older all of our resources maybe scarce" (Male, Circle, 7th grade). "I am worried about climate change because in the future, the world may be so different that humans might have a hard time living" (Female,

	Circle, 7th grade). "I'm somewhat worried about climate change because the world we know today may not be in the future" (Female, South Kernel, 8th grade) "Climate change is somewhat important because it effects are lifestyle and conditions that we can live in" (Female, Main St, 8th grade) "I am worried about climate change because I don't know the effects. I know that if people don't start changing their ways, things are going to get bad fast" (Female, South Kernel, 8th grade) "I am slightly worried because so many people don't seem to care when we are just using up the Earth and it may one day, not support us and the habitats" (Male, North Central, 8th grade)
Worried will impact environment and animals	"I like warm weather. Dont really like cold weather. So if the earth were to get warmer, I would be ok with that. But I am concerned for some animals that need the colder areas to survive. So the areas would get warmer and cause animals that live in the cold areas to relocate and move north to colder spots." (Male, Circle, 7th grade). "I'm somewhat worried about climate change because climate change can effect everything we do, and also effect other living organisms such as polar bears, because the ice caps are melting" Female, Circle, 7th grade). "I am worried because a big climate change might cause a horrific natural disaster" (Female, Main St, 8th grade). "I am worried about climate change because it can affect so many animals and people too. I think that many animals will become extinct in future years because of climate change warming and cooling certain parts of the earth. I think that it will cool and heat certain parts of the earth too fast, causing animals to die from the heat or cold coming into their homes" (Female, Village, 6th grade) "I am a little worried about the climate because of the plants and animals going extinct. (some of those plants could cure cancer)" (Female, Circle, 7th grade)
Not impacting me/ will happen in distant future	"if anything happens it wont happen in my lifetime so im not too worried about what will happen"(Female, Circle, 7th grade). "I'm not very worried because it isn't affecting me right know" (Male, Circle, 7th grade). "I'm not very worried because it is not affecting me" (Male, South Kernel, 8th grade) "i will be dead by the time any thing bad happens" (Male, North Central, 8th grade). "Because that wouldn't happen for millions of years" (Female, Circle, 7th grade). "Since it seems to be happening so slow that it wont really affect my life" (Male, South Kernel, 8th grade). "Bye the time it really effects earth I wont be aliove anyways" (Female, North Cenrtral, 8th grade).
igious	"God said the Earth would never flood again" (Male, KY rural, 8th grade) "I am not worried because I don't believe in in Global Warming besides if the world wants the world to end he will make it end" (Male, King St, 7th grade).

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