ADDRESSING CLIMATE CHANGE THROUGH BIOLOGY CONCEPTS: INSIGHTS FOR EDUCATORS

By

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IPCC	Intergovernmental Panel on Climate Change
SQ 1	Science Quest week one
SQ 2	Science Quest week two
SSTP	Student Science Training Program

Abstract of Thesis Presented to the Graduate School
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Climate change is recognized by a majority of climate scientists as a critical issue that will impact natural and human environments. It is important for students to learn about climate change so they are able to make decisions about this issue. While both students and teachers are interested in addressing climate change in the science classroom, several strategies for doing so raise interesting questions. Although climate change is already part of earth science standards, using this issue to enhance biology standards could enable more students to learn about climate. However, preconceptions and attitudes students bring into the classroom could be a barrier to learning if students do not believe climate change has anthropogenic causes. This research endeavored to understand how students perceive a carbon cycle and sequestration lesson that is integrated with climate change concepts and explore the factors associated with students' attitudes toward climate change.

We experimentally tested two activities with high school sophomores. The group receiving the treatment integrating carbon concepts and climate change showed a significant increase in knowledge of carbon concepts ($p=0.0102$); the group that received these concepts separately did not ($p=0.5430$). Interviews with students support

our conclusion that integrating these concepts can increase student knowledge about carbon concepts and interest. In two of three groups of students, perception of parents' climate change attitudes were significantly associated with student attitudes (0.6081, 0.5881), while prior knowledge, religiousity, and political preference were not.

CHAPTER 1
OVERVIEW

The Intergovernmental Panel on Climate Change (IPCC) recently concluded that evidence for global warming over the last half century is unequivocal and unusual given the pattern of the previous 1,300 years (IPCC, 2007). In addition, the IPCC established that there are both human and natural drivers of observed global climate change and that the global climate is projected to continue to change. Observations indicate that these changes to the climate system are currently impacting both natural and human environments and models are increasing knowledge about the nature of future impacts (IPCC, 2007). These future impacts include changes to freshwater resources, marine, coastal, and terrestrial ecosystems, food and forest products, industry and communities, and human health. These impacts will be seen around the world, on every continent (IPCC, 2007). Mitigation techniques can help to delay, avoid, or reduce these impacts. Additionally, adaptation will be necessary to decrease vulnerability to future climate change which is unavoidable based on emissions already in the atmosphere (IPCC, 2007). In order to face this pressing environmental problem a knowledgeable citizenry is necessary to make decisions about mitigation and adaptation strategies.

Public Attitude toward Climate Change

Despite the consensus among the scientific community about climate change, the U.S. public is still divided on the issue. In 2008, 2010, 2011, and 2012 the Yale Project on Climate Change and the Center for Climate Change Communication at George Mason University surveyed U.S. adults to assess their attitudes about climate change (Leiserowitz, Maibach, Roser-Renouf, Feinberg, & Howe, 2012). The results of the project grouped people into six categories: alarmed, concerned, cautious,

disengaged, doubtful, and dismissive. The people in the alarmed category are convinced climate change is happening and that humans are one of the causes; they are very concerned and perceive it as an urgent threat. They also have already started to make changes in their lives due to climate change. At the other end of the spectrum are people in the dismissive category; they are also actively engaged in the topic of climate change but they are convinced that it is not happening, it is not a threat, and that there should be no national response (Leiserowitz, Maibach, & Roser-Renouf, 2009). In 2008 18 percent of Americans were in the alarmed category but by 2012 that number had dropped to 13 percent; the number of Americans in the dismissive category grew from 7 percent in 2008 to 10 percent in 2012 (Leiserowitz et al., 2009; Leiserowitz et al., 2012). Slight changes in public perception have been noted with each national survey.

Communication Challenges for Climate Change

In addition to the challenges posed by the diversity of attitudes about climate change, there are several characteristics of climate change which make it a difficult subject to communicate. Many of the causes and impacts of climate change are invisible; people cannot see the greenhouse gases that are emitted during their actions (Moser, 2010). The impacts are also often temporally and geographically distant from the people causing them. The ecosystem changes due to climate change lack immediacy and are often detected in places where people do not live such as the Arctic, high elevations, and coral reefs (Moser, 2010). Short term natural variations and cycles in the climate system can complicate long-term data trends. Climate changes due to natural phenomenon are challenging to discern from anthropogenic changes and models are not easy to communicate (Moser, 2010).

Due to the complexity there are many models of climate change and uncertainty among scientists over the intensity of the impacts; this uncertainty is sometimes misinterpreted by the public as a question of whether the climate is changing or what is causing it. The fossil fuel industry and other conservative forces have effectively used the media to foster an atmosphere of doubt and disbelief by creating messages of inadequate scientific understanding, lack of scientific consensus, and alternative explanations for climate change evidence (Moser, 2010). People also have less personal evidence of subtle environmental changes because they spend more time indoors and less time interacting with nature (Moser, 2010).

Because changes in the levels of greenhouse gases are the result of cumulative action, some people may feel that they cannot impact the climate negatively or positively. When people do take steps to mitigate climate change they will likely not be able to attribute any change to their action. Some people are skeptical that society can or is willing to take steps to mitigate climate change (Moser, 2010). The complexity of the issue makes it unrealistic to expect people to have a full understanding of the issue but exactly what people need to understand to make informed decisions is not clear (Moser, 2010).

Climate Change Education

Youth need to be better prepared to become members of a knowledgeable citizenry that will face challenges imposed by climate change. This means that education on climate change in high school is important. Climate change is generally covered in the earth and environmental science classrooms (Monroe, Oxarart, & Plate, in press; Wise, 2010). However, opportunities exist for climate change to move beyond the earth science classroom (Fortner, 2001) and into biology classrooms since the

impacts will significantly affect ecosystems (IPCC, 2007). One way to incorporate it into other classes would be to infuse it with the concepts already covered in those classes, as a real world example to increase student interest (Bennett, Lubben, & Hogarth, 2007). For example, the carbon cycle could serve as a way to connect climate change to the biology classroom. If high school students mirror the diverse opinions found in the adult population, however, it could be a challenge to educate some students about climate change due to the connection between attitudes and learning (Robinson, 2011).

Need for Research

Although the serious nature of climate change points to a clear need for education on the subject, the complex nature of climate change and climate change communication makes this difficult. This suggests a rich arena for research on how to effectively incorporate climate change into the biology curriculum. The next chapter describes a study that investigated a strategy for incorporating climate change into biology concepts at the high school level. It examined if teaching about carbon and climate change in an integrated manner increased student knowledge about carbon and interest in the lesson. In addition, since student attitudes may play a significant role in impacting student learning this study explored different factors that may be associated with student attitude toward climate change.

CHAPTER 2
INTEGRATING CLIMATE CHANGE WITH BIOLOGY CONCEPTS

Introduction

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) concluded that global warming is unequivocal and due to human and natural causes (IPCC, 2007). According to the IPCC the effects of climate change are already being observed and these changes will continue to impact natural and human environments (IPCC, 2007). Because the issue and potential consequences raise important questions in many areas of policy and commerce for the foreseeable future, high school students should learn about climate change so they can become knowledgeable citizens who are able to make informed decisions about mitigation and adaptation activities.

Despite the interest among U.S. high school students for climate change education, they have a limited knowledge of climate change (Leiserowitz, Smith, & Marlon, 2011; Shepardson, Niyogi, Choi, & Charusombat, 2009; Wise, 2010). High school science teachers need to be able to incorporate climate change into the curriculum despite the controversy created by the diversity of opinions on the issue and the challenge of misconceptions that students bring to the classroom. Since, as in adults, these diverse opinions may be related to outside influences, such as politics and religion, providing a successful climate change lesson may be dependent on better understanding the influence these outside forces can have on student attitude. Understanding how best to incorporate climate change into the biology curriculum given the challenges of this controversial topic is an important area for research.

This study aimed to further the research on effectively incorporating climate change into biology concepts given the diversity of attitudes that students may hold. It measured whether connecting traditional biological science lessons to climate change impacted student knowledge gain and interest in the activities. It also explored the influence of different factors outside the classroom on students' attitude toward climate change.

Literature Review

Although global climate change is a critical environmental issue, high school students in the United States lack a basic knowledge of the subject. A national study of 517 youth ages 13 to 17 assessed the following four dimensions:

- "Knowledge of how the climate system works
- Specific knowledge about the causes, consequences, and potential solution to global warming
- Contextual knowledge placing human-caused global warming in historical and geographic perspective
- Practical knowledge that enables individual and collective action" (Leiserowitz et al., 2011).

Unfortunately, only 25 percent of respondents would have received a passing grade (Leiserowitz et al., 2011).

Students' knowledge gaps or misconceptions often are the result of over-generalizing, such as believing all types of air pollution cause climate change (Shepardson et al., 2009; Wise, 2010) or confusing different environmental problems, such as believing that the hole in the ozone layer is the primary cause of climate change (Leiserowitz et al., 2011; Porter, Weaver, & Raptis, 2012; Shepardson, Niyogi, Choi, & Charusombat, 2011; Shepardson, Niyogi, Roychudhury, & Hirsch, 2012). A poor

understanding of greenhouse gases and the greenhouse effect and failing to differentiate between climate and weather also contribute to their reported lack of knowledge (Porter et al., 2012; Shepardson et al., 2011; Shepardson et al., 2012; Wise, 2010). While students may understand basic concepts, such as the carbon cycle, they are less likely to be able to explain how humans impact the carbon cycle (Shepardson et al., 2012), how climate change impacts humans (Shepardson et al., 2009; Shepardson et al., 2012), or differential regional impacts (Porter et al., 2012; Shepardson et al., 2009; Wise, 2012).

As a result of these basic and fundamental problems in understanding climate and climate change, high school students are unprepared to address the issue (Leiserowitz et al., 2011). To better prepare these youth to take on these future challenges, high school biology classes should include the causes and impacts of climate change. Despite the requirements that earth and environmental science courses cover climate change, most students are not well informed on this issue (Leiserowitz et al., 2011).

The same national study of teen knowledge on climate change reported that only 27 percent of teens said that they learned ‘a lot’ about global warming in school and 70 percent said that they would like to know more (Leiserowitz et al., 2011). Climate change has been inconsistently addressed in state education standards, with only eleven states having standards that addressed the historical mechanisms, human causes, and the impacts of climate change in 2010; among those only three included climate change mitigation (Wise, 2010). The national Next Generation Science Standards of 2013, however, have incorporated anthropogenic climate change as a

core concept (NGSS Framework, 2013). As states adopt these standards teachers will be expected to include climate change in their lessons, but there are several different ways they might do so.

One strategy to include climate change in the classroom is to integrate climate into existing concepts already covered in key classes. By including information about climate change in biology courses, more students are likely to learn about climate change than if it were included in earth science courses; in 2009, 95.6 percent of high school graduates took high school biology and only 27.7 percent took earth science (Digest of Education Statistics, 2011). The carbon cycle, for example, is a required component in the biology standards and is also an important part of understanding the causes of climate change and the greenhouse effect (Shepherd, 2011). Carbon sequestration in forest ecosystems is a key strategy in mitigating climate change. These concepts could be opportunities to introduce climate change into biology classes. Understanding the causes of climate change is a predictor of intentions to take voluntary actions to reduce greenhouse gas emissions (Bord, O'Connor, & Fisher, 2000).

Attitudes could affect learning, however, and integrating a controversial topic like climate change, which has deeply divided the American public (Leiserowitz et al., 2012), with biology concepts could affect knowledge gain. On the one hand, applying basic scientific principles to real world issues can improve student interest in science (Bennett et al., 2007). At the same time, however, if students do not believe climate change has anthropogenic causes, their attitudes can be a barrier to learning (Robinson, 2011). Students' confusion about the controversy surrounding climate change can become an

obstacle to deeper learning and lead students to become disengaged with the issue. Some students adopt the viewpoint of climate skeptics based on their incomplete knowledge of the topic (Robinson, 2011). If students' attitudes about climate change are an important influence on their learning, then an exploration of several factors that could affect student attitudes could be useful.

Research has shown that students' attitudes can be influenced by their parents' attitudes in environment and politics (Eagles & Demare, 2010; Tedin, 1974). Home is where the foundation of interest and sensitivity to the environment are developed, making parents an important influence on student attitudes (Eagles & Demare, 2010). Discussing the environment at home and reading about the environment for example, have been correlated with increased ecologistic and moralistic attitudes toward the environment in students (Eagles & Demare, 2010). There is also a strong correlation between parental political attitudes and the political attitudes of their children (Tedin, 1974), suggesting parents could be an important influence on students' attitudes toward an issue like climate change. However, students often do not perceive their parents' opinions accurately so it is not the actual attitude of the parents that is the predictor of the student's attitude but rather the perceived attitude (Acock & Bengston, 1980). The correlation between student attitudes and perception of their parent attitudes increases with the importance of the issue to the parent, the frequency of the parent-student discussions about the issue, and the parent's concern if the student adopted a different attitude on the issue (Tedin, 1974). Perception of parental attitudes toward climate change could be an important factor in understanding students' attitudes about the issue.

Adults' attitudes toward climate change are correlated with their political affiliation. People who are more concerned about climate change skew strongly to the left and are more likely than national averages to be Democrats, Independents, and liberal (Leiserowitz, Maibach, & Roser-Renour, 2007). People who are not convinced that climate change is happening are skewed strongly to the right and are more likely to be Republican and conservative (Leiserowitz et al., 2007; McCright and Dunlap, 2011). In addition, willingness to change behavior to mitigate climate change is higher among Democrats than Republicans and the environment in general is viewed as more of a Democratic issue (ABC News, 2007). If youth have political preferences, these preferences might also affect their attitude toward climate change.

Religious views have also been correlated with adults' climate change attitudes. Adults who are more concerned about climate change are less religious than national averages and a majority rarely or never attends religious services (Leiserowitz et al., 2007). Adults who are not convinced climate change is happening are more likely to attend religious services weekly and be Evangelical Christians (Leiserowitz et al., 2007). Students' concern about climate change could also be impacted by their religious views. A negative correlation has been found between high school students' attitudes toward Christianity and interest in science (Fulljames, Gibson, & Francis, 1991).

A lack of public concern over climate change is often attributed to a lack of understanding. However, members of the public with the highest degree of scientific literacy and technical reasoning capacity are not the most concerned about climate change (Kahan et al., 2012). Research has also shown that while those most concerned about climate change score higher on some knowledge questions, climate change

skeptics score higher on others (Leiserowitz et al., 2011). High school students have shown higher concern for environmental issues when they feel more knowledgeable about those issues (Lyons & Breakwell, 1994). Therefore, it is unclear if students' prior knowledge about climate change impacts their attitude about climate change.

Integrating climate change into the biology classroom by connecting it to the carbon cycle and carbon sequestration is a potential strategy to allow more students to learn about climate change while increasing interest in these lessons. There is the potential that students' attitudes toward climate change could be a potential barrier, however (Robinson, 2011). Therefore, a better understanding of students' attitudes and factors associated with their attitude could be helpful to educators.

Research Questions

This study was designed to explore a strategy for teaching about climate change given the diversity of high school students' attitudes about the issue. It aimed to further understand the influence of a variety of factors on student attitudes about climate change. This study addresses the following questions:

1. Does teaching about climate change, the carbon cycle, and carbon sequestration in an integrated manner increase student interest in and knowledge about these carbon concepts?

2. To what extent are the following factors associated with student attitude about climate change?

   a) Students' perception of the parents' attitude about climate change
   b) Religiousity
   c) Prior knowledge
   d) Political preferences

Methods

Data were collected from two summer science programs, Science Quest and Student Science Training Program, for high school students organized by the University

of Florida's Center for Precollegiate Education and Training in June, 2012. The first research question on integrating the carbon cycle and carbon sequestration with climate was answered with pre and post treatment survey data that were collected during Science Quest. The second research question was answered with data on factors associated with student attitude collected in both programs. Since the study sample was composed of high-achieving students interested in science the results are not generalizable to the wider population of high school students. This small experiment could, however, be helpful in gaining insights about advanced students that could be expanded in future research. Other dimensions of the summer science programs, such as a residential experience, less familiarity with peers, University instructors, and an outdoor setting could have influenced students' readiness to learn and their interest in the activities. These limitations also restrict the study's generalizability.

Integrating Climate, Carbon Cycle and Carbon Sequestration

Participants in the Science Quest (SQ) program were rising high school sophomores in two offerings of a one-week summer science program. There is no reason that the students in the two offerings should be different. Students in each program engaged in a half-day educational experience about forest carbon. One activity focused on the carbon cycle and was adapted from Project Learning Tree's "Water Wonders" activity. The other activity focused on carbon sequestration and is a typical tree measurement activity used in forestry classes with sequestration and emissions data added for discussion. Both activities were reviewed by an advisory committee of twenty educators and also underwent expert review for accuracy. The activities were led by faculty, who have experience teaching these concepts, with support from four students and staff.

The week one group (SQ 1) learned about carbon in the context of climate change (Figure 2-1). They first took a pretest (Appendix A) on their carbon and climate change knowledge and began the lesson by becoming carbon atoms and moving through the biological portion of the carbon cycle. The geological portion of the carbon cycle was then introduced through lecture and students worked in groups to draw a complete carbon cycle. Students discussed how humans are changing the quantities in carbon pools and the impacts this could have for the climate. Students then measured the height and diameter of trees in a pine forest and determined carbon storage and sequestration rate. They calculated an average carbon emissions rate for the state and the sequestration potential of the pine forests across the state, comparing the two and discussing other land uses that sequester carbon, how this relates to climate, and what could be done to reduce atmospheric carbon. Students then took a posttest (Appendix A) on their knowledge of carbon and climate change. Group interviews (Appendix C) exploring their attitudes about the lesson concluded the session. Each interview consisted of six students and a trained facilitator. The facilitator recorded and took notes during the interviews.

The week two group (SQ 2) participated in the same activities but without the context of climate change (Figure 2-1). The pretest (Appendix B) did not contain knowledge questions on climate change. The discussion of climate change, Florida's emissions rate, and the sequestration potential of Florida's pine forests occurred after students took the posttest (Appendix B). Group interviews (Appendix C) were conducted after the discussion to explore students' attitudes about the lesson.

Survey and Interview

The knowledge assessment questions on the pretest and posttest were developed to reflect the objectives and content of the lesson. The climate change attitude questions were adapted from questions used in Roper polls from 2000 to 2010 (McCright & Dunlap 2011). The pretest and posttest were pilot tested for length and vocabulary with ten rising high school freshmen and sophomores. Based on the results of the pilot test, some vocabulary was changed. For example, the word “exponential” was removed because students were unfamiliar with the word. Two experts also reviewed the pretest and posttest for content validity.

The SQ 1 pretest and both posttests contained seven multiple-choice questions that covered carbon and climate change knowledge. The SQ 2 pretest had five questions on carbon knowledge. The pretest and posttest were closely linked with the student learning objectives. The discussion questions during the lesson were scripted and linked with the knowledge assessment questions. One member of the teaching team observed whether all pertinent information was covered and interjected if something was missed.

Student interest in the carbon activities was assessed from open-ended interviews. Students were asked if they felt that knowing the carbon cycle and carbon sequestration are important parts of climate change made the activities more or less interesting to them. Students were also asked if they preferred learning about this connection throughout the lesson or preferred the connection to be saved for the end. Group interviews during the Science Quest program were used to enable us to hear from all the students in a limited time period. One disadvantage of this format is that students may have felt pressured to provide similar answers to those who already

responded, creating more agreement than might have existed. However, individual interviews would not have been feasible and a random sample to reduce the number of interviews could have easily missed minority views.

Data Analysis

For the knowledge questions on the Science Quest pretest and posttest a value of 1 was given for a correct answer and 0 for an incorrect answer; independent and paired t-tests ($p<0.05$) were used to compare students' knowledge gain during the two treatments of Science Quest. Students' answers to the interview question about whether they were interested in the lesson were tallied. Themes arising from comments related to students' interest in climate change were determined using inductive category coding by noting each student's answer and combining answers which were similar (Thomas, 2006).

Student Attitude toward Climate Change and Possible Associated Factors

To answer the second research question the Science Quest posttest also included items about students' attitudes about climate change, perception of their parents' opinions on climate change, and demographics. In addition to the data collected from the Science Quest participants, data were also collected from students in the Student Science Training Program (SSTP). Participants were rising high school juniors and seniors in a seven-week residential summer science research program. All of the students took a pretest (Appendix E) which assessed their climate change knowledge, attitudes and their perception of their parents' attitude, listened to a lecture about climate change and reasons people hold different opinions about it, participated in homework, and took a posttest (Appendix E) which measured their climate change knowledge and attitude.

The SSTP pretest contained 20 multiple choice questions measuring climate change knowledge, student attitude toward climate change, student perception of parents' attitudes about climate change, and parent political views and education level. The SSTP posttest had 22 multiple choice questions and 2 open-ended questions. These questions measured climate change knowledge, student attitude about climate change, demographic questions, and their attitude toward the lecture.

All three programs covered a substantial amount of information and were limited by time. Therefore, we developed a short survey to collect data. A longer survey may have more accurately measured students' attitudes and enabled the results to show more significant differences.

Data Analysis

Students' attitudes toward climate change were determined by combining answers from four questions and creating a new variable on a five-point scale (Figure 2-2). Participants in Science Quest answered these questions only on the posttest. SSTP participants answered these questions on the pretest and the posttest. Students' beliefs about their parents' attitudes were determined by combining answers from three questions and creating a new variable with a scale of one to five (Figure 2-3). For both students' and perception of parents' attitudes the answers were scored on a scale of one to five, then averaged to obtain a value for the new variable. Students were allowed to mark different answers for each parent; those two responses were averaged. A score of one indicates someone who believes the media exaggerates the seriousness of climate change, thinks it will not ever happen, and that any climate change is caused by natural forces. A score of five indicates the individual believes the media

underestimates the seriousness of climate change, believes that it is happening now, and that humans are causing it.

Students' religiousity was measured by combining two items and creating a new variable with a scale of one to four. One question asked how often their family attended religious services and the other asked them to check adjectives that described their friends; the adjective religious was included in the list. A score of one indicates an individual whose family never attends religious services and who would not describe their friends as religious. A four indicates someone who attends religious services regularly and would describe their friends as religious.

Spearman's correlation was used (due to the limited sample size) to measure the relationship between students' attitudes about climate change and their perception of their parents' opinion about climate change, their political views, religiousity, and pre-existing knowledge. To assess the relationship between attitude and pre-existing knowledge only the pretest score from SSTP was used since the SQ tests focused on carbon knowledge rather than climate. A forward stepwise regression was used to predict a relationship between student attitude about climate change and other factors. The predictors included were pretest score, posttest score, how informed they felt about climate change, their trust in scientists, perception of parents' attitudes and political views, religiousity, their own political views, and gender.

Results

The results for each research question will be presented separately starting with the question of integrating climate change, the carbon cycle, and carbon sequestration.

Demographics

The twenty-two students in SQ 1 were evenly split between males and females. Most (21) of the students were rising sophomores and one was a year younger. All of the students indicated that they intended to go to college. All but two of the students had learned about global climate change in school.

There were twenty-four students in SQ 2, twelve males, eleven females, and one student who preferred not to say. Twenty-three of the students were rising sophomores and one was a year older. All of the students indicated that they intended to go to college. Nineteen of the students had learned about global climate change in school.

Student Knowledge Gain

Student knowledge gain for the two weeks of the Science Quest program was compared using the mean student scores on the pretest and posttest. A t-test ($p<0.05$) of the *carbon knowledge* questions found that there was no significant difference between the two *pretests*, suggesting the two treatment groups had statistically similar knowledge prior to the activities. There was no significant difference between the *carbon posttest* means. A significant difference was found between the *climate change knowledge* questions on the two posttests, verifying that the week 1 program conveyed information about climate change and the week 2 program did not. A significant difference ($p<0.05$) between the SQ 1 pretest and posttest indicates that SQ 1 students learned significantly more about both carbon and climate change during the activity. SQ 2 students did not, as measured by the same posttest (Table 2-1). Figure 2-4 displays the comparison between the pretest and posttest for both weeks of Science Quest.

Student Interest

Student interest in activities that covered carbon and climate change together or activities that taught them separately was assessed during the interviews at the conclusion of the Science Quest activities. Both treatments were explained and students were asked if they felt the connection to climate change made the activities more interesting and if they preferred the treatment they received or if they would have preferred the other. All but three of the forty-seven students indicated that they felt that knowing that carbon is an important part of climate change made the activities more interesting. Of the students who found the connection interesting, thirty-three preferred the connection throughout the activities and nine students preferred the connection at the end. Student responses varied on why they found the connection to climate change interesting or not; five themes emerged from student responses. Each theme is described below with two representative quotes and the number of quotes within the theme. A full list of the quotes that formed each theme can be found in Appendix D.

1. Relevance (15): a) I thought it made it much more interesting because then you could actually relate to the carbon cycle and how it really does affect the environment. b)Yeah. I just need to know what I should wear for the day, that's the only reason why I think about climate; if I should wear jeans or shorts. So it doesn't really matter to me.

2. Importance (7): a)"I think that it made it more important because we find out more about how really important carbon is and just try to find ways to reduce the amount of carbon that we let out into the environment." b) I guess the only thing that I can really add is just that it gives it definitely a more of an urgent tone.

3. Understanding (10): a) It was nice to learn more in depth about the carbon cycle, just not looking at a chart and just telling a paragraph or two about it. b)I thought it made it more interesting because you could see how they both interact with each other.

4. Experiential (3): a)I think giving a purpose to something, to anything really, learning but showing you hands on with math you can give a problem that links

the math problem to the real world, but doing it hands on in this way, it really shows you the facts up front and I think that's really helpful and I think it would make students want to become active in helping the environment and global warming.b)Probably more interesting because I got to interact with things.

5. Controversial (2): a)I thought it made it more interesting because global warming is kind of a controversial issue, like some people are like "oh no, we need to make this our top priority." and other people are saying it doesn't really matter, so I thought it made it more interesting because you got to see the people who really care about the trees, you got to see their perspective on the issue. b)A lot of kids don't always get too excited about learning about saving the environment and their effects on it, so I think if you were to explain that the whole activity would be about carbon in the atmosphere and the effect from fossil fuels then it would be less interesting throughout the whole activity and they'd be less motivated to do the beginning portion of the whole lesson.

Demographics

There were ninety-one students in the Student Science Training Program (SSTP) though consent and assent forms were obtained for only forty-two participants. The people who did not give consent appear to have forgotten to return it; no one voiced an objection to the study. There were forty responses for the posttest because two students were not present. Of these respondents, there were twenty-one males and nineteen females. Two students were rising juniors and the rest were rising seniors. Thirty-nine of the students indicated that they intended to attend college and one was undecided. Thirty-one of the students had learned about global climate change in school.

Students' Climate Change Attitudes

Students' attitudes about climate change were significantly lower for SQ 1 than SQ 2 and SSTP (Table 2-2). Students' perception of parents' attitudes about climate change varied across the three programs but did not differ significantly. Students were asked how often they talked with parents about climate change; this question was scored on a scale of one to three, one being never and three being often. A t-test of how

often they talked to their parents about climate change showed no significant difference between the three programs at the $p<0.01$ level. Students' religiousity also varied between the three groups but did not differ significantly. For SQ 1 six students selected "Republican," two "Independent," four "Democrat," two "other," and eight chose "I don't know." For SQ 2 five students selected "Republican," four chose "Independent," eleven "Democrat," one "other," and three selected "I don't know." For SSTP five students selected "Republican," nine "Independent," twelve "Democrat," seven "other," six chose "I don't know," and one did not answer.

There was a significant correlation between students' attitudes and their perception of parents' attitudes about climate change for only two groups, SQ 2 and SSTP, but not SQ 1 (Table 2-3). There was not a significant correlation between students' religiousity and their attitude toward climate change for any of the groups. For SSTP participants, there was not a significant correlation between the pretest knowledge score and students' attitudes toward climate change.

How informed they felt they were about climate change was ranked on a scale of one to four with four being "Very well informed" and one being "Not at all informed". Their trust in information from scientists was ranked on a scale of one to five with five being "Very accurate" and one being "Very inaccurate". How much students' worry about climate change was ranked on a scale of one, "not at all," to four, "a great deal". For parents' education level students were allowed to mark a different answer for each parent; answer choices ranged from "did not finish high school" to "graduate/professional school." Participants in SQ 1 reported feeling more informed about climate change and having a greater trust in information from scientists than

students in SQ 2 and SSTP (Table 2-4). Students' level of worry about climate change and their parents' education level did not differ significantly between the three groups.

The forward stepwise regression determined a R square value of 0.15 for SQ 1, with students' political views being the most and only significant term. For SQ 2 a R square value of 0.41 was found and perception of parents' attitude was the most and only significant term. A R square value of 0.46 was found for the Student Science Training Program and perception of parents' attitude was the most significant term, followed by one parent's political views.

Discussion

In exploring whether climate change information can be successfully integrated into biological concepts such as the carbon cycle, this study found that students who learned about carbon in the context of climate change made significant improvements in knowledge of the carbon cycle and carbon sequestration over those who did not. Embedding the carbon cycle and sequestration lesson in climate change appears to have significantly increased student knowledge about carbon, given the difference in SQ 1 knowledge scores compared to SQ 2; although this conclusion would be stronger had there been a significant difference between the posttests. Comments from the interviews confirm that knowing that carbon is related to and could help address climate change made the activity about forest carbon sequestration more interesting and important to nearly all the students. Students explained that linking carbon cycle and sequestration activities with climate change helps them learn, because the content becomes more interesting, relevant, and meaningful. A majority of students recommended that the connection to climate change should be made throughout the lesson. Students in SQ 1 found the connection to climate change interesting and had

significant knowledge gain even though they had a significantly lower attitude than students in SQ 2, suggesting that integrating the carbon cycle and sequestration with climate change could be beneficial even for students who care less about climate change.

In examining students' attitude about climate change and possible factors associated with it, this study found that students' attitudes varied between the groups and in two groups perception of parents' attitude was significantly related to students' attitudes. One reason that the mean student attitude about climate change may have been significantly lower for SQ 1 than the other two groups is that it was the only group in which Democrat was not the dominant political view. It is unclear why SQ 2 and SSTP demonstrated a high correlation between student attitudes and perception of parents' attitudes but SQ 1 had almost no correlation between the two attitudes. The two groups for which we report a high correlation between student attitudes and perception of parents' attitudes also had a strong R square value in the stepwise regression and the most significant term was perception of parents' attitude. The R square value for SQ 1 was weak and the most significant term was students' political views, but there are clearly other factors that account for student attitude. This suggests that in some groups there could be a significant relationship between students' attitudes about climate change and their perception of their parents' attitude about this topic.

This research suggests that students come into the classroom already holding opinions about climate change which are influenced by factors outside the teacher's control, such as perception of parents' attitude and the political party they tend to favor. However, because student attitudes for SSTP changed between the pretest and

posttest to become less similar to their perception of parents' attitudes, it appears that instruction on climate change could make students more able to overcome the influence of their parents' attitudes.

Future Research

Future research could include a more representative sample of students, schools, classes, and teachers. It could also focus on measuring the extent that other factors influence students' attitude toward climate change. For example, the influence that media or friends have on students' attitude toward climate change could be more explicitly tested with more survey items or open-ended questions. Studies could confirm the findings for integrating the carbon cycle and sequestration with climate change by exploring other concepts in biology. More studies could track how students whose beliefs about climate change differ from the scientific consensus experience science lessons and how various teaching strategies may engage them appropriately.

Conclusion

Educators face a number of challenges when conveying the science that underpins a controversial issue. The opportunity to infuse a current issue into traditional biological concepts appears to make those concepts more meaningful and interesting, regardless of preexisting attitudes. In communities where parents play a significant role in shaping student attitudes it may be wise to engage parents in students' homework on climate change so that students and parents can talk and think about climate change together. Adult education on climate change in the community could also help improve climate change knowledge and help alleviate the pushback teachers might feel when introducing the topic.

Connecting biology lessons to climate change can make it easier for teachers to include climate change in the already overloaded curriculum. Students said that the carbon cycle and climate change are usually taught in two different chapters and they appreciated seeing how the two were connected. It may not be enough to cover the information in the same year; students may need to work with both concepts simultaneously. Students also recognized that the experiential nature of these activities enabled them to learn more than merely memorizing the textbook diagram. Climate change may be a difficult topic for teachers to cover but it is a critical issue that many students want to learn about. Using the science of the carbon cycle and the impacts of sequestration to better understand climate change and possible mitigation strategies appears to be a teaching technique that provides multiple benefits.

SQ 1		SQ 2	
10 minutes-	Welcome and introduction to the day	10 minutes-	Welcome and introduction to the day
10 minutes-	Pretest	10 minutes-	Pretest
10 minutes-	Lecture on connection between carbon cycle and climate change	5 minutes-	Introduction to carbon cycle
15 minutes-	Activity on biological portion of the carbon cycle	15 minutes-	Activity on biological portion of the carbon cycle
10 minutes-	Discussion about previous activity and introduction of geological portion of carbon cycle	10 minutes-	Discussion about previous activity and introduction of geological portion of carbon cycle
15 minutes-	Group work to map entire carbon cycle	15 minutes-	Group work to map entire carbon cycle
10 minutes-	Discussion of human changes to the carbon cycle and connection to climate change	10 minutes-	Discussion of human changes to the carbon cycle
10 minutes-	Explanation of how to measure trees	10 minutes-	Explanation of how to measure trees
40 minutes-	Group work to measure trees	40 minutes-	Group work to measure trees
5 minutes-	Explanation of carbon storage calculations	5 minutes-	Explanation of carbon storage calculations
10 minutes-	Group work to calculate carbon storage	10 minutes-	Group work to calculate carbon storage
10 minutes-	Discussion of results and explanation of carbon sequestration and emission rates calculations	5 minutes-	Discussion of results
10 minutes-	Group work to calculate carbon sequestration and emissions rates	10 minutes-	Posttest
10 minutes-	Discussion of results	10 minutes-	Lecture on connection to climate change
10 minutes-	Wrap-up questions and discussion	5 minutes-	Explanation of carbon sequestration and emission rates calculations
10 minutes-	Posttest	10 minutes-	Group work to calculate carbon sequestration and emissions rates
30 minutes-	Group interviews	10 minutes-	Discussion of results
		10 minutes-	Wrap-up questions and discussion
		30 minutes-	Group interviews

Figure 2-1. Detailed Science Quest schedule

1. In your opinion, the news media reports on the seriousness of climate change are:
    - Generally exaggerated
    - Generally correct
    - Generally underestimated
    -
2. Which one of the following statements do you think is more accurate?
    - Most climate scientists believe that climate change is occurring
    - Most climate scientist believe climate change is not occurring
    - Most climate scientists are unsure about whether climate change is occurring or not
3. From what you have heard or read, do you believe increases in the Earth's temperature over the last century are caused by:
    - Mostly the effects of pollution from human activities and some natural changes
    - Mostly natural changes in the environment and some human activities
    - Both human and natural effects equally
    - Only natural changes in the environment
    - Only the effects of pollution from human activities
4. Which of the following statements reflects your view of when the effects of climate change might begin to happen?
    - They have already begun to happen
    - They will start happening within a few years
    - They will start happening within my lifetime
    - They will not happen within my lifetime, but they will affect future generations
    - They will never happen

Figure 2-2. Students' climate change attitude questions

Please answer the following questions based on what YOU THINK your parents/guardians believe.
If your parents agree with each other, mark only one answer.
If your parents have different opinions, mark both answers.

1. My parents would agree most with the following statement:
    - Most climate scientists believe that climate change is occurring
    - Most climate scientists do not believe that climate change is occurring
    - Most climate scientists are unsure about whether climate change is occurring or not
    - I do not know
2. My parents believe that increases in the Earth's temperature over the last century are due mostly to:
    - Mostly the effects of pollution from human activities and some natural changes
    - Mostly natural changes in the environment and some human activities
    - Both equally
    - I do not know
3. My parents think the news media reports on the seriousness of climate change are:
    - Generally exaggerated
    - Generally correct
    - Generally underestimated
    - I do not know

Figure 2-3. Students' perception of their parents' climate change attitude questions

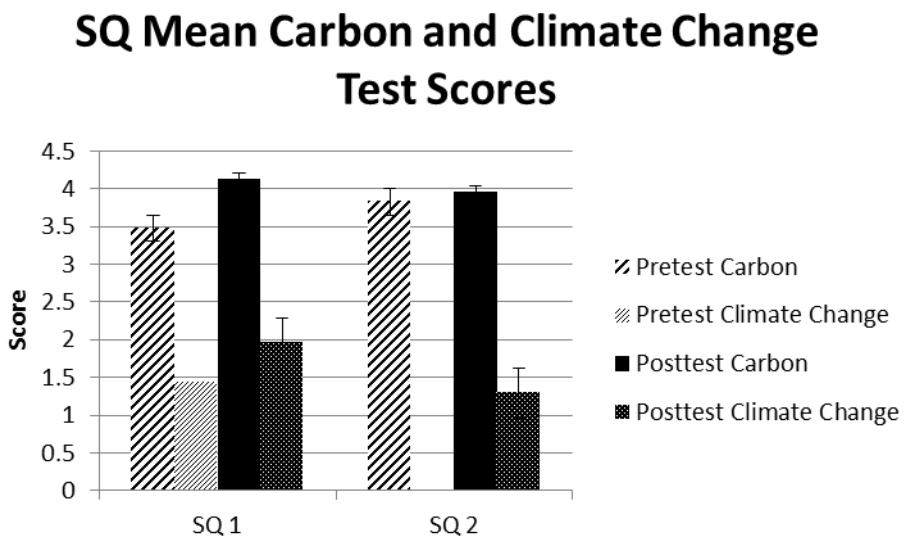

Figure 2-4. Science Quest Mean Test Scores

Table 2-1. SQ mean test scores

	SQ 1 (n=22)	SQ 2 (n=24)	P Value	Standard Error
Mean Pretest Score	3.48 carbon 1.43 climate change	3.83 carbon	0.2247 carbon	0.2784 carbon
Mean Posttest Score	4.13 carbon 1.96 climate change	3.96 carbon 1.29 climate change	0.2951 carbon 0.0002* climate change	0.1622 carbon 0.1595 climate change
P Value	0.0102* carbon 0.0004* climate change	0.5430 carbon		
Standard Error	0.2319 carbon 0.1238 climate change	0.2025 carbon		

*Significant at the $p<0.05$ level

Table 2-2. Student Attitude about Climate Change and Possible Associated Factors

	SQ 1 (n=23)	Standard Deviation	SQ 2 (n=24)	Standard Deviation	SSTP (n=42)	Standard Deviation
Mean Student Attitude[1]	2.07	0.6450	3.40	0.6031	3.45 pre 3.43 post	0.5953 0.5250
Mean Perception of Both Parents' Attitude[2]	2.27	0.4729	2.32	0.6673	2.75	0.6788
Student Political Views						
(Republican	27.3%		20.8%		12.8%	
Independent	9.1%		16.7%		23.1%	
Democrat	18.2%		45.8%		30.8%	
Other)	9.1%		4.2%		17.9%	
Religiousity[3]	2.68	0.9455	2.21	1.1025	2.55	0.8458
Pretest Score[4]	--		--		4.64	0.6560

[1]Scale of 1 (less concerned) to 5 (more concerned).
[2]Scale of 1 (less concerned) to 5 (more concerned).
[3] Scale of 1 (less religious) to 4 (more religious).
[4] Scale of 0 to 7 based on the number of correct answers.

Table 2-3. Correlations with Student Attitude about Climate Change

Factor Correlated with Student Attitude	SQ 1 (n=23)	SQ 2 (n=24)	SSTP (n=42)
Perception of Parents' Attitude	0.0065	0.6081	0.5881 pre 0.4338 post
Religiousity	0.0192	-0.0886	0.0832
Pretest Score	--	--	0.0438

Table 2-4. Additional Factors Included within Regression Analysis

	SQ 1	Standard Deviation	SQ 2	Standard Deviation	SSTP	Standard Deviation
Informed about Climate Change[1]	3.39	0.4990	3.08	0.7173	2.86 pre 3.1 post	0.6077 0.5905
Trust in Scientists[2]	4.52	0.5108	4.0	0.6594	3.90 pre 3.2 post	0.6172 1.1591
Worry about Climate Change[3]	2.78	0.8505	2.46	0.8836	2.55 pre 2.78 post	0.9160 0.8619
Discuss CC with Parents[4]	1.64	0.6580	1.63	0.7109	1.67	0.6115
Parents' Education Level[5]	4.96 5.26	1.0651 0.9638	4.88 5.29	1.5690 0.9991	5.02 5.46	1.3691 0.8688
Perception of Parents' Politics (Republican Independent Democrat Other)	48% 4% 26% 4% 39% 9% 30% 4%		29% 13% 46% 4% 21% 17% 50% 0%		32% 15% 37% 0% 24% 12% 46% 0%	

[1] Scale 1 (not at all informed) to 4 (very informed).
[2] Scale 1 (very inaccurate) to 5 (very accurate)
[3] Scale 1 (not at all) to 4 (a great deal)
[4] Scale 1 (never) to 3 (often)
[5] Scale 1 (did not finish high school) to 6 (graduate/professional school)

CHAPTER 3
SUMMARY

Climate is typically a unit for the earth science classroom but it can help to enhance the biology curriculum by providing an interesting purpose for learning about topics such as the carbon cycle. The preceding study investigated a strategy for integrating climate change with biological concepts. If climate change can be connected to biology concepts, this could help biology teachers include the issue in their lessons which would allow more students to learn about the subject. Connecting biology lessons to climate change could increase student interest in the activities and student knowledge. This means that teachers do not need to think of climate change as an additional burden on an already overloaded curriculum. Rather climate change can be connected with material already taught in the classroom, serving two purposes. It will help students become more knowledgeable about climate change, creating an informed citizenry, and make these subjects more interesting by giving them a real world application. Students said that the carbon cycle and climate change are usually taught from two different chapters in school and they appreciated seeing how the two were connected. Students recognized that the experiential nature of the activities enabled them to learn more than merely memorizing the textbook diagram. They enjoyed seeing that what they were learning had real world applications.

In addition, this study explored several factors that could be associated with student attitude about climate change. In some instances students' perception of parents' attitudes can significantly influence students' attitude about climate change. For other students, different factors, such as political views, may carry more weight. If

parents play a significant role in shaping student attitudes than it may be wise to focus on engaging adults as well as students in climate change education.

Teachers should be aware that students come into the classroom with knowledge and attitudes influenced by outside sources. Changing these attitudes may be possible with careful instruction but their existence could affect how students learn. Being aware of the diversity of student attitudes toward climate change will help teachers structure their unit, teach more effectively, and develop a more realistic expectation for what they can accomplish in class. Future research should investigate strategies to help teachers overcome these preconceived ideas.

APPENDIX A
SQ 1 Pretest, Posttest

Name: _____

□ By checking this box, I give permission for my responses today to be used for Stephanie's graduate project.

Please help by answering the following questions. Please circle only 1 answer for each question unless otherwise indicated.

1. There is a limited amount of carbon on the Earth.
    - True
    - False
2. A carbon atom moving from the atmosphere to a tree would be going through the process of:
    - Respiration
    - Photosynthesis
    - Decomposition
3. A carbon pool is…
    - A body of water that contains carbon
    - The process by which carbon moves
    - Any place where carbon can be found
4. How does burning fossil fuels change the carbon cycle?
    - It removes carbon from the biological carbon cycle and adds it to the geological carbon cycle
    - It removes carbon from the geological carbon cycle and adds it to the biological carbon cycle
    - It adds carbon to both the geological and biological carbon cycles
    - It is not big enough to significantly change the carbon cycle
5. Which of these would be more effective to remove more carbon from the atmosphere?
    - Planting more trees
    - Planting more corn
    - Planting more grass
6. Which of these would be more effective to remove more carbon from the atmosphere?
    - Planting more trees
    - Planting more corn
    - Planting more grass
7. How can trees help to slow climate change?
    - By storing carbon through photosynthesis
    - By releasing oxygen through respiration
    - By providing shade to keep the Earth cool

Name: _____

Section 1

Please help by answering the following questions. Please circle only 1 answer for each question unless otherwise indicated.

1. There is a limited amount of carbon on the Earth.
    a. True
    b. False
2. A carbon atom moving from the atmosphere to a tree would be going through the process of:
    a. Respiration
    b. Photosynthesis
    c. Decomposition
3. A carbon pool is…
    a. A body of water that contains carbon
    b. The process by which carbon moves
    c. Any place where carbon can be found
4. How does burning fossil fuels change the carbon cycle?
    a. It removes carbon from the biological carbon cycle and adds it to the geological carbon cycle
    b. It removes carbon from the geological carbon cycle and adds it to the biological carbon cycle
    c. It adds carbon to both the geological and biological carbon cycles
    d. It is not big enough to significantly change the carbon cycle
5. How does carbon dioxide in the atmosphere influence Earth's temperature?
    a. By trapping heat and increasing Earth's average temperature
    b. By allowing more heat to escape into space and decreasing Earth's average temperature
    c. By creating a hole in the ozone layer allowing more UV radiation in.
6. Which of these would be more effective to remove more carbon from the atmosphere?
    a. Planting more trees
    b. Planting more corn
    c. Planting more grass
7. How can trees help to slow climate change?
    a. By storing carbon through photosynthesis
    b. By releasing oxygen through respiration
    c. By providing shade to keep the Earth cool

Section 2

8. How informed do you feel about climate change?
    - Very well informed
    - Fairly well informed
    - Not very well informed
    - Not at all informed
9. In your opinion, information from scientists is:
    - Very accurate
    - Mostly accurate
    - Somewhat accurate
    - Mostly inaccurate
    - Very inaccurate
10. In your opinion, the news media reports on the seriousness of climate change are:
    - Generally exaggerated
    - Generally correct
    - Generally underestimated
11. Do you worry about climate change?
    - A great deal
    - A fair amount
    - Only a little
    - Not at all
12. Which one of the following statements do you think is more accurate?
    - Most climate scientists believe that climate change is occurring
    - Most climate scientist believe climate change is not occurring
    - Most climate scientists are unsure about whether climate change is occurring or not
13. From what you have heard or read, do you believe increases in the Earth's temperature over the last century are caused by:
    - Mostly the effects of pollution from human activities and some natural changes
    - Mostly natural changes in the environment and some human activities
    - Both human and natural effects equally
    - Only natural changes in the environment
    - Only the effects of pollution from human activities
14. Which of the following statements reflects your view of when the effects of climate change might begin to happen?
    - They have already begun to happen
    - They will start happening within a few years
    - They will start happening within my lifetime
    - They will not happen within my lifetime, but they will affect future generations
    - They will never happen
15. My parents/guardians and I talk about climate change:
    - Often

- Sometimes
- Never

Please answer the following questions based on what YOU THINK your parents/guardians believe.
If your parents agree with each other, mark only one answer.
If your parents have different opinions, mark both answers.

16. My parents would agree most with the following statement:
    - Most climate scientists believe that climate change is occurring
    - Most climate scientists do not believe that climate change is occurring
    - Most climate scientists are unsure about whether climate change is occurring or not
    - I do not know
17. My parents believe that increases in the Earth's temperature over the last century are due mostly to:
    - Mostly the effects of pollution from human activities and some natural changes
    - Mostly natural changes in the environment and some human activities
    - Both equally
    - I do not know
18. My parents think the news media reports on the seriousness of climate change are:
    - Generally exaggerated
    - Generally correct
    - Generally underestimated
    - I do not know
19. In general, which party's views and policies do your parents tend to agree with?
    - Republican
    - Independent
    - Democrat
    - Other
    - I don't know
20. What is the highest level of education completed by either of your parents or guardians?
    - Did not finish high school
    - High school diploma or GED
    - Some college
    - Technical school
    - Bachelor's degree
    - Graduate/professional school

Section 3

Now, a few more questions about you.

21. I am:
    - Male
    - Female
    - Prefer not to say
22. Which grade will you start in the fall?
    - 9th
    - 10th
    - 11th
    - 12th
23. Do you think you will attend college?
    - Yes
    - No
    - Undecided
24. Does your immediate family attend religious services? (Immediate family is the family that you live with)
    - Regularly
    - On occasion
    - Never
25. Which adjectives describe your group of friends (circle all that apply)?
    - Athletic
    - Religious
    - Artistic
    - Academic
    - Out-going
    - Politically active
    - Geeky
    - Quiet
    - Popular
26. In general, which party's views and policies do you tend to agree with?
    - Republican
    - Independent
    - Democrat
    - Other
    - I don't know
27. Have you learned about global climate change in school?
    - Yes
    - No

APPENDIX B
SQ 2 PRETEST, POSTTEST

Name: _____

□ By checking this box, I give permission for my responses today to be used for Stephanie's graduate project.

Please help by answering the following questions. Please circle only 1 answer for each question unless otherwise indicated.

1. There is a limited amount of carbon on the Earth.
    - True
    - False
2. A carbon atom moving from the atmosphere to a tree would be going through the process of:
    - Respiration
    - Photosynthesis
    - Decomposition
3. A carbon pool is…
    - A body of water that contains carbon
    - The process by which carbon moves
    - Any place where carbon can be found
4. How does burning fossil fuels change the carbon cycle?
    - It removes carbon from the biological carbon cycle and adds it to the geological carbon cycle
    - It removes carbon from the geological carbon cycle and adds it to the biological carbon cycle
    - It adds carbon to both the geological and biological carbon cycles
    - It is not big enough to significantly change the carbon cycle
5. Which of these would be more effective to remove more carbon from the atmosphere?
    - Planting more trees
    - Planting more corn
    - Planting more grass

○

Name: _____

Section 1

Please help by answering the following questions. Please circle only 1 answer for each question unless otherwise indicated.

1. There is a limited amount of carbon on the Earth.
    a. True
    b. False
2. A carbon atom moving from the atmosphere to a tree would be going through the process of:
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    c. Decomposition
3. A carbon pool is…
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4. How does burning fossil fuels change the carbon cycle?
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    b. Planting more corn
    c. Planting more grass
7. How can trees help to slow climate change?
    a. By storing carbon through photosynthesis
    b. By releasing oxygen through respiration
    c. By providing shade to keep the Earth cool

Section 2

8. How informed do you feel about climate change?
    - Very well informed
    - Fairly well informed
    - Not very well informed
    - Not at all informed
9. In your opinion, information from scientists is:
    - Very accurate
    - Mostly accurate
    - Somewhat accurate
    - Mostly inaccurate
    - Very inaccurate
10. In your opinion, the news media reports on the seriousness of climate change are:
    - Generally exaggerated
    - Generally correct
    - Generally underestimated
11. Do you worry about climate change?
    - A great deal
    - A fair amount
    - Only a little
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12. Which one of the following statements do you think is more accurate?
    - Most climate scientists believe that climate change is occurring
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    - Most climate scientists are unsure about whether climate change is occurring or not
13. From what you have heard or read, do you believe increases in the Earth's temperature over the last century are caused by:
    - Mostly the effects of pollution from human activities and some natural changes
    - Mostly natural changes in the environment and some human activities
    - Both human and natural effects equally
    - Only natural changes in the environment
    - Only the effects of pollution from human activities
14. Which of the following statements reflects your view of when the effects of climate change might begin to happen?
    - They have already begun to happen
    - They will start happening within a few years
    - They will start happening within my lifetime
    - They will not happen within my lifetime, but they will affect future generations
    - They will never happen
15. My parents/guardians and I talk about climate change:
    - Often

- Sometimes
- Never

Please answer the following questions based on what YOU THINK your parents/guardians believe.
If your parents agree with each other, mark only one answer.
If your parents have different opinions, mark both answers.

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    - Mostly the effects of pollution from human activities and some natural changes
    - Mostly natural changes in the environment and some human activities
    - Both equally
    - I do not know
18. My parents think the news media reports on the seriousness of climate change are:
    - Generally exaggerated
    - Generally correct
    - Generally underestimated
    - I do not know
19. In general, which party's views and policies do your parents tend to agree with?
    - Republican
    - Independent
    - Democrat
    - Other
    - I don't know
20. What is the highest level of education completed by either of your parents or guardians?
    - Did not finish high school
    - High school diploma or GED
    - Some college
    - Technical school
    - Bachelor's degree
    - Graduate/professional school

Section 3

Now, a few more questions about you.

21. I am:
    - Male
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    - Prefer not to say
22. Which grade will you start in the fall?
    - 9th
    - 10th
    - 11th
    - 12th
23. Do you think you will attend college?
    - Yes
    - No
    - Undecided
24. Does your immediate family attend religious services? (Immediate family is the family that you live with)
    - Regularly
    - On occasion
    - Never
25. Which adjectives describe your group of friends (circle all that apply)?
    - Athletic
    - Religious
    - Artistic
    - Academic
    - Out-going
    - Politically active
    - Geeky
    - Quiet
    - Popular
26. In general, which party's views and policies do you tend to agree with?
    - Republican
    - Independent
    - Democrat
    - Other
    - I don't know
27. Have you learned about global climate change in school?
    - Yes
    - No

APPENDIX C
SCIENCE QUEST INTERVIEW GUIDE

Name: _____

Science Quest Interview

Thank you so much for helping me by answering these questions; your responses will be valuable to our project and evaluation of the activities. Remember that we will not use your name with any of your responses.

1. What did you like about today's activity? What did you dislike about today's activity?
   Why did you like/dislike it?

2. What did you think was the most interesting part of today's activity? What was the most boring part? What made it interesting or boring?

3. What do you think was the main idea from today's activities? Why do you think that was the main idea?

4. In your opinion, how important is the information from the activity?

5. When you found out how carbon related to climate change did it make it more or less interesting? Why? Would you have preferred it if we had related carbon to climate change throughout both activities?

6. Would you be interested in doing more activities on this same topic? Why?

7. Should other students in your school be learning about this?

8. Would your biology teacher do this? What improvements could we make to help teachers do this activity?

APPENDIX D

QUOTES REPRESENTING THEMES FROM SQ INTERVIEWS

Relevance

- “Impacts always increase the ability to understand what you’re learning, so you can make a bunch of claims and facts, but if you don’t apply that, if you don’t connect that to what’s going on now, you won’t understand the components of it. So you can learn about the carbon cycle, but if you learn about what’s going on now, how severe it is to keep the carbon cycle going, how serious it is to keep the carbon cycle going, you’ll understand and you’ll appreciate it more, rather than just learning.”
- “It made it more interesting because everybody hears about global warming and the polar bears and ice bergs melting, but when you connect it like that with carbon it has a more scientific approach to it, it made it more interesting.”
- “To me it was kind of both, because it was less interesting because I’m not a person who’s into all the climate change, but also more interesting because the amount of trees and carbon that we put out affects that.”
- “It made it more interesting and more relevant, because you hear the phrase climate change thrown around all the time, but no one ever really says on the news what is actually behind it, what’s causing the climate to change, sometimes people are like “oh yeah, it’s CO_2 in the atmosphere.” but that’s meaningless unless you know the facts and the statistics behind it and the cycle that it goes through, so it’s pretty important in terms of knowing how they’re connected.”
- “I think it made it more interesting, not that the whole carbon cycle isn’t interesting, it’s very interesting, but the climate change part of the day really oomphed it up because you can think that the carbon cycle is interesting , but once you add the climate change part it kind of gets personal. But it definitely made it more interesting.”
- “More, I mean otherwise it would just be us measuring some trees and getting some weights, that’s about all. So the actual connection was nice and that gave us the big picture.”
- “I thought it made it much more interesting because then you could actually relate to the carbon cycle and how it really does affect the environment.”
- “It made it more interesting. Because I can apply it to things now.”
- “Because just like before, you can relate. You can see the world in an additional way.”
- “It did make it more interesting because like they said again, you can relate to it. I also have a suggestion, if you would’ve incorporated the fact that the carbon cycle affects climate change throughout the entire thing, it would’ve given us an objective and you could’ve recorded how we felt about global warming and climate change before and after we realized the damages and the consequences and what affect it is, you could’ve recorded how we felt about it after.”
- “When you related it, the first part of the question, I thought it was interesting because it was relatable because it’s something that I can actually understand.”
- “I thought it was interesting related to climate change because you could make a link of what it affects and stuff, although I personally would’ve preferred if it had

been more spaced out instead of just blobbing it all at the end, maybe just lesser blobs."

- "I thought that it made it more interesting because of how the carbon affects us all and stuff and so it made it more interesting and I liked the way we did it, because since we're all on summer vacation, it's a good refresher on the carbon cycle and the affects that it has on us."
- "Yeah. I just need to know what I should wear for the day, that's the only reason why I think about climate; if I should wear jeans or shorts. So it doesn't really matter to me."
- "I think that talking about the climate change in the beginning and then following up with it in the end as well would've been more relevant because if you explained it, like [they] said, when we went out and were taking the measurements, if you were taking them, we knew we were trying to figure out how much carbon was in them but we didn't realize that it was going to be put into perspective that with that thought and the amount of carbon that's coming from that, you would need however many times that much, I think it would've been more relevant when you were taking the measurements if you knew you were trying to figure out how we can slow down or reverse the climate change. And then at the end you would obviously follow up with it, once you had the actual data and you could look at what you would take in and how many times that area you would need to fix the climate change."

Importance

- "I think that it made it more important because we find out more about how really important carbon is and just try to find ways to reduce the amount of carbon that we let out into the environment."
- "I think it made it more important, well this is based on personal experiences, but a long time ago, like seven years ago, I was actually shown something about the ozone layer so this is kind of the same thing about global warming and hurting the environment so it made it more important knowing that just the reason behind it and I was always interested in thinking how terrible it is."
- "I guess the only thing that I can really add is just that it gives it definitely a more of an urgent tone, everybody just basically said exactly what I was thinking of."
- "Basically giving it a more urgent tone, making it more personal, and all of that together. Basically what all they said, put into one."
- "I think it would've better in the beginning because then it's the whole idea of this is to find out how carbon is in the climate and it affects us and how it helps us, the advantages and disadvantages."
- "I agree with [their] opinion and I think that at the end after reinstating the fact that carbon is literally absolutely everywhere on Earth it gives the students a sense of importance because they realize how much carbon there really is and how much we're producing."
- "I believe that the information regarding climate change was extremely important and it made it a lot more interesting as well because it kind of set things in focus so we knew truly what we were doing."

Understanding

- “Kids now a days, kids my age, they hear all of this but they don’t know why so they block themselves from it and then connecting the two dots, it just matters.”
- “It was nice to learn more in depth about the carbon cycle, just not looking at a chart and just telling a paragraph or two about it. This actually went more in depth and hands on activities, schools should do that more often.”
- “I thought that it was more interesting because as years progress in each grade we learn a little bit more about each cycle, and so out here I learned a little bit more than previous years and so it made it more interesting.”
- “I wasn’t so aware that it affected it.”
- “More interesting because I learned things about carbon and climate change that I didn’t know before.”
- “It was more interesting because I learned more things about carbon than I know before. “
- “It definitely makes it more interesting because the first step in solving the problem is knowing what’s causing it.”
- “It made it quite interesting because people always blame climate change on greenhouse gases so I think people will be surprised that a lot of that is from an unbalanced carbon cycle and that people will be quite interested in that.”
- “It made it more interesting for me because I didn’t actually realize when we were measuring the trees how that would later play into the activity so I would have liked it to be explained in the beginning; it would’ve been more interesting for me.”
- “I thought it made it more interesting because you could see how they both interact with each other but I would’ve preferred it if you had talked about it through the whole entire thing because I think it would’ve made it easier to understand and how they’re interconnected.”

Experiential

- “I think giving a purpose to something, to anything really, learning but showing you hands on with math you can give a problem that links the math problem to the real world, but doing it hands on in this way, it really shows you the facts up front and I think that’s really helpful and I think it would make students want to become active in helping the environment and global warming.”
- “Probably more interesting because I got to interact with things.”
- “I believe it kind of stayed the same interest level for me because I had already done stuff similar to this.”

Controversial

- “I thought it made it more interesting because global warming is kind of a controversial issue, like some people are like “oh no, we need to make this our top priority.” and other people are saying it doesn’t really matter, so I thought it made it more interesting because you got to see the people who really care about the trees, you got to see their perspective on the issue.”
- “I thought it was better and more interesting that it was placed at the end because if it’s placed at the beginning, a lot of kids don’t always get too excited about learning about saving the environment and their effects on it, so I think if

you were to explain that the whole activity would be about carbon in the atmosphere and the effect from fossil fuels then it would be less interesting throughout the whole activity and they'd be less motivated to do the beginning portion of the whole lesson."

APPENDIX E
SSTP Pretest, Posttest

Name: _____

□ By checking this box, I give permission for my responses to be used for Stephanie's graduate project.

Section 1

Please help by answering the following questions. Please mark only 1 answer for each question unless otherwise indicated.

1. The greenhouse effect refers to:
    - Pollution that causes acid rain
    - How plants grow
    - The Earth's protective ozone layer
    - Gases in the atmosphere that trap heat
2. Climate refers to:
    - Long-term average atmospheric conditions
    - Atmospheric conditions over a short period of time
    - Changes in the atmosphere
    - Daily weather conditions
3. Which of the following is thought to be altered by climate change? (Check all the apply)
    - Temperature
    - Sea level
    - Extreme weather events
    - Ozone hole
4. The amount of carbon dioxide in the atmosphere over the past 500 years has:
    - Not changed
    - Increased
    - Decreased
5. Why do people tend to focus on carbon dioxide when discussing current climate change?
    - People have changed carbon dioxide levels the most
    - It is the only greenhouse gas
    - It is the only greenhouse gas people have changed
6. Climate change will have the same effects in all regions.
    - True
    - False
7. Which one of the following makes the biggest contribution to sea level rise?
    - Warmer ocean temperatures
    - Decreased evaporation
    - Melting of polar ice caps
    - Melting of glaciers

Section 2

8. How informed do you feel about climate change?
    - Very well informed
    - Fairly well informed
    - Not well informed
    - Not at all informed
9. In your opinion, information from scientists is:
    - Very accurate
    - Mostly accurate
    - Somewhat accurate
    - Mostly inaccurate
    - Very inaccurate
10. In your opinion, the news media reports on the seriousness of climate change are:
    - Generally exaggerated
    - Generally correct
    - Generally underestimated
11. How much do you worry about climate change?
    - A great deal
    - A fair amount
    - Only a little
    - Not at all
12. Which one of the following statements do you think is more accurate?
    - Most climate scientists believe that climate change **is** occurring
    - Most climate scientists believe climate change is **not** occurring
    - Most climate scientists are **unsure** about whether climate change is occurring or not
13. From what you have heard or read, do you believe increases in the Earth's temperature over the last century are caused by:
    - Mostly the effects of pollution from human activities and some natural changes
    - Mostly natural changes in the environment and some human activities
    - Both human and natural effects equally
    - Only natural changes
    - Only the effects of pollution from human activities
14. Which of the following statements reflects your view of when the effects of climate change might begin to happen?
    - They have already begun to happen
    - They will start happening within a few years
    - They will start happening within my lifetime

- They will not happen within my lifetime, but they will affect future generations
- They will never happen

15. My parents/guardians and I talk about climate change:
    - Often
    - Sometimes
    - Never

Please answer the following questions based on what YOU THINK your parents/guardians believe.
If your parents agree with each other, **mark only one answer**.
If your parents have different opinions, **mark two answers**.

16. My parents would agree most with the following statement:
    - Most climate scientists believe that climate change **is** occurring
    - Most climate scientists do **not** believe that climate change is occurring
    - Most climate scientists are **unsure** about whether climate change is occurring or not
    - I do not know
17. My parents believe that increases in the Earth's temperature over the last century are due to:
    - Mostly the effects of pollution from human activities and some natural changes
    - Mostly natural changes in the environment and some human activities
    - Both equally
    - Only natural causes
    - Only the effects of pollution from human activities
    - I do not know
18. My parents think the news media reports on the seriousness of climate change are:
    - Generally exaggerated
    - Generally correct
    - Generally underestimated
    - I do not know
19. What is the highest level of education completed by either of your parents or guardians?
    - Did not finish high school
    - High school diploma or GED
    - Some college
    - Technical school
    - Bachelor's degree (four year college degree)
    - Graduate/professional school

20. In general, which political party's views and policies do your parents tend to agree with?
    - Republican
    - Independent
    - Democrat
    - Other
    - I don't know

Name: _____

Please circle whether you think each of the following statements is or is not supported by scientific evidence. You can also circle that you do not know.

1. **The Earth's climate is changing.**
   Supported by science Not supported by science I don't know

2. **Climate change will affect regions of the Earth differently, with some areas becoming wetter and others becoming drier.**
   Supported by science Not supported by science I don't know

3. **The impacts of climate change will not impact people or the systems we depend upon (such as food, water, places to live, etc.)**
   Supported by science Not supported by science I don't know

4. **Sea level rise is caused mostly by the polar ice caps melting.**
   Supported by science Not supported by science I don't know

5. **Burning fossil fuels is the only cause of climate change.**
   Supported by science Not supported by science I don't know

6. **The annual melting of arctic sea ice is an example of climate change.**
   Supported by science Not supported by science I don't know

7. **The greenhouse effect is a natural process that supports life on Earth.**
   Supported by science Not supported by science I don't know

8. **Most scientists disagree about the causes of climate change.**
   Supported by science Not supported by science I don't know

Name: _____

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Section 2

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    - They will start happening within my lifetime

- They will not happen within my lifetime, but they will affect future generations
- They will never happen

Section 3

15. I am:
    - Male
    - Female
    - Prefer not to say
16. Which grade will you be starting in the fall?
    - 9th
    - 10th
    - 11th
    - 12th
17. Do you think you will attend college?
    - Yes
    - No
    - Undecided
18. Does your family that you live with attend religious services?
    - Regularly
    - On occasion
    - Never
19. Which adjectives describe your group of friends (check all that apply)?
    - Athletic
    - Religious
    - Artistic
    - Academic
    - Out-going
    - Politically active
    - Geeky
    - Quiet
    - Popular
20. In general, which political party's views and policies do you tend to agree with?
    - Republican
    - Independent
    - Democrat
    - Other
    - I don't know
21. Have you learned about global climate change in school?
    - Yes
    - No
22. Did you think the lecture on Monday was (mark all that apply):
    - Interesting
    - Accurate

- Biased
- Important
- Boring
- Incomplete
- Surprising

23. Any other comments about the lecture on Monday? What would improve it?

24. What additional questions do you have about climate change?

Name: _____

Please circle whether you think each of the following statements is or is not supported by scientific evidence. You can also circle that you do not know.

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   Supported by science Not supported by science I don't know

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7. **The greenhouse effect is a natural process that supports life on Earth.**
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8. **Most scientists disagree about the causes of climate change.**
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BIOGRAPHICAL SKETCH

Stephanie Hall grew up in Orlando, Florida and developed an interest in the environment at an early age. She received her Bachelor of Arts in environmental science from the University of Florida in the spring of 2011. After her bachelor's degree she continued her education at the University of Florida and completed her Master of Science in forest resources and conservation, with a certificate in environmental education and communication, in spring of 2013. After finishing her degree, she began a career in informal environmental education.