

USING A GIS-BASED FRAMEWORK TO TEACH CLIMATE CHANGE IN KANSAS

by

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B.A., Kansas State University, 2006

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AN ABSTRACT OF A DISSERTATION

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Abstract

Scientists agree that there is ample evidence of climate change and that a significant portion of the change is anthropogenically driven. Leiserowitz et al. (2011b) asked teenagers about their understanding of the climate system and the causes of climate change. Fewer than 20% of respondents classified themselves as “very well informed” and only 27% reported that they learned “a lot” about climate change in school. However, of these teenagers, 70% expressed a desire for more climate change education. Even though the idea of human impacts on the climate system and a changing climate have been known and discussed within science education for several decades, dedicating classroom time for teaching climate change is not a common practice.

Focus group discussions with science and agricultural education teachers (Pytlikzillig et al., 2013) emphasized the need for the use of locally relevant data in the classroom as a means to engage students in critical thinking activities that require them to use and draw conclusions from these data. However, most teachers do not have access to such data or a working knowledge of technological platforms from which they can have the students observe, manipulate, and analyze these data.

This study used a mixed methods research design to explore the use of a GIS-based framework for teaching climate change. A two-part intervention was used: 1) teacher training, and 2) classroom implementation. Student-, teacher-, and classroom-centered data were collected to address student outcomes, teacher perceptions of GIS use in teaching climate change, and both students’ and teachers’ perceptions of challenges and successes of using GIS in the classroom. Students showed an overall positive growth in knowledge. Teachers shared a positive perception regarding the use of GIS to teach climate change, going so far as to report

that they will all continue to teach climate change and use GIS in their classrooms. Successes and challenges were observed in classrooms, recognizing the benefits of student engagement and learning, as well as the challenges of using technology and supporting student needs. This exploratory research supports the premise that using a GIS-based framework to teach climate change is practical, reproducible, and effective.

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Dedication

This work is dedicated to my dear friend Jim Wells, for without him it never would have been completed. He supported and sheltered me in the times I needed it most, in the most beautiful place on Earth.

Chapter 1 - Introduction

Science...gives us the means to predict the consequences of our actions and perhaps, with wisdom, to save us from ourselves (Hazen and Trefil, 2009, p. 345).

There is growing evidence that the climate of the Earth is changing. Large-scale changes can be seen through increases in the average global temperature, decreases in the quantity of sea ice, variations in sea level, and alterations in the composition of the atmosphere. In recent decades, climate scientists have made consistent and credible observations of these changes, leading to consensus in the scientific community that climate change is occurring (Anderegg, Prall, Harold, and Schneider, 2010; Oreskes, 2004).

When asked about their understanding of the climate system and the causes of climate change, fewer than one in five teenagers categorized themselves as “very well informed” about climate and climate change, with only 27% reporting that they learned “ a lot” about climate change in school. Yet 70% of these teenagers reported that they would like to learn more about climate change (Leiserowitz, Maibach, Roser-Renouf, and Smith, 2011a). Today’s students are interested but not informed.

Understanding Climate Change and Societal Interest

The Science behind Climate Change

Climate change is

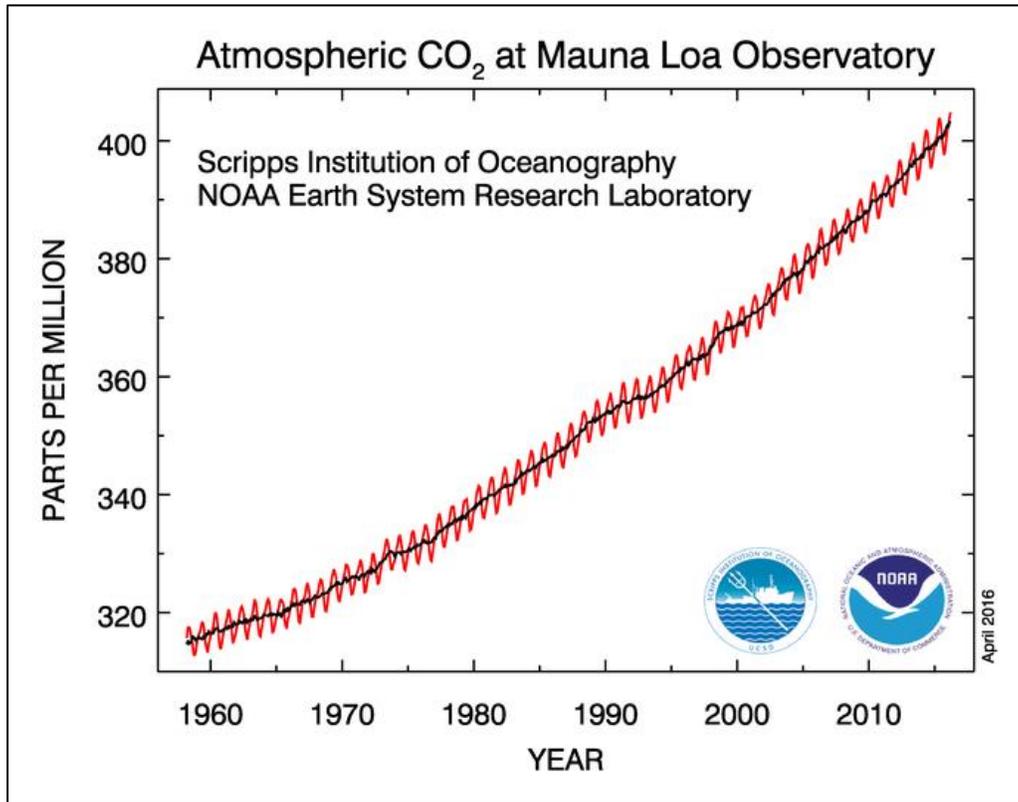
a significant and persistent change in the mean state of the climate or its variability. Climate change occurs in response to changes in some aspect of Earth’s environment: these include regular changes in Earth’s orbit about the sun, re-arrangement of continents through plate tectonic motions, or anthropogenic modification of the atmosphere (USGCRP/CCSP, 2009, p. 17).

On planet Earth, the average global temperature has risen 1.5°F since 1900 and is projected to rise an additional 2.0-11.5°F by 2100 (Intergovernmental Panel on Climate Change (IPCC), 2007). Sea levels have risen and precipitation patterns have changed as well (Karl, Melillo, and Peterson, 2009). Climate changes on Earth occur from both natural and anthropogenic (human) forces. The primary natural influences on climate variability are the earth-sun relationship and plate tectonics. The earth-sun relationship influences climate through the amount of solar radiation received. This amount varies with an 11-year sunspot activity cycle and the Milankovitch cycles during which the Earth's eccentricity, obliquity, and precession change over time. Volcanic eruptions tend to cool the planet for a short time period (one-five years) following an eruption (IPCC, 2014; Karl et al., 2009).

Human activities have also been responsible for climate changes on Earth, mainly through the emissions of heat-trapping gases. These gases include carbon dioxide, methane, nitrous oxide, ozone, water vapor, and others. Among these, carbon dioxide has been noted as the most impactful greenhouse gas emitted (IPCC, 2014). The carbon dioxide record from Mauna Loa is the longest record of direct measurements of CO₂ in the atmosphere and consistently used to illustrate increases in CO₂ concentration (Figure 1). In Figure 1, the red line shows the carbon dioxide concentration measurements and the black line represents the seasonally corrected data. Seasonally corrected data removes the fluctuations in CO₂ concentration between seasons to provide an overall trend line. From 1960 to 2010 the concentration of CO₂ in the atmosphere (as measured in parts per million) increased by approximately 25%, with higher concentration levels being reached each subsequent year.

Figure 1 - Atmospheric Concentrations of Carbon Dioxide at the Mauna Loa Observatory from 1960-present

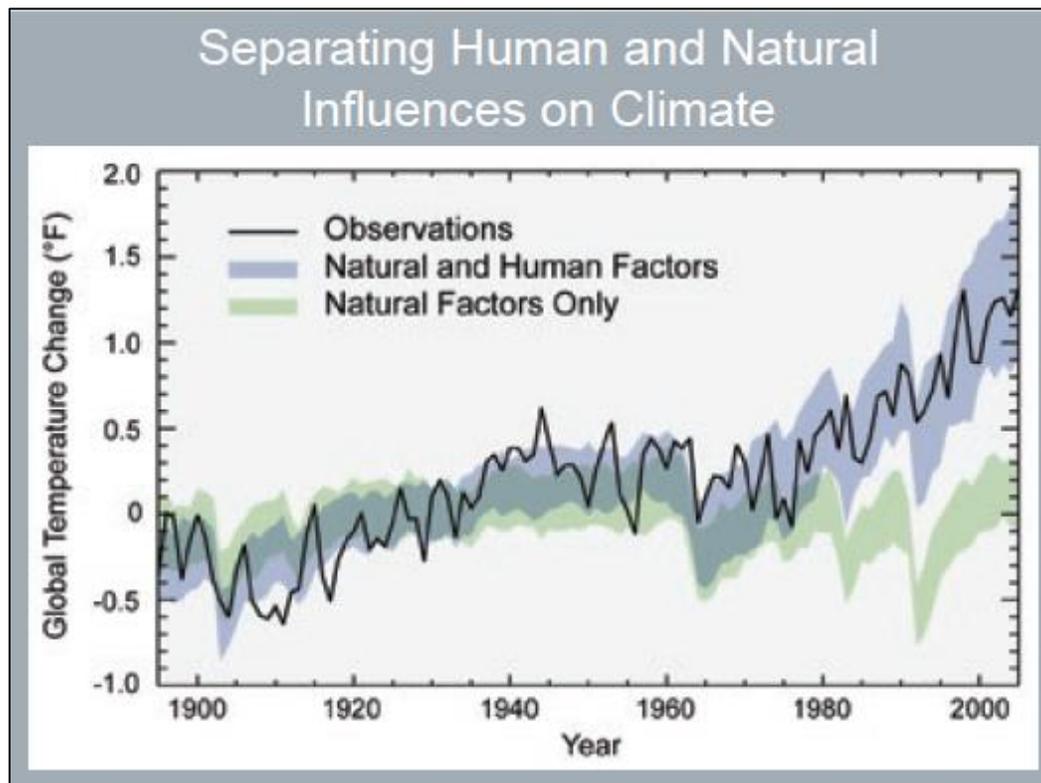
(Source <http://www.esrl.noaa.gov/gmd/ccgg/trends/full.html>)



In general, increases in heat-trapping gases are attributed to the burning of fossil fuels, deforestation, warming oceans, intensive agriculture, animal agriculture, mining, and transportation (IPCC, 2014). Most climate scientists believe that the rise in the global average temperature observed over the last 50 years “is due primarily to human-induced emissions of heat-trapping gases” (Karl et al., 2009, p. 9). Figure 2 contrasts global temperature changes attributable to natural forces (in the green) with the combination of natural and human forces (in the blue) overlaid with what has actually been observed (the black line). Natural influences alone are not great enough to explain the change in global temperature currently being experienced (IPCC, 2014; Karl et al., 2009).

Figure 2 - Impacts of Human and Natural Influences on Climate

(Source: Melillo, Richmond, and Yohe, 2014, p. 8)



Changes in climate mean more than just changes in the average global temperature.

Other changes expected on a global scale are warmer days and nights, increased heat waves and droughts, more heavy precipitation events, increased tropical cyclone intensity, and a greater occurrence of high sea levels, just to name a few (IPCC, 2014). Large scale impacts projected to occur due to these changes include decreased water availability and increased water stress, coral bleaching and mortality, weakening of ocean circulation, decreased production of food, large loss of coastal land, increased and greater spread of disease, and an increase in morbidity and mortality from extreme events. These impacts will vary based on mitigation and adaptation tactics that may be employed as the average global temperature rises.

Mitigation and Adaptation to Climate Change

Climate change is not a problem without solutions. John Holdren, science advisor to President Obama, voiced the most general options well when he said we can choose to “mitigate, adapt, or suffer” (Cohen, 2010, p. 1). Mitigation is the effort to reduce impacts through planning and management techniques and adaptation is changing or modifying current conditions to fit a determined standard. An example of adaptation is to expand green spaces in urban environments to moderate increases in temperature and output from heat sources (Environmental Protection Agency (EPA), 2014). In terms of planning for and/or adjusting to the impacts of climate change, mitigation and adaptation are inextricably linked. The IPCC (2007) suggests, “mitigation reduces all impacts (positive and negative) of climate change and thus reduces the adaptation challenge, whereas adaptation is selective; it can take advantage of positive impacts and reduce negative ones” (p. 750). The planning of mitigation and adaptation methods presents a significant challenge at all scales and requires an understanding of how the climate system works; it is important to also note that some mitigation and adaptation measures occur without planning as people simply adjust to changing conditions. There are many components to consider when planning mitigation and adaptation strategies to climate change; these include consideration of the stakeholders, spatial and temporal scales, and the nature of the change. Looking for inter-relationships between mitigation and adaptation to avoid potential adverse reactions is also strongly encouraged. For example, an adaptation strategy in response to higher temperatures might be to increase indoor cooling sources; however, this adaptation would negatively impact mitigation efforts to reduce energy use (IPCC, 2014) and thus illustrates the idea that mitigation and adaptation are complexly connected.

There are numerous mitigation and adaptation techniques. Most are dependent on the nature of the situation being experienced, so local and regional knowledge matters greatly. The mitigation strategies promoted by the United Nations Environmental Program (UNEP, 2013) include increasing the use of renewable energy, reducing agricultural waste and inefficiency, preserving existing forests, re-designing manufacturing processes, increasing the use of low or no-carbon transportation, encouraging sustainable tourism, promoting more efficient modification to or production of more efficient buildings, and reducing waste and recycled materials, for instance. Examples of adaptation possibilities from the United States Environmental Protection Agency (EPA, 2014) are to breed more weather tolerant crop varieties, implement a greater number of shore protection techniques, increase national migration corridors for wildlife, increase energy efficiency, expand green spaces, and enhance water storage capacities.

Changing Climate Conditions in Kansas

Climate change impacts will be felt globally and the state of Kansas is no exception. In a century of record keeping, a rise of one degree Fahrenheit on average can be seen across the state, with the summer and fall seasons experiencing the most significant warming (Brunsell, Feddema, Jackson, Jones, and Logan, 2008). Given the topographic differences between the wetter, cooler, and lower elevation eastern part of the state and the drier, warmer, and higher western part of Kansas, the effects of climate change will be felt at all levels of scale, from regional to local. However, the general effects are projected to be the same across the state (Table 1).

Table 1 - Kansas Climate Change Expectations by 2100

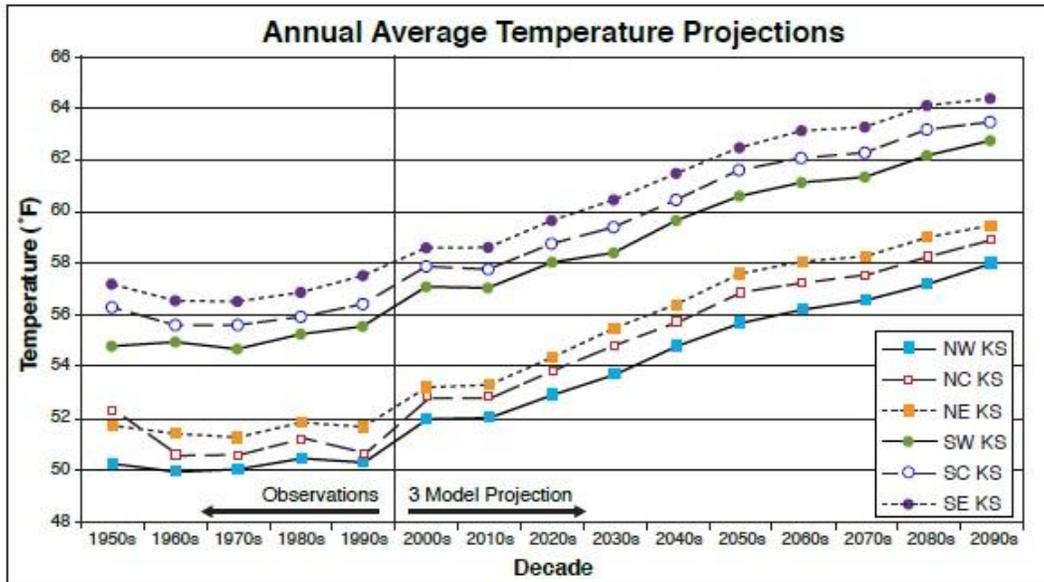
(Source: Modified from Brunsell et al., 2008, p. 2)

Climate Change Projections for Kansas by 2100
• Increased temperatures
• Fewer frost days
• More heat waves
• More intense storm cycles – precipitation intensity increases, while frequency decreases
• Higher probability of flooding
• Less predictable precipitation patterns
• Higher evapotranspiration rates
• Decreases in soil moisture and annual moisture supply
• Need for more water with less total moisture available

Overall weather patterns are projected to increase in variability (Brunsell et al., 2008; Feddema, Brunsell, Jackson, and Jones, 2008), especially related to temperature and precipitation. As shown in Figure 3, the projected rise in the average temperature for all regions of the state is between two and four degrees Fahrenheit by 2100. Although precipitation totals are expected to remain about the same, the precipitation events are expected to become less frequent but more intense with longer dry periods between each storm. It is also likely that there will be less snowfall (Brunsell et al., 2008). With a rise in temperatures there will be an increase in evapotranspiration rates; the altered pattern of rainfall will not be able to keep up with this increase in evapotranspiration, thus modifying the water cycle. Given these changes, heat waves and drought are expected to increase as well (Brunsell et al., 2008).

Figure 3 - Temperature Projections for the Six GCM Grid Cells of Kansas

(Source: Brunsell et al., 2008, p. 9)



The rise in temperature will cause an increase in the number of cooling degree-days and decrease in the number of freezing days. Fewer freezing days means a decline in the number of hard freezes, which will increase the number of insects and related disease in the state. Higher temperatures exaggerate health problems, affecting both humans and other animals. There is the potential for increased incidence of heart disease, respiratory ailments, and epidemic diseases (Brunsell et al., 2008; Center for Integrative Environmental Research (CIER), 2008).

Furthermore, the warmer temperatures will impact the growing cycle of plants and put stress on livestock and crops (Brunsell et al., 2008). The same impacts will be felt among wildlife. The changes may alter their natural ranges, which could make way for more invasive species (Brunsell et al., 2008). Finally, with alterations to the water cycle there will be less available moisture, which will greatly impact cities, agriculture, and the natural environment (Brunsell et al., 2008; CIER, 2008).

Climate change is expected to put significant stress on Kansas. However, it is “important to remember – these are projections. They are not predictions. If we change how we use energy and if we reduce our emissions, then we still have the power to alter these outcomes” (Brunsell et al., 2008, p. 2). Mitigation and adaptation steps that could be taken include reducing greenhouse gas emissions, increasing energy use efficiency, employing enhanced water management plans, implementing more renewable energy sources, changing agricultural practice, and modifying animal agriculture methods (Brunsell et al., 2008; Feddema et al., 2008).

Disagreement about Climate Change

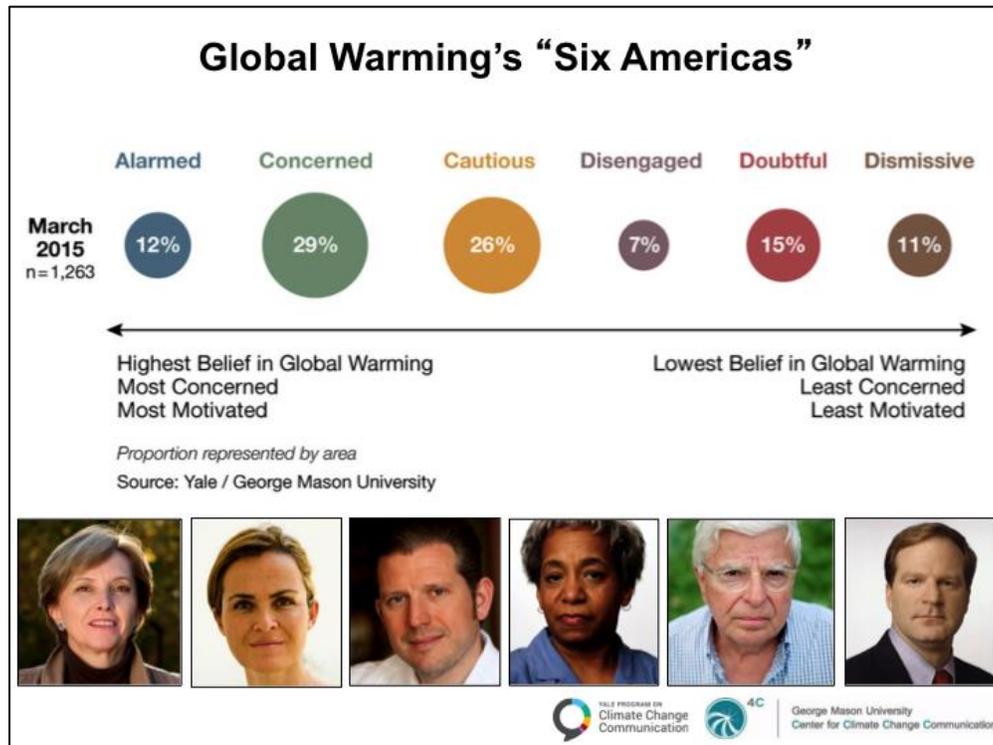
There are numerous reasons why people have doubted and continue to question whether climate change is occurring. Climate change is not the first scientific understanding to be questioned, denied, or even violently rejected by the public – examples include Galileo and the heliocentric theory of the solar system, Einstein and the theory of relativity, and Darwin and the theory of evolution (McCaffrey, 2012; Sherwood, 2011). However, any disagreement from the public aside, the scientific community is in agreement that climate change is occurring (Oreskes, 2004). This conclusion is based on a series of long-term observations (Anderegg et al., 2010; Oreskes, 2004). Given the consensus among scientists and the still controversial position of climate change among the general public, there has been much research completed in recent years over what society perceives about climate change and why those perceptions exist.

According to three Gallup polls, America’s level of concern about climate change has varied over time. In 2004, 26% of the U.S. population “worried a great deal” about climate change; in 2007 this value increased to 41%; and then in 2010 those who “worried a great deal” only accounted for 28% of the population (Brulle, Carmichael, and Jenkins, 2012). Similarly,

Leiserowitz et al. (2011a) report varying levels of concern about climate change using a six point spectrum called the “Six Americas” (Figure 4).

Figure 4 - “Six Americas”: Proportions of U.S. Population by Feelings about Climate Change in 2015

(Source: <http://climatecommunication.yale.edu/visualizations-data/six-americas/>)



Why do people feel the way they do about climate change and why are their feelings so inconstant? Hulme (2009) framed several reasons why people disagree about climate change. He reasoned that people often feel that science is not eliciting the results and innovations that they expect from it and tend to lose personal belief in the validity of scientific research and findings. He also suggested that the public frequently receives conflicting messages about climate change from the media, which increases the potential for their inconsistent feelings. Furthermore, people have different values and beliefs that they relate to climate change as they

evaluate risks, mitigation, and adaptation options from different perspectives (Hulme, 2009). Couple these reasons together and there is rationale for why people's feelings are variable.

Somerville and Hassol (2011) agreed, stating that “in difficult times, people seem more likely to reject science” (p. 48), whether it is because they are concerned about the potential impact of its findings or because it feels like just one more thing about which to worry. Additional factors stirring disagreement about climate change include the well-funded and organized disinformation campaigns that have been waged (Oreskes and Conway, 2010), the fact that much of the general population lacks science and climate literacy (Bybee and Fuchs, 2006; McCaffrey, 2012; McCaffrey and Buhr, 2008), and that for much of human history significant and traumatic weather events have been seen as “acts of God” (Somerville and Hassol, 2011). Climate change has also been portrayed as a controversial debate topic in the media, which has encouraged doubt amongst the public. Furthermore, given that scientific communication about climate change is often complex in nature, there have been many misunderstandings and misconceptions generated about climate (Harrington, 2009). Finally, Somerville and Hassol (2011) conclude that people care most about what climate change means to them personally. They emphasize the idea that climate change is frequently portrayed as an environmentally-focused issue rather than “an issue threatening the economy and affecting humanity's most basic needs: food, water, safety, and security” (p. 49).

A study conducted by Brulle et al. (2012) specifically examined factors as to why public opinion on climate change has shifted throughout the prior decade. Using aggregate opinion measures from a collection of 74 surveys given over a nine year period, five factors were examined: 1) extreme weather events, 2) public access to accurate scientific information, 3) media coverage, 4) elite cues (following the actions of the major political party and/or higher

social class), and 5) movement/countermovement advocacy. The results showed that elite cues and structural economic factors had the greatest effect on public opinion, with media coverage as the next most influential factor. Dissemination of scientific information had minimal impact. Also of note, the higher the educational level of individuals, the more likely they were to take elite cues in how they respond to climate change (Brulle et al., 2012).

It is clear that Americans have differing opinions about climate change and that those feelings fluctuate. Disagreements over science will always occur. In the meantime “we must find ways to help the public realize that not acting is also making a choice, one that commits future generations to serious impacts” (Sommerville and Hassol, 2011, p. 53). A study published in 2013, (Pytlikzillig, Steffensmeier, Hibbs, Champion, Hunt, Harrington, Spears, Umphlett, Abdel-Monem, Bruning, and Kahl) took a public engagement approach to determining needs in climate change education focused on the regional population of the Central Great Plains (CGP). As part of this Climate Change Education Project (CCEP), a series of focus groups with science and agricultural educators, community members, and agricultural producers were conducted, from which four prominent themes were identified. The first theme, trust, demonstrated participant desire for unbiased, non-politicized, and reputable information from a reliable source. Deliberative formats, the second theme, were that participants wanted to be able to decide on their trusted sources and the impacts of the information on their own. The third theme was personal and local relevance, which suggested that participants were interested in and influenced by how their local landscape and activities would be impacted more so than changes at a global scale. And finally, ease of access to accurate and reliable data was important. The researchers found that the “themes that emerged from the focus groups not only provide direction for

developing effective climate change education programs in the CGP, but also demonstrated the need and desire for such climate change education” (Pytlikzillig et al., 2013, p. 171).

Climate Change Education

The idea of anthropogenic forcing of the climate system has been part of science education, however inconsistently and variably, for nearly 60 years” (McCaffrey and Buhr, 2008). Teaching climate change in the 7-12 classroom, however, has not yet become a widespread practice. The controversy surrounding climate change can evoke powerful emotions, causing occasional conflicts over its teaching within school systems and communities. A 2011 poll by the National Science Teachers Association reported that 82% of teachers who responded had faced skepticism about climate change from students and 54% from parents (Petrinjak, 2011). Climate change is typically not listed in state science standards, receives very little attention in most science textbooks (McCaffrey, 2012; McCaffrey and Buhr, 2008), and has only recently appeared in national science standards (Next Generation Science Standards (NGSS), 2013a). Teachers have little training in teaching climate change and face public and curricular pressures to teach the topic one way or another. Additionally, climate change is a multi-disciplinary (e.g, geography, atmospheric science, chemistry, agronomy, education), complex subject, which can be challenging to teach without the confidence of a clear understanding of the content (McCaffrey, 2012; McCaffrey and Buhr, 2008; Schreiner, Henriksen, and Kirkeby Hansen, 2005).

The NGSS are a set of “voluntary, rigorous, and internationally benchmarked standards for K-12 science education” (NGSS, 2013a, p. 1). These standards are expressed as student performance expectations that integrate science and engineering practices, disciplinary core ideas, and cross-cutting concepts (NGSS, 2013a). With the release of the NGSS and adoption as

the state science standards in Kansas in 2013, science teachers will be required to integrate climate change into their curriculum. Four student performance expectations address climate change explicitly; most of the language directly specifying climate change can be found in the clarification statements for each standard (Table 2). A number of performance expectations are related to climate change, but do not reference it specifically.

Table 2 - Climate Change in the Next Generation Science Standards

(Source: Next Generation Science Standards, 2013b)

Student Performance Expectations that Address Climate Change	
Student Performance Expectation	Clarification Statement
MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.	“Examples of factors include human activities and natural processes... emphasis on the major role that human activities play in causing the rise in global temperature” (p. 6).
HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth’s surface can create feedbacks that cause changes to other earth systems.	“Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth’s surface, increasing surface temperatures and further reducing the amount of ice...” (p. 8).
HS-ESS2-4. Use a model to describe how variation in flow of energy into and out of Earth’s systems result in changes in climate.	“Examples of the causes of climate change differ by timescale...” (p. 10).
HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.	“Examples of evidence, for both data and climate model outputs, are for climate changes... and their associated impacts” (p. 10).

What do climate change educators need in order to feel prepared and confident to teach and discuss climate change? By further exploring the teacher-specific data gathered by Pytlikzillig et al. (2013), agriculture and science teachers expressed the desire for educational

materials that: 1) are tailored to specific course content, 2) emphasize the nature of science/process of inquiry as vehicles through which to address climate change, 3) explore the relative impact humans have on climate change, 4) integrate locally specific or regional climate data into classroom activities, 5) engage students in critical analyses of the credibility of information and the inferences or conclusions drawn from that information, 5) examine climate data that is integrated into agricultural productivity data, and 6) include labs or hands-on activities that enable students to collect data and draw inferences (J. Spears, personal communication, December 9, 2014). The expressed interest in materials that emphasize the process of inquiry is consistent with the student performance expectations in NGSS.

Interest in climate change education has been increasing and a number of educational materials are available. Government and private entities, like the U.S. Global Change Research Program and the Climate Change Science Program have started to generate materials supporting the teaching of climate change. Teacher education associations and journals are also beginning to contribute support and materials for climate change education, including the National Science Teachers Association, the National Earth Science Teachers Association, and the National Council for Geographic Education. Journals that have published dedicated issues and invited articles on this topic include *Physical Geography*, the *Natural Inquirer*, and the *Earth Scientist*. Furthermore, there are a number of reputable internet-based climate change education networks, including the Climate Literacy and Energy Awareness Network (CLEAN) (<http://cleanet.org/index.html>). In general, lessons relevant to climate science and climate change exist in larger numbers than lessons specific to the human impact on climate change. However, lessons related to climate science and climate change specific to Kansas are relatively

few (J. Spears, personal communication, December 9, 2014). Integrating locally specific or regional climate data into the classroom is a challenge.

Geographic Information Systems

Geographic information systems (GIS) are any system capable of integrating, storing, editing, displaying, analyzing, and sharing geographically referenced information. Today GIS is almost always related to a computer program, however the first successful identified use of a GIS was completed in 1854 with the use of paper maps during a cholera outbreak in London. Dr. John Snow mapped the relationship between cholera deaths and water pumps using multiple map overlays, enabling him to visualize and establish cholera as a water-borne pathogen, stopping the outbreak. Then, in 1969, Ian McHarg presented the idea of transparent overlays of data in his book Design with Nature (McHarg, 1969). GIS was founded on using these paper-based overlays until computerized GIS became increasingly available. GIS is both a tool and a science, as Geographic Information Science was first acknowledged as a separate science from the technology in 1992 (Goodchild, 1992).

The role of GIS as it pertains to education can be described as combining “computerized maps of different phenomena, from local to global, together with computer software that allows a user to create, interact with, and analyze the mapped data to make decisions based on spatial patterns” (Baker, Kerski, Huynh, Viehrig, and Bednarz, 2012, p. 256). Current research suggests that using GIS in the classroom “helps students think critically, use authentic data, and connects them to their own community” (Baker et al., 2012, p. 255). McClurg and Buss (2007) state four reasons why GIS is important in the K-12 environment: 1) GIS is a powerful tool for analyzing conditions, changes, and looking for solutions, 2) local applications of GIS enable students to complete in-depth studies of local issues, 3) GIS technology used in a meaningful nature

enhances student interest and understanding of geography and geographical concepts, and 4) students who gain familiarity with useful technologies and their applications will be more likely to use them later in life. GIS has been recognized as a classroom tool and method that effectively teaches geography (Battersby, Mohan, Cooper, Curtis, Lane, Tabor, and Wessell, 2013; Schell, Roth, and Mohan, 2013). GIS has been successfully used in the classroom with problem-based learning (Baker and White, 2003; Drennon, 2005; Liu, Bui, Chang, and Lossman, 2010; Read, 2010) and inquiry-based instruction (Edelson, Gordin, and Pea, 1999; Edelson, 2001). Battersby et al. (2013) suggest that using geospatial technology, like GIS, for problem-solving in the classroom encourages spatial thinking and higher-order thinking skills.

Using GIS to Understand and Teach Climate Change

A GIS-based approach to learning about, analyzing, and understanding climate change provides a tool for focusing on the entire scope of climate change concerns in a holistic manner, while offering the ability to also concentrate on different levels of scale (Dangermond and Artz, 2010). “The key to understanding our dynamic climate is creating a framework to take many different pieces of past and future data from a variety of sources and merge them into a single system” (Dangermond and Artz, 2010, p. 7). GIS can be used to assess climate change and plan for mitigation and adaptation measures. Use of GIS is helpful to understanding climate change through its powers of visualization and modeling. Visualization, as part of GIS, is used to organize, analyze, and display maps of spatial data layers and related information (Esri, 2014). Modeling in the context of GIS can occur when the execution of the algorithm in the GIS is meant to mimic processes in the real world (Goodchild, 2005).

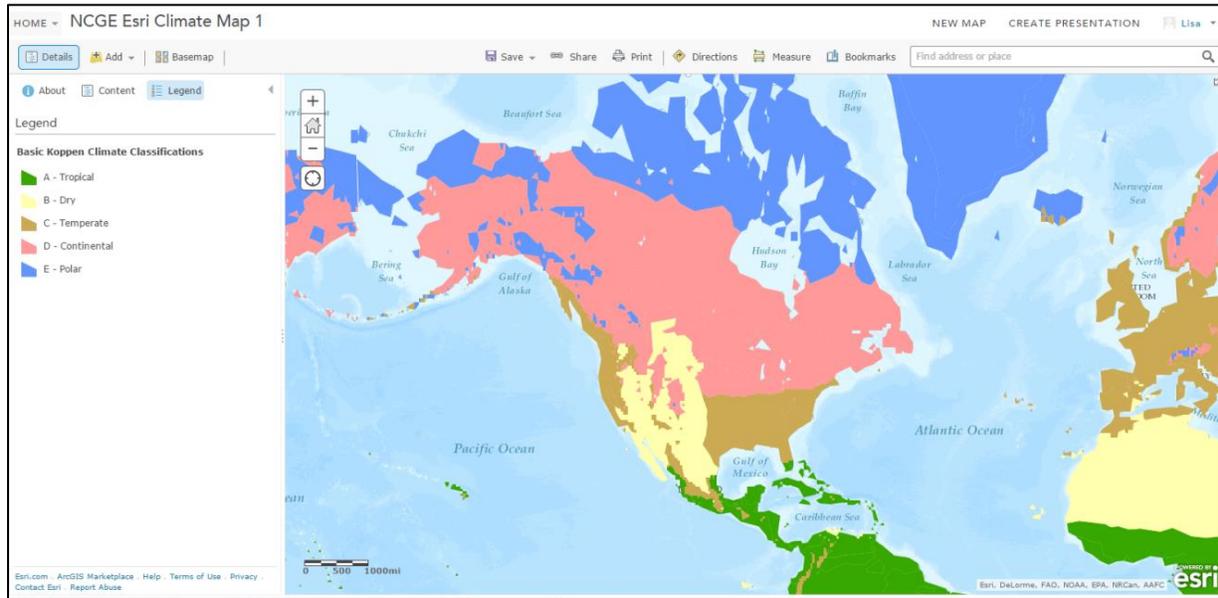
Visualization and modeling have been consistently used in climate science research and is frequently suggested as a strong method of communicating climate knowledge to the public

(Edelson, Gordin, and Pea, 1999; Nocke, Sterzel, Bottinger, and Wrobel, 2008). Sinton (2009) discussed the strength of GIS visualization, stating that

even at the most basic level, GIS software displays digital images of mapped objects and attributes, allowing students quickly and easily to visualize spatial patterns from large, complex, multi-layered datasets...They do not require changing the content of what is being taught, but they will provide students with a visual appreciation for how geography influences that content (p. S9).

Figure 5 is an example of a GIS map illustrating the most general Köppen climate classification for North America using the program ArcGIS Online. The Köppen climate classification system classifies and divides the world based on temperature and precipitation records. Though the Köppen climate classification system can be very specific, this map uses five basic distinctions: tropical (A), dry (B), temperate mesothermal (C), continental microthermal (D), and polar (E) climates. Other real life examples of analyzing climate change using a GIS include mapping Arctic sea ice shelf breaks and monitoring national carbon sequestration (Dangermond and Baker, 2010).

Figure 5 - Two Dimensional GIS Visualization Using ArcGIS Online of Basic Köppen Climate Classifications for North America



There are limited examples of using GIS to teach about climate and climate change in the literature (Bodzin and Anastasio, 2006; Edelson et al., 1999; Esri Education Team, 2012). Bodzin and Anastasio (2006) discuss the success of using web-based GIS-inquiry educational modules with pre-service teachers to teach earth science and environmental systems content focused on authentic local issues. Use of the modules increased the pre-service teachers' sense of personal involvement with the topic, improved their investigation skills and understanding of a real problem, and improved their knowledge of spatial concepts and data analysis. Edelson et al. (1999) used GIS visualization to help school age students understand climatology content and scientific practices. The study explored challenges in the classroom to using science-based inquiry to implement a specific program to teach the content, determining that challenges could be reduced.

Research Problem

Climate change education is not currently routine in the classroom (McCaffrey, 2012; McCaffrey and Buhr, 2008); yet scientists, educators, and societal members want to better integrate the topic into the curriculum (Leiserowitz et al., 2011b; Schreiner et al., 2005). Moreover, climate change is an explicit part of the NGSS currently being implemented in Kansas. Focus groups of educators in Kansas have called for educational materials on climate science that are locally relevant. Given the lack of locally focused materials, the accessibility of the integration of GIS technology in the classroom – with its capacity to visualize and provide students with easy analysis capabilities of climate change data from the local to global scale – is theoretically ideal for teaching climate change. This research explored the use of GIS in teaching climate change with a local perspective. The ultimate goal of this research was to **determine if a GIS-based framework is a practical, reproducible, and effective method for focusing climate change education on local conditions in the 7-12 classroom.**

Purpose of the Study

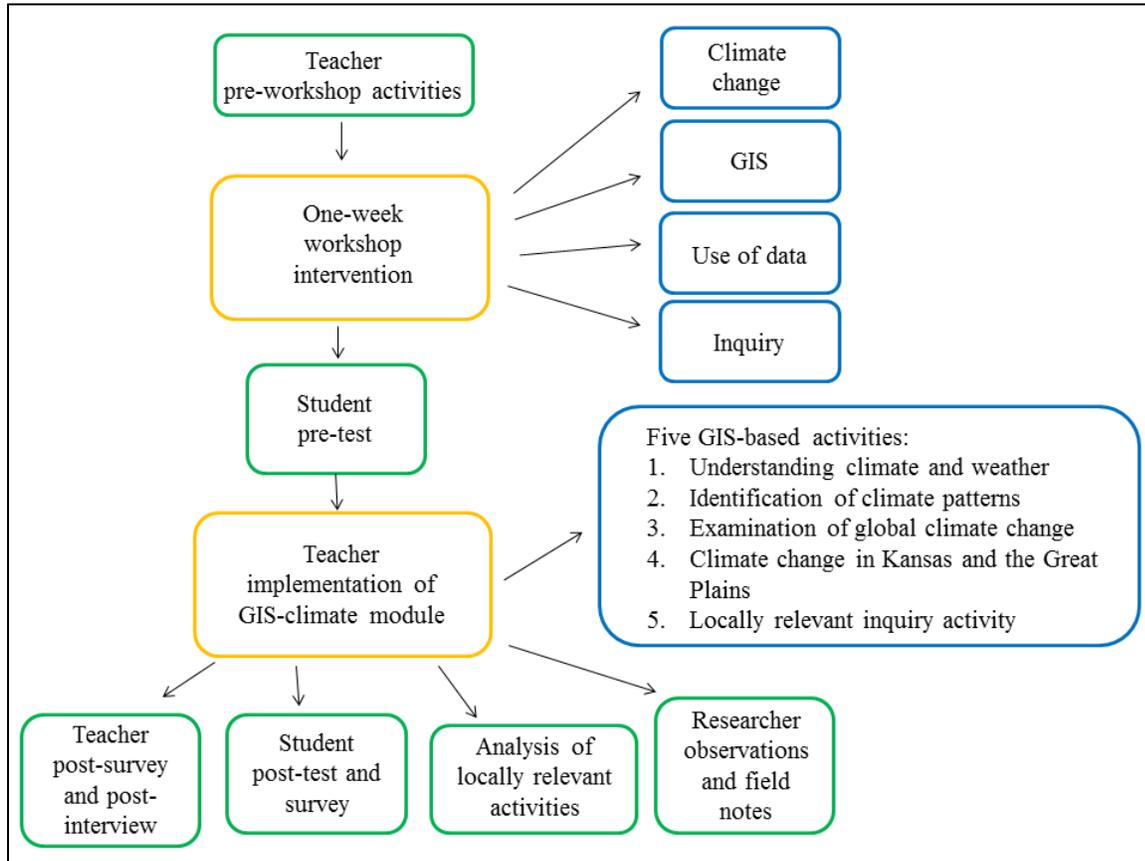
The purpose of this study was to document the practicality for teachers, reproducibility in the classroom, and effectiveness on students to using a GIS-based framework to teach climate change at the 7-12 level in order to focus on locally relevant data and conditions. It examined how a GIS-based framework impacts the teaching and learning of the climate change content. Teachers evaluated implementation and provided insights, focusing on successes and challenges. Students were assessed for knowledge gains and changes in perceptions.

Description of the Study

Figure 6 presents the research design of the study. A one-week workshop intervention for 12 middle school and high school science teachers was held at Kansas State University.

Teacher recruitment and selection was based on a background in and/or current teaching within a discipline of science (i.e., biology, physics, physical science, life science, chemistry, earth science, environmental science, and/or agricultural science), an interest in enhancing how they teach climate and climate change, and an interest in using GIS in the classroom. The workshop was followed by implementation of a GIS-climate module that uses a GIS-based framework. The workshop took place during June 15-19, 2015, and classroom implementation occurred from August through November 2015. The workshop focused on climate change, GIS, use of data, and inquiry-based lessons. Teachers were provided with a GIS-climate module consisting of five GIS-based activities.

Figure 6 - Research Design of the Study



Research Questions

1. Did completion of the GIS-climate module contribute to the growth of the students' knowledge and dispositions about climate change?
2. How did the workshop participation and implementation of the module impact the teachers' perception about teaching the climate change content integrated with GIS technology within their classroom?
3. What successes and challenges were identified in order to implement the use of a GIS in the 7-12 classroom for both teachers and students?

Data collected at multiple times throughout the project were used to answer the research questions. The first research question was student oriented and student knowledge gains were assessed over the climate change content, as well as their attitudes toward climate change and the use of GIS. Student data was accumulated through the use of one pre-test, one post-test and one post-survey. The second research question was teacher oriented and teacher perceptions regarding their participation in the workshop intervention, the feasibility of using the GIS-climate module, and the successes and challenges they experienced in order to implement the use of GIS in their classroom were collected. These data were gathered through surveys and interviews once the teachers completed the workshop and implemented the GIS-climate module. Lastly, the third research question was classroom oriented and a qualitative analysis of the inquiry activity created by each teacher and classroom observations by the researcher were used to characterize how Activity 5, the locally-focused activity, was implemented and connected to local phenomena.

Significance of the Study

Our duties as educators is to convey the complex, often challenging and sometimes counter-intuitive consensus of current scientific research so that students can master the content and gain proficiency to help them become more scientifically literate individuals, as well as better informed and better prepared citizens (McCaffrey, 2012, p. 28).

There is a global concern about the current and future impacts of climate change, and the United States needs to be prepared to handle these issues. In order to best understand, plan for, mitigate impacts on, and adapt to our changing world, there needs to be an educated population that understands the climate system, the changes that are occurring, and possible pathways to

move forward. Fortunately this need is starting to be recognized within the education community and in the national science standards. As an increasing number of teachers start to include climate change in their classroom, they need reputable information, materials, tools, and methods with which to teach climate change. This research will contribute to efforts that enable teachers in Kansas to teach climate change and empower their student populations through learning with and about locally relevant knowledge.

This research will contribute to the growing body of literature on this relatively new educational topic. The contributions will include, but are not limited to: building climate change education pedagogy, examining the importance of the local perspective in climate change education, and documenting GIS education content and pedagogies. Furthermore, this research will benefit teachers who participated in the study and their students, the state of Kansas and its implementation of the Next Generation Science Standards through increased availability of local data that is classroom ready. Finally the research will benefit society as a whole by contributing to the growth of a more climate literate population.

Definition of Terms

Climate Change: “A significant and persistent change in the mean state of the climate or its variability. Climate change occurs in response to changes in some aspect of Earth’s environment: these include regular changes in Earth’s orbit about the sun, re-arrangement of continents through plate tectonic motions, or anthropogenic modification of the atmosphere” (USGCRP/CCSP, 2009, p. 17).

Geographical Information Systems (GIS): “GIS combines computerized maps of different phenomena, from local to global, together with computer software that allows a user to create,

interact with, and analyze the mapped data to make decisions based on spatial patterns” (Baker et al., 2012, p. 256).

GIS-based Framework: Refers to a GIS-centric teaching approach focused on teaching *with* GIS, not *about* GIS; specific to this research in the form of a GIS-climate module.

Summary

Scientists agree that there is ample evidence of climate change and that a significant portion of the change is anthropogenically driven. The expected impacts of climate change in Kansas include increased temperatures, higher likelihood of flooding, and less predictable precipitation variations (Brunsell et al., 2008; Feddema et al., 2008). Although there is scientific consensus, public perceptions about whether climate change is occurring vary significantly among groups and can even fluctuate for a single individual over time. Leiserowitz et al. (2011b) asked teenagers about their understanding of the climate system and the causes of climate change. Fewer than 20% classified themselves as “very well informed” and only 27% reporting that they learned “a lot” about climate change in school. However, of these teenagers, 70% expressed a desire for more climate change education.

Even though the idea of human impacts on the climate system and a changing climate has been known and discussed within science education for several decades, dedicated classroom time for teaching climate change is not a common practice. Kansas’ adoption of the NGSS will include that climate change become part of the middle and high school science curricula, though without additional training teachers will only be able to teach what they know. Focus group discussions with science and agricultural education teachers (Pytlikzillig et al., 2013) emphasized the need for use of locally relevant data in the classroom as a means to engage students in critical thinking activities that require them to use and draw conclusions from these

data. However, most teachers do not have access to such data or a working knowledge of technological platforms from which they can have the students observe, manipulate, and analyze these data. This need can be met by GIS. The purpose of this study was to examine the impact on classroom teaching and learning of a GIS-based framework to teach climate change through a focus on locally relevant data and conditions.

Chapter 2 - Review of the Literature

As the world becomes increasingly scientific and technological, our future grows more dependent on how wisely humans use science and technology. And that, in turn depends on the effectiveness of the education we receive (Nelson, 1999, p. 14).

This research takes a constructivist perspective and seeks to relate three major components: climate change education, GIS, and an inquiry point of view. The following is a review of climate change education with a focus on climate literacy, climate misconceptions, framing communication about climate change, educational methods, and empirical research that were used to inform the design of this study. The position of climate change education is discussed within science education in the United States, Kansas, and the Next Generation Science Standards. GIS education and an introduction to discussion of inquiry in science education are also described.

Constructivist Approach

Learning is not a linear process. Prior knowledge and experiences impact the construction of learning and understanding (Brooks and Brooks, 1999). Savery and Duffy (1995) define constructivism as the “philosophical view on how we come to understand or know” (p. 31). They characterize this way of knowing through three major points: 1) understanding is achieved through interactions with the environment, 2) cognitive questioning is a significant stimulus for learning and aids in determining what is learned and how it is stored within our memory, and 3) knowledge grows through social interactions and personal evaluation of what we learn and understand.

A constructivist perspective of learning underlies the recent calls for reform and transformation in science education, as “at its core, the constructivist position argues that

knowledge is not transmitted directly from one person to another but must be actively built by the learner” (Lehman, George, Buchanan, and Rush, 2006, p. 77). Brooks and Brooks (1999) suggest five guiding principles of constructivism: 1) pose problems of emerging relevance to students, 2) structure learning around primary concepts, 3) seek and value students’ points of view, 4) adapt curriculum to address student suppositions, and 5) assess student learning in the context of teaching. Brooks and Brooks (1999) also share a few key classroom actions of constructivist teachers, which include framing tasks so students engage in activities that have them classify, analyze, and predict; inquiring as to students’ conceptions before sharing their own; having students engage in meaningful dialogue and discussion; and nurturing natural curiosity and interest of the students on a particular topic. The direction of questioning in a constructivist activity is essential not only to constructing the knowledge that the teacher hopes the student will gain from the activity itself, but also to building a greater sense of understanding the relevance that the knowledge has in application to the real world. This focus can be demonstrated when assessing students on what it is that they know, rather than whether they know the material (Brooks and Brooks, 1999).

The role of constructivism in this research can be seen in the major educational components of the study: climate change, GIS, and inquiry. Students enter the classroom each day with their own set of perceptions and understanding of the world, all varying and depending on their prior personal learning experiences. Students tend to hold on to their understandings, whether correct or not, throughout their formal education (Staver, 1998). Conceptions of climate are no exception. This practice of building knowledge through an active learning process differs from the traditional education, which encourages students to imitate their teachers. Constructivism promotes deeper understanding over memorization (Brooks and Brooks, 1999).

The five guiding principles of constructivism (Brooks and Brooks, 1999) align well with inquiry activities. Recent pushes for changes in science pedagogy “emphasize engaging students in inquiry to promote active development of understanding by individuals, and having students collaborate while learning to promote communication and the development of shared learning” (Lehman et al., 2006, p. 77). Moreover, the use of the constructivist approach will be helpful in implementing the Next Generation Science Standards, as they require that students’ knowledge builds on the previous years’ learning. This perspective is extended to GIS, as it is a 21st century skill that can be cultivated by the students through the use of real data and relevant applications to contemporary problems. GIS also requires students to use critical thinking and problem solving skills to answer their questions. Multiple studies support the use of GIS as a constructivist educational tool in the classroom (Baker and Kerski, 2014; Bednarz and Ludwig, 1997; Kerski, 2003; Meyer, Butterick, and Zack, 1999). The use of local data to study and learn about climate change is also driven by constructivism as the students are engaged in constructing their own learning as they investigate a dataset and its possible implications.

Inquiry Activities in the Classroom

Inquiry-based lessons enable students to participate in open-ended, hands-on activities that allow them to do their own analyses and come to their own conclusions (Colburn, 2000), which is a constructivist learning experience. Inquiry is consistently identified as an important process within science and is widely suggested for use in most standards (Colburn, 2000; Windschitl and Buttemer, 2000). However important inquiry is in the classroom, inquiry-based lessons can be difficult for teachers to implement well (Bell, Smetana, and Binns, 2005). A full understanding of the differing levels of inquiry can assist teachers with better implementation of inquiry activities.

Four levels of inquiry can be used in the classroom based on the amount of information provided to the student and the degree of complexity of the problem: confirmation inquiry, structured inquiry, guided inquiry, and open inquiry (Bell et al., 2005). The amount of information students are provided at each level of inquiry instruction is broken into three categories, question, method(s), and solution. Table 3 shows what categories of information the teacher provides to the students at each level of inquiry by using the “X” as an indicator. All levels of inquiry activities will engage students in a personally meaningful way, build confidence in science as a way of knowing, and provide students with time to “do science” and act as scientists do (Windschitl and Buttemer, 2000).

Table 3 - Differences in Information Provided to Students in Inquiry Instruction

(Source: Modified from Bell et al., 2005, p. 32-33)

Amount of Information Provided to Students at Different Levels of Inquiry Instruction			
Level of Inquiry	Question	Method(s)	Solution
1: Confirmation Inquiry	X	X	X
2: Structured Inquiry	X	X	
3: Guided Inquiry	X		
4: Open Inquiry			

Inquiry requires that activities be flexible yet systematic, always start with a question, and typically use real life data (Bell et al., 2005). Inquiry-based instruction is built around three sequential components: 1) exploring the question and what it concerns, 2) investigating the conditions for answers, and 3) presenting and defending the answers to an audience (Pyle, 2008; Windschitl and Buttemer, 2000). Suggested classroom practices to enhance the strength of the inquiry implementation are to guide students in understanding and creating meaningful questions that elicit deeper answers than only description-based responses and to encourage students to make their own decisions regarding methods and practice trial and error as needed. Aiding the students in seeing the process as a whole and not individual steps to accomplish, orienting them

to developing written scientific reports, and discussing their findings with their peers in a presentation also are recommended (Bell et al., 2005; Windschitl and Buttemer, 2000).

The inquiry framework adopted for this study was structured inquiry, which occurs when “students investigate a teacher-presented question through a prescribed procedure” (Bell et al., 2005, p. 33). Bell et al. (2005) classified structured inquiry as a basic or entry-level form of inquiry instruction in the classroom. Given that inquiry is often a difficult pedagogy to implement, the use of structured inquiry should be helpful to equalize classrooms, as it is “valuable to learners who have little experience in developing questions for themselves” (Windschitl and Buttemer, 2000, 346) as well as to assist teachers who are new to using inquiry in their instruction. Furthermore, if a topic is being newly introduced in the classroom where inquiry is not regularly practiced, this classroom would not be well suited for the more advanced levels of inquiry.

Teacher participants in this study were introduced to inquiry and asked to follow the 5 E Learning Cycle Model created by the Biological Sciences Curriculum Study. The five Es are a sequential model used in lesson planning to assist with inquiry activities. In order, they are: 1) engagement, 2) exploration, 3) explanation, 4), elaboration, and 5) evaluation (Table 4).

Table 4 - 5 E Learning Cycle Model

(Source: Bybee, Buchwald, Crissman, Heil, Kuerbis, Matsumoto, and McInerney, 1989)

The Five E Learning Cycle Model		
1	Engagement	Object, event, or question used to engage students where connections are facilitated between with the student knows and what the student can do.
2	Exploration	Phenomena are explored with guided hands-on activities.
3	Explanation	Students explain their understanding of concepts and processes and new ideas and skills are introduced as clarity of material is expressed.
4	Elaboration	Activities allow students to apply concepts in contexts, and build on or extend understanding and skill.
5	Evaluation	Students assess their knowledge, skills, and tasks completed through activities that allow for the evaluation of student knowledge gain and lesson effectiveness.

Integrating Inquiry, GIS Education, and Climate Change Education

In an effort to tie together inquiry in the classroom, climate change education, and GIS education, specific studies using all three components were sought out. Only one scholarly article has linked GIS and inquiry as a pedagogical method for teaching climate change and there was minimal research linking the use of inquiry and GIS as part of climate change education. Edelson, Gordin, and Pea (1999) make a compelling argument for the use of inquiry and GIS for teaching climate in a modular format. Additionally, Porter, Weaver, and Raptis (2012) stated that an inquiry-based approach is appropriate for teaching to correct misconceptions regarding climate in the classroom. Kerski (2003) noted “inquiry-oriented learning through GIS requires teachers and students to tolerate uncertainty, take risks, and to change their traditional roles” (p. 134).

Climate Change Education is Science Education

Science Education in the United States

Science education from the 1990s to present has been dominated by standards assessment testing; an emphasis on science, technology, engineering, and mathematics (STEM); and 21st Century skills. There has been a strong call for science education reform and concern that the

“reform movement has become stalled and politicized” (Hurd, 2000, p. 283). Standards-based testing is highly criticized. Nonetheless, the encouragement towards STEM fields and 21st century skills are beneficial to the science education community.

The focus of education changes over time. In 1958, along with introducing the term scientific literacy, Hurd wrote “there is a concern about the next generation’s ability to continue the accelerated momentum of science” (p. 14). In the last twenty years there have been numerous calls for science education reform given that:

Science today is changing...Less attention is being devoted to the establishment of new theories and laws... Today more attention is focused on the functional aspects of science/technology as it relates to human welfare, economic development, social progress and quality of life... Science is also becoming more holistic in nature, blending the natural and social sciences... These and related efforts influence how we live, learn, and work (Hurd 1997, p. 409).

Socially relevant science, initially promoted during the first half of the 20th century, received emphasis again during the 1970s and 1980s, and is seeing a resurgence today. DeBoer (1991) gives three reasons for teaching socially relevant science: 1) “teaching science in the context of what is already familiar from daily experience...the student is motivated to learn the science that relates to those daily experiences” (p. 234-235) (e.g., media, pollution, recycling, ozone layer, electronic devices), 2) science should enlighten and enhance the student’s daily life, and 3) science is imperative to the quality of life and survival of human society as we know it. Hurd (1998; 2000) supports a similar ‘lived curriculum’ to make science education something to which all students can relate. The American Association for the Advancement of Science, Project 2061, supported the lived curriculum idea and emphasized scientific literacy (AAAS, 2007).

Next Generation Science Standards

In April 2013, the Next Generation Science Standards (NGSS) were released. The goals of the NGSS are to increase U.S. student global competitiveness through teaching deeper content knowledge and the application of science to better prepare students for college and careers. As of 1 April 2016, 17 states – Arkansas, California, Connecticut, Delaware, Hawaii, Illinois, Iowa, Kansas, Kentucky, Maryland, Michigan, Nevada, New Jersey, Oregon, Rhode Island, Vermont, Washington, and West Virginia – and the District of Columbia had adopted the NGSS (Academic Benchmarks, 2016).

The NGSS are comprised of three dimensions: 1) science and engineering practices, 2) crosscutting concepts, and 3) disciplinary core ideas (NRC, 2012). Practices are designed to model the activities in which scientists and engineers engage, crosscutting concepts are interdisciplinary topics that apply to all of the sciences, and disciplinary core ideas are a set of key concepts that are expected to be included in science lessons. The first component, science and engineering practices, was designed to encourage classrooms to operate like laboratories and offices, where students engage in real scientific practices. Among others, these practices include developing and using models, constructing explanations and designing solutions, and analyzing and interpreting data. The disciplinary core ideas are arranged into four categories spanning all grades (K-12): 1) physical science, 2) life science, 3) earth and space science, and 4) engineering, technology and application of science. The NGSS are not a curriculum but rather a framework that is intended to set goals for what students should know in order to be scientifically literate. (NRC, 2012).

The goal of the Next Generation Science Standards is for content to be taught in context and in a manner that the science concepts progressively build from one year of schooling to another. It is believed that a deeper knowledge of scientific inquiry and content application is of

greater importance than the memorization of scientific facts or procedures (NRC, 2012). Each NGSS standard lists three items: 1) performance expectations which specify what students should be able to do; 2) scientific and engineering practices, cross-cutting concepts, and disciplinary core ideas; and 3) linkages with the Common Core Standards. An example of middle school earth and space science standards (one that related to climate change) is provided in Figure 7.

Figure 7 - Middle School Weather and Climate Standard from the NGSS

(Source: Next Generation Science Standards, 2013b, p. 6)

MS.Weather and Climate		
MS.Weather and Climate		
Students who demonstrate understanding can:		
MS-ESS2-5. Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions. [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.]		
MS-ESS2-6. Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates. [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.]		
MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. [Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.]		
The performance expectations above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i> :		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Asking Questions and Defining Problems Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, clarify arguments and models.</p> <ul style="list-style-type: none"> Ask questions to identify and clarify evidence of an argument. (MS-ESS3-5) <p>Developing and Using Models Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.</p> <ul style="list-style-type: none"> Develop and use a model to describe phenomena. (MS-ESS2-6) <p>Planning and Carrying Out Investigations Planning and carrying out investigations in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.</p> <ul style="list-style-type: none"> Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. (MS-ESS2-5) 	<p>ESS2.C: The Roles of Water in Earth’s Surface Processes</p> <ul style="list-style-type: none"> The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. (MS-ESS2-5) Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. (MS-ESS2-6) <p>ESS2.D: Weather and Climate</p> <ul style="list-style-type: none"> Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (MS-ESS2-6) Because these patterns are so complex, weather can only be predicted probabilistically. (MS-ESS2-5) The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. (MS-ESS2-6) <p>ESS3.D: Global Climate Change</p> <ul style="list-style-type: none"> Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth’s mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5) 	<p>Cause and Effect</p> <ul style="list-style-type: none"> Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS2-5) <p>Systems and System Models</p> <ul style="list-style-type: none"> Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. (MS-ESS2-6) <p>Stability and Change</p> <ul style="list-style-type: none"> Stability might be disturbed either by sudden events or gradual changes that accumulate over time. (MS-ESS3-5)
<p><i>Connections to other DCIs in this grade-band:</i> MS.PS1.A (MS-ESS2-5); MS.PS2.A (MS-ESS2-5),(MS-ESS2-6); MS.PS3.A (MS-ESS2-5),(MS-ESS3-5); MS.PS3.B (MS-ESS2-5),(MS-ESS2-6); MS.PS4.B (MS-ESS2-6)</p> <p><i>Articulation of DCIs across grade-bands:</i> 3.PS2.A (MS-ESS2-6); 3.ESS2.D (MS-ESS2-5),(MS-ESS2-6); 5.ESS2.A (MS-ESS2-5),(MS-ESS2-6); HS.PS2.B (MS-ESS2-6); HS.PS3.B (MS-ESS2-6),(MS-ESS3-5); HS.PS3.D (MS-ESS2-6); HS.PS4.B (MS-ESS3-5); HS.ESS1.B (MS-ESS2-6); HS.ESS2.A (MS-ESS2-6),(MS-ESS3-5); HS.ESS2.C (MS-ESS2-5); HS.ESS2.D (MS-ESS2-5),(MS-ESS2-6),(MS-ESS3-5); HS.ESS3.C (MS-ESS3-5); HS.ESS3.D (MS-ESS3-5)</p> <p><i>Common Core State Standards Connections:</i></p> <p>ELA/Literacy –</p> <p>RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts. (MS-ESS2-5),(MS-ESS3-5)</p> <p>RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ESS2-5)</p> <p>WHST.6-8.8 Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources. (MS-ESS2-5)</p> <p>SL.8.5 Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. (MS-ESS2-6)</p> <p>Mathematics –</p> <p>MP.2 Reason abstractly and quantitatively. (MS-ESS2-5),(MS-ESS3-5)</p> <p>6.NS.C.5 Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (MS-ESS2-5)</p> <p>6.EE.B.6 Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. (MS-ESS3-5)</p> <p>7.EE.B.4 Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (MS-ESS3-5)</p>		

It has been suggested that the NGSS coordination, planning, and goals will lead to these standards being more successful in improving science education than previous efforts (Stage,

Asturaias, Cheuk, Daro, and Hampton, 2013). The Next Generation Science Standards were released after the Common Core State Standards for reading and math, which share similar learning perspectives and goals. The GIS-climate module being used for this study is aligned with student performance expectations of the NGSS.

Teaching Climate Change: Lessons Already Learned

Climate Literacy

There is agreement that confusion exists amongst the public in regard to the climate system, the role humans are playing in climate change, and the consensus amongst the scientific community (Harrington, 2008; McCaffrey, 2012; McCaffrey and Buhr, 2008; Niepold, Herring, and McConville, 2007; Niepold, Herring, and McConville, 2008; Sherwood, 2011; Sommerville and Hassol, 2011). This lack of understanding can be attributed to the small amount of climate change education regularly available in schools. Until recently, climate change was not typically found in state science standards. Even less frequently present is the concept of anthropogenic forcing in the climate system (McCaffrey, 2012; McCaffrey and Buhr, 2008).

However well intended, state education standards, which often lag behind the science and are infrequently updated, and high-stakes testing to meet No Child Left Behind requirements, make it difficult to integrate inherently interdisciplinary climate science and related topics in the curriculum (McCaffrey and Buhr, 2008, p. 514).

This lag between scientific research and curriculum is amplified by differences in teacher training programs and course requirements, often leaving science teachers with little or no training from which to draw in fostering climate literacy in their classrooms (McCaffrey and Buhr, 2008).

In order to promote climate literacy and increase awareness, the American Association for the Advancement of Science (AAAS, 2007) released an abbreviated guide for teaching

climate change titled *Communicating and Learning about Climate Change*. The AAAS Project 2061 (2007) provided detailed progression maps on what the public should know in order to be climate-literate. Furthermore, it included climate literacy as part of scientific literacy. Niepold et al. (2007) reinforced the work of the AAAS (2007) and described climate literacy as based on three premises: 1) the planet's climate system is understandable and thus predictable; 2) the climate is composed of multiple complex systems; and 3) climate science is based on peer reviewed empirical evidence that is valid and reproducible.

In 2009, the U.S. Global Change Research Program and Climate Change Science Program (USGCRP/CCSP) set out to describe climate literacy and why it matters to the U.S. public in their work titled *Climate Literacy: The Essential Principles of Climate Sciences*. The USGCRP/CCSP (2009) defines climate science literacy as an “understanding of the climate’s influence on you and society and your influence on the climate” (p. 2). They characterize the climate-literate citizen as someone who:

understands the essential principles of Earth’s climate system, knows how to assess scientifically credible information about climate, communicates about climate and climate change in a meaningful way, and is able to make informed and responsible decisions with regard to actions that may affect climate (p. 2).

The USGCRP/CCSP (2009) concludes with seven essential principles of climate science (Table 5). These seven principles were emphasized during this study’s teacher workshop as an overarching learning objective for students and as a guide to major points in teaching climate science and linking it to climate change.

Table 5 - Essential Principles of Climate Science

(Source: USGCRP/CCSP, 2009, pgs. 8-14)

Essential Principles of Climate Science	
1	The sun is the primary source of energy for Earth's climate system.
2	Climate is regulated by complex interactions among components of the Earth system.
3	Life on Earth depends on, is shaped by, and affects climate.
4	Climate varies over space and time through both natural and man-made processes.
5	Our understanding of the climate system is improved through observations, theoretical studies, and modeling.
6	Human activities are impacting the climate system.
7	Climate change will have consequences for the Earth system and human lives.

Climate and Climate Change Misconceptions

Climate change is a tough subject to teach: it is complex, multi-disciplinary, and has the potential to spark controversy (McCaffrey and Buhr, 2008). Even if a teacher is prepared to teach climate change and does so in a non-controversial manner, the many misconceptions that students are likely to have about climate and climate change can be yet another obstacle.

Students enter classrooms with previous knowledge, not all of which is accurate.

Misconceptions in learning occur as students “search for meaning as they interact with the world around them” (Thompson and Logue, 2006, p. 553), receive conflicting information from sources they believe credible, and/or simply misinterpret factual information. Misconceptions can be difficult to correct (Thomas and Logue, 2006), which makes it helpful to understand common misconceptions in a content area.

Geographers and educational researchers, amongst others, have put together lists of common climate misconceptions (Harrington, 2008; McCaffrey and Buhr, 2008; Schreiner et al., 2005). Often these common misconceptions are used as the basis for research on climate change education (Porter et al., 2012; Shepardson, Niyogi, Choi, and Charusombat, 2011). Harrington (2008) discusses three common climate misconceptions: the 3-cell model of global circulation, ocean circulation as the reason that Western Europe has a mild winter climate, and the rain

shadow effect as the cause of eastern Colorado's climate. McCaffrey and Buhr (2008) share a related list of misconceptions: that climate is often considered to just be long-term weather, human activities have caused the greenhouse effect, the atmosphere is so big and vast that small changes will not have a large impact on Earth, and that fossil fuels have been present on the planet since its genesis. Schreiner et al. (2005) explored misconceptions that cause confusion over the relationship between the ozone hole and climate change, confusion between the natural greenhouse effect and global warming, sources of greenhouse gases, connecting global warming to human energy use, and misinterpretation and misunderstanding of climate models and scenarios. All of these researchers provide scientifically accurate explanations of the phenomena and strategies for overcoming the misconceptions.

It is important to note that these misconceptions do not constitute an exhaustive list. Given the prevalence of climate misconceptions and the importance of correcting misinformation in the classroom, these concepts should be well known to educators teaching climate change. Teachers at the workshop were made aware of common climate misconceptions, provided with accurate information about these misconceptions, and given time to discuss any questions they had about them.

Framing and Communicating Climate Change

People tend to care more about what climate change means to them personally than understanding the science behind it (Somerville and Hassol, 2011). "The idea of 'frames' and 'framing' has emerged in the social psychology community over recent decades and has been particularly applied to how news, ideas, and issues are reported" (Hulme, 2009, p. 226). Frames offer interpretive storylines for discussants to shape the conversation in a manner that may better

serve specific goals (Harrington and Tabor, 2012; Hulme, 2009; Nisbet, 2009; Shanahan, 2007). In fact, it can be argued that there is no such thing as unframed information (Nisbet, 2009).

Hulme (2009) and Shanahan (2007) share six ways to frame climate change and Nisbet (2009) suggests an additional eight frames, all of which are summarized in Table 6. Any framework for communicating “climate change emphasizes certain aspects of the issue, while de-emphasizing [others]” (Hulme, 2009, p. 227). Hulme (2009) discusses how none of the ways of framing climate change that he discusses can be declared as wrong in any absolute sense. When used appropriately and ethically, frames prove to be especially useful in communicating climate change in an understandable and approachable way.

Table 6 - Climate Change Frames by Audience

(Source: Modified from Hulme, 2009, Nisbet, 2009, p. 18, and Shanahan, 2007)

Ways of Framing Climate Change	
Frame	Description of Audience to Engage
Scientific Uncertainty	Those who do not want to change; consensus of expert opinion and understanding
National Security	Those who do not want to change but are inspired to act
Polar Bears	Wildlife lovers
Money/ Economic development and competitiveness	Politicians and the private sector; economic investment; market benefits
Catastrophe	Those who are worried about the future
Justice and Equity	Those with strong ethical leanings
Social progress	Means to improving quality of life; achieving harmony with nature
Morality and ethics	Matter of right or wrong
Pandora’s box/Frankenstein’s monster/runaway science	Need for precaution or action in face of possible catastrophe and out-of-control consequences
Public accountability and governance	Research or policy either in public interest or serving special interests
Middle way/alternative path	A third way between conflicting or polarized views or opinions
Conflict and strategy	A game among elites; battle among personalities for influence

In 2012, Harrington and Tabor described four frames for teaching climate change and noted that understanding the audience being taught is important in selecting a frame. The four reference frames are: 1) science, 2) theology, 3) national security, and 4) conservative political philosophy (Table 7). These frames seek to lessen any controversy and challenges that climate change education faces. The four frames may not all be appropriate for the elementary or middle school classroom (e.g., national security or conservative political philosophy), but they are appropriate for high school and university students. The reference frames from which to teach climate change provide a solid perspective when talking to administrators, parents, or community members about how climate change is being taught and why it should be taught. Overlap can be seen between the frameworks discussed but it is important to note that some are meant to frame conversations (Hulme, 2009; Nisbet, 2009; Shanahan, 2007) and others are specific to teaching climate change (Harrington and Tabor, 2012).

Table 7 - Reference Frames to Teach Climate Change

(Source: Harrington and Tabor, 2012)

Reference Frames to Teach Climate Change: How We Know What We Know	
Reference Frame	Description
Science	A way of knowing based on evidence, measurement, and repeatability; comparative method
Theology	“Stewardship of the garden”
National Security	Potential dangers and threat from a government perspective
Conservative Political Philosophy	Methods to both gain and save money from a free enterprise perspective

In order to engage the intended audience, it is best to speak from a perspective that appeals and makes the most sense to its members. This concept is important to climate change education. The teachers in this research were educated on framing climate change for communication both within their classroom and outside of their classroom with parents, administrators, and community members. Again, it should be noted that the frames above

(Tables 6-7) are not an all-inclusive list. The teacher participants were introduced to the concept of framing climate change discussions and different framing types. The researcher suggested the use of the science teaching frame for implementation of the GIS-climate module and the justice and equity and social progress frames were suggested to guide school-based conversations.

Methods of Teaching Climate Change

There has yet to be established one preferred method for teaching climate change. However, many researchers have made pedagogical suggestions for the subject (Kenis and Mathijis, 2012; McCaffrey, 2012; Schreiner et al., 2005; Somerville and Hassol, 2011). Many education-oriented journals and related publications are beginning to publish climate change activities and lesson plans (see, e.g., Clark, Marks, Haden, Bell, and Hungate, 2012; Dempsey, Bodzin, Cirucci, and Sahagian, 2012; Golden, Grooms, Sampson, and Oliveri, 2012; O'Donoghue, 2011). Additionally, there are numerous online resources and materials available on the subject of teaching climate change.

There are a number of ways to approach the topic of climate change and these approaches build on framing. McCaffrey (2012) specifically discussed how to teach climate change given its controversial nature. He urged teachers to *not* use the approach of teaching controversy or “two sides” of climate change in their classroom. Though this type of activity may seem like a good idea, McCaffrey (2012) discussed two significant limitations to in-class debates about climate change: 1) teaching through debate suggests that there is something to debate within the scientific community about climate change, while the scientific community is indeed in consensus on the topic; and 2) it is important that students master content before they engage in a meaningful debate about that content. O'Donoghue (2011) recommends focusing the discussion on the scientific evidence of climate change.

Another approach to teaching climate change is through education for empowerment and social change. Schreiner et al. (2005) reasoned that science education has significant means to enable citizens to make good decisions for society based on scientific knowledge. Kenis and Mathijis (2012) also looked at empowerment and social change as important in climate change education. They found that learner knowledge of the root causes of climate change and strategies for mitigation and adaptation are essential information. Without strategies for managing the impacts of climate change, students can be left feeling powerless.

Other lesson plans and activity-focused examples suggested in recently published climate change education materials vary greatly. Clark et al. (2012) teach about the carbon cycle through the use of a game in which students play out the life of a carbon molecule while attempting to maintain balance in the global carbon cycle. Dempsey et al. (2012) used an inquiry activity for teaching about past environmental concepts using paleo environmental data as climate proxy to create a real paleoclimate record. Golden et al. (2012) suggested the use of evidence-based written argumentation essays to teach climate change. They reason that using real data allows the students to draw conclusions and make sense of real phenomena. O'Donoghue (2011) incorporates children's literature into activities about weather and natural hazards.

A consistent theme in the literature is a positive, non-controversial, and action-oriented perspective that provides the learner with holistic knowledge through the use of real data and situations in order to provide contexts for solutions and future outcomes. These characteristics were communicated to workshop participants in order to provide a helpful perspective for thinking about and further planning for climate change education efforts.

Related Empirical Research on Climate Change Education

A moderate amount of empirical research has been reported in the climate change education literature. This literature is broad in topic and methods used. Three studies were identified as related to this research based on student grade level, content, methods, instrumentation, length of study, and theoretical framework (Table 8). Work by Pruneau, Gravel, Bourque, and Langis, (2003), Shepardson et al. (2011), and Porter et al. (2012) is summarized in the following paragraphs.

The work by Pruneau et al. (2003) is an extension of prior efforts by the authors. Their first work, published in 2001, identified and verified public misconceptions about climate change in order to inform teaching pedagogy. This research focused on a teaching approach designed to improve middle school students' conceptions of climate change, which was defined as "explanation of the phenomenon, its causes, signs, consequences, possible human actions and possibilities that the general population will mobilize to minimize their impact" (Pruneau et al., 2003, p. 430). The pedagogy was based in socio-constructivist experiential learning and emphasized having students implement their own local study of climate change through research and observation. Students were also encouraged to generate their own hypotheses and seek out answers to accept or reject their hypotheses. The testing of this pedagogy took place over a school year with approximately two one-hour periods being dedicated to this pedagogy per month involving 39 students in Canada. Data were gathered through semi-structured interviews, surveys, content analysis of student work, and classroom observation. The notable findings of this research were that after the classroom intervention, the majority of students were able to accurately describe climate change, demonstrated the ability to recognize signs of climate change, and could identify factors contributing to it. Students were able to identify both physical impacts of and consequences from the impacts occurring due to the changing climate (e.g., rising

sea level, changes in precipitation, flooding, shrinking of beaches, changes to water quality). They were able to name how their actions impact the climate and what they could do to reduce their impacts (e.g., recycle, plant a garden, walk or use a bicycle instead of using a car). Finally, following the class sessions students felt better informed about how to organize people to help combat climate change. The authors said they plan to continue this work by implementing a second intervention that includes a control group.

Shepardson et al. (2011) described a study that explored student understanding of the greenhouse effect, global warming, and climate change. The study used a constructivist perspective and gathered data through surveys and content analysis of student written and drawn responses from three secondary school classes in the Midwest. A total of 51 students were surveyed. “This study was descriptive in nature...involving the collection of qualitative data (i.e., student written and drawn responses)...analyzed for content in an inductive manner to identify concepts and patterns in student responses” (Shepardson et al., 2011, p. 484). The assessment instrument was made up of five-questions that included graph readings as well as written and illustrated responses. Notable findings from this study were that 86% of students connected evidence of global warming with use of the carbon dioxide and temperature graphs and they expected a rise in sea level from the melting of polar ice. Most students believed climate change will impact plants and animals more than humans. However, only about one-quarter of the students could provide their own accurate written definition of the greenhouse effect. The majority of students associated more driving with increased CO₂ emissions and recognized that steps should be taken to decrease transportation emissions. The authors recommended that common climate content (e.g., climatic region, weather events, complex interaction, natural variability, human activities) be aligned with the National Research Council’s

National Science Education Standards (1996) and the *USGCRP/CCSP Essential Principles of Climate Literacy* (2009).

Porter et al. (2012) examined student knowledge growth about climate change through assessment of teacher-led classroom instruction and outside presenter-led classroom instruction using what was described as a pretest-posttest control group design. The research took place in four 6th grade classrooms, totaling 66 students in Canada, using a climate unit that emphasized weather and climate, the carbon cycle and human impacts, and global warming and the greenhouse effect. Group one, the control group, received the traditional unit and not the climate change-specific unit as did the treatment groups. There was no further explanation of the differences between the traditional unit and the treatment unit. The treatment groups (two teacher-led and one outside presenter-led) used the same unit, content, and time to deliver information specific to climate change. The outside presenter-led group was led by two people, one a certified teacher and one an experience informal educator. Data were gathered through pre, post, and follow-up surveys of the students that assessed fundamental topics in climate science (e.g., weather and climate, carbon cycle, greenhouse effect, human impacts, climate change). The pre-test showed that students in all groups knew the most about weather and climate and least about the carbon cycle and human impacts on climate. The post-test showed that students demonstrated the greatest knowledge gain in the teacher-led groups, followed by the outside presenter-led group, and lastly, the control group. However the follow-up survey showed approximately equal knowledge retention among all groups. It was suggested that the teacher-led group was more effective than the outside presenter-led group because teachers were trained to teach. A survey of the two teachers after completion of the classroom research

indicated that the information and background knowledge provided on climate was very helpful, but more time was needed to teach climate change given the complexity of the subject.

These three studies were influential in the construction of the methods for this research intervention and provided useful examples of data-collection instruments (Table 8). Design elements included from the three studies were used for the plan and design of this research. Specifically the constructivist approach, support for use of the *Essential Principles of Climate Literacy* (2009), the length and focal topics of the GIS-climate unit, and the types of instrumentation used. Additionally Fink's (2003) taxonomy for significant learning (foundational knowledge, application, integration, human dimension, caring, and learning how to learn) was incorporated.

Table 8 - Common Themes of Related Climate Change Research

Commonalities between Related Empirical Research on Climate Change Education				
Common Themes		Pruneau et al., 2003	Shepardson et al., 2011	Porter et al., 2012
Student Grade Level	Grades 6-8	X	X	X
	Grades 9-12		X	
Number of Students	N = 30-50	X		
	N = 50-70		X	X
Content	Greenhouse Gases and/or Effect	X	X	X
	Misconceptions	X	X	X
	Carbon Cycle		X	X
	Human Impacts	X	X	X
	Weather and climate	X		X
	Nature of Science			X
	Solutions/Strategies	X		
	Empowerment	X		
Methods	Teacher Led Instruction		X	X
	Third Party Led Instruction	X		X
	Use of Graphics to Illustrate Concepts	X	X	
	Local, Experiential Learning	X		
Instrumentation	Semi-Structured Interviews	X		
	Surveys	X	X	X
	Content Analysis	X	X	
	Observation	X		
Length of Study	One Classroom Unit		X	X
	School Year	X		
Framework/ Perspective	Constructivist		X	X
	Socio-constructivist	X		
	Experiential	X		

GIS Education

GIS education is focused on teaching *about* GIS and teaching *with* GIS. Teaching about GIS emphasizes the uses of geographic information, practices involved, and career possibilities. Teaching with GIS implements the use of GIS to engage students in problem solving and deeper concept learning (Baker et al., 2012). GIS courses, programs, and degrees are available at most universities. As GIS has become more publicly available and easier to use, teaching with GIS has grown. Due to its interdisciplinary applications, GIS can be found in programs of

geography, computer science, earth science, math, literacy, psychology, biology, and business, among others (Baker et al., 2012).

Effectiveness of GIS on Learning

“GIS education research is primarily focused on whether GIS influences student learning” (Baker et al., 2012, p. 258). There is much discussion of the effectiveness of the use of GIS in education, especially as a reason for increasing the use of GIS in schools. In the studies described in subsequent paragraphs, effectiveness is defined as whether teaching with GIS is more impactful on student outcomes than other methods. Some evidence suggests that students learn content just as well as with traditional methods, or better in some cases, while also learning a skill and engaging in active critical thinking and problem solving (Kerski, 2003).

Research on GIS effectiveness relevant to this study include Kerski (2003) and Baker and White (2003). Kerski’s (2003) goals were to summarize the extent that GIS was being used in secondary classrooms across the U.S., to explain why GIS was being used in the classroom the way it was, and “to assess the effectiveness of GIS on secondary geography teaching and learning” (p. 128). Through a mailed survey, Kerski found that approximately 2% of all U.S. secondary schools were using GIS during this time period. The small number of secondary schools using GIS was attributed to lack of time to create lessons, few tested and reliable GIS lesson/modules available, perceived complexity of GIS use, and little technological and administrative support for use of GIS.

Kerski’s (2003) effectiveness experiments took place in six different settings at three public high schools in Denver, Colorado. An experimental design was used in a social studies classroom. Students completed the same activities with one group using paper maps and another group using GIS. A standardized geography exam and a spatial analysis assessment created by

Kerski were administered after students completed the activities and “analyses of the data were conducted on individual classes, between classes, in each school, and between schools” (Kerski, 2003, p. 133). Notable findings were that test scores from the GIS group demonstrated that average and below-average students improved more than above-average students. It was also noted that “GIS appears to improve learning of geographic content, not just skills. Furthermore, GIS fostered higher-order analytical and synthetic thinking, and increased students’ knowledge of absolute and relative locations across the globe” (Kerski, 2003, p. 134). The overall impact of the use of GIS on student performance, from both the standardized geography exam and the spatial analysis assessment at all three schools, showed mixed results. Spatial analysis test scores did not change between the beginning and end of the semester, but GIS made “a [positive] difference in the relationship between GIS and the difference in [standardized] test scores from the beginning to end of the semester” (Kerski, 2003, p. 134).

Baker and White (2003) used a non-equivalent quasi-experimental design to test for middle school student knowledge, attitude, and self-efficacy in science and technology use through implementation of a problem-based learning unit. Two classes were administered the same nine-day classroom intervention, one using paper maps and the other using internet-based GIS. The experiment took place in an eighth grade middle school science classroom in Kansas. Two instruments were used to collect data at both pre- and post-intervention: an affective survey for attitude and self-efficacy and a performance assessment on content. It was found that compared to their paper map-using counterparts, the students using GIS demonstrated greater gains in science content, geographic data analysis, and science self-efficacy, but not in technology self-efficacy or attitudes towards science or technology.

From the limited number of GIS effectiveness studies, there is uncertainty as to the impact of GIS on student learning. Based on two qualitative case studies on teacher implementation of GIS in the K-12 classroom, Meyer et al. (1999) suggested that classroom and learning goals must be explicitly stated and emphasized to enhance the learning of geographical concepts through GIS, and that teachers must be comfortable with GIS before they can effectively use it in their classroom. Acknowledging the limited number of studies, Battersby et al. (2013) recommended that more studies on the effectiveness of the use of GIS in education are needed, yet a fundamental rationale for its use has also clearly been established. “Teaching with GIS provides the opportunity for issues-based, student-centered, standards-based, inquiry-oriented education, but its effectiveness is limited primarily by social and structural barriers,” according to Kerski (2003, p. 134).

Successes and Challenges in Implementing GIS in the Classroom

When the topic of using GIS in the K-12 classroom is brought up in educational discourse, challenges are frequently discussed. In 1997, Bednarz and Ludwig published a frequently cited list of ten statements regarding what higher education needs to know about the implementation of GIS in the K-12 classroom (Table 9).

Table 9 - What Higher Education Needs to Know About GIS in K-12 Education

(Source: Compiled from Bednarz and Luwig, 1997, p. 123-130)

Ten Things Higher Education Needs to Know About GIS in the K-12 Classroom	
1	GIS use is growing in the K-12 classrooms.
2	The growth and diffusion of GIS is fuelled by a number of factors.
3	The diffusion of GIS in K-12 education follows different models.
4	Barriers impede the diffusion of GIS (e.g., hardware and software difficulties, education policy does not include GIS).
5	The use of GIS as an instructional tool depends on teachers’ perceptions of disciplinary subject matter.
6	GIS enhances student learning and supports innovative teaching.

7	A careful research agenda in GIS and education is needed.
8	The implementation of GIS is more widespread in the K-12 science than geography classrooms.
9	Preservice teacher training is a key to the diffusion of GIS in the K-12 classroom.
10	Conduct research, and ask not what GIS can do for K-12 education, but what K-12 (and higher) education must do to implement GIS.

Bednarz and Ludwig's (1997) fourth statement identified a major challenge that has been largely overcome: difficulties with hardware and/or software of GIS programs. GIS is now available through a web connection and does not require teachers or administrators to obtain, load, and maintain computer software. Baker (2005) built the case for use of internet mapping/GIS as better suited for the K-12 classroom than traditional desktop GIS. The use of internet-based GIS acts as an equalizer for schools with varying resources and offers greater access to data that can be acquired online. "Internet-based mapping will not meet the analytical needs of every K-12 classroom, but it has great potential for introducing every classroom to geography and GIS while supporting meaningful, authentic learning" (Baker, 2005, p. 49), as well as assisting with overcoming the obstacle of computer program installation and maintenance.

The need for a research agenda in GIS and education (Bednarz and Ludwig, 1997) was formalized and published research agenda in Baker et al. (2012). Baker et al.'s (2012) research agenda in GIS education was based on four factors: 1) the growing importance of GIS in society both holistically and in education specifically, 2) the state of GIS education today, 3) an outline of key GIS education research questions that need to be answered, and 4) identification of gaps in GIS education research, which include the need for a more comprehensive research agenda. Furthermore, research groups in GIS education have started meeting annually to support, build on, and make progress with this research focus.

Kerski (2003) identified a number of successes and challenges in his large-scale research project that surveyed U.S. high schools using GIS. A total of 1520 participants, identified by their use of Esri GIS software at the time, completed a mailed survey. The successes Kerski identified were that teachers using GIS find that it enhances learning, is a practical and real-world tool for data analysis, provides real-world relevance to content, and enhances student motivation and interest. The challenges Kerski pinpointed were that teachers felt they did not have enough time to develop good GIS-based lessons, there was little GIS training available, and little technical support was available. Furthermore, there was a perceived complexity of GIS and no mandate to use GIS in the curriculum. To further assist with overcoming challenges in implementing GIS in education, Kerski (2011) created guidelines for conducting a successful GIS professional development or educational intervention, including event planning strategies, core messages, best educational practices, career connections, philosophies, materials, hardware, lab preparation, and top GIS skills on which to focus. These guidelines were integrated into this study's workshop intervention.

Through a series of teacher workshops, Tabor and Harrington (2014) collected data on successes and barriers to teacher professional development in GIS. The findings were that: 1) teachers want to learn about how to use GIS in their classrooms, 2) training sessions to support implementation are important, 3) opportunities to network with GIS professionals and other teachers using GIS were helpful to better understanding of applications of GIS, 4) numerous online resources are available for teachers to use, and 5) making training discipline-relevant and standards-aligned is essential. Challenges included minor technological difficulties and technology-induced frustration while learning a new skill, the need to have multiple workshop

leaders present to assist participants, time requirements for finding classroom- and standards-relevant examples, and the desirability of follow-up workshops.

It is becoming easier to implement the use of GIS in the classroom. Through interviews with teachers who employed GIS in their classroom in the 1990s, Baker and Kerski (2014) determined that the progress of GIS education could be characterized using Rogers' (2003) "Diffusions of Innovations model." The Diffusions of Innovations model "is often used to organize and describe the events surrounding the movement of innovations throughout a social system over time" (Baker and Kerski, 2014, p. 253). Rogers (2003) described five classes of adopters of an innovation in sequence: 1) innovators, 2) early adopters, 3) early majority, 4) late majority, and 5) laggards. The researchers interviewed eight teachers by phone (the average interview lasted 25 minutes). Interview questions were focused on when and how the educators learned about teaching with GIS, what (if any) professional development program they attended, what successes and challenges they experienced in implementing GIS in the classroom, what support they received for using GIS in their classroom, and why they chose to teach with GIS long term. In their work, Baker and Kerski (2014) discussed how to move GIS education from innovation to early adoption. Most teachers interviewed (innovators) found out about GIS through national and state education events. The teachers were mostly self-taught and sought out any professional development they could find having once seen the value in using GIS in their classroom. How can GIS move from the innovators to the early adopters? According to the Diffusions of Innovation model, early adopters must see that the use of GIS offers a comparative advantage over their current instruction, is consistent with their educational philosophies, is easy to use and apply in the classroom, and can produce observable results. In order for teachers to

see the comparative advantage, it is suggested that early adopters need specific instructional materials to help them get started teaching with GIS (Baker and Kerski, 2014).

Common themes between Bednarz and Ludwig (1997), Kerski (2003), and Tabor and Harrington (2014) illustrate likely successes and challenges in using GIS in the classroom. Kerski (2011) made recommendations for organizing an effective GIS education workshop and Baker and Kerski (2014) addressed getting teachers started using GIS. The identified successes, challenges, and recommendations were used as a guide by the researcher while working with the teachers in this study in order to coordinate and manage a useful and non-stressful workshop and enable smooth classroom implementation of the GIS-climate module.

Summary

The constructivist approach in science education, with the learner building his/her own knowledge and understanding as guided by the teacher, can be enacted in the classroom through the use of inquiry and GIS. The use of inquiry and GIS fits the goals and measures of the Next Generation Science Standards well. Climate literacy has been well defined. It is now a question of how to build and promote this content and technology in the classroom. A great deal of information on climate misconceptions and framing intelligent conversations on climate science and climate change is available; this material should prove useful for educators teaching about climate change. Literature on teaching climate change and teaching with GIS was used in the construction of the research design of this study, described in the next chapter.

Chapter 3 - Research Methods

...research methods should *follow* research questions in a way that offers the best chance to obtain useful answers. Many research questions and combinations of questions are best and most fully answered through a mixed research solution. (Johnson and Onwuegbuzie, 2004, p.17-18).

Chapter three describes the study design and methods used for this exploratory mixed methods research. The research questions identified below were answered through data collected via a two-part intervention. The first intervention component was a teacher training workshop on the content included in a GIS-climate module and instruction in the use of GIS technology. The second part included classroom implementation of the GIS-climate module, as well as feedback on the use of the module and its components in the participating teachers' classrooms. Issues of validity, reliability, and working with a school age population are also addressed.

Research Questions

This study answers research questions specific to student outcomes, teacher perceptions of the integration of GIS in teaching climate change, and both students' and teachers' perceptions of challenges and successes of using GIS in the classroom:

1. Did completion of the GIS-climate module contribute to the growth of the students' knowledge and dispositions about climate change?
2. How did the workshop participation and implementation of the module impact the teachers' perception about teaching the climate change content integrated with GIS technology within their classroom?
3. What successes and challenges were identified in order to implement the use of a GIS in the 7-12 classroom for both teachers and students?

The results were used to build evidence-based rationale for the use of GIS to enable the inclusion of locally relevant examples in teaching climate change.

Research Perspective and Design

This research was exploratory and used a mixed method concurrent triangulation design. In education the purpose of exploratory research “is to investigate approaches to education problems to establish the basis for design and development of new interventions or strategies, and/or to provide evidence for whether an established intervention or strategy is ready to be tested in an efficacy study” (Institute of Education Sciences, U.S. Department of Education, and the National Science Foundation (IES/USDE/NSF), 2014, p. 12). The teaching of climate change aligned with the recently adopted NGSS and the regular use of GIS are both relatively new to the 7-12 classroom, thus this research was exploratory in nature.

Mixed methods research “combines elements of qualitative and quantitative research approaches...for the broad purpose of breadth and depth of understanding and corroboration” (Johnson, Onwuegbuzie, and Turner, 2007, p. 123). Given the investigative and descriptive nature of this research, a singular qualitative or quantitative approach would not generate sufficient data from which to answer the research questions. Furthermore, mixed methods research works well with complex research topics and provides a mix of techniques that researchers frequently use together in practice (Johnson and Onwuegbuzie, 2004). A concurrent triangulation design, also called a convergent parallel design, was used. This design is appropriate when qualitative and quantitative data can be collected during the same phases of research and then integrated into an overall interpretation (Creswell and Plano Clark, 2011).

A quasi-experimental design was considered. Although it would have made for a stronger research design, such a research method was not feasible. The GIS-climate module is

aligned to teaching the Next Generation Science Standards, which were just being introduced into classrooms. Given that the state science assessment aligned to these new standards was not yet available, finding classrooms in which climate change was taught was unrealistic.

Furthermore, GIS was not regularly used in the classroom for any subject or at any grade level, also making comparisons difficult. These two factors made the inclusion of a control group infeasible. However, the data from this exploratory research can be used to identify a control group for future research, perhaps leading to later confirmatory research using a quasi-experimental design.

The GIS-based framework and locally relevant inquiry activities were delivered to teachers in the form of a GIS-climate module during a one-week workshop conducted in June 2015. Following the workshop, the teachers implemented the GIS-climate module in their classrooms and participated in all data collection activities during the fall 2015 semester. The following sections describe the GIS-climate module, design of the one-week teacher workshop, and follow-up activities.

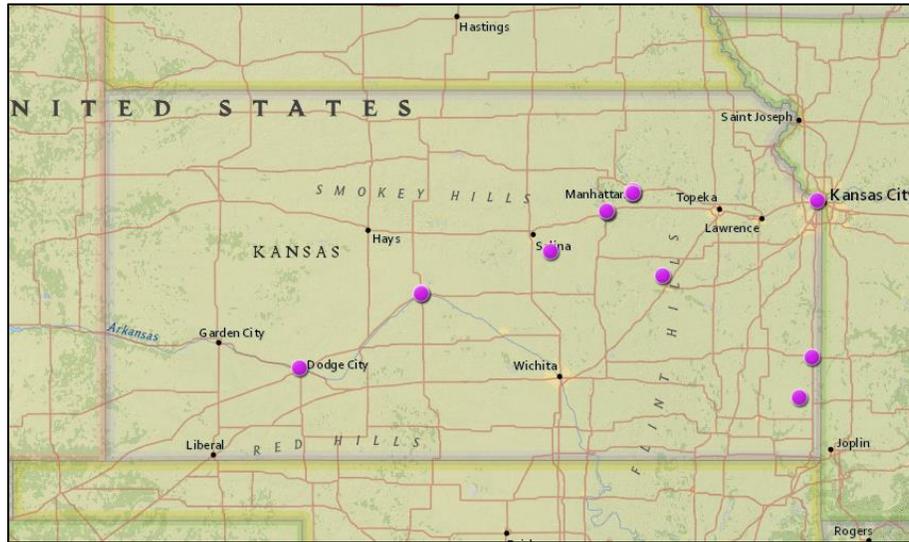
Participants and Setting

The teacher participants for this study were chosen through a criterion-based selection process. Teacher applications were solicited through email listservs of the Kansas State Department of Education (KSDE) science consultant, Kansas Association of Teachers of Science (KATS), Kansas Association of Agricultural Educators (KAAE), Kansas Geographic Alliance (KGA), and Kansas Association for Conservation and Environmental Education (KACEE), as well as through teacher participants in three Kansas State University programs (Climate Change Education Project (CCEP); Evidence-based Inquiry into the Distant, Remote, or Past: Linking Evidence to Inference in the Kansas Science Classroom (EIDROP); and Infusing System Design

and Sensor Technology in Education (INSIGHT)). Teacher application forms asked for demographic and professional information, current classes in which the GIS-climate module would be implemented, past experience in summer workshops/professional development, and self-assessment of knowledge about climate change and GIS technology. Teacher applications had to include a letter of support from the school principal, as well as a description of the technology infrastructure in the school. Selection criteria were based on: 1) high school or middle school level teaching assignment, 2) teaching a discipline of science in which climate change is appropriate (e.g., earth science, environmental science, and/or agricultural science), 3) expressed interest in teaching climate and climate change, 4) willingness to use new technologies in teaching, and 5) ability to participate for the duration of the study. A stipend was provided to the teacher participants; half was paid upon completion of the teacher's participation in the workshop and the remainder was paid post-classroom implementation. The stipend was provided by the Kansas State University Center for Science Education and funding for the one-week teacher workshop was provided by Esri and the Kansas Geographic Alliance. Twelve teachers were involved in this research. Teacher participants taught at schools across the state of Kansas (Figure 8), with three pairs of teachers coming from the same school districts.

The student participants were from the classrooms of the teacher participants. Research on student outcomes involved 550 students. An IRB application was approved by Kansas State University. Parents of students did not have to provide consent for participation because the student-focused materials and instrumentation were administered by the classroom teacher in a normal classroom setting. No student names or identifiable information was attached to the student data.

Figure 8 - Spatial Distribution of Teacher Participants Home City



GIS-Climate Module

Teachers were provided with the GIS-climate module aligned with the Next Generation Science Standards and the Essential Principles of Climate Science. The GIS-climate module consists of four GIS-based activities. The first four activities were prepared by the researcher and reviewed by a panel of interdisciplinary and multi-level educators. They were the same for all teachers and students. Teachers used the online GIS program, *ArcGIS Online*, to examine, understand, and learn about the climate system, climate science, and climate change. The decision to use *ArcGIS Online* as the GIS program was due to the availability of the program to all U.S. classrooms free of charge from the national ConnectEd Initiative agreement between the White House and the GIS software producing company, Esri. It was expected that the teachers would create a fifth, and final activity that engaged students in a study of a locally relevant issue related to climate change. Teacher participants created this fifth activity, also called Activity 5, based on a set of criteria provided during the intervention. Consequently the fifth activity should have been unique to each teacher.

The GIS-climate module was designed to require approximately two weeks for classroom implementation, including time for the use of instrumentation to document student outcomes (timetable outlined in Appendix 1). All lesson plans, resources, and handout materials were provided to the teachers to help ensure similar implementation across classrooms. Each GIS-climate module activity followed the 5 E Learning Cycle described in Chapter 2.

The student performance expectations from the Next Generation Science Standards with which the module was aligned are listed in Table 10. The four pre-planned GIS-climate module activities are described in the following sections using an overview of the activity and student learning objectives. The fifth activity, which the teacher participants created, used a set of prescribed guidelines.

Table 10 - Student Performance Standards of the GIS-Climate Module

(Source: Next Generation Science Standards, 2013a)

Student Performance Standards the GIS-Climate Module is Aligned with from the NGSS
Middle School Earth and Space Science:
<u>MS-ESS2-5.</u> Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.
<u>MS-ESS2-6.</u> Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
<u>MS-ESS3-5.</u> Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
High School Earth and Space Science:
<u>HS-ESS2-2.</u> Analyze geoscience data to make the claim that one change to Earth’s surface can create feedback that causes changes to other Earth systems.
<u>HS-ESS3-1.</u> Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influences on human activity.
<u>HS-ESS3-4.</u> Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
<u>HS-ESS3-5.</u> Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
<u>HS-ESS3-6.</u> Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Activity Descriptions and Learning Objectives

In Activity 1, *Understanding Climate and Weather* (Appendix 2), students will distinguish the difference between climate and weather, identify major climate controls, and collect data on these climate controls to demonstrate how the factors work together to determine the weather conditions and climate of a region. After completing this activity, a student is able to do the following:

- Recognize and define the difference between weather and climate,
- Identify key climate controls, and

- Collect data to complete the basic components of a climatology and weather report.

In Activity 2, *Identification of Climate Patterns* (Appendix 3), students will identify regional climate types based on the Köppen climate classification system and explain how topography, the Earth’s rotation and unequal heating, and ocean currents influence climate.

After completing this activity, a student is able to do the following:

- Identify regional climate types using the Köppen climate classification system and
- Recognize and explain how topography, the Earth’s rotation, and ocean currents influence climate types.

In Activity 3, *Examination of Global Climate Change* (Appendix 4), students will identify past and present trends of the Earth’s climate. They will be introduced to these trends using an interactive online modeling program from the Concord Consortium and asked to write explanations based on the findings from the models. After completing this activity, a student is able to do the following:

- Identify and explain past and present trends of the Earth’s changing climate,
- Use models to explain how the interactions between planet systems cause climate change, and
- Use models to make predictions about climate change.

In Activity 4, *Climate Change in Kansas and the Great Plains* (Appendix 5), students will identify at least one local/regional climate change concern and explain this concern in scientific terms. After completing this activity, a student is able to do the following:

- Identify and understand an example of climate change in Kansas and the Great Plains and
- Engage in a locally relevant analysis and scientific communication about these projected events.

In Activity 5, the locally relevant inquiry activity, teachers were asked to create their own inquiry activity based on a local climate issue. The design criteria asked the teachers to align the

activity with NGSS student performance standards, use the 5 E model, use *ArcGIS Online*, incorporate an analysis of local data, and have students share their work.

Validity Assessment

The validity of the researcher prepared portion of the GIS-climate module (Activities 1-4) was confirmed through an external review. The external review was conducted by a four-person panel consisting of a climatologist, a university science/curriculum educator, a grade 7-12 science teacher, and a GIS professional. The GIS-climate module was examined for accurate content, sequence, and classroom formatting to confirm the validity and usability of the module from the expertise of each external review panel member using a guided review sheet (Appendix 6). The researcher made revisions to the GIS-climate module based on the input from the external review panel.

One-Week Teacher Workshop

A one-week workshop was held at the Kansas State University campus on Monday, June 15, through Friday, June 19, 2015. Prior to the workshop, the selected teachers were asked to complete two online short courses: 1) the Esri “Teaching with GIS: Introduction to Using GIS in the Classroom” (3 hours) (<http://training.esri.com/gateway/index.cfm?fa=catalog.webCourseDetail&courseid=2198>) and 2) the Climate Literacy and Energy Awareness Network (CLEAN) Module on “Teaching Climate Science” (1 hour) (http://cleanet.org/clean/literacy/climate_lit.html). Both short courses were publically available at no cost. Completion of the online short courses was used as the starting point for all workshop activities. The teachers were each also asked to do an initial investigation of climate change impacts in their home area and to devise a list of three to five topics and/or questions of interest around which they may have wanted to structure their local

inquiry activity. The schedule of the workshop is outlined in Table 11. Intervention content is described in the paragraphs that follow.

Table 11 - Schedule of the Planned Teacher Workshop

Workshop Schedule					
	Mon June 15	Tue June 16	Wed June 17	Thu June 18	Fri June 18
AM 1	Travel to KSU	Frameworks and Methods for Teaching Climate Change	Review and Questions	Review of Climate Change and Local Impacts	Review and Work Time
			ArcGIS Online Organizational Accounts		
AM 2	Program Overview	GIS	Using GIS to Teach Climate Change	Collaborative Work Time	Collaboration and Activity Sharing
PM 1	Climate Change Content	GIS	GIS-Climate Module	Collaborative Work Time	Program Debriefing
	Local Impacts of Climate Change				
PM 2	Climate Change Content	GIS	GIS-Climate Module	Activity 5 Sharing and Discussion	Travel Home
	Visualizing Climate Change with GIS		Independent Work/Early Release at 3:45pm		

The intervention was focused on three principal parts: 1) climate change content, 2) GIS technology, and 3) implementation of the GIS-climate module. The climate change content focused on covering the *Essential Principles of Climate Literacy*. First, there was emphasis on teaching the nature of science and uncertainty. Second, multiple ways to frame climate change in the classroom were discussed in order to prepare teachers to teach the science of climate change while avoiding arguments based on political and/or religious ideology. Lastly, evidence for climate change from past to present, energy budget concepts and the roles of the sun, greenhouse gases and the greenhouse effect, the role of human-environment interaction and

anthropogenic impacts on climate, and the current status of mitigation and adaptation efforts were presented. The researcher presented the information in a lecture style format that included semi-structured discussions and time allotted for questions.

GIS was presented as a tool for analyzing current conditions, change, and comparisons between places, using *ArcGIS Online* as the GIS technology platform. First, teachers were introduced to teaching with maps through a series of paper and online map-based activities. Second, they learned the history of GIS and were provided examples of its capabilities. Third, teachers were shown how to use a GIS, which incorporated multiple classroom-ready examples related to climate change. Finally, teachers learned more about possible uses of GIS and practiced GIS applications, culminating in the preparation and discussion of their own locally relevant inquiry and GIS lesson plan at the end of the workshop. After their GIS training, teachers were able to use *ArcGIS* to complete basic functions such as adding data, feature manipulation, and displaying/visualizing data in map output. The researcher presented the GIS information using mostly hands-on activities in which students all worked on independent devices.

The four researcher-prepared activities in the GIS-climate module were provided to the teacher participants. The teachers were given time to create the fifth activity (locally relevant) of the module. Teachers used their worktime to collaborate and share ideas with the group. They also formally reported their progress to the group at the end of each day.

There was a formalized review of the researcher's expected process of implementation, as well as the instruments to be administered to students by the teachers. Teachers provided feedback on the instruments and the researcher made adjustments to which all teachers agreed.

The teachers also shared their plans for classroom implementation; this set the tone for consistent implementation of the lessons across the diverse classrooms.

Follow-Up Activities

Teacher participants were asked to implement the GIS-climate module and assist in the data collection activities outlined as part of the research effort during the fall semester of the 2015-2016 academic year. Support was provided to the teachers through personal contact with the researcher.

Instrumentation and Data Collection

The instrumentation consisted of three student-centered instruments, two teacher-specific instruments, and two classroom-oriented instruments. The student survey data, focused on climate knowledge, climate disposition, and GIS, were collected immediately before and after the implementation of the GIS-climate module and the teacher's locally-focused Activity 5. The teacher data from the survey and semi-structured interview were collected after each teacher finished implementation of the activities in his/her classroom because all teachers implemented the GIS-climate module at different times throughout the semester. The two classroom-oriented instruments had to be completed separately. The researcher completed a classroom observation of each teacher and kept field notes. The qualitative analysis of the local teacher-created activity (Activity 5) was completed before and after the classroom observation, depending on when the activity was given to the researcher by the teacher. Again, based on differing implementation schedules, this occurred throughout the semester. An overview of the data collection process is shown in Table 12. A detailed description follows.

Table 12 - Connection between Research Questions and Instrumentation

Instrumentation Used to Answer Each Research Question		
Research Questions	Outcome to be Measured	Instrumentation (*created by researcher unless otherwise noted)
Question 1: How did completion of the GIS-climate module contribute to the growth of the students' knowledge, skills, and dispositions?	Increase student knowledge of climate science and understanding of the data that provides evidence of climate change.	Student climate change content knowledge assessment.
	Identify possible changes in student dispositions towards climate change.	<i>Knowledge of Climate Change Across Global Warming's Six Americas</i> , 15-question version (Maibach et al., 2011).*
Question 2: How did the workshop participation and implementation of the module impact the teachers' perception about teaching the climate change content integrated with GIS technology in their classroom?	Identify teachers' perceptions regarding teaching through the integration of GIS technology and climate science/climate change.	Teacher survey of perceptions.
		Teacher semi-structured interview.
	Describe the role the teachers had during the structured inquiry part of the project (e.g. what evidence is there that teachers are used as resources, that students direct their own projects).	Teacher survey of perceptions.
		Teacher semi-structured interview protocol.
Question 3: What successes and challenges were encountered in order to implement the use of a GIS in the 7-12 classroom for both teachers and students?	Identify technological successes and challenges teachers face in integrating the use of GIS technology into their classrooms.	Teacher survey of perceptions.
		Teacher semi-structured interview protocol.
		Student survey of GIS use.
	Identify what kinds of inquiry projects were completed and what kind of GIS technology was used.	Rubric for analysis of locally relevant inquiry activity.
		Researcher classroom observation protocol and field notes.

Student-Centered Instrumentation

The climate change content knowledge assessment was created by the researcher and reviewed by the participating teachers (Appendix 7). The purpose of the instrument was to

assess the content covered in the GIS-climate module and determine growth of student knowledge. Topics included: 1) the difference between climate and weather, 2) how climate is impacted, 3) how climate classification is determined, 4) uses of modeling, and 5) factors regulating climate. The assessment consisted of six multiple-choice questions completed by students using the online survey system *Qualtrics*.

To assess student dispositions about climate change, the *Knowledge of Climate Change across Global Warming's Six Americas* 15-question version was used (Appendix 8). This instrument was created for and is being used in a national long-term study of Americans' perceptions of climate change being conducted by the *Yale Project for Climate Change Communication* (Maibach et al., 2011). Participants are asked climate change disposition related questions. Based on past responses, participants are placed into one of the "Six Americas" categories: alarmed, concerned, cautious, disengaged, doubtful, and dismissive (Leiserowitz and Smith, 2010). Three versions are currently available (55-questions, 36-questions, and 15-questions). The 15-question version was selected based on its suitability for middle- and high-school student use and its focus on participant dispositions. The instrument is composed of 15 multiple choice questions, administered online through *Qualtrics*, with brief directions provided.

The student survey of GIS use was created by the researcher (Appendix 9). The purpose of this survey was to gain an understanding of the students' perspectives on the usefulness of the GIS. It asks how much the students liked using the GIS, what the best part about using GIS was, and what the worst part was. This instrument consisted of one ten-point Likert-type rating scale question and two student constructed response questions. Like the other student-centered questionnaires, it was administered through *Qualtrics*.

Teacher-Centered Instrumentation

The teacher perceptions questionnaire was developed by the researcher (Appendix 10). It surveyed teacher perceptions of the project as a whole, the incorporation of GIS and climate change, student reactions and response, and covered each component of the module. The survey was aligned with the semi-structured interview protocol with the goal of corroborating findings from the two data formats. The instrument consisted of thirteen multiple-choice questions, five Likert-type scale questions, and five open-ended response questions administered through *Qualtrics*.

The teacher semi-structured interview protocol was also developed by the researcher (Appendix 11). Its goal was to cover the project from start to finish (e.g., the workshop, climate change content, GIS technology use, local focus, student response). It emphasized identifying successes and challenges experienced by teachers as part of integrating GIS in their classroom as well as overall teacher perceptions of the climate change content, and how the teacher planned to continue these activities in their classrooms. The interviews took place by phone and generally lasted between twenty and thirty minutes.

Classroom-Centered Instrumentation

The classroom observational protocol was created by modifying the *Reformed Teaching Observational Protocol* (http://physicsed.buffalostate.edu/AZTEC/RTOP/RTOP_full/about_RTOP.html) (Appendix 12). The observational protocol had seven sections: 1) background information (i.e., teacher, location, class times), 2) contextual background information (i.e., space, seating arrangement, number of students), 3) record of classroom events by time, 4) lesson design and implementation, 5) content, 6) communicative interactions, and 7) additional notes, thoughts, and observations.

These components were documented using open-ended field notes and Likert-type tables. A scoring rubric was created for the Likert-type tables and is described in Chapter 4.

The rubric for analysis of inquiry activities was created by the researcher (Appendix 13). It was a two-part rubric. The first part consisted of seven components scored on a three-point scale, as “beginning,” “developed,” or “accomplished.” The components evaluated were: alignment with the GIS-Climate module, use of the 5E model, local data, use of GIS, questions posed, student investigation, and student reporting. The second part is four analysis questions set to record the guiding question of the lesson, the local issue examined, the specific climate change content used, and how the GIS was integrated into the lesson.

Validity and Reliability

The student knowledge assessment, student GIS survey, teacher perception survey, teacher semi-structured interview protocol, inquiry activity rubric, and observation protocol were reviewed by an external panel for validity. The instrumentation panel consisted of three external reviewers: a climatologist, university science and curriculum educator, and 7-12 science teacher. All reviewers were asked for feedback through the use of a survey (Appendix 14). The questionnaire asked general questions about content (based on the reviewer’s expertise), cohesion between documents, and usability, as well as open-ended questions for a specific review of each instrument.

Data Analysis

Table 12 summarizes how data gathered through the instrumentation were grouped to correspond to each research question. Figures 9, 10, and 11 show how data from each instrument worked together to answer the research questions. The following section explains how each instrument was analyzed.

Figure 9 - Data Analysis for Research Question 1

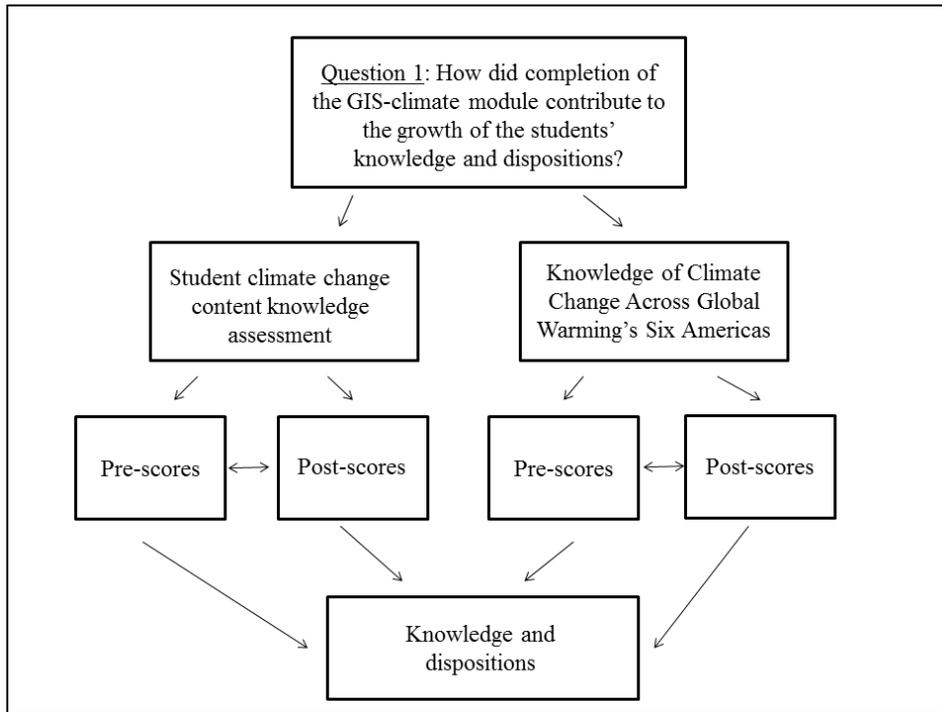


Figure 10 - Data Analysis for Research Question 2

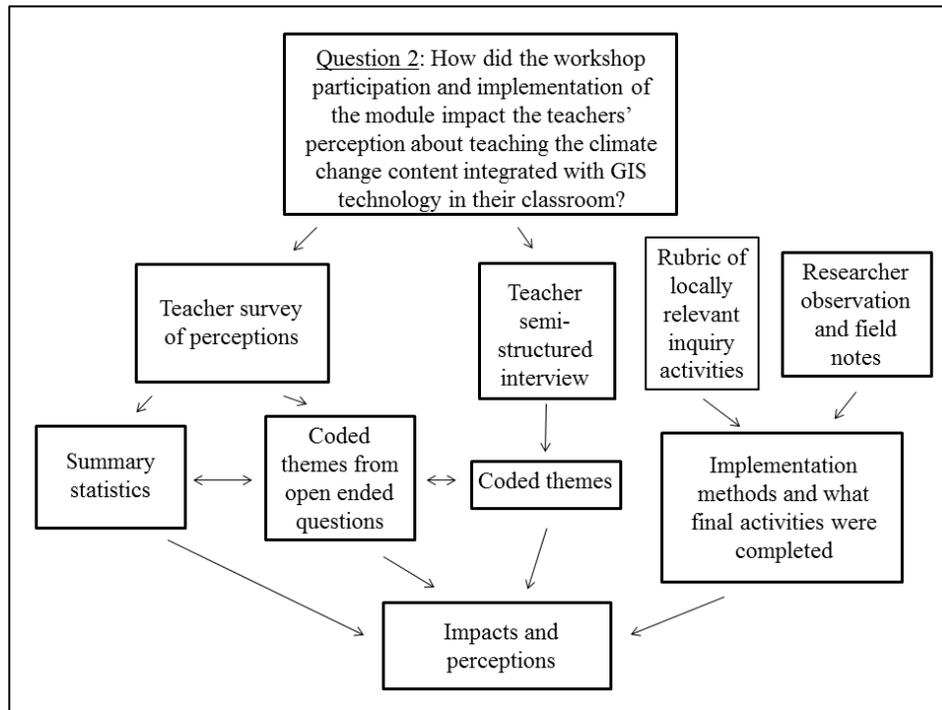
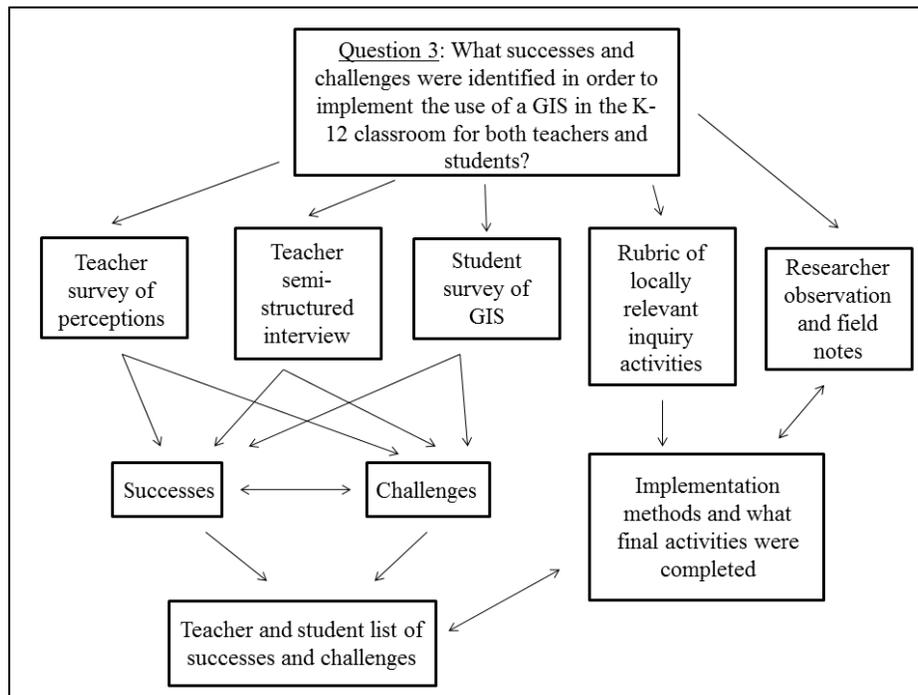


Figure 11 - Data Analysis for Research Question 3



Student pre- and post- knowledge assessment outcomes to determine knowledge growth and student responses to the *Knowledge of Climate Change across Global Warming's Six Americas* assessment to determine change in perceptions were used to address research question one (Figure 8). The pre- and post- knowledge assessments were analyzed using descriptive statistics based on how many times the question was answered correctly on the pre- and post-assessment. It was originally planned to gather paired student data but gathering paired student data proved unworkable with the teachers in this study. The *Knowledge of Climate Change across Global Warming's Six Americas* was analyzed using statistical script created by the tool's originators to place the students within the categories of the Six Americas. The statistical script was provided along with the survey in Maibach, et al. (2011). The script gives instructions on how to format the data in the statistical program *SPSS* and then is copied and pasted into *SPSS*.

Software output (the results of the script) place the student response data into the dominant category of the *Six Americas*.

Research questions two (Figure 9) and three (Figure 10) were addressed using data from the teacher perception survey, teacher semi-structured interview, student survey of GIS, rubric analysis of locally-focused activities, and the classroom observations. The teacher perception survey was analyzed for qualitative codes and themes from the open-ended responses and summary statistics from the multiple choice and Likert-type scale questions. The teacher semi-structured interviews were evaluated using qualitative analysis for codes and themes. The student survey of GIS was also analyzed for qualitative codes and themes and used descriptive statistics to analyze the forced response questions (e.g., yes/no), similar to the teacher perception survey. The analysis of the rubric was used to characterize the locally-focused, teacher-created Activity Fives. In order to do this each activity was individually described and then the rubric was used to calculate totals and ascertain commonalities generalities between the different Activity Fives. The classroom observation protocols used Likert-type rubrics that were averaged along with a description of certain characteristics of the activities observed (e.g., type of technology used by student, amount of time taken to log in to the GIS program) to characterize the overall nature of the classroom activities.

The qualitative coding was completed by the researcher without the aid of any computer technology. The coding process was the same for each instrument with open-ended response questions. Responses were compiled into one spreadsheet and were first color coded using anticipated codes (when applicable); the remaining responses were grouped into like categories and coded based on likeness, and also color-coded for organization. Once all the responses were

coded, the codes were then placed into themes based on like ideas to further organize the responses. The themes were used as a means to summarize the codes.

Summary

This chapter presents the mixed methods research design to explore the use of a GIS-based framework for teaching climate change that included a locally relevant activity. A two-part intervention was used. The first part was teacher training on the use of the GIS technology, GIS-based climate module, and creation of a locally-focused inquiry activity, which was distinctive to each class. The second part was classroom implementation and student data collection of the module. The one-week teacher training on the GIS-climate module took place June 15-19, 2015, at Kansas State University in Manhattan, Kansas. The locally-focused activities were constructed using online GIS and the 5E Model and were aligned with student performance expectations of the Next Generation Science Standards. Student-, teacher-, and classroom-centered data were collected to answer the three research questions. These data were used to determine if a GIS-based framework is a practical, reproducible, and effective method for focusing climate change education on local conditions in the 7-12 classroom.

Chapter 4 - Results

Numbers have an important story to tell. They rely on you to give them a clear and convincing story (Few, 2013, p. 136).

This chapter presents the data collected from the seven instruments used in this research. It is formatted using the three research questions as its guide. There was some data overlap between instruments and research questions; those intersections will be discussed in more detail in Chapter 5. Data collection did not go as planned in the initial research design (discussed in Chapter 3); where relevant the variations are described in the appropriate sections below. Complications included: non-equivalent teacher implementation of the GIS-climate module, with impacts on the student knowledge survey and teacher interviews; reliability issues with student knowledge survey; some teachers collaborated in creating a locally-focused lesson; and the researcher was unable to observe in every classroom as planned.

Demographics

Twelve teachers participated in this research; they taught a mix of science and agricultural education classes (Table 13). Three were middle school teachers and nine were high school teachers. Collectively the science teachers taught a mix of general science, earth science, biological science, and environmental science. The two agricultural education teachers taught applied courses related to plant and animal science. The teacher participants had a range of classroom experience from two years to thirty years teaching.

Table 13- Demographics of Teacher Participants

Teacher Participant Grade Level and Courses Taught		
Teacher	Level	Courses Taught
A	Middle	General Science
B	Middle	General Science
C	Middle	Earth Science
D	High	Atmosphere and Space Science
E	High	Atmosphere and Space Science
F	High	Biology/Advanced Placement Biology
G	High	Biology/Advanced Placement Biology
H	High	Biology/Human Anatomy and Physiology
I	High	Biology
J	High	Environmental Science
K	High	Animal Science
L	High	Floriculture/Greenhouse Science

The students participating in the research were in the teacher participants’ classrooms during the fall 2015 semester. A total of 550 students took part in this research. Not every student took every student survey; the sample size per survey is reported in the relevant section.

Data Collected from the Students

Student Climate Change Knowledge Assessment

The student climate change knowledge assessment consisted of six questions. Questions one through five were multiple-choice questions with only one correct answer. Question six was a “select all that apply” question with four answers that should have been selected out of six options. Teachers were unwilling to allow the researcher to match student responses on the pre- and post-assessment. Consequently, student responses to the climate change knowledge assessment were analyzed using descriptive statistics based on how many times the question was answered correctly on the pre- and post-assessments (Table 14). Student absences also led to a

different number of responses on the pre- and post-assessments. The numbers of student responses are listed in Table 14 and range between 442 and 550 students.

Table 14 - Student Climate Change Knowledge Assessment Data

Pre and Post Student Climate Change Assessment Data				
Assessment Question	Sample Size	% Answered Correctly	Change in Percentage Points	
Question 1: (<u>Weather</u>) is the daily conditions of the atmosphere in a place.	Pre (N=550)	409 (74.4%)	+10.7%	
	Post (N=470)	400 (85.1%)		
Question 2: (<u>Climate</u>) is a description of long term average conditions for a region.	Pre (N=550)	375 (68.2%)	+15.1%	
	Post (N=442)	368 (83.3%)		
Question 3: The climate is impacted by both (<u>human</u>) and (<u>natural</u>) processes.	Pre (N=550)	224 (40.7%)	+12.6%	
	Post (N=443)	236 (53.3%)		
Question 4: Which two factors are used in determining the basic Koppen climate classification of a region? (precipitation and temperature)	Pre (N=550)	278 (50.5%)	+7.1%	
	Post (N=443)	255 (57.6%)		
Question 5: Modeling is used to project future climate change through (<u>constructing mathematical simulations</u>).	Pre (N=550)	234 (42.5%)	+2.6	
	Post (N=443)	200 (45.1%)		
Question 6: Which of the following play a role in regulating climate?	Topography	Pre (N=550)	173 (31.4%)	+21.6%
		Post (N=443)	235 (53.0%)	
	Proximity to water	Pre (N=550)	263 (47.8%)	+3.6%
		Post (N=443)	228 (51.4%)	
	Temperature of ocean currents	Pre (N=550)	294 (53.4%)	+11.1%
		Post (N=443)	286 (64.5%)	
	Geographic position on the planet	Pre (N=550)	415 (75.4%)	-0.05%
		Post (N=443)	332 (74.9%)	

Among the multiple-choice questions, questions one, two, and three had the largest percentage point increases in correct responses: +10.7% (Question 1), +15.1% (Question 2), and +12.6% (Question 3). The increase in the number of correct responses suggests that the students learned the most about the difference between climate and weather and what processes impact

climate. Questions four and five also showed a greater number of correct responses on the post-survey, suggesting that the students also learned about climate classification and models, but the increase was less than the first three questions about climate and weather, with a +7.1% change (Question 4) and +2.6% change (Question 5). Question 6, the “select all that apply” question, asked the student to identify which factors impact climate. The correct response options demonstrated a varying range of the amount of increase (or decrease) in the number of correct responses, from +21.6% on “topography” to the decrease in the number of correct responses (0.05%) on “geographic position on the planet.”

Knowledge of Climate Change across Global Warming’s Six Americas

Students completed the 15-question survey for *Knowledge of Climate Change across Global Warming’s Six Americas* (Maibach et al., 2011). The analysis consisted of running a pre-constructed statistical script using the statistical analysis program SPSS. The statistical script to analyze the student data as one group was made available with the survey (Maibach et al., 2011) and made it possible compare the student data from this research with data from the same instrument used in other studies (Leiserowitz et al., 2011a).

The survey was completed by the students before (N=488) and after (N=402) the classroom intervention, with fewer students taking the post-survey than the pre-survey. The pre- and post-intervention categories on the “knowledge” continuum were the same for both pre- and post-data. As a group, student responses placed them in the “alarmed” category (among “alarmed,” “concerned,” “cautious,” “disengaged,” “doubtful,” and “dismissive”) both before and after the intervention. Those whose survey responses placed them in the “alarmed” category are described as those having the highest amount of belief in global warming as well as being the

most concerned and motivated to take action about global warming (Leiserowitz et al., 2011a). Specific student responses by question can be found in Appendix 15.

Student Survey of GIS

Students were asked to complete a post-intervention three-question survey on using GIS. The first question was a one to ten scale rating question and the second and third questions were open-ended response questions. Eleven of the twelve teachers had their students complete this survey. This was the only student dataset where not all twelve teachers were successful in gathering student data; teacher L experienced technical difficulties with the online survey and did not survey his/her students. In addition, not all students answered each question. The number of respondents is reported by question.

Table 15 - Rating Data from Student GIS Survey

Question 1: Rate how much you liked using GIS on a scale from 1 (the worst) to 10 (the best)					
Teacher	Min. Value	Max. Value	Average Value	Standard Deviation	# of Student Responses
A and B	1	10	7.0	2.2	30
C	5	10	7.2	1.8	32
D	1	10	5.5	2.5	62
E	1	10	5.8	2.4	41
F	3	10	6.8	2.0	12
G	1	9	4.7	2.1	22
H	1	10	4.6	2.9	43
I	1	10	4.1	2.8	81
J	3	10	6.9	2.0	22
K	1	3	1.8	0.9	8
	Average Min. Value = 1.8	Average Max. Value = 9.2	Average Value = 5.4	Average SD = 2.1	Total Number of Responses = 353

The first question asked the students to rate how much they liked using a GIS on a ten point scale, with a rating of one being the worst and ten being the best (Table 15). Teachers A and B used the same survey link, thus their data was reported as one group and Teacher L was unable to give his/her students this survey as planned. The total number of student respondents for this question was 353. The average minimum value was 1.8 and the average maximum value 9.2, demonstrating that students used most of the ten point scale. Mean scores ranged from a low of 1.8 (Teacher K) to a high of 7.2 (Teacher C), with an average of 5.4 across all classrooms. Students generally did not rate GIS at the scale extremes as far as “liking” GIS. The average standard deviation was 2.1 and reflected the tendency of standard deviation to increase with increased sample size.

Questions 2 and 3 were open-ended response questions that asked students “what was the best part about working with GIS?” and “what was the worst part about working with the GIS?” Both questions were analyzed and coded using anticipated codes (e.g., working with the online map, using local data, program loading issues, needing more time to learn to use the program) included on the survey instrument itself and additional codes that emerged from the student responses. The anticipated codes were examples included on the student GIS survey to prompt student response. It was understood that this could have impacted the data, but based on teacher participant feedback, it was agreed upon that it was likely that students would provide more useful responses if examples these were provided. Once all the responses were coded, the codes were then placed into themes based on similar ideas to further organize the student responses. All responses were only counted and recorded once under a singular code.

Question 2, “what was the best part about working with GIS?” was answered by 382 students. The responses were placed in eight categories grouped into four overarching themes

(Table 15). The generalities theme, “liked it” and “did not like it” was used when the student made a positive non-explanatory (e.g., “I liked all of it;” “it was cool”) or negative non-explanatory (“e.g., “there was nothing I liked”) response. The second theme focused on map-based student responses and was divided into three codes: “using maps was the best part” (e.g., “...working with the online map”), “visualizing the content” (e.g., “...being able to use all the different map layers and being able to control the effects of the layers”) and “using local data” (e.g., “being able to learn more about the local phenomenon and there are some that show so much detail...”). The third theme was learning-centric and consisted of two codes: “helped me learn” (e.g., “helped me learn new things”) and “made my work easier” (e.g., “so much more accessible...[for learning]”). The fourth, and final, theme was labeled “indeterminable.” Indeterminable answers were responses that made no sense (e.g., “ikyigiukhku”) or specified that the student did not have an answer (e.g., “IDK;” “I don’t know I never used it”).

Table 16 - What Students Liked about Using GIS

Themes, Codes, and Responses on What Students Liked About Using GIS			
Overarching Theme	Individual Code	Number of Responses Per Code (N=382)	Number of Responses per Theme (N=382)
Generalities	“Liked it”	31 (8.1%)	76 (19.9%)
	“Did not like it”	45 (11.8%)	
Map-theme	“Using maps was the best”	125 (32.7%)	216 (56.5%)
	“Visualizing the content”	71 (18.6%)	
	“Using local data”	20 (5.2%)	
Learning-centric	“Helped me learn”	16 (4.2%)	27 (7.1%)
	“Made my work easier”	11 (2.9%)	
Undeterminable	“Undeterminable”	63 (16.5%)	63 (16.5%)

Table 16 displays total response counts of what students liked best per code and per theme. When asked what students liked best, the map theme had the highest number of total student responses at 56.5%, with the individual code of “using maps was the best” having the highest total of individual code responses at 32.7%. This was followed by the generalities

theme, the undeterminable theme, and lastly the learning-centric theme. The code “made my work easier” received the fewest responses of all the codes at 2.9%. All example student responses used to describe the coding implemented by the researcher use verbatim student responses.

Question 3 asked, “what was the worst part about working with the GIS?” There were 384 student replies to this question. Responses to question three also consist of eight codes and four themes (Table 17). The first theme was also generalities and was coded in the same manner as question two, with non-explanatory responses, but this time there were three categories: “liked it,” “did not like it,” and “boring” (e.g., “so boring”). The next theme was program issues and consisted of two codes: “difficult to use” (e.g., “it was difficult to move around on the map”) and “map did not load/technical issues” (e.g., “the map took forever to load”). The third theme was personal struggles and had two codes: “needed more time to learn to use the program” (e.g., “I needed more time to use the program”) and “the map did not correspond with the activity” (e.g., “I couldn’t find what I needed to do my work”). The final theme was again undeterminable with the “undeterminable” code decided the same way as in question two.

Table 17 - What Students Did Not Like about Using GIS

Themes, Codes, and Responses on What Students Did Not Like About Using GIS			
Overarching Theme	Individual Code	Number of Responses Per Code (N=384)	Number of Responses per Theme (N=384)
Generalities	“Liked it”	19 (4.9%)	75 (19.5%)
	“Did not like it”	23 (6.0%)	
	“Boring”	33 (8.6%)	
Program Issues	“Difficult to use”	84 (21.9%)	208 (54.2%)
	“Map did not load/technical difficulties”	124 (32.3%)	
Personal Struggles	“Needed more time to learn to use the program”	32 (8.3%)	43 (11.2%)
	“The map did not correspond with the activity”	11 (2.9%)	
Undeterminable	“Undeterminable”	58 (15.1%)	58 (15.1%)

The highest number of student responses fit within the theme of program issues at 54.2% with the individual code “map did not load/technical issues” having the largest number of responses at 32.3%. The next most recurrent theme was the generalities theme, followed by the undeterminable theme and personal struggles theme. “Needed more time to learn the program” (8.3%) and “the map did not correspond with the activity (2.9%), reflected the fewest student responses.

Data Collected from the Teachers

Teacher Perceptions Survey

Teachers were asked to complete a survey probing their perceptions of the primary components of the intervention. Eleven of the twelve teacher participants completed the survey for a response rate of 91.7%. The survey consisted of yes/no forced response questions, open-ended questions, and rating scale matrices and was divided into six sections: 1) the workshop, 2) GIS, 3) the GIS-climate module, 4) the locally-focused activity, 5) climate change content, and 6) other. Each section is discussed in the following paragraphs.

Table 18 - Teacher Perceptions Survey Forced (Yes/No) Response Data

Teacher Survey Yes/No Responses		
Question	Yes	No
Did the workshop prepare you to implement the GIS-climate module?	11 (100.0%)	0 (0.0%)
Did the workshop enhance your ability to teach climate and climate change content?	10 (91.0%)	1 (9.0%)
Did the workshop prepare you to teach with GIS?	11 (100.0%)	0 (0.0%)
Do you consider your workshop experience to be positive?	11 (100.0%)	0 (0.0%)
Do you plan to continue the use of GIS in your classroom in the future?	11 (100.0%)	0 (0.0%)
Do you plan to expand the use of GIS in your classroom in the future?	10 (91.0%)	1 (9.0%)
Did you find the use of GIS to be helpful for teaching the climate change content?	11 (100.0%)	0 (0.0%)
Do you plan to use GIS to teach climate change again?	11 (100.0%)	0 (0.0%)
Did you find the use of local data to be motivating in teaching the content?	10 (91.0%)	1 (9.0%)
Did you find the use of inquiry to be engaging and illustrating in teaching the content?	9 (82.0%)	2 (18.0%)
Do you plan to continue teaching about climate change in your classroom in the future?	11 (100.0%)	0 (0.0%)
Would you use this specific pedagogical mix (GIS-local data-inquiry) to teach about climate change again?	11 (100.0%)	0 (0.0%)

The first section inquired about the training workshop held in June 2015. All survey respondents (100.0%) considered their workshop experience to be positive (Table 18). Everyone (100.0%) reported that the workshop prepared him or her to teach with GIS and to implement the GIS-climate module. Ten of the eleven teachers (91.0%) responded that the workshop enhanced their ability to teach about climate and climate change. The one teacher who said the workshop

did not enhance his/her ability to teach about climate and climate change explained that the workshop did not contain as much climate change content as he/she would have preferred.

All teachers (100.0%) reported that they planned to continue using GIS in their classroom and ten (91.0%) said they planned to expand their GIS use. All agreed (100.0%) that the use of GIS was helpful for teaching the climate change content and they will use GIS to teach climate change again. Teachers were asked to share successes and challenges that occurred while using GIS in their classrooms. Eleven teachers reported successes and ten shared challenges. These responses were divided into like categories and then given a code that described the teacher responses statements. In the following lists, the teacher responses are organized by code.

- Reported successes in using GIS:
 - Code 1) Ability to explore and learn autonomously benefited the students
 - “Students generally like the autonomy of the GIS projects.”
 - “Awareness of GIS; The tie to existing curriculum; It allows self paced learning”
 - “Students enjoyed the activity because they got to do different things and they got to explore.”
 - Code 2) Students were engaged in the activities.
 - “The students love using technology and in some situations, are more intuitive when using the system than some adults. They were much more engaged with the information than from a standard powerpoint lecture!”
 - “Students were engaged! It was fun to watch them explore the layers beyond the questions.”
 - “I feel like student engagement was great. They were interested in the topic and I feel the GIS program kept the students interested.”
 - “The greatest success story would be when one of my LR students said, "Wow! This is fun! I like this site." The modules were self-paced, thought provoking, and provided beneficial information on climate change...”
 - Code 3) Students liked the use of maps and technology

- “Students seemed surprised that a map could reaffirm what I had taught them. Surprised at the info that could be obtained from a map.”
 - “The use of map layers while using GIS in the classroom was a great help in teaching climate change. It makes it easier for me to show to the students how climate varies from one region to another and the different factors affecting the regions climate. At first, there was little difficulty in the part of the students using the GIS since it was a new site that they have never experienced using before, however, I see more success with my students getting more and more familiar using the GIS with activity 2, 3 & 4. The use of map layers and using maps validates the teaching of climate change because students can see visual evidences and current data to support their learning. The use of GIS makes it more sense in learning climate change because students can directly verify their ideas from using the map layers and the GIS in general.”
 - “The kids loved it.”
- Reported challenges in using GIS:
 - Code 1) Technological issues
 - “Internet connectivity.”
 - “The greatest challenge was the video. I do not know if it was our building and/or firewall, but one day it worked and then it didn't. I was able to pull it up on my computer and it worked. However, since students worked independently, the video was played multiple times.”
 - “Some of the real time data did not always work. It may have been user error though.”
 - “I had some issues with certain aspects of story boards being blocked by our school server.”
 - “Technology! Getting websites approved through the school firewall - not only for the arc gis site but also for the sources of all the layers used.”
 - “The current weather map layer we use in Activity 1 was on and off with the data while we were using it in class. Sometimes, the schools internet firewall will block the use of ArcGIS site.”
 - “For the most part the only problem we had was with our network. The firewall was an issue at first and then bandwidth became an issue later on in the day as more students were using the internet.”
 - “Some students had trouble following my directions and we had a few computer issues. However once we got logged in and they followed directions it went ok.”

- "Finding appropriate maps; Catching students up with their peers after missing a class period; Vocabulary was difficult for the 10th grade students I worked with."
- Code 2) Providing student support to do things students are not used to doing
 - "Unless you completely spell out for a High School student what to look up they are not very creative in coming up with GIS solutions on their own."
 - "Lower level students need a lot of support when using the program. It took me much longer to cover the unit than I had intended. However, as my skills improve I should be able to be more effective at assisting the students in using the program."

The third section asked the teachers to rate the four GIS-climate module activities using a five-point Likert scale to rate four components: 1) content, 2) ease of use, 3) student response, and 4) the likelihood that the teachers would use the specific module activity again. Not every teacher used, and thus rated, each activity. Table 18 presents the average rating for each activity based on a four-point scale with standard deviation in parentheses; the full tables can be found in Appendix 17.

Table 19 - Average Teacher Ratings of GIS-Climate Module

Teacher Average Ratings of GIS-Climate Module Activities				
Activity #	Activity One (N=11)	Activity Two (N=7)	Activity Three (N=6)	Activity Four (N=5)
Average Rating on a Four-Point Scale	4.1 (0.8)	4.0 (0.9)	3.6 (1.0)	3.7 (1.0)

The four activities received mean ratings of 3.6 to 4.1, with Activity three receiving the lowest overall rating and Activity one receiving the highest overall rating (Table 19). As shown in Appendix 15, the tables with the four components rated by the teachers, which show that teachers reported that they were most willing to use Activities one and two again. Also, the activity ratings show that the activities successfully taught the content and overall were moderately easy to use.

Teachers were asked to rate the process of creating and implementing their own locally-relevant activity, also called Activity 5. They were asked to rate the creation and implementation components of the activity using a five-point Likert-type scale, of “very difficult” to “very easy.”

Table 20 - Teacher Ratings of Activity 5

Teacher Rating of Creation and Implementation of the Locally-Relevant Activity (Activity 5)								
Question	Very Difficult	Difficult	Neither Difficult nor Easy	Easy	Very Easy	Total Responses	Mean	SD
Creation	0	3	5	2	1	11	3.1	0.9
Implementation	0	0	2	7	1	10	3.9	0.6
Average Overall Rating for Activity 5							3.5	

Table 20 presents the creation and implementation rating data. The mean rating of creating Activity five was 3.1, indicating that it was “neither easy nor difficult.” Teachers rated the implementation of their Activity five with a mean rating of 3.9, which is close to the four-point indicator of “easy.” The overall average rating of creating and implementing Activity five was 3.5, which is exactly between “neither easy nor difficult” and “easy.”

The next section asked teacher participants questions about using the climate change content and local data (Table 18). Ten of the eleven teachers (91.0%) reported that using local data was motivating in teaching the content. The one teacher who said the local data was not motivating explained his/her response, “Most of the effects in Kansas have to do with agriculture. My urban students are very disconnected from the rest of the state.” Respondents were also asked if the use of inquiry was beneficial to teaching the content and nine (82.0%) reported that it was. The two teachers who said inquiry was not beneficial shared the rationale for their response by reporting “student frustration level was high due to their lack of vocabulary pertaining to the lessons” and “just did not connect with the students.” All teachers (100.0%)

said they plan to continue teaching about climate change in their classroom in the future and all reported that they would use the specific pedagogical mix of GIS-local data-inquiry, as used in this research, again. Nine teachers shared successes and challenges to teaching the climate change content. The climate change success and challenge codes are organized below with the teacher responses bulleted under them; the number of teacher responses below each code quantifies how many responses were associated with each code.

- Reported successes in teaching climate change:
 - Code 1) Student engagement and understanding
 - “They started to get it. Most had not had this before.”
 - “I think the successes I have had come in small bits. Student by student a day at a time. It just fun to see the Aha moments when kids grasp the concept of what is happening.”
 - “My students really seemed to enjoy the change of pace that this lesson allowed. They enjoyed using technology and having the latitude to explore this subject. Thanks for all of your help and support. Thanks for being an exceptional instructor this summer.”
 - “Students are beginning to understand why we need to be concerned and what they can do to help.”
 - Code 2) Visualization of information helped student learning
 - “Students were able to visualize and discuss potential climate issues they would not have otherwise taken the opportunity or put forth the effort.”
 - “Being able to use the maps and make comparisons with areas they may never get to visit left an impression. The mapping activity I designed allowed them to see things from a more global perspective. They were eager to learn more!”
 - “When the students could 'see' the data, it made more of an impact.”
 - “I love teaching climate change in class. The use of GIS and map layers makes it easier for me to teach climate change because I have the visual tools to use and show to my students. It really helps them understand much better when I use map layers whenever I talked about climate and weather, climate patterns and factors affecting the region's climate because the idea can be verified with the data from the maps. The use of GIS was a huge help in making my students understand much better about climate

change because the maps are interactive and gives them the opportunity to simulate conditions and verify results and learn how climate change over the region. By the end of activity 4, I saw more students finally learn the difference between climate and weather and more success in activity 4 (personally planned activity). I would estimate about 60% of my students have more concrete understanding of climate change.”

- “Throughout the project new technology was introduced to the students. This included GIS, tree core sampling, and Google Maps. The GIS provided insight into how scientists collect and analyze data. The modules gave a spring board for discussing additional climate topics. It has also made students more aware that climate change is happening and that they do have a stake in helping to change the course of global warming.”
- Reported challenges in teaching climate change:
 - Code 1) Needed more preparation time
 - “The tree cores we collected were difficult to read with the equipment I had for the rings that were very close. The students did the best they could. Counting rings even proved difficult for me on some.”
 - “The preparation time spent familiarizing students with the maps and models was lengthy compared to the actual instruction time relevant to the content.”
 - “Finding relevant data for my kids.”
 - Code 2) Misconceptions in knowledge and student learning
 - “I think the biggest struggle, and its really not that big, is common misconceptions towards the subject. Mostly brought on by prior knowledge they gained from parents or other teachers.”
 - “Using data that the students can understand.”
 - “Making the information real and relevant [sic] for the students is necessary if you want them to engage the subject matter. They aren't worried about what is happening in other areas, but if the change can be seen in their own back yards, the information becomes more impactful and memorable to them.’
 - “Often times, students think that climate change is global warming and I find it very challenging for them to understand that climate change isn't just about global warming. For my students to understand the difference between climate and weather is also challenging especially when you ask them questions like " how do you describe climate?" and often times you

will hear them talking about current temperature instead of temperature range or average temperature. At the start of activity 1, I would estimate only 25% of my students are really interested and motivated in learning climate change.”

○ Code 3) First time teaching the climate change content

- “Biggest challenge was myself sitting on the fence, not knowing if it is a real thing and if it is something to worry about. I have decided it is a real thing and as I continue to study the issues I am concluding that it is something to be concerned about.”
- “This is my first year of teaching climate change. I am looking forward to teaching it better in future years because of this class.”

Teacher Semi-Structured Interviews

All twelve teachers participated in individual semi-structured interviews with the researcher. Responses from the interview questions were kept in the form of handwritten notes and all teachers were asked the same ten questions. The interview question responses were qualitatively coded using the data analysis procedure described in Chapter 3. The codes and themes are specified separately by question. The goal of the interview was to characterize the range of teacher responses on the workshop, using GIS in the classroom, teaching the climate change content, and using local data. The data are reported in the sequential format of the interview protocol itself.

The first question in the interview asked the teachers to share their overall thoughts about the project in three words.

Table 21 - Teacher Overall Thoughts on the Project

Three Words Used to Describe Teacher Thoughts on the Project			
*If used more than once, the number of occurrences can be found in parentheses at the end of the word			
Three Word Phrases:	Positive Words:*	Negative Words:	Outliers:
<ul style="list-style-type: none"> • A great tool • Challenging but fun • Extreme educational benefits • Maps need catalogued 	<ul style="list-style-type: none"> • Challenging (2) • Detailed • Educational • Engaging (2) • Enjoyable • Eye-opening (3) • Fun (2) • Innovative • Insightful • Interesting • Potential • Real-world • Useful • Well-developed 	<ul style="list-style-type: none"> • Struggle 	<ul style="list-style-type: none"> • K-State • Modeling • Technology

Teachers took two approaches in responding, the first in using all three words to create a descriptive phrase and the second to use three independent expressive words (Table 21). The words were categorized into four groups: 1) three-word phrases, 2) positive words, 3) negative words, and 4) outliers. The descriptive words used by teachers to describe their feelings about their experience in the project were positive, noting only one word that was considered negative and three outliers that were considered neutral. The descriptive words that were used most often were “challenging,” “engaging,” “eye-opening,” and “fun.” The word “challenging” by definition itself could have been placed under the positive or negative words category but based on researcher understanding of how “challenging” was used by the teachers during the interviews, it was placed in the positive word category.

Second, teachers were asked to describe their workshop experience and prompted to share three components: 1) the best parts of the workshop, 2) what could have made it better, and 3) what they found they needed after the workshop itself. The teachers did not answer each

component specifically, and their responses were coded and divided into themes to establish specific answers the question. The response data is reported as two categories: 1) workshop and 2) post-workshop, with themes and codes used to elaborate on and document the teachers' responses to this question and its components.

Table 22 - Teacher Perception of the One-Week Workshop and Post-Workshop Needs

Teacher Response to Workshop and Post-Workshop Needs	
Theme 1: Workshop	Theme 2: Post-Workshop
<p><u>Code 1) General positive response</u></p> <ul style="list-style-type: none"> • Lots of time allotted for learning the program • One-on-one help from the researcher • Good size group • Being able to have a say on the student instruments (knowledge and GIS use) • Liked having input on the student instruments 	<p><u>Code 1) Positive response</u></p> <ul style="list-style-type: none"> • Once home found the materials to be fairly self-explanatory • Good to go post workshop – “no issues stick out” in his/her mind • Didn’t need anything after the fact
<p><u>Code 2) Potential improvements</u></p> <ul style="list-style-type: none"> • Differentiate technological instruction level (middle v. high school; high tech v. low tech) • Have a database or online site where everyone could see each other’s locally-focused lessons • Put more focus on the climate change content 	<p><u>Code 2) Difficulties</u></p> <ul style="list-style-type: none"> • Took time after the workshop to complete their locally-focused activity • Had to spend more time with the GIS site to ensure they could successfully navigate the site and properly instruct their students to access the parts they needed them to • Searching for data – the process the GIS program uses is limiting and frustrating • Had to work with schools to get sites and data unblocked

From the information provided on the workshop itself, two themes were identified: 1) the workshop and 2) post-workshop (Table 22). The bullet points of summarized teacher responses express their feedback as well as the quantitative count of the information provided (e.g. if there are three bullet points then this code was recorded three times). The generally positive responses focused on the time allotted for learning the program, one-on-one help from the researcher, size of the group and comfortable atmosphere, and being able to have input on the construction of the student instruments. The second code, suggestions to make it better, were to differentiate by grade level and technology confidence as well as provide a database or online site where

everyone could see each other’s locally-focused activity. One teacher commented that he/she felt the workshop emphasized the technology and didn’t provide enough climate change content.

Two codes were determined in the analysis of the post-workshop response category. The first code was again ‘positive response;’ some teachers reported no post-workshop needs or difficulties. To illustrate this sentiment, one teacher said “I was brand new to GIS and tentative at first but the workshop experience was so well planned and helpful that I was ready by the end of it.” The second code was ‘difficulties;’ these also might be reframed as additional ‘potential improvements.’ Difficulties included time to complete the fifth activity, time to work with the GIS program, using the GIS program search function, and working with the teacher’s school to get GIS program sites and data unblocked by school firewalls/accessible from school computers.

The third and fourth interview questions asked teachers what challenges and great moments they had in using GIS in their classroom.

Table 23 - Teaching with GIS Challenges

Teacher Identified Challenges and Great Moments in Teaching With GIS		
	Themes	Codes
Challenges	Technology	<u>Code 1) GIS program based</u> <ul style="list-style-type: none"> • Getting students logged into the program • Limited search for data function • Use of specific browsers for best program performance
		<u>Code 2) School based</u> <ul style="list-style-type: none"> • School bandwidth; internet speed and connectivity • Blocked sites and data
	Students	<u>Code 1) Learning-oriented</u> <ul style="list-style-type: none"> • Needed extra time and classroom support for some students • New technology was challenging for the students • Students sometimes became disengaged once experiencing many technological difficulties
		<u>Code 2) Planning-oriented</u> <ul style="list-style-type: none"> • Student absences

Two themes and four codes were found within the challenges data (Table 23). The challenges were separated into two themes: 1) technology challenges and 2) student challenges.

Both themes consisted of two codes. The technology challenge theme codes were: 1) GIS program-based and 2) school-based. The program-based challenge codes were based on difficulties in getting students logged into the program, the limited search for data capabilities in the GIS program (finding useful data), and use of specific browsers for best program performance. The school-based challenge codes were based on school bandwidth, internet speed, internet connectivity issues, and blocked sites and data. The second theme, student challenges, consisted of two codes: 1) learning oriented and 2) planning oriented. The learning oriented challenge code included the need for more time and greater classroom support for lower performing students, teaching the students to use new technology challenging the student's abilities, and overcoming the fact that students were often impatient and became disengaged when there were technology difficulties. The planning oriented challenge code was student absences. It was reported that if students missed a day it was hard to get them caught up given the use of the technology and the teacher guidance needed to learn to use and support using the technology.

Table 24 - Teaching with GIS Great Moments

Teacher Identified Great Moments in Teaching With GIS			
Great Moments	Themes	Codes	
		<u>Theme/Code 1) Engagement through real-world applications</u>	
		<ul style="list-style-type: none"> • Watch students get comfortable with the maps and find their own information and data on real world problems • Meaningful applied use of real life data 	
	Support of student learning	<u>Code 1) “Aha!” moments</u>	
<ul style="list-style-type: none"> • Watching students have “aha” moments • Overlaying of the maps really gave the students “aha” moments 			
<u>Code 2) Visualization of the content</u>			
	<ul style="list-style-type: none"> • Watching students excel at using visual information – it helped the content make better sense • Students could actually see how the data supported what is happening in the world around them • Students being able to see models and have discussions about the future 		
	<u>Code 3) Equalized student learning</u>		
	<ul style="list-style-type: none"> • Students really enjoyed it, especially the lower level students • It worked well for the average student as well as the advanced students • The activities supported more advanced student learning 		

When asked what great moments in teaching with GIS the teachers experienced, the teacher responses were separated into two themes and four codes, with the overlap of one theme and code (Table 24). The two themes were: 1) student engagement through real-world applications and 2) supported student learning. The first theme was also the code associated with that theme, engagement through real-world application. This was a unique circumstance where the other three codes fit well together under the second theme and this code was a standout, so for organizational purposes was also given its own theme. Engagement through real-world application was based on student use of data about real world problems and meaningful applied use of real life data. Described by one teacher as “[teaching with GIS] provided real life real time data that was meaningful to them.” The second theme, supported student learning, was composed of three codes: 1) “a ha!” moments, 2) visualization of the content, and 3) equalized student learning. The “a ha!” moments code was based on teacher description of “a ha!”

moments in the classroom specific to using GIS. One teacher explained it as “seeing all the light bulbs going off above their heads because often when you’re teaching high school kids it’s hard to get them interested long enough to get to that moment.” The visualization of the content code was based on students making better sense of the content from being able to “see” the data and the use of visual content as a means for students to have conversations about the future.

Teachers expressed visualization of the content as first, “[using the GIS, the students] could draw connections visually better than just talking about climate in class” and second, “[the students were] surprised you could learn that much with maps.” The third code, equalized student learning, was based on teacher reports that using the GIS was an equalizer for lower, average, and high academic functioning students. One teacher said, “[it] empowered my lower level students.”

Question 5 asked teachers to characterize their students’ response to using GIS. In this case, the qualitative codes were determined to be sufficiently different and were not divided into themes.

Table 25 - Teacher Characterize Student Response to Using GIS

Teacher Characterization of Student Response to GIS Use	
Codes	
Code 1) <u>Students liked using technology</u>	<ul style="list-style-type: none"> • Positive – enjoyed it • They liked it • New and different They liked using new technology
Code 2) <u>Students felt that using GIS in an applied real world context was useful</u>	<ul style="list-style-type: none"> • Some students wanted to use the program in their free class time, which led to students finding map information related to the current events they were studying at the time (on mass shootings) and that led to an impromptu student led investigation • Students felt they could use GIS for other classes or even outside of class activities • Very positive to use technology and content that was applied in a real world context – and the students liked this application side
Code 3) <u>Technology challenges</u>	<ul style="list-style-type: none"> • Internet speed frustrations • Issues with search for layers function in the program • Students are used to being spoon fed and this was harder for them – and that type of challenge is a really good thing!

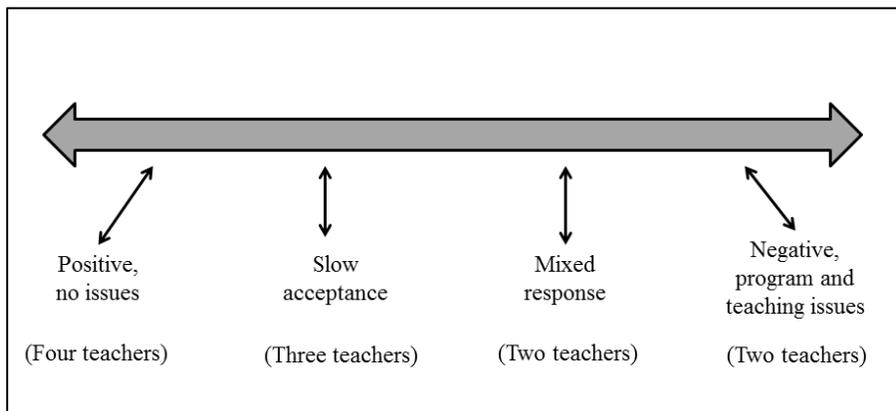
The responses shared by the teachers were organized into three codes (Table 25). Code one, students liked using the technology was based on positive non-explanatory responses. One teacher even said “they loved it.” The second code, students felt that using GIS in an applied real world context was useful, was based on student interest in using GIS in other classes and for other topics and students liking the application possibilities of GIS. One teacher reported, “they liked exploring and that no one’s map was the same.” The third code was technology challenges and based on frustrations with internet speed, the search for layers function within the program itself, and students being challenged by learning the new technology. Three teachers agreed that using the GIS was a beneficial challenge for their students - it made them use problem solving skills without direct teacher guidance.

The sixth question asked whether the teachers would use GIS again; and if so, how they would do this. All teachers (100.0%) responded that they would use GIS in their classroom

again. Seven teachers said that they wanted to revise and adjust the lessons they used as part of this research, with one teacher sharing, it “was the perfect tie in to teach the Next Generation Science Standards on climate change.” Most (nine of twelve) also elaborated on how they would expand their GIS usage. Teachers shared that that they planned to use GIS during lessons on ecology, pollution, urban sprawl, land use, and geology. One teacher reported he/she planned to incorporate GIS into his/her science fair activities. Three teachers said they had already begun planning new activities that use GIS.

The seventh question asked teachers to share how their students responded to the climate change content. Four codes were used to describe the teacher reports of how their students responded.

Figure 12 - Spectrum of Student Response to Climate Change Content



The four codes were types of student reactions to the climate change content arranged on a spectrum (Figure 10). Starting with the positive side of the spectrum of responses, four teachers reported that the climate change content was well received with no issues or student pushback. One teacher said “it did not raise any red flags or was controversial; it was just as though they were analyzing data – which was good!” Next on the spectrum was slow acceptance, three teachers reported this type of student response. Slow acceptance was described as moderate disinterest at first followed by student interest and understanding of the content and expressed as

“[it was] slow getting them to come around, just like me, but [they] came to the conclusion that yes there is.” Also in the middle of the spectrum was a mixed response category. In this category two teachers reported that student response was very dependent on the student and described as “positive overall but some were apathetic still.” Two teachers described their student response at the negative end of the spectrum. The first reported his/her students not connecting well to the content because they did not like using the GIS. A second teacher reported a poor response based on his/her own teaching approach and said he/she needed to start broader and with a better general introduction the next time he/she taught this unit.

Eighth, teachers were asked whether they found the use of local data to be helpful. Teachers responded in a “yes/no” manner. All but one teacher (91.7%) responded that using local data was helpful. The teacher who reported that the local emphasis was not useful explained that his/her specific curriculum was broad and the local data were not needed. From the teachers who reported the local data being helpful, eight teachers reported that use of the local perspective engaged their students and increased their interest in the content, while the other three teachers said the local data was useful but mentioned that Kansas lacks startling climate change issues and they felt this sentiment was identified by the students as well.

Teachers were asked to explain the process of creating their own locally-relevant activity. The teachers’ responses were divided into two themes and five codes (Table 26).

Table 26 - Teacher Response to Creating Activity 5

Teacher Successes and Challenges in Creating Locally-Relevant Activity	
Themes	Codes
Successes	<u>Code 1) 'Easy enough' to create and use</u> <ul style="list-style-type: none"> • Technically making a story map was not hard • Liked components of it during teaching – specifically having all parts on one screen • Easy enough to put together
	<u>Code 2) Fit well into existing curriculum</u> <ul style="list-style-type: none"> • Fits in perfectly with what he/she already does regularly in the classroom • Built on existing lesson to make it interactive • Seamlessly fit with content and made lesson better
	<u>Code 3) Providing a good introduction to GIS</u> <ul style="list-style-type: none"> • Used workshop activities to make a good introduction to using GIS
Challenges	<u>Code 1) Identifying the local issue</u> <ul style="list-style-type: none"> • Challenge to find an engaging local issue but once they did they defined what was most important and split up the tasks to complete • Coming up with an obvious idea for the students to grasp was the most difficult followed by finding useful data
	<u>Code 2) GIS program difficulties</u> <ul style="list-style-type: none"> • Finding/maintaining the web link for the map itself • Frustrated with limited Esri's web resources – the maps she wanted were not necessarily there – • Couldn't find “best” desired map for content but made do

The five codes were organized into two themes: 1) successes and 2) challenges (Table 26). The successes were composed of three codes. The first code, was easy “enough” to create and use, were based on story maps being easy to create and teachers liked having all features on one screen. The second code, fit well into existing curriculum, was based on reports that the lesson aligned with existing curriculum and activities. One teacher reported that the addition of GIS to her curriculum “just made it better.” The third code, providing a good introduction to GIS, was based on the use of workshop hands-on activities to create an understanding for students in the teacher’s classroom. The challenge theme was composed of two codes. The first code, identifying the local issue, was based on teacher reports of concerns with finding a local issue that they thought suitable for their classroom and finding data about the local issue they wanted to cover. The second code, GIS program difficulties, was based on reports of problems finding

needed web links, finding useful data in the program, and making due with what the teacher could find. All the teachers reported plans to use their locally-relevant activity again.

The final question of the interview asked teachers to share any other thoughts or comments about their experience. The teachers overwhelmingly reported enthusiasm for the project, with one teacher stating that “it took more time than anticipated but it was well worth it.” Many teachers noted how important this content and technology is for their students and one said, “[it] gave students a whole different perspective on global warming.” Several teachers also shared technical recommendations (e.g., difficulties using the search function, the tagging system while saving maps is not consistent) that were passed on to Esri, which partially funded this research..

Data Collected from the Classroom

Analysis of Locally Relevant Inquiry Activities

Analysis of the locally relevant inquiry activities is reported below in two different ways. First, the activities are reported individually, with each locally focused teacher-created activity qualitatively described. Second, the activities as a whole were assessed using the rubric created by the researcher. The rubric focuses on eleven components of inquiry lessons which align with the instructions given to the teacher participants during the workshop to create their Activity 5. A total of eight lessons were provided to the researcher for analysis (see Appendix 16). In two cases, two teachers worked together; in three cases, teachers simply modified a lesson from the GIS-climate module; one teacher did not provide the researcher with his/her locally-focused lesson.

The following paragraphs describe the teacher-created locally-focused lessons. The only lessons described are the lessons created by the teachers, not the lessons modified from the GIS-

climate module. The modifications to the GIS-climate lessons were minimal (e.g., wording, change of example location). Those lessons' descriptions would all be nearly alike.

In two cases, two teachers chose to work together and thus their activity is only described one time. Four teachers worked independently. The activity descriptions are listed alphabetically based on teacher designated letter; to maintain anonymity, no teacher information has been provided except their designated letter (Table 13). The title of the lesson is included in the section title for each lesson description and each description contains four parts: 1) the teacher-reported guiding question of the lesson, 2) the local issue on which the lesson focused, 3) the climate change content used, and 4) how the GIS was used. The lesson descriptions varied greatly in format and detail.

Teacher C: Making Climate Change Local

This lesson was used in a middle school earth science class. In this lesson students used local tree ring data, county temperature and precipitation data, and oral history interviews of long time county residents to examine perceptions of changes to their county's climate conditions. No specific guiding question for the lesson was given to the researcher. The local data used were average temperature and precipitation at the county level. The climate change content focused on changing temperature and precipitation patterns and using paleo-environmental proxies as evidence of climate change (tree rings, ice cores, and sediment cores). Students cored local trees as part of a field trip. The GIS was used to map the GPS coordinates of the tree core samples taken, create data layers using the map note function, and make a story map or presentation in *ArcGIS Online* of the overall lesson findings. Data included in the map notes layer included coordinates, age of tree, name of tree, descriptions of the tree, and precipitation and temperature record. The oral history information was integrated into the student presentations.

Teachers D and E: Ogallala Aquifer Study

This lesson was used in high school atmosphere and space science classes. One pair of teachers worked together to construct a lesson about the Ogallala aquifer and its importance in Kansas agriculture, the effect of agriculture on the depth of the aquifer, and the significance of climate change on the aquifer region. The guiding questions were: “how are you impacting climate?”; “what is climate change?”; and “how are climates and biomes being impacted?” The local climate change concern explored in this lesson was the impact of changes in precipitation, temperature, and agricultural use on aquifer depth up to the present and then projected into the future using climate models. The students used the GIS functions of measuring and manipulating data layers to visualize change of aquifer water depth and agricultural practices over time. The lesson culminated with students using map-based evidence to make predictions about future changes for agriculture in the Ogallala Aquifer region.

Teachers G and H: Evolution of Skin Color

This lesson was used in high school biology, advanced placement biology, and anatomy and physiology classes. The activity used a teacher-created story map to teach students about the evolution of skin color. This pair of teachers worked together to build their story map during the June workshop. The activity was centered around four research questions: 1) “do only light skinned people get skin cancer?”; 2) “what are the causes of skin cancer?”; 3) “why are light skinned populations more at risk of skin cancer than other populations?”; and 4) “at what age does skin cancer typically occur?” These questions led the students into a discussion of how climate change could impact the evolution of skin color, at both the global to local scale. The locally-focused questions asked students how they thought they could personally be impacted in their hometown. The climate change content emphasized climate change impacts on the ozone

layer, the amount of radiation reaching the earth, and increasing temperatures. The GIS used was a multi-tabbed story map that had corresponding text, map, and activity question created specifically for this activity. The students were directed to explore the map to visually identify relationships and derive answers from the connections that they saw, and used the map data as evidence. They interacted with the map at varying levels of scale.

Teacher I: Impact of Mining and Climate Change in Kansas

This lesson was used in a high school biology class. It was designed as a capstone to a unit on mining. There was not a specified guiding question, but students were asked to create a profile presentation on an element/mineral they were assigned to research using GIS. The locally-focused data were changes in mining in Kansas from projected climate change impacts. Students used data from the 2014 National Climate Assessment in making their GIS map of mining sites with data on projected impacts of climate change. The students then used their maps in a formal classroom presentation on their assigned element/mineral.

Teacher J: Biome Mapping Comparison

This lesson was used in a high school environmental science class. It used a teacher-created GIS map that compared biomes in southeast Kansas to a similar biome in Nigeria. The lesson provided did not include any specific guiding questions. The local issue was the biome in which the school is located, with an emphasis and comparison on plant life with the same biome in Nigeria. This lesson tied directly into a hands-on plant-growing lab the students were simultaneously completing during which the students were asked to grow four of the same plants using different precipitation regimes. The climate change content emphasized changing precipitation patterns. The students used the GIS to visually analyze and manage multiple data layers to answer the activity questions.

Teacher K: Kansas Climate Change Impact on Population

This lesson was used in a high school animal science class. It used a teacher-created GIS map to study changing populations in Kansas over time. The guiding question was: “can climate change impact the decision to live in a certain environment?” The local emphasis of the activity examined the state of Kansas as a whole. The climate change content was precipitation changes over time based on climate classification. Additional data included in the map were historical and present day data on human population and migration. The GIS map required student exploration and manipulation of the layers in drawing conclusions about the data to answer the student response questions posed by the activity worksheet.

Rubric Analysis

The rubric was used to review and summarize the locally-focused teacher-created activities based on seven components the teachers were asked to include in their locally-focused activity. The rubrics were scored based on identifying (e.g., was the 5E model used?) and counting (e.g., how many sources of data were used?) the rubric components in the lesson plans provided by the teachers. Table 27 uses data from only six rubrics. The modified lessons used in classrooms where teachers did not create their own locally-focused Activity 5 were not included in the assessment.

Table 27 - Rubric-based Analysis of Local Inquiry Activity

Rubric for Analysis of Inquiry Activities (Response numbers and percentages shown below the descriptions)			
	Beginning	Developed	Accomplished
Aligned with GIS-Climate Module	Alignment is not clear or vaguely identified in this activity.	Alignment is evident but not clearly addressed in the activity.	Alignment is evident and clearly addressed in the activity.
	1 (16.7%)	0 (0.0%)	5 (83.3%)
Use of 5E Model	Some of the 5E Model components are used.	Most of the 5E Model components are used.	The complete 5E Model is used.
	2 (33.3%)	2 (33.3%)	2 (33.3%)
Type and Use of Local Data	One type and small set of data was used.	Two to three data sources of any size were used and compared with other data.	Two to three data sources of any size were used and compared with other data that the students also identified to be used.
	1 (16.7%)	3 (50.0%)	2 (33.3%)
Use of GIS	The GIS is used for referencing content.	The GIS is used for referencing and manipulating data.	The GIS is used for reference, manipulating, and analyzing data.
	0 (0.0%)	0 (0.0%)	6 (100.0%)
Question Posed	The question was very specific and leads to one right answer.	The question was specific but allowed for student exploration of several possible answers.	The question was specific but allowed for student exploration and interpretation of multiple possible answers.
	0 (0.0%)	3 (50.0%)	3 (50.0%)
Student Investigation	Students led the investigation with a lot to some help from the teacher.	Students led the investigation with some to little help from the teacher.	Students led the investigation with little to no help from the teacher.
	0 (0.0%)	4 (67.7%)	2 (33.3%)
Student/Class Sharing/Reporting	Students informally shared or presented their findings.	Students presented formal presentations of findings.	Students presented formal presentations of findings followed by in-discussions with peer feedback.
	4 (67.7%)	1 (16.7%)	1 (16.7%)
Total Counts	8 (19.0%)	13 (31.0%)	21 (50.0%)

Overall, the requirements of the locally relevant inquiry activity were adequately met, based on the rubric. Thirty-one percent of the activities overall were in the “Developed” category and 50.0% were in the “Accomplished” categories. Five lessons (83.3%) received an

“Accomplished” rating of alignment with the GIS-climate module. Parts of the 5E model were used in each lesson, but only two lessons (33.3%) used the complete 5E model. Five lessons (83.3%) used two or three local data sources identified by the teacher and two of those lessons (33.3%) also used data gathered by students. The GIS was consistently used for referencing, manipulating, and analyzing data, with all six lessons (100.0%) receiving an “Accomplished” rating. The questions posed by the lessons were split with three lessons (50.0%) receiving a “Developed” rating and three lessons (50.0%) receiving an “Accomplished” rating. Four of the lessons (67.7%) were student-led with some to little help from the teacher and two lessons (33.3%) were student led. Four lessons (67.7%) had the students informally share their findings.

Classroom Observation

Classroom observations during the fifth activity (the locally-focused teacher-created activity) in each participating teacher’s classroom were planned as part of the research design. Due to scheduling conflicts and unanticipated transportation issues, only eight of twelve classroom observations were completed and not all took place during Activity 5. Of these eight observations, six were completed by the researcher and two were completed by the researcher’s adviser. The paragraphs that follow describe the classroom contexts for the observations. The results of the classroom observation protocol focus on lesson design and implementation, content, communicative interactions, and a qualitative summary of the events in each classroom observation.

All of the eight classroom observations took place in high schools, encompassing grades nine through twelve. Half of the classrooms were on block scheduling (where class periods last for 90-minutes) and half were on a traditional bell schedule (50-minute class periods).

Observations took place throughout the GIS-climate unit, with one occurring at the beginning,

two during the middle of the unit, and five taking place during the final activity as planned. Notable occurrences during the classroom observations were that in one observation the web maps to be used in the lesson did not work throughout the entire observation and another observation was under the instruction of a substitute and student teacher (neither of whom had attended the research training) due to the teacher participant not being able to be present that day.

The classroom observation protocol consisted of three rubrics that measured multiple dimensions of classroom activity: 1) lesson design and implementation, 2) lesson content, and 3) communicative interactions (see descriptions, Tables 28-30). The rubrics use a five point scale (zero is “Never Occurred” and four is “Very Descriptive”), along with a “Not Applicable” category. The lesson plans each teacher provided to the researcher were used to corroborate what the researcher saw during the classroom observation to help distinguish what received a zero score of “Never Occurred” and a “Not Applicable” score. For example, in Table 30 - Communicative Interactions item 1, “Students were involved in the communication of their ideas to others using a variety of mean and media.” If the lesson plan provided to the researcher did not specify communication of student ideas and the researcher confirmed that this action did not take place during the classroom observation, then “Not Applicable” was selected on the observation protocol.

Table 28 - Rubric-based Analysis of Classroom Observation Lesson Design and Implementation

Lesson Design and Implementation (Table IV from Classroom Observational Protocol)							
		0 Never Occurred	1	2	3	4 Very Descriptive	Not Applicable
1	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (12.5%)	7 (87.5%)	0 (0.0%)
		Distinguished based on whether or not the teacher verbalized past knowledge and/or connection to prior materials and/or if students could be observed in classroom dialogue referencing past lessons and/or materials.					
2	The lesson was designed to engage students as members of a learning community.	0 (0.0%)	1 (12.5%)	1 (12.5%)	3 (37.5%)	3 (37.5%)	0 (0.0%)
		Determined by observing on and off task behavior as well as comfortable/relaxed the classroom atmosphere felt.					
3	In this lesson, student exploration preceded formal presentation.	0 (0.0%)	0 (0.0%)	2 (25.0%)	1 (12.5%)	2 (25.0%)	3 (37.5%)
		Rating based on how much time was given and how often teachers had students explore ahead of their presentation.					
4	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	1 (12.5%)	0 (0.0%)	2 (25.0%)	2 (25.0%)	1 (12.5%)	2 (25.0%)
		Rating based on how much time was allotted for student investigation and if this investigation was verbally encouraged.					
Total Counts		1 (3.1%)	1 (3.1%)	5 (15.6%)	7 (21.9%)	13 (40.6%)	5 (15.6%)

Table 28 presents the number of occurrences of four dimensions of the lesson design and implementation. Overall the lesson design and implementation were rated highly with 21.9% of the classrooms receiving a three-point rating and 40.6% receiving at four-point rating. The lesson design and implementation observed during these observations showed that teachers respected and acknowledged students' prior knowledge with 87.5% receiving a four-point rating. Six observations received either a three- or four-point rating (75.0%) indicating that the lessons were designed to engage students in a learning community. Student exploration preceded formal teaching in three observations (37.5%) with it being non-applicable 37.5% of the time. The amounts of the times that the lessons encouraged students to seek alternative modes of investigation occurred some of the time, with two classrooms (50.0%) receiving a two-point mark.

Table 29 - Rubric-based Analysis of Classroom Observation Content

Content (Table V from Classroom Observational Protocol)							
		0 Never Occurred	1	2	3	4 Very Descriptive	Not Applicable
1	The lesson involved fundamental concepts of the subject.	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (25.0%)	6 (75.0%)	0 (0.0%)
		Scored based on balance between climate change content and other lesson-specific content.					
2	The lesson promoted strongly coherent conceptual understanding.	0 (0.0%)	0 (0.0%)	1 (12.5%)	1 (12.5%)	6 (75.0%)	0 (0.0%)
		Based on if the lesson did what it said it was going to do and this student learning was evident through classroom observation.					
3	The teacher had a solid grasp of the subject matter content inherent in the lesson.	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (12.5%)	7 (87.5%)	0 (0.0%)
		Teacher taught with confidence and content accuracy.					
4	Connections with real world phenomena were explored and valued.	0 (0.0%)	0 (0.0%)	1 (12.5%)	1 (12.5%)	6 (75.0%)	0 (0.0%)
		The real world concept seemed of value to the student.					
5	Students used GIS to represent phenomena.	0 (0.0%)	0 (0.0%)	1 (12.5%)	2 (25.0%)	4 (50.0%)	1 (12.5%)
		Based on if the GIS was used to reference actual scientific content and not serve as a reference map of a geographic area; higher rating based on how in-depth students has to interact with the GIS content.					
6	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0 (0.0%)	0 (0.0%)	1 (13.0%)	5 (62.5%)	0 (0.0%)	2 (25.0%)
		Balance of thought-provoking and assessment of the methods being used.					
7	Students were reflective about their learning.	2 (25.0%)	0 (0.0%)	2 (25.0%)	2 (25.0%)	2 (25.0%)	0 (0.0%)
		Based on if teachers encouraged reflection verbally or as indicated through the lesson and if students could be seen as engaged in their learning. (Learning defined as “thinking in the moment” because observations only capture the moment.)					
Total Counts		2 (3.6%)	0 (0.0%)	6 (10.7%)	14 (25.0%)	31 (55.4%)	3 (5.4%)

The second rubric focused on climate change content; Table 29 examined seven dimensions of the observation. The climate change content observed was highly rated with 25.0% receiving a three-point mark and 55.4% receiving a four-point mark. Teachers

demonstrated inclusion of fundamental concepts conceptual understanding of climate change with six observations receiving a four-point rating (75.0%). Seven observations (87.5%) showed a solid grasp on the subject matter itself and received a four-point rating. Connections to real-world applications were emphasized and visibly valuable 75.0% of the time at the four-point mark. Students were asked to use GIS as representation of the climate change content and engage in assessment of the methods they were using most of the time, with six observations receiving a two- or three-point ratings (75.00%). The amount of observations that asked students to be reflective in their learning occurred twice at the two-point mark (25.0%), twice at the three-point mark (25.0%), and twice at the four-point mark (25.0%).

Table 30 - Rubric-based Analysis of Classroom Observation Communicative Interactions

Communicative Interactions (Table VI from Classroom Observational Protocol)							
		0 Never Occurred	1	2	3	4 Very Descriptive	Non- Applicable
1	Students were involved in the communication of their ideas to others using a variety of means and media.	0 (0.0%)	0 (0.0%)	2 (25.0%)	1 (12.5%)	2 (25.0%)	3 (37.5%)
		Based on how much and through what mean the student communicated their ideas.					
2	The teacher's questions triggered divergent modes of thinking.	0 (0.0%)	1 (12.5%)	3 (37.5%)	1 (12.5%)	3 (37.5%)	0 (0.0%)
		Based on how much and how often the teacher asked probing questions.					
3	There was a climate of respect for what others had to say.	0 (0.0%)	0 (0.0%)	1 (12.5%)	2 (25.0%)	5 (62.5%)	0 (0.0%)
		Based on the classroom atmosphere and the interactions between teacher-student and student-student.					
4	Active participation of students was encouraged and valued.	0 (0.0%)	0 (0.0%)	1 (12.5%)	1 (12.5%)	6 (75.0%)	0 (0.0%)
		Teacher provided verbal encouragement and respectful and useful feedback to student participation.					
5	Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	0 (0.0%)	0 (0.0%)	2 (25.0%)	0 (0.0%)	5 (62.5%)	1 (12.5%)
		Students were encouraged by teachers and/or students to generate new ideas.					
6	The teacher acted as a resource person, working to support and enhance student investigations.	0 (0.0%)	0 (0.0%)	1 (12.5%)	0 (0.0%)	7 (87.5%)	0 (0.0%)
		Teacher provided obvious visual and verbal actions that supported students.					
Total Counts		0 (0.0%)	1 (2.0%)	10 (20.4%)	5 (10.2%)	29 (59.9%)	4 (8.2%)

The six dimensions of the communicative interactions rubric are presented in Table 30.

The communicative interactions are overall highly rated with 10.2% receiving a three-point mark

and 59.9% receiving a four-point mark. The number of times the students shared their own ideas occurred at varying level between the observations with two receiving a two-point rating (25.0%), one receiving at three-point rating (12.5%), two receiving a four-point rating (25.0%), and it not being applicable to three observations (37.5%). The amount of probing teacher questioning to trigger divergent thinking occurred most at the two-point and four-point scale with 38.0% each. All classrooms exhibited a climate of respect for what others had to say, with five receiving a four-point rating (62.5%). Active participation was encouraged and six observations received a four-point rating (75.0%). Students were encouraged to generate their own conclusions, with five receiving a four-point rating (62.5%). In seven observations teachers consistently worked as a resource to support learning in their classrooms at the four-point scale mark (87.5%).

In each classroom observation, events were recorded in a chronological manner. The events recorded focused on understanding eight specific practices that occurred during the classroom implementation of the GIS-climate module. The eight practices were: 1) student engagement, 2) comfortable learning environment, 3) type of device used, 4) teacher-student-technology interaction, 5) focus of lesson, 6) student working groups, 7) time to get logged on to the GIS program, and 8) common technical directions given by the teacher.

Table 31 - Observed Practices during Classroom Observation

Observed Practices								
	Teacher D	Teacher E	Teacher F	Teacher G	Teacher H	Teacher I	Teacher J	Teacher K
Student engagement	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Comfortable learning environment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Type of device used	Student laptop	Student laptop	Library desktop	Student laptop	Student laptop	Student laptop	Student laptop	Student laptop
Teacher-student-technology interaction	Student working alone	Teacher guides student	Student working alone	Teacher instructs then student work alone	Teacher guides student	Teacher instructs then student work alone	Teacher instructs then student work alone	Student working alone
Focus of lesson	Content	Content	Content & GIS	Content	Content & GIS	Content & GIS	Content & GIS	Content
Student working groups	Groups or alone	Groups or alone	Groups or alone	Groups or alone	Groups or alone	Alone	Groups or alone	Alone
Minutes to get logged on	3 min	X	4 min	5 min	X	7 min	4 min	X

As seen in Table 31, during all observations (100.0%), students were consistently engaged in their work and the classrooms were comfortable learning environments. In the majority of the observations (87.5%), classroom laptops were used to complete the assignments. The teacher-student-technology interaction varied between classrooms, with some students working individually on computers to complete their own tasks (37.5%) to the teacher projecting the activity and guiding the students along on their own computers (25.0%) to the class being

first teacher-led instruction followed by independent student work time (37.5%). The emphasis on either the content and the technology or the content while only using the technology as the delivery mechanism occurred four times each. The majority of the lessons (75.0%) gave the students the option to complete their work in groups or independently. It took between three and seven minutes for students to get logged in and navigate to the GIS maps they needed to use for their lesson. Finally, the most common teacher supplied technical directions occurring during the observations were: “refresh the screen to reload the map,” how to turn layers on and off, how to read the legend, how to use the transparency function, and how to use the bookmarks function.

Summary

This chapter reported the findings from all instruments used to gather the data. Modifications from the original research plan were reported in the related section. The findings emphasized the data itself and the methods used for analysis. Students demonstrated growth in knowledge and maintenance in dispositions about climate change. Teachers reported positive perceptions about teaching the climate change content and GIS technology content in combination. The classroom experience was engaging and unique. No interpretation of the data was completed here, Chapter Five synthesizes these data to answer the three research questions, answer the over-arching question of “is a GIS-based framework a practical, reproducible, and an effective methods for focusing climate change education on local conditions in the 7-12 classroom?”, and make recommendations to a variety of stakeholders.

Chapter 5 - Interpretations and Conclusions

Seeing all the light bulbs going off above their heads because often when you're teaching high school kids it's hard to get them interested long enough to get to that moment... [they] could draw connections visually better than just talking about climate in class... [watching them use] real life real time data that was meaningful to them. (from Research Teacher Participants Semi-Structured Interviews).

This chapter is organized around interpreting and answering the research questions, drawing conclusions from the investigation and discussing plans for continued research. First, the three individual research questions are answered; their outcomes are then integrated to describe the extent to which the overall goal of this research was accomplished. Finally, the results are analyzed for contribution and connection to the academic literature. The conclusion includes a discussion of research limitations and implications of this study for academic research and the general public, and finally presents plans for the future.

Answering the Research Questions

Research Question 1: Students

The first research question was student-centric and asked: **did completion of the GIS-climate module contribute to the growth of students' knowledge and dispositions about climate change?** Data from the student climate change knowledge assessment was used to measure student knowledge growth and the *Knowledge of Climate Change across Global Warming's Six Americas* survey was used to evaluate student dispositions. Two comparative methods between pre and post intervention scores were utilized to determine possible growth of knowledge and possible change in dispositions.

Overall the student climate change knowledge assessment data shows an increase in student knowledge based on the comparison of correct and incorrect answers on all questions except a sub-part on the sixth question, which demonstrated negative growth (Table 32). From this analysis, the completion of the GIS-climate module did contribute to growth of the students' knowledge about climate change.

Table 32 - Student Climate Change Knowledge Assessment Data Compared with Number of Teachers Who Implemented Each Activity

Pre and Post Student Climate Change Assessment Data				
Content from Activity	Number of Teachers Who Used Module	Assessment Question	% Increase in Correct	
Activity 1	11 teachers	Question 1: (<u>Weather</u>) is the daily conditions of the atmosphere in a place.	+10.7%	
		Question 2: (<u>Climate</u>) is a description of long term average conditions for a region.	+15.1%	
Activity 2	7 teachers	Question 3: The climate is impacted by both (<u>human</u>) and (<u>natural</u>) processes.	+12.6%	
		Question 4: Which two factors are used in determining the basic Koppen climate classification of a region? (precipitation and temperature)	+7.1%	
Activity 3	6 teachers	Question 5: Modeling is used to project future climate change through (<u>constructing mathematical simulations</u>).	+2.6	
Activity 2&3	5 teachers	Question 6: Which of the following play a role in regulating climate?	Topography	+21.6%
			Proximity to water	+3.6%
			Temperature of ocean currents	+11.1%
			Geographic position on the planet	-0.05%

The unequal implementation of the GIS-climate module by teacher participants is believed to be evident in the student knowledge data. Table 32 shows the pre and post student knowledge questions and data aligned with what activity from the GIS-climate module the questions came from and how many teachers implemented each activity. There are visible connections between how much student knowledge grew and how many of the students were actually exposed to activities that taught this assessment content. These connections can be seen in the first three activities and the changes in student knowledge growth, as with each activity being successively used less than the prior and relative knowledge gains within those relative proportions, with the exception of the “topography” answer on question six. However identification of this relationship does not explain the student data knowledge growth conclusively or concretely, rather is part of the interpretation of the data.

Issues of validity and reliability of the student climate change knowledge assessment data and instrument were identified during data collection. As stated in Chapter 3, it was anticipated that the student data would be paired, and this would have given the option to assess the student knowledge data using a paired t-test for statistical significance. With unequal sample sizes and an unpaired report of assessment results from the use of the Qualtric online survey system, descriptive statistics were used instead. Additionally, two unexpected issues of validity and reliability of the student responses and the instrument itself arose during research from informal feedback in the form of conversations between the teachers and the researcher. First, most of the teachers shared concerns about their student responses due to a constant questioning of “is this for a grade?” experience in their classrooms. The assessment was not used as a student grade in any classroom. The teachers were concerned that this student mindset impacted how much time students spent doing the assessment. This concern was validated by the researcher as the online

survey system confirmed that students spent between 38 seconds and 18 minutes on the assessment. Second, teachers reported student confusion on assessment questions three and five. Question three asked for two responses and it was agreed upon by the researcher and teacher participant that the format in which the question was written was confusing for students. Question five asked about climate models and several of the teachers shared with the researcher that they felt the topic was not adequately covered during the unit for students to answer it correctly.

The *Knowledge of Climate Change across Global Warming's Six Americas* survey was used to measure student dispositions pre- and post-intervention. The data showed that students started participation in this research in the “alarmed” category and stayed in this category after participation. There was no change in concern demonstrated; rather there was maintenance of disposition, which indicates that the students took climate change seriously both before and after the intervention. However, this maintenance of the highest level of the spectrum means there can be no true understanding of whether or not this research impacted student participant dispositions.

Figure 4 (in Chapter 1) displays the percentage of where Americans adults fell within the categories of the Six Americas in 2015, demonstrating that this particular student population in 2015 is more highly concerned compared to the adults as a whole in 2015. Consideration should be given to the fact that Convention of Parties 21 (COP21), also known as the 2015 Paris Climate Conference was taking place in Paris, France during the research implementation period. This conference, focused on global climate change, was widely publicized and could have impacted students’ responses. Also of importance is the consideration that it may take longer

than the implementation period of the GIS-climate module in the classroom (7-14 days) to make a sustained change in student dispositions.

To answer the first research question, positive growth of student knowledge and maintenance of student dispositions were evident in this study. Concerns about the reliability of the assessment itself and validity issues regarding the student data emerged and these concerns made it impossible to concretely determine if this knowledge growth is statistically significant. Nonetheless, the data and classroom occurrences were useful in refining methods for this research in the future and still show growth for consideration. Student dispositions did not change pre- and post-intervention, but based on the scale being used to measure dispositions, students started and stayed at one end of the continuum, thus maintaining the highest level of belief, concern, and motivation about climate change.

Research Question 2: Teachers

The second research question was teacher-centric and asked: **how the workshop participation and implementation of the module impacted the teachers' perception about teaching the climate change content integrated with GIS technology within their classroom?** To answer this question, data from teacher survey of perceptions, teacher semi-structured interviews, rubric analysis of the locally-focused activities, and classroom observations were used. The data were compared and triangulated to characterize teacher perception.

Teachers reported a high level of agreement in the success of and satisfaction with the teacher workshop, as well as used positive words to describe their overall characterizations on the project. They recounted a positive workshop experience that enhanced their ability to teach about climate and climate change, and prepared them to teach with GIS and use the GIS-climate

module. All teachers said they intend to use the specific pedagogical mix of GIS-local data-inquiry again, with a large majority reported that using local data was motivating to the teacher in teaching the content and most, but not all, stating the use of inquiry was helpful to teaching the content. These data were evident in the teacher survey of perceptions and semi-structured interviews.

From the teacher survey of perceptions, teachers unanimously agreed that the use of GIS was helpful in teaching climate change. This was reinforced by the analysis of the locally-relevant activity and the classroom observations. The analysis of the locally relevant inquiry activity demonstrated a wide use of possibilities for using GIS to teach climate change. The classroom observation data demonstrated that thoughtful, well-organized, and successful locally-focused lessons were created and implemented by the teachers. Overall the lessons created and implemented by the teacher participants were excellent (see Appendix 16 for complete locally-focused lessons).

Successes and challenges with the research components (e.g., GIS, climate change) were identified in the teacher survey of perceptions and semi-structured interview. Shared successes indicated that all teachers were able to learn the GIS and capably create and comfortably implement a useful lesson that they intend to use again; enough so that they planned to continue teaching climate change and expand their use of GIS in the classroom. They reported that students were engaged and that visualization of the information helped student learning. Challenges reported by the teachers included the need for greater preparation time for themselves than anticipated, and struggles based on teaching new content for the first time. The successes reflect a positive experience teaching with GIS, and the challenges were considered reasonably easy to overcome, with both challenges being manageable with time and through practice.

To answer the second research question, workshop participation and implementation of the module positively impacted teachers' perceptions about teaching climate change content integrated with GIS technology. This conclusion is based upon teacher responses and characterization of their participation in this project, shared future plans for use of the climate change content and GIS technology, and researcher review of the teacher-created lessons and classroom observations. The positive perceptions were accompanied by challenges, as recognized through student response to the content; however, the challenges identified (e.g., slow acceptance, apathetic) are not absolute barriers and do not detract from the positive descriptions and reports shared by the teacher participants regarding workshop participation and implementation.

Research Question 3: Classroom

The third research question was classroom-centric and asked: **what successes and challenges were identified in order to implement the use of a GIS in the 7-12 classroom for both teachers and students?** To answer this questions, data from the teacher survey of perceptions, teacher semi-structured interviews, student survey of GIS, rubric analysis of the locally-focused activities, and classroom observations were used. From the teacher survey of perceptions, teacher semi-structured interviews, and student survey about GIS, a list of teacher and student successes and challenges was generated and the analysis of the locally-relevant activity and classroom observation was used to corroborate and expand on these identified topics.

Teachers were asked to report successes, also called “great moments in teaching with GIS,” and challenges in using GIS in the classroom on both the teacher perceptions survey and during the semi-structured interview. The responses were similar, with the interview data

corroborating the survey data. Four main reported teacher successes were identified (Table 33): 1) student engagement, 2) the GIS supporting student learning, 3) student ability to explore and be autonomous, and 4) students liked the use of maps and technology. From the observed practices made during the classroom observation (Table 31), one of the practices supported the teacher-reported successes, that students were noticeably engaged throughout the duration of the lesson. Finally, the construction of the locally-focused activities supports the teacher-reported successes that students were given the ability to explore and learn autonomously.

Table 33 - Teacher Reported Successes in Teaching with GIS

Teacher Reported Successes in Teaching with GIS	
Data	Themes
Teacher Interview Codes	1) Student engagement, 2) The GIS supporting student learning, 3) Student ability to explore and be autonomous, and 4) Students liked the use of maps and technology.
Student engagement through real-world applications	
It supported student learning (e.g., “Aha!” moments, visualization of the content, equalized student learning)	
Teacher Survey Codes	
Students were engaged in activities	
Ability to explore and learn autonomously benefited students	
Students liked the use of maps and technology	

The teachers shared challenges they experienced teaching with GIS. The three main challenges reported were: 1) GIS program technology issues, 2) school technology issues, and 3) supporting student learning (Table 34). Two additional themes from the classroom observation supported the teacher-reported challenges in teaching with GIS. The seventh theme, time to get logged on to the GIS program, which was between three and seven minutes, and the eighth theme, common technical directions given by the teacher, further substantiate the technological challenges reported by the teachers.

Table 34 - Teacher Reported Challenges in Teaching with GIS

Teacher Reported Challenges in Teaching with GIS	
Data	Themes
Teacher Interview Codes	1) GIS program technology issues, 2) School technology issues, and 3) Supporting student learning.
GIS program	
School technology	
Learning	
Harder to get students caught up if they miss a day	
Teacher Survey Codes	
Technological issues	
Providing student support to do things they are not used to doing	

Students reported likes and dislikes regarding using GIS that were interpreted into successes and challenges and supported by teacher interview data. The students neither loved nor hated using the GIS, with the median average rating of 5.4 on a ten-point scale of worst (one) to best (ten). Excluding the generalities and undeterminable themes, students reported that what they most liked about using GIS was the online maps, being able to visualize the content, and using local data. Furthermore some students reported that using the GIS helped their learning and made their work easier. Again, excluding the generalities and undeterminable themes, students reported that what they disliked the most about using GIS was that there were map loading issues and technical difficulties, that it was difficult to use, and that students needed more time to learn to use the program. These student-reported data were substantiated by the teachers in their semi-structured interviews, when asked to describe how students responded to the GIS.

To answer the third research question, successes and challenges in using GIS were generated by both teachers and students. To summarize these findings the teacher and student successes and challenges were synthesized (Tables 35-36). The two primary successes articulated by both teachers and students were: 1) students were engaged and liked using GIS and 2) using GIS supported student learning. The two main challenges identified by both

teachers and students were: 1) technology issues with the program and at schools, and 2) students need additional support in learning to use new technology. The successes identified are important to encouraging teachers and students to continue using GIS and the challenges can be overcome, especially if anticipated ahead of time. These successes and challenges mean that continued and growing use of GIS in education can be functional in the classroom.

Table 35 - Teacher and Student Reported Successes in Using GIS

Teacher and Student Reported Successes in Using GIS in the Classroom	
Data	Synthesized Successes
Teacher Successes	1) Students were engaged and liked using GIS and 2) Using GIS supported student learning.
Student engagement	
The GIS supporting student learning	
Student ability to explore and be autonomous	
Students liked the use of maps and technology	
Student Successes	
Using maps was the best	
Visualizing the content/Using local data	
Helped me learn/Made my work easier	

Table 36 - Teacher and Student Reported Challenges in Using GIS

Teacher and Student Reported Challenges in Using GIS in the Classroom	
Data	Synthesized Challenges
Teacher Challenges	1) Technology issues with the program and at schools and 2) Students need additional support in learning to use new technology.
GIS program technology issues	
School technology issues	
Supporting student learning	
Student Challenges	
Map did not load/technical difficulties	
Difficult to use	
Needed more time to learn to use the program	

Conclusions

The conclusions of this research are presented in three parts. The three parts consist of: 1) answering the overarching research question, 2) analyzing the research question outcomes and how they contribute to the academic literature, and 3) identifying and discussing notable data that emerged from outside the research questions themselves.

Answering the Overarching Question: Practical, Reproducible, and Effective

The research questions were designed to be answered individually and then used together to answer the ultimate goal of this research: **is a GIS-based framework a *practical, reproducible, and effective* method for focusing climate change education on local conditions in the 7-12 classroom?** The three descriptors of the question - practical, reproducible, and effective – each align with a different research question. Practicality was associated with the second research question, examining teacher perceptions of teaching climate change using GIS. Based on the positive perception and response to the workshop, content, and technology, as well as the teacher reported plan to use the activities again in the same format, the method was considered practical. Reproducibility was related to the classroom-centric third research question, which identified successes and challenges in using GIS by both teachers and students, distinguishing if the study could be successfully completed again. The importance of the successes and limited number of challenges, many of which can be addressed with planning and time, suggest that this method and research was reproducible. Lastly, effectiveness was related to the first question focused on student knowledge and dispositions. There was measurable positive growth of knowledge and maintenance of the ‘alarmed’ disposition, which gives reason that revisions to the methods surrounding this part of the research, effectiveness is possible and should continue to be studied in order to gain a more definitive understanding. Thus, based on the findings of this research, a GIS-based framework is a *practical, reproducible,* and an *effective* method for focusing climate change education on local conditions in the 7-12 classroom.

Connections to the Research Literature

The findings of this research have many connections to the research literature. These research question specific connections are the type of student knowledge gained, effectiveness of

using the GIS in teaching, methods for teaching climate change, the GIS-climate module as an available set of climate change activities, and successes and challenges in using GIS. Additional connections to the literature are in the following section on other notable data as well.

The greatest amount of student knowledge gains, based on number of correct responses between the pre- and post-test, could be seen in the first three questions of the student climate change knowledge assessment. All three of these questions were about the differences between weather and climate. In Porter et al. (2012), similar results were found; the treatment group, who received the climate change unit, showed that the student participants knew most about weather and climate after the treatment on a post-test.

As seen in the literature, there are a limited number of studies on the effectiveness of GIS on student learning and the existing literature demonstrates uncertainty/a mixed response (Baker and White, 2003; Kerski, 2003) showing small quantitative gains. The student effectiveness measures in this research, gathered from the student climate change knowledge assessment, show similar uncertainty and a mixed response in regards to student learning. It seems possible that this can be attributed to the idea that GIS education is still in the early adoption phase (Baker and Kerski, 2014) based on the diffusions of innovations (Rogers, 2003) model, which makes refined and controlled studies more difficult to implement in classrooms where teachers are still implementing GIS for the first time. More effectiveness studies are needed in the future to concretely determine the impact using GIS has on learning. Paired student pre- and post-data is needed to most soundly test for statistical significance of knowledge gain. This can be difficult to gather in the 7-12 classroom, but certainly is feasible with teacher cooperation.

As consistently noted in the existing literature, there are many pedagogical suggestions on how to teach climate change, but no dominant pedagogical method (Kenis and Mathijis, 2012;

McCaffrey, 2012; Schreiner et al., 2005; Somerville and Hassol, 2011). The findings of this research contribute another method: using a GIS-based framework (and local data). Given that this is exploratory research, as are the sources of most of the current pedagogical suggestions, these methods and pedagogical suggestions need additional support through continued research and more reliable empirical findings before it can be suggested as a best practice.

This research also contributes to the range of climate change activities available to teachers. Since the GIS-climate module has been field tested and revised post-field testing based on teacher implementation feedback and student response (from the climate change knowledge assessment), the GIS-climate module should be a more reliable and useful set of activities made publically available to educators in an online format.

The lists of successes and challenges in using GIS in the classroom in this study demonstrate that challenges in using GIS are being reduced in comparison with earlier studies (Bednarz and Ludwig, 1997; Kerski, 2003; Tabor and Harrington, 2014). The two primary successes (students were engaged and liked using GIS and using GIS supported student learning) aligned with the enhanced learning as well as the increased student motivation and interest identified by Kerski (2003). The two main challenges (technology issues with the GIS program and at schools and increased student support in learning to use new technology), demonstrated that however much growth in technology, technology continues to be an issue, even with the availability of online GIS (Baker, 2005; Bednarz and Ludwig, 1997; Tabor and Harrington, 2014). Teaching with technology is an ongoing changing process. As technology changes over time it requires adjustments to teaching methods and a continual review of the successes and challenges in teaching with GIS is needed for GIS educators to continue to build and maintain an understanding how the integration of GIS technology works in the classroom. The identified

successes and challenges, which are really the ‘good’ and the ‘bad’ of teaching with GIS, resonates with the benefits and the complexities of using this technology. What Kerski said in 2003 still stands true,

Clearly, GIS is not the type of tool that a teacher can implement into the curriculum as soon as it is obtained, nor can it be easily expanded in the curriculum. This is the irony of GIS – if it were “plug and play,” more teachers would use it, but much of the functionality and flexibility would have to be removed (p. 131).

Bringing the findings of these research questions together, **one question emerges: how can using GIS in the classroom become a routine practice?** There were positive teacher and student data on using it as a tool; the recognition of this question has implications for the GIS education research and teaching community.

Other Notable Data

Several notable observations emerged that did not directly follow from the research questions. Student-oriented findings were that in the teacher interview a few teachers reported the use of GIS equalized student learning. This idea is not new and has been hypothesized informally amongst GIS education researchers and practitioners; Kerski (2003) also noted that test scores of his student population using GIS improved more among the average and below-average student than the above-average students. Specifics of how the use of the GIS worked as an equalizer (e.g., what part of learning with the GIS, instructional practice that was essential) were not apparent from this research; however the suggestions of the possibility of equalized student learning from this research should be added to the growing cumulative research on student learning with GIS. It would be momentous for research in GIS education to empirically prove this perception. Additionally, teachers stated that students liked using the GIS in an applied real world context, supporting prior work from Baker et al. (2012) and McClurg and

Buss (2007) that asserts GIS works well as a teaching method for student learning on real world content.

Other pieces of teacher-relevant information emerged from these data. First, from the rubric analysis of the locally-focused activity, there was a range in what teachers considered to be “local.” Teachers focused on a region (e.g., southeast Kansas; Ogallala Aquifer), a specific city, a specific county, and the state as a whole when asked to “include the local perspective.” These differences in use of scale lead to questions of whether the teachers based their local scale on what data they could find? Or, do teachers not often use/teach the idea of scale in their classrooms and thus had different connotations on what is local?

Second, the majority of teachers reported that the use of local data was useful, but its usefulness was not emphasized or covered much in the teacher survey or semi-structured interview, giving the impression that using local data, though useful, was a less important component of the GIS-climate module in the classroom. Adding to this notable observation were the few teacher reports from the interview that Kansas “lacks” startling climate change issues and thus educational engagement opportunities with learners. This finding presents a possible concern for the climate change education community in engaging students around an already complex and challenging content.

Third, teachers repeatedly mentioned, in both the interviews and the survey, that the data available in the GIS program used, *ArcGIS Online*, needs to be better organized and provide a more efficient search function. Some students made similar comments in the student GIS survey. These program difficulties were accounted for in challenge identification as part of the third research question, but were mentioned consistently enough by individual teachers to be

noteworthy. The observed technical difficulties should be addressed in future teacher trainings, so others would hopefully be better informed.

Lastly, many teachers reported on the benefits of encouraging student autonomy in using the GIS as a mechanism for enhanced learning. Student autonomy in using the GIS was not specified as part of the GIS-climate module; teachers made this pedagogical decision on their own. This teacher participant-led choice may be indicating a direction for greater research by supporting the idea that GIS lends itself to student-paced autonomous learning, especially given that exploration is a goal of the NGSS (NGSS, 2013).

About the classroom, two notable findings emerged. The classroom observations proved a high level of student comfort and ease of use of the GIS technology, indicating a positive likelihood that GIS is very incorporable into the contemporary classroom, and thus continued to build the rationale for use of GIS in the classroom. It was also evident that GIS works on almost any device in the classroom with any teacher-student-technology infrastructure, which GIS classroom use suggestions from the literature (Baker, 2005; Baker and Kerski, 2014). This was seen in the observed practices (Table 31) from the classroom observation of the use of individual student laptops and library desktop computers, as well as the three different teacher methods to teach the activity (e.g., student working alone, teacher guiding student, teacher instruction followed by individual work).

This research was successful in its intent and provided insight for two grade bands and multiple content areas on teaching climate change using GIS through pre-prepared and teacher-created activities. Among the sample of teachers, some were challenged by the teacher-created locally-focused activity, while some were enthusiastic and created wide ranging educational activities. The next steps can be taken to refine this study and do additional research, as well as

contribute to and inform best practices in the integration of GIS technology in climate change education. The results are exploratory and provide a starting point for identifying a control group, on which to conduct a more controlled study and determine more accurate estimates of student learning.

Limitations of the Study

This was exploratory research and though deemed an overall success, a few limitations need to be acknowledged. The classroom is a difficult environment to control in a natural manner, so three limitations were apparent. One, teacher participants did not equally implement and use the GIS-climate module, causing issues for analysis of teacher activities and student response (e.g., the student knowledge data represented student responses from students who were not exposed to each GIS-climate module activity, not every teacher created a locally-focused activity). Two, the student knowledge data had validity concerns based on the amount of time used by students to take the assessment, student attention based on it not being a graded activity, and students not being taught all components of the GIS-climate module; and there are reliability concerns with the student climate change knowledge assessment based on the format of some questions. Third, teachers volunteered and were paid to participate in this research, thus they were likely to be more naturally motivated and inclined to teach the content, learn the new technology, and respond positively.

Implications

This research has implications for the research community and the general public. For research two main topics may be affected: 1) climate change education, and 2) GIS education. Implications for the general public relate to educational needs and building a climate literate population. These implications are followed by a discussion of next steps for this research. All

implications highlight the need for science, technology, and education to continue to work together in an interdisciplinary manner.

For Research

Good climate change education is attainable in today's K-12 classroom. It is now becoming a required content topic and teachers and students are interested. However, climate change education research and suggested pedagogies are still in preliminary phases with little cohesion except for a strong desire to improve climate change education in the classroom. The climate change education community needs to build a research agenda to align research efforts. The findings from this research suggest that the research agenda could include using the local perspective and teaching with technology, such as GIS.

GIS use in the classroom is now clearly accessible and easy to implement with formal training. The research on GIS education is broad in scope and nature, and was recently synthesized into an organized research agenda (Baker et al., 2012). This agenda addresses knowledge within four areas of identified research needs. The first area is on learning with and about GIS, which is the idea upon which the GIS-based framework was built. This study contributed to the practicality, reproducibility, and effectiveness of using a GIS-based framework. Second is the measurement of GIS knowledge and application, which focuses on how effectiveness of learning with GIS can be measured. The student outcomes from this study, even with the issues noted, suggest the collection of paired student data in order to conduct better statistical analyses to answer the effectiveness question. Third, the GIS education for educators category (teacher training) recognizes the need for greater data on identifying best practices in teaching teachers to use GIS. This research used a one-week training model reported to be successful among participating teachers and provided evidence for one method of integrating

GIS in an applied context. Moving away from the research agenda, the final implication of this study for the GIS education community is to share the findings from teacher and student feedback needs with Esri and other GIS companies with the hopes of the program-based technology challenges to be addressed (e.g., the data searching issue).

For the Public

With a better understanding of climate change from the scientific perspective, that knowledge and progress now must be translated into climate change education. Although it is a complicated subject, climate change education is not difficult to implement and it is needed. Furthermore, student populations in general (Leiserowitz et al., 2011b), and documented in this study population, are showing high levels of belief, concern, and motivation. This research sets an example for the public to support educational initiatives in local classrooms and schools. In one semester, 550 Kansas students were exposed to an enhanced climate change education and demonstrated knowledge growth based on teaching by 12 Kansas teachers. These teachers plan to continue to teach climate change and expand the use of a new technological tool, GIS, in their classrooms. Greater climate change education will lead to greater climate literacy which will make decision-makers and future decision-makers better able to make informed climate decisions.

Next Steps: Recommendations for Future Research

This work contributes to the researcher's research agenda. The next step will be to take lessons learned from the exploratory stage and transform the research design into mid-stage research. To do so consists of refining the student knowledge assessment tool for increased reliability, the inclusion of paired pre- and post-student assessments, and recruiting a controlled group of teacher participants. The suggested control group, based on findings from this research,

is high school teachers who teach the same content course, with biology, earth science, or environmental science being optimal. There is the possibility of creating more than one control group of different content courses. The now revised GIS-climate module would be presented to the teacher participants in the same one-week workshop form, with the addition of a pre-semester one-day gathering of teacher participants to refresh teachers on implementation of the GIS-climate module to ensure equal implementation across classrooms, assist teachers in setting up mechanisms to gather paired pre- and post-assessment student data, and help address any school infrastructure issues that emerge. Locally-focused activities would also be made mandatory as part of the project. The teacher-created local lessons would be amassed into a publically available database for other teachers to use, adding to the lessons from this research with the hopes of make local climate change lessons highly accessible.

The successful June workshop that the teacher participants took part in is also being used in ongoing research. The researcher has a separate project that is building a professional development model for educating teachers on GIS. This workshop, with the positive feedback from the related teacher interview and semi-structured survey data, will serve as an example of how to couple the GIS technology with content in a week long teacher training session. It is likely that the teacher trainings from the next stages of this research, as described in the paragraph above, will also contribute to this GIS education professional development model.

Summary

This exploratory research supports using a GIS-based framework to teach climate change: it is practical, reproducible, and effective. Students showed an overall positive growth in knowledge data, even with reliability and validity concerns. Students also identified within the *Six Americas* category of alarmed, being the population with the most concerned, motivated,

and having the highest belief in climate change. Teachers shared a positive perception regarding the use of GIS to teach climate change; going so far as to report that they will all continue to teach climate change and use GIS in their classrooms. Successes and challenges were observed in classrooms that recognized the benefits of student engagement and learning, as well as the challenge of using technology and supporting student needs in learning technology. Using GIS in the classroom is becoming easier for teachers to implement, especially if they can anticipate certain challenges.

There was an identifiable need for this research. The global climate is changing and in order to best understand, mitigate, and adapt to these changes, a climate-literate society will help ensure a better path forward for the planet and human civilization. The education community has started to respond to this need and this work contributed to that response. It directly impacted the climate change education of 12 teachers and 550 students in Kansas. Now this research needs to continue, implementing a greater level of control in the research design, to continue to grow the understanding of how to best teach climate change. The climate is going to continue to change; education needs to keep up.

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Appendix A - Classroom Schedule for Implementation of Module and Implementation

The GIS-climate module was implemented in the teachers' home classroom. A suggested schedule was provided and described to the teacher participants. The following implementation timetable was based around the schedule of a typical seven-period high school or middle day where classes run at approximately 50-minutes (Table 37). It is anticipated that the GIS-climate module takes 10-12 days for complete classroom implementation.

Table 37 - Classroom Schedule for Implementation of Module and Instrumentation

Suggested Timetable for Implementation of GIS-Climate Module and Instrumentation			
Pre-Module Student Instrumentation	Climate Change Knowledge Assessment	30 minutes	= 1-2 class periods
	<i>Knowledge of Climate Change Across Global Warming's Six Americas</i>	20 minutes	
GIS-Climate Module	Activity 1	45 minutes	= 1 class period
	Activity 2	45 minutes	= 1 class period
	Activity 3	45 minutes	= 1 class period
	Activity 4	45 minutes	= 1 class period
Locally Relevant Inquiry Activity	Activity 5	90-120 minutes	= 2-4 class periods
Post-Module Student Instrumentation	Climate Change Knowledge Assessment	30 minutes	= 2 class periods
	<i>Knowledge of Climate Change Across Global Warming's Six Americas</i>	20 minutes	
	Student Survey of GIS	15 minutes	

Appendix B - GIS-Climate Module Activity 1: Understanding

Climate and Weather

Activity 1: Understanding Climate and Weather

Activity Overview

Students will be able to distinguish the difference between climate and weather, identify two major climate controls, and collect data on these climate controls to demonstrate how the controls work together to determine the weather conditions and climatology of a region.

Materials

Internet access and device for connection (www.arcgis.com/home)

Teacher instruction, student instructions with questions, and answer key

Objectives	Learner Assumptions
After completing this activity, a student is able to do the following: Recognize and define the difference between weather and climate, Identify two climate controls, and Collect data to complete the basic components of a climatology and weather report.	In order to complete this activity, students should already have the following: map reading skills, an introductory understanding of weather, climate, and an understanding of Earth's rotation and unequal heating from the sun.

Day 1: Student Tasks 1 and 2

Engagement

Share with your students that they are going to explore the difference between weather and climate using a GIS web map. Write on the board, "Climate is what you expect, weather is what you get." To engage the students, have them briefly describe the weather that is happening outside and the climate that they live in. When they are finished writing their responses, ask them: what is the difference between climate and weather?

Exploration

To begin, have students access the web map for this activity. Navigate to <http://arcg.is/14zXbg2>. Take a few minutes to let your students become acquainted with the map and its features. In this activity, students will be working with four data layers: 1) average monthly temperature, 2) basic Koppen climate classifications, and 3) NOAA current weather. They are going to explore the major climate controls of latitude and topography. They will use the Koppen climate classification system as part of their study. From their exploration, they will identify climate controls.

Explanation

The second task of this activity has the students analyzing the climatic controls of latitude and topography. Using the web map they will answer questions about the Earth-Sun relationship and influence of latitude on climate, as well as identification of the relationship between topography and climate.

Day 2: Student Task 3

Elaboration

For this part of the activity, the students will start a basic climatology report and a weather report for Minneapolis, Minnesota. They will report on the climate controls they have been previously examined in the activity, as well as near real time weather data. They will use a modified weather station model to assist with their weather report. They will complete a table for both the climatology report and the weather report and conclude by brainstorming what additional information they would need if they were to finish the reports.

Evaluation

When the class has finished the activity, lead a short discussion that summarizes the conclusions the students reached. Be sure to highlight patterns and relationships that they discovered. Close the activity by bringing it back to the engagement question and have the students define weather and climate.

Activity 1: Understanding Climate and Weather

Q1) Describe the weather outside right now (temperature, clouds, wind, etc.).	Q2) Describe the climate you live in (temperature, precipitation, seasonal changes, wind, etc.).
Q3) What is the difference between climate and weather?	

In this activity, you will distinguish the difference between climate and weather, identify two major climate controls, and collect data on these climate controls to demonstrate how the controls work together to determine the weather conditions and understand the climatology of a region.

Task 1: Recognize the difference between weather and climate. Go to <http://arcg.is/14zXbg2>. Take a few minutes to become familiar with the map, specifically using zoom to explore the map, click layers on and off, and view the legend.

You will be working with four map layers:

Average monthly temperature for selected cities,

Basic Koppen climate classifications,

NOAA current weather.

Review climate classes and climate controls.

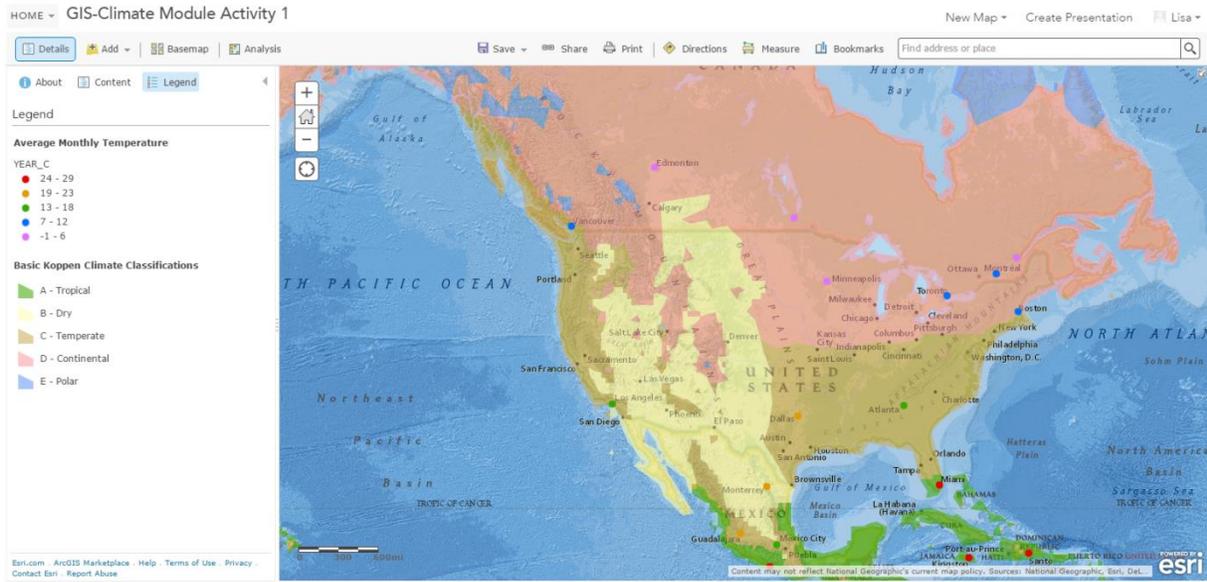
Click the contents button  and turn on the “average monthly temperature” and “Basic Koppen climate classifications” layers by clicking the box next to it.

Set the basemap to “topographic.” Click on the basemap button  Basemap to change it if needed.

Adjust the transparency of the “Basic Koppen climate classifications” layer by scrolling your mouse over the “Basic Koppen climate classifications” to see an arrow  will appear to the right of it. Click on the arrow  and select “transparency” from the menu.

Click the legend button .

The bookmarks button  Bookmarks will automatically zoom and move the map. Click the bookmarks button and select “North America”. Your screen should appear as:



Read the legend. Note the climate types and where they are within North America. Pay extra attention to the topography of the landscape and its relationship to climate types (click the layers off and zoom in close to the basemap if needed to see the topography). Finally, think about latitude and the geographic position of North America and the United States on the planet (the latitude and longitude are not labeled on this map, but there so you can identify how they divide the planet; use the measurement tool if needed to find specific coordinates).

Move around the map to examine each of the layers on the map. Click on the different cities to see a pop-up that provides more information and compare that with the Basic Koppen climate classification information available in the legend.

Examine how the climate types change from west to east across the United States. Think about why these differences occur in preparation to answer the following question.

Use the map and your knowledge of climate and weather to answer. A climate control is a factor that influences the type of climate in a region, like how hot or cold it gets and how much rain or snow is received. Based on this definition, Q4) what limits how hot or cold a region is and how much rain or snow is received? Use topographic evidence to support your answer.

Task 2: Examine two climatic controls: latitude and topography. Your web map should look just as it did in the image above. Re-visit the previous instructions if you changed any layers or features or re-open the web map with the link <http://arcg.is/14zXbg2>.

Review the map to answer the following questions:

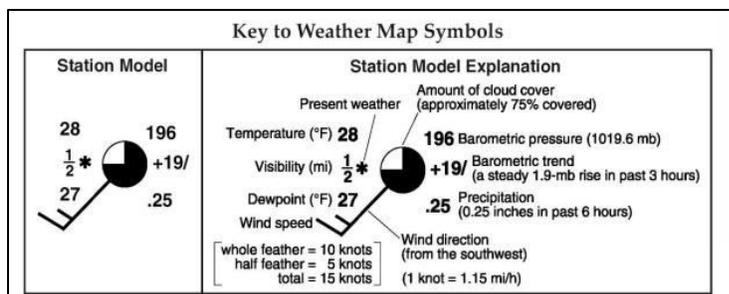
Q5) The sun is the primary source of energy for the Earth's climate system. Explain the seasonal relationship between the sun, the Earth, and latitude (hint: the answer is not in the map).

Q6) Examine the pattern of climate types between the equator and the Arctic Circle. Use specific examples from the map to help answer this question. Based on your examination, how does latitude influence climate?

Look around the world and study the relationships between topography and climate type.

Q7) Share two observations that explain the relationship between topography and climate.

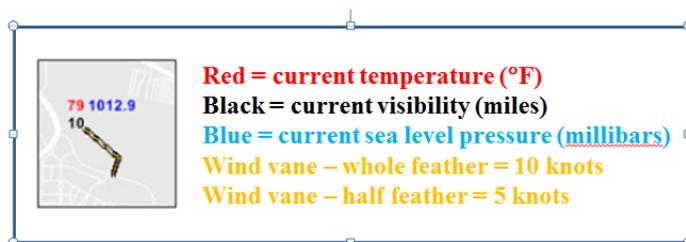
Task 3: A weather station model is symbolic illustration showing the weather occurring at a given weather reporting station. Local weather information is constantly gathered and compiled into models such as this weather station model. It is helpful in knowing how to read a weather station model when working with real data, because often only the model is included. A full weather station model can look like this:



(Source:

[http://regentearth.com/Illustrated%20ESRT/Page%2013%20\(Weather%20Map%20Symbols\)/Station%20Model.htm](http://regentearth.com/Illustrated%20ESRT/Page%2013%20(Weather%20Map%20Symbols)/Station%20Model.htm))

The basic weather station model you will be using looks like this:



A climatology report is a written description of the average and seasonal conditions of a place. Complete a basic climatology report and weather report for Minneapolis, Minnesota, as shown below (use labels °F, etc.). Note in the image above, that wind vanes may have multiple feathers to report the current wind speed; a whole vane is equal to 10 knots and a half vane is equal to 5 knot, add up the feathers to find the wind speed. The radar color scheme is blue for clouds and storm, yellow and green for moderate intensity storms, and red for intense storms.

To make the climatology report:

Use the “Basic Koppen climate classifications,” “average monthly temperature,” and “latitude and longitude” layers. Turn the layers on as needed.

Use the “Minnesota” bookmark and fill in the table below.

To make the weather report:

Use the “NOAA current weather” layer, found under ‘Content.’ Turn it on and adjust the layer’s transparency if needed to see the base map or layer information more clearly.

Use the “Minneapolis” bookmark to analyze the weather station data and the “Minnesota” bookmark to examine the current radar in the region.

Fill in the table below (you may have to use information from the whole area); if no information can be found, write “No information currently available.”

Minneapolis, Minnesota			
Climatology Report		Weather Report	
Average temperature in January		Current temperature	
Average temperature in July		Current wind speed	
Climate classification type		Current sea level pressure	
Approximate latitude		Current visibility	
Description of regional topography (use information on basemap to describe, not current weather layer)		Description of current radar (radar will show clouds or rain, if none are present, report none)	

Compare the information in the weather report with the information in the climatology report for differences and similarities. Reflecting on what you have learning in this activity, answer:

Q8) Define climate.	Q9) Define weather.
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Activity 1: Understanding Climate and Weather
 Student Questions Suggested Answer Key

Task 1:

<p>Q1) Describe the weather outside right now (temperature, clouds, wind, etc).</p> <p>Answers will vary depending on your current weather conditions, but will likely include a discussion of temperature, precipitation, cloudiness, humidity, etc.</p>	<p>Q2) Describe the climate you live in (temperature, precipitation, seasonal changes, wind, etc.).</p> <p>Answers will vary depending on where you live, but will likely include a discussion of topography and typical weather patterns and conditions (e.g. average temperature and precipitations, seasons, etc.).</p>
<p>Q3) What is the difference between climate and weather?</p> <p>Answers will vary but are likely to include identification of types of weather, climate types, and time-based concepts like weather happens daily and climate is a long-term average of conditions.</p>	

Q4) What limits how hot or cold a region is and how much rain or snow is received?

Answers will vary but should be similar to the following. The temperature and precipitation of a region are dependent on latitude, proximity to water, air pressure, winds, topography, and/or ocean currents.

Task 2:

Q5) Explain the seasonal relationship between the sun, the Earth, and latitude (hint: the answer is not in the map).

The amount of solar radiation a specific location on Earth receives from the sun is a function of time of year and its latitude. The sun is the primary heating source for the Earth and the direct rays vary in place as the planet rotates and tilts. The Earth is hotter at noon than it is at sunset, and is hotter in the tropics than it is at the poles. Both temperature differences have to do with the spherical nature of the earth which changes the angle of sunlight. The Earth curves away from the sun. This causes the sun's rays to hit at a low angle at sunrise and sunset and at a high angle (more directly) at noon. The lower the angle, the more diffuse the sunlight because it becomes spread over a larger and larger area. The higher the angle, the more intense the sunlight, the greater its heating power. Direct sunlight is very intense because the high angle causes it to be concentrated into a small area. Thus, the sun is more intense (more concentrated) at noon and less intense (more spread out) at sunrise and sunset.

Q6) Based on your examination, how does latitude influence climate?

Answers will vary, but could include:

The polar climate type is the coldest of the climate classification types and located nearest the poles, which are the region of the Earth that receive the least amount of solar radiation each year.

The mid-latitudes tend to have the most variation in climate and many areas experience significant seasonality, which corresponds with the changing amount of solar radiation the region receives throughout the year.

The equatorial zone consist mainly of tropical and dry climate types, which are the hottest climate classification types and they are in the region that receives the most direct solar radiation each year.

Coastal locations are more likely to have a temperate climate because of their proximity to water; the average temperatures vary depending upon their latitudinal placement.

Latitude affects climate because it determines the amount of solar radiation received from the sun and during which parts of the year.

Q7) Share two observations that explain the relationship between topography and climate.

Answers will vary, but could include: mountainous regions tend to have dry or polar climates, coastal regions tend to have tropical or temperate climates, deserts tend to be dry climates, and central regions tend to have temperate climate types.

Task 3:

Minneapolis, Minnesota			
Climatology Report		Weather Report	
Average temperature in January	6°F	Current temperature	Answers are dependent on day.
Average temperature in July	69°F	Current wind speed	Answers are dependent on day.
Climate classification type	Continental	Current sea level pressure	Answers are dependent on day.
Approximate latitude	40°N	Current visibility	Answers are dependent

			on day.
Description of regional topography (use information on basemap to describe, not current weather layer)	Plains, nearby lake	Description of current radar (radar will show clouds or rain, if none are present, report none)	Answers are dependent on day.

<p>Q8) Define climate.</p> <p>Answers will vary but should be similar to “a description of long term average of conditions for a region.”</p>	<p>Q9) Define weather.</p> <p>Answers will vary but should be similar to “daily conditions of the atmosphere in a place.”</p>
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Appendix C - GIS-Climate Module Activity 2: Identification of Climate Patterns

Activity 2: Identification of Climate Patterns

Activity Overview

Students will be able to identify regional climate types based on the Koppen climate classification system and explain how topography, the Earth’s rotation and unequal heating, and ocean currents influence climate.

Materials

Internet access and device for connection (multiple websites visited)

Teacher instruction, student instructions with questions, and answer key

Objectives	Learner Assumptions
<p>After completing this activity, a student is able to do the following:</p> <p>Identify regional climate types using the Koppen climate classification system and Recognize and explain how topography, the Earth’s rotation, and ocean currents affect climate types.</p>	<p>In order to complete this activity, students should already have the following:</p> <p>map reading skills, can describe weather, climate, related reporting methods, an introductory understanding of climate classification, and an understanding of Earth’s rotation and unequal heating from the sun.</p>

Day 1: Student Task 1

Engagement

Tell your students that they are going to explore climate types using the Koppen climate classification system and major factors that influence climate types using a GIS web map. To connect with the Activity 1, have students explain the difference between climate and weather. To engage and prepare them for this activity, ask the students: Can the climate of a region be predicted? Why or why not?

Exploration

To begin, have students access the GIS map:

http://esri3g.maps.arcgis.com/apps/Compare/storytelling_compare/index.html?appid=3015bbd78e4e42c5b5b7484b2f254af9. Their task is understand the connection between climate classification types and precipitation, and temperature. Then, combined with their prior knowledge of climate, the students will be asked to answer questions about their home climate, global climate, and the influence of Earth's rotation and unequal heating on climate.

Day 2: Student Tasks 2 and 3

Explanation

Navigate to <http://arcg.is/1KrG5nf>. Provide students with a few minutes to become acquainted with the map and its features (e.g. zooming, measuring, changing the basemap, accessing layers and legends, and clicking for pop-ups).

In this part of the activity, students will be working with three data layers: 1) average monthly temperature, 2) basic Koppen climate classifications, and 3) global ocean currents. These three data layers are be used to expand the prior investigation of climate types (from both Activity 1 and the first task of this activity) by examining factors that affect climate, specifically topography and temperature. Students will list all of the factors that they think influence and shape climate classification types. Then students will explore climate classification within three regions of the world (Africa, Australia, and South America) and answer questions connecting climate classification types to topography and temperature.

Elaboration

The final study of factors that affect climate types focuses on ocean currents. Students are asked to describe the patterns they identify between climate types and the presence of warm and/or cool ocean currents. To synthesize the students' data gathering and observations, as well as prior knowledge, they will discuss the connections that can be determined between the location of climate types and Earth's rotation and unequal heating.

Evaluation

When the class has finished the activity, lead a discussion that summarizes the conclusions the students reached. Be sure to highlight patterns and relationships that they discovered. Close the activity by bringing it back to the engagement question and ask them to reflect on how climate can be predicted based on the basic Koppen climate classifications.

Activity 2: Identification of Climate Patterns

Q1) Explain the difference between climate and weather.

Q2) Can the climate of a region be predicted? Why or why not?

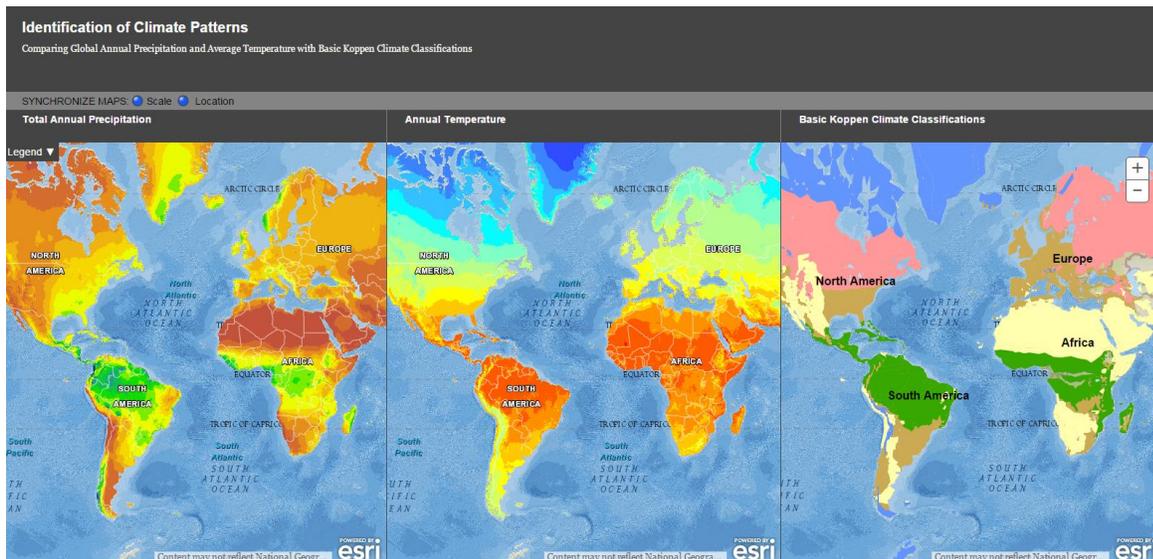
In this activity, you will identify regional climate types based on the Koppen climate classification system and explain how topography, the unequal heating of the Earth, and ocean currents influence climate.

Task 1: First, we'll explore the relationship between precipitation, temperature, and climate classifications. Go to:

http://esri3g.maps.arcgis.com/apps/Compare/storytelling_compare/index.html?appid=3015bbd78e4e42c5b5b7484b2f254af9.

Investigate and explore these three maps for similarities, differences, and connections. Take a few minutes to become familiar with the maps and their features. Try zooming (+ and – boxes) and viewing the legend (Drop down arrow for Legend in upper left (below ‘Total Annual Precipitation’).

Your screen should appear as (note: the Basic Koppen Climate Classification may take a minute to load):



Q3) What climate classification type exists on Greenland?

Q4) Describe the total annual precipitation and annual temperature of the climate classification type for Greenland.

Q5) Name two climate types can be found closest to the equator. Name the type and what continent you found it on. (There are several, but pick two).

Q6) Describe the total annual precipitation and annual temperature of the two climate classifications you've selected in Q5 (remember to use measurement labels of mm and C).

Q7) Describe each climate classification using two words.	
A – Tropical	1. 2.
B – Dry	1. 2.
C – Temperate	1. 2.
D – Continental	1. 2.
E - Polar	1. 2.

Unequal heating occurs around the world for several reasons (for example: location on the planet, tilt of the Earth, rotation around the sun), Q8) How do you think this affects climate types and their distribution? (Think about how the climate zones are different in Greenland than those at the equator).

Q9) Describe the relationship between precipitation, temperature, and climate classification using information from these maps as illustrations.

Task 2: Review the climate classification types and examine two major factors that affect climate. Go to <http://arcg.is/1KrG5nf>.

Take a few minutes to become familiar with the map and its features. Try zooming, viewing the legend, and clicking for pop-ups at the various colored dots.

You will be working with four map layers:

Average monthly temperature,

Basic Koppen climate classifications,

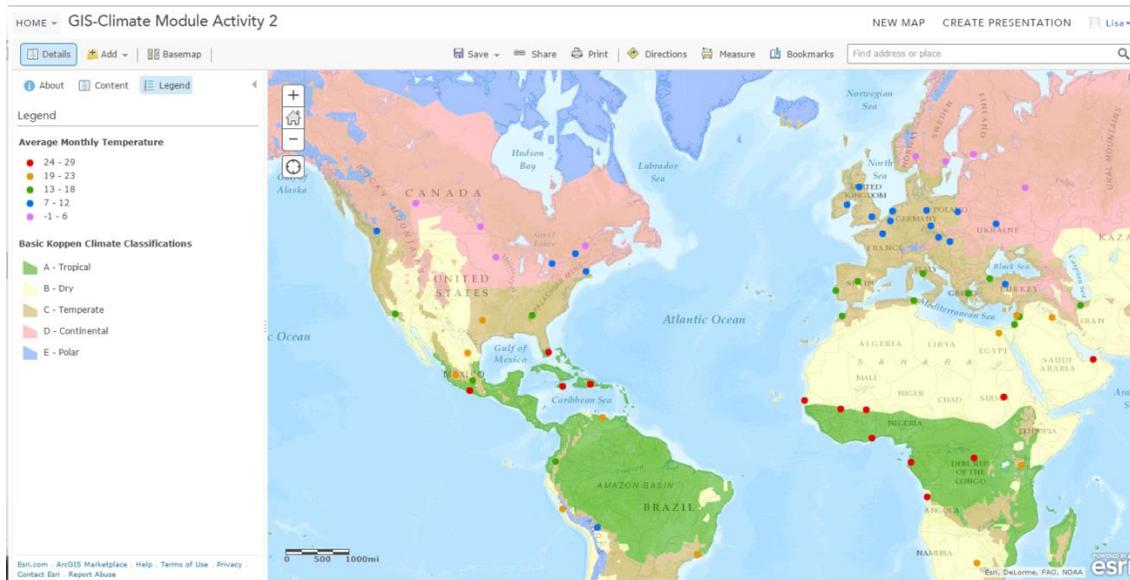
Global ocean currents.

Click the “Content” button  and turn on the “Basic Koppen Climate Classifications” and “Average Monthly Temperature” map layers by clicking the box next to them.

Set the Basemap to “Topographic.” Click on the “Basemap” button  Basemap to change it if needed.

Adjust the transparency of the “Basic Koppen Climate Classifications” layer by scrolling your mouse over it. An arrow  will appear to the right of it. Click on the arrow and select “transparency” from the menu. Set the transparency to 50%.

Click the “Legend” button. Your screen should appear as the image does below:



Q10) Based on what you've learned so far, list what factors you think affect climate classification types.

Use the map to explore the following:

Zoom in and scroll around the map to look for the factors you identified in the question above.

Begin to pay close attention to the topographic basemap under the climate classification layer.

You may have to zoom in close to see the basemap and click for pop-ups.

Study the influence of topography on climate types in different locations. The "Bookmarks"

button  **Bookmarks** will automatically zoom and move the map.

Go to "Bookmarks," select "Africa," and look for the following items:

The climate type located just south of the Sahara Desert.

The transitions between climate types from north to south.

Go to "Bookmarks," select "Australia," and look for the following items:

The climate types found in the deserts of Australia.

The location of the tropical climate type.

Go to "Bookmarks," select "South America," and look for the following items:

The climate types that are in the Andes Mountain range.

The transition between climate types from west to east.

Go to “Bookmarks” and select “World.” Review the distribution of climate classification zones across the globe. Use the web map and data you just reviewed to answer these questions:

Q11) What climate types did you identify in the mountainous areas that you observed? Include the names of the mountains where you found these climate types in your response.

Q12) What climate types are located in and around desert environments?

Task 3: Analyze the influence of ocean currents on climate.

Click the “Contents” button and turn the “Global ocean currents” layer on.

Go to “Bookmarks” and select the “World.”

Review the map using your knowledge of climate types to find a relationship and identify patterns between climate types and the warm and cool ocean currents. You may have to zoom in to find and follow the cold currents because they are colored blue on the blue ocean. Zoom over and look at the United States on the map.

Q13) Compare and contrast the climate classifications, ocean current type, and temperature data (use pop-up) of Los Angeles and Miami. Describe your findings for each city and how you think that related to the temperature of the ocean current that the city is near.

	Describe the climate of the city	Describe how the climate relates to the temperature of the ocean current near it
Los Angeles		
Miami		

Q14) Explain the patterns that you can identify between climate types and the warm and cool ocean currents.

Reflect on your earlier response regarding the role of unequal heating of the Earth from the sun has on climate and its distribution, Q15) What other connections can you make between the Earth's rotation, unequal heating, the climate types, and their distribution? List two additional conclusions or relationships than what you discussed in the earlier question.

Q16) Describe the data you would need use to identify the Koppen climate classification of a region.

Activity 2: Identification of Climate Patterns

Student Handout Answer Key

Q1) Explain the difference between climate and weather.

Answers will vary but should be similar to climate is “a description of long term average of conditions for a region” and weather is “daily conditions of the atmosphere in a place.”

Q2) Can the climate of a region be predicted? Why or why not?

Answers will vary based on what students know about climate, but a yes is the goal. You might look for something like regional climates can be predicted and are influenced by topography, temperature, the Earth’s rotation and unequal heating (the sun), and movement of ocean currents.

Task 1:

Q3) What climate classification type exists on Greenland?

Polar climate.

Q4) Describe the total annual precipitation and annual temperature of the climate classification type for Greenland.

Cold temperatures and little precipitation.

Q5) Name two climate types can be found closest to the equator? (There are several, but pick two).

Tropical climate

Dry climate

Q6) Describe the total annual precipitation and annual temperature of the two climate classifications you’ve selected in Q5.

Tropical climates are warm to hot in temperature and receive lots of precipitation.

Dry climates are warm to hot in temperatures but receive little precipitation.

Q7) Describe each climate classification using two words.

A – Tropical	1. Warm 2. Wet
B – Dry	1. Warm or cool 2. Dry
C – Temperate	1. Cool 2. Wet
D – Continental	1. Warm and cool 2. Wet and dry
E - Polar	1. Cool 2. Wet

Q8) How do you think this affects climate types and their distribution? (Think about how the climate zones are different in Greenland than those at the equator).

Answers will vary but should include a discussion of places like the tropics receiving more sun than other places, such as the poles, as well as the seasonality of the Northern and Southern Hemispheres, all of which contribute to differing climate types and their distribution around the planet.

Q9) Describe the relationship between precipitation, temperature, and climate classification using information from these maps as illustrations.

Answers will vary, but something like climate classifications are directly related to (and based on) amount of precipitation received and average temperatures of a region.

Task 2:

Q10) Based on what you've learned so far, list what factors you think affect climate classification types.

Answers will vary but could include topography, physical geography, proximity to water, temperature, precipitation, latitude, geographic position, and winds.

Q11) What climate types did you identify in the mountainous areas that you observed?

Polar, temperate, and dry climate classification types are located in mountainous regions are possible answers

Q12) What climate types are located in and around desert environments?

Dry climates are located in and around desert environments.

Task 3:

Q13) Compare and contrast the climate classifications, ocean current type, and average temperature data (use pop-up) of Los Angeles and Miami. Describe your findings for each city and how you think that related to the temperature of the ocean current that the city is near.		
	Describe the climate of the city	Describe how the climate relates to the temperature of the ocean current near it
Los Angeles	At the intersection of a temperate and dry climate, average temperatures ranges from 57-70 degrees, and a cool current is near	The cool ocean current that runs nearby has a cooling effect on the city and regional climate system
Miami	In a tropical climate, average temperature ranges from 68-83 degrees, and warm current is near	The warm ocean current that runs nearby has a warming effect on the city and regional climate system

Q14) Explain the patterns that you can identify between climate types and the warm and cool ocean currents.

Warm ocean currents tend to circulate past tropical and temperate climate types, while cool ocean currents tend to circulate around dry and polar climate types.

Q15) What other connections can you make between the Earth’s rotation, unequal heating, the climate types, and their distribution? List two additional conclusions or relationships than what you discussed in the earlier question.

Answers will vary but they should enhance their answer to the related question in the exploration section of the activity (tropics receiving more sun than other places, such as the poles, as well as

the seasonality of the Northern and Southern Hemispheres, all of which contribute to differing climate types and their distribution around the planet).

Q16) Describe the data you would need use to identify the Koppen climate classification of a region.

Regional climates can be predicted and are influenced by topography, temperature, the Earth's unequal heating from the sun, and movement of ocean currents.

Appendix D - GIS-Climate Module Activity 3: Examination of Global Climate Change

Activity 3: Examination of Global Climate Change

Activity Overview

Students will be able to identify and explain past and present trends of the Earth’s changing climate, use models to explain how interactions between planet systems cause climate change, and use models make predictions about future climate change.

Materials

Internet access and device for connection (multiple websites visited)

Teacher instruction, student instructions with questions, and answer key

Objectives	Learner Assumptions
<p>After completing this activity, a student is able to do the following:</p> <p>Identify and explain past and present trends of the Earth’s changing climate,</p> <p>Use models to explain how the interactions between planet systems cause climate change, and</p> <p>Use models to make predictions about climate change.</p>	<p>In order to complete this activity, students should already have the following:</p> <p>map reading skills,</p> <p>graph reading skills, and</p> <p>can describe weather, climate, climate classifications, climate controls, and explain a weather report and a climatology report.</p>

Day 1: Student Task 1

Engagement

Connect the students back to the last activity and the discussion of if the climate of a region can be predicted. Bridge that conversation into the question, “can climate change be predicted?” Share with your students that they are going to explore how the earth’s climate is changing and what evidence of systems-based interactions there is to support this conclusion.

Exploration

In this task, students will be completing the High-Adventure Science activity, Earth's Changing Climates, accessible at the following website:

http://authoring.concord.org/sequences/47/activities/278?show_index=true. This online activity walks students through recorded climate data for the past 120 years and encourages them to observe, analyze, and engage with the climate materials through interactive videos, graphs, and images. The task culminates with a discussion and prediction of the future climate of the earth.

Explanation

The Earth's Changing Climates module has the option to generate a report of students' responses upon completion. The report can then be printed or shared as a URL. This option could be used instead of the Activity 3 student handout/worksheet.

Day 2: Student Tasks 2 and 3

Elaboration

In this task, students will be completing the High-Adventure Science activity, Using Models to Make Predictions, accessible at the following website:

http://authoring.concord.org/sequences/47/activities/282?show_index=true. This online activity uses models to explore and explain how Earth's systems work together to cause climate change. The same report option is available as with the first module to be used if preferred.

Evaluation

When the class has finished the activity, lead a short discussion that summarizes the conclusions the students reached, based on the Elaboration activity. As homework, have students write a three-part summary statement of what they learned about 1) the Earth's changing climate, 2) using models to make and understand climate change, and 3) predict what changes could occur in Kansas. (This three-part summary statement will be used in the engagement activity of Activity 4: Climate Change in Kansas and the Great Plains).

Activity 3: Examination of Global Climate Change

In this activity, you will explore how the earth's climate is changing and what evidence there is to support this conclusion.

Task 1: This activity explores the past and future of climate on Earth. Go to the following website to access the activity:

http://authoring.concord.org/sequences/47/activities/278?show_index=true.

Take your time to watch the media clips and read the graphs; they are essential to understanding this material.

Your screen should appear as:

The screenshot shows a web page titled "What is the future of Earth's climate?" from High-Adventure Science. The page is for "Activity 1: Earth's changing climates" and is currently on page 1 of 8. The main heading is "Earth's changing climates". Below the heading is a paragraph: "What is the future for Earth's climate? Explore data from NASA showing temperature changes over the past 120 years and data from the Vostok ice core to look at climate trends over different time scales. Evaluate what information the data provides and consider the limitations of conclusions that can be drawn from the data." Below this is a small credit: "Thumbnail credit: NASA Goddard Institute for Space Studies". There is a clock icon and text: "Estimated Time to Complete This Module: 45 minutes". On the right side, there is a "Pages in This Activity" list with 8 items: 1. What will Earth's climates be in the future?, 2. Trends of the past (part 1), 3. Trends of the past (part 2), 4. Predicting the future, 5. Way, way back in time, 6. Vostok Research Station, Antarctica, 7. Predicting the future from the past, 8. Looking to the future. At the bottom right is a yellow "Begin activity" button. The page also has social media icons for Like and Tweet, and a user greeting "Hi, Anonymous".

Answer the following questions as prompted by the online activity.

Q1) What do the colors indicate about the change in average temperature over time from 1884 to 2012?

Q2) In the past 50 years, where has the temperature changed the most?

Q3) Describe the average temperature change from 1880 to 2010.

Q4) Why is the curve between 1950 and 1980 relatively flat and centered around zero degrees difference from the baseline? (Hint: how is the temperature change being compared over time?)

Q5) The green bars are called "error bars." They indicate the range of uncertainty that scientists have about the data on the graph. (Note: Not all error bars are shown.) Why do you think these error bars are smaller near the year 2000 than in the 1890s?

Q6) Why is the black line so much more variable than the red line? What's the difference between the data they show?

Q7 & Q8) After drawing in your prediction, explain why you drew the prediction curve as you did.

Q9) How certain are you about your prediction based on your explanation?

- (1) Not at all certain
- (2) Somewhat certain
- (3) Certain
- (4) Mostly certain
- (5) Very certain

Q10) Explain what influenced your certainty rating.

Q11) Why do you think the winter layers are darker than the summer layers in the ice core (hint: what would you put in an ice cube tray filled with water to produce dark ice)?

Q12) The trend in the graph shows short warm periods between long periods of highly variable cold climate. Which statement is supported by the information in the graph? The graph shows that the temperature for the past 10,000 years, compared with the previous 400,000 years, has been:

Getting warmer.

Staying fairly stable.

Getting colder.

Q13) Top of Form

Bottom of Form

Describe how current climate trends (from 1880 to 2010) might change the pattern of warming and cooling shown on the Vostok ice core graph.

Q14) Explain how scientists can be both fairly certain that Earth is warming and still actively researching the unknown factors.

Question 14 is the final question. You have completed the module. Generate a report (using the button) if your teacher directs you to do so.

Task 2: This activity uses models to explore and explain how Earth's systems work together to cause climate change. Go to the following website to access the activity:

http://authoring.concord.org/sequences/47/activities/282?show_index=true

Take your time to read the graphs, watch the media clips, and use the simulation; they are essential to understanding this material.

Your screen should appear as:

What is the future of Earth's climate? High-Adventure Science

Menu Activity 5: Using models to make predictions Hi, Anonymous

Like Tweet

Using models to make predictions

Explore how solar radiation, Earth's surface and oceans, and greenhouse gases interact to cause global warming. Change variables to determine how much greenhouse gas emissions might need to fall to mitigate the temperature increase.

Thumbnail credit: Intergovernmental panel on Climate Change, Third Assessment Report, Technical Summary of Working Group I Report, 2001

Estimated Time to Complete This Module: 45 minutes

Pages In This Activity

1. Complex climate models
2. Time lags in temperature changes
3. Meet a climate scientist: Mark Chandler
4. Societal effects
5. Millions of years of data
6. How much reduction?

[Begin activity](#)

Answer the following questions as prompted by the online activity.

Q1) Why is there a lag between changes in CO₂ levels and temperature? (Hint: Remember that there are many reservoirs for carbon dioxide. Where can carbon dioxide be stored when the temperature is low?)

Q2) Are models necessary to understand climate change?

Top of Form

Yes

No

Bottom of Form

Q3) Explain your answer to Q2.

Q4) How can you (and scientists) tell that a model is good? What kinds of tests can you run to assess the validity of a model?

Q5) How can scientists be sure that Earth is getting warmer when they are not completely certain about what is going to happen to Earth's temperature in the future?

Q6) Based on all of what you've learned from this module, how can scientists look at 542 million years of temperature data (in the graph) and still be fairly confident that humans are contributing to the current warming trend?

Q7) How much did you need to change the human emissions to reduce the average global temperature in the model?

Top of Form

0-25% of 2010 emissions

25-50% of 2010 emissions

50%-75% of 2010 emissions

100% of 2010 emissions (to zero human emissions)

Q8) Explain your conclusion. Describe the outcomes of experiments that you tried. In your explanation, include as many factors as possible that might affect the global temperature (hint: you will need to look at the graphs on the right and on the bottom).

Q9) How certain are you about your claim based on your explanation?

(1) Not at all certain

(2) Somewhat certain

(3) Certain

(4) Mostly certain

(5) Very certain

Q10) Explain what influenced your certainty rating.

Q11) What additional factors would you like to add to the model to be able to make a better prediction of the impact of a reduction of human emissions on the global temperature?

Bottom of Form

Task 3: For homework, write a three-part summary statement of what you have learned about:

- 1) the Earth's changing climate,
- 2) using models to make predictions and understand climate change, and
- 3) predict what changes could occur in Kansas.

Activity 3: Examination of Global Climate Change

Student Questions Suggested Answer Key

Task 1:

Q1) What do the colors indicate about the change in average temperature over time from 1884 to 2012?

Answers will vary slightly, but should include that the blue colors indicate lower average temperature and the yellow, orange, and red colors indicate areas of higher average temperature.

Q2) In the past 50 years, where has the temperature changed the most?

Answers will vary but should include the poles, mid-latitudes, and over the oceans (specific place names such as Greenland, Russia, Canada, etc. should be acceptable).

Q3) Describe the average temperature change from 1880 to 2010.

Answers will vary but should focus on that fact that that average temperature has risen over time (specifically 1.2°C).

Q4) Why is the curve between 1950 and 1980 relatively flat and centered around zero degrees difference from the baseline? (Hint: how is the temperature change being compared over time?)

Answers will vary but should be something like “the temperature change is being compared to an average, which is the 0°C on the graph, thus between 1950 and 1980 the average temperature was around the same as the baseline average temperature.”

Q5) The green bars are called "error bars." They indicate the range of uncertainty that scientists have about the data on the graph. (Note: Not all error bars are shown.) Why do you think these error bars are smaller near the year 2000 than in the 1890s?

Answers will vary but should be something like “because there is more technical and precise equipment and thus reliable data from the year 2000 than from the 1890s.”

Q6) Why is the black line so much more variable than the red line? What's the difference between the data they show?

The black line is the annual mean (average) temperature and the red line is the 5 year mean (average) temperature. The red line covers larger chunks of time (5 years) and thus can be drawn more smoothly than the annual data (black line).

Q7 & Q8) After drawing in your prediction, explain why you drew the prediction curve as you did.

Q7 will be drawn on the computer and Q8 will vary but should be something like “I drew the possible temperature trend to 2100 in an upward fashion, indicating a warming trend, because that is the current and past trend in the data.”

Q9) How certain are you about your prediction based on your explanation?

- (1) Not at all certain
- (2) Somewhat certain
- (3) Certain
- (4) Mostly certain
- (5) Very certain

Q10) Explain what influenced your certainty rating.

Answers will vary.

Q11) Why do you think the winter layers are darker than the summer layers in the ice core (hint: what would you put in an ice cube tray filled with water to produce dark ice)?

Answers will vary but are likely to include a discussion of difference in debris/particulate matter in the air and on the ground during different seasons.

Q12) The trend in the graph shows short warm periods between long periods of highly variable cold climate. Which statement is supported by the information in the graph? The graph shows that the temperature for the past 10,000 years, compared with the previous 400,000 years, has been:

Getting warmer.

Staying fairly stable.

Getting colder.

Q13) Top of Form

Bottom of Form

Describe how current climate trends (from 1880 to 2010) might change the pattern of warming and cooling shown on the Vostok ice core graph.

Answers will vary but should be something like “the currently typical interval of the Vostok ice core graph will likely be altered by the 1880-2010 time period because there has been little to no cooling and the average temperature change is increasing more than it ever has during this time period.”

Q14) Explain how scientists can be both fairly certain that Earth is warming and still actively researching the unknown factors.

Answers will vary but should include a discussion of what the average temperature data indicates and reputable and reliable means of measurement. Such as “mathematical climate models cannot model every eccentricity of the complex climate system yet, but they can be made to model certain aspects (such as temperature change). Modeling these certain aspects using reputable gathered data from the last 100 years is the act of merging what we can do with what we do know for sure in order to work with the many uncertain factors.”

Task 2:

Q1) Why is there a lag between changes in CO₂ levels and temperature? (Hint: Remember that there are many reservoirs for carbon dioxide. Where can carbon dioxide be stored when the temperature is low?)

Answers will vary but should be something like “because the movement of CO₂ between different storage sinks (atmosphere, ocean, land, and sediments) takes time.”

Q2) Are models necessary to understand climate change?

Top of Form

Yes

No

Bottom of Form

Q3) Explain your answer to Q2.

Answers will vary based on student opinion/response

Q4) How can you (and scientists) tell that a model is good? What kinds of tests can you run to assess the validity of a model?

Answers will vary based on student knowledge of models and response to the video but are likely to include mention of precise and reliable measurements, reputable record keeping over time, and a growing understanding of how the Earth's systems work together.

Q5) How can scientists be sure that Earth is getting warmer when they are not completely certain about what is going to happen to Earth's temperature in the future?

Answers will vary but should include a discussion of the ability of scientists to run multiple possible model outputs, access to better measurements every day, and a growing understanding of how the Earth's systems work together.

Q6) Based on all of what you've learned from this module, how can scientists look at 542 million years of temperature data (in the graph) and still be fairly confident that humans are contributing to the current warming trend?

Answers will vary but should include a discussion about uncertainty, understanding trends and patterns, and understanding the earth-systems processes that humans are impacting that influence the climate system.

Q7) How much did you need to change the human emissions to reduce the average global temperature in the model?

Top of Form

0-25% of 2010 emissions

25-50% of 2010 emissions

50%-75% of 2010 emissions

100% of 2010 emissions (to zero human emissions)

Q8) Explain your conclusion. Describe the outcomes of experiments that you tried. In your explanation, include as many factors as possible that might affect the global temperature (hint: you will need to look at the graphs on the right and on the bottom).

Answers will vary but should reference changes in human emission levels, temperature change, and impacts/occurrences within the air, ocean, and atmosphere (vapor).

Q9) How certain are you about your claim based on your explanation?

- (1) Not at all certain
- (2) Somewhat certain
- (3) Certain
- (4) Mostly certain
- (5) Very certain

Q10) Explain what influenced your certainty rating.

Answers will vary based on student opinion/response.

Q11) What additional factors would you like to add to the model to be able to make a better prediction of the impact of a reduction of human emissions on the global temperature?

Answers will vary but possibilities include: change year of human emissions percentages (the constant to be manipulated is 2010), change cloud cover, and season.

Task 3: For homework, write a three-part summary statement of what you have learned about: the Earth's changing climate,

Answers will vary but key points should include that average temperature has changed over time, there is scientific consensus on the current changes in climate, and greenhouse gases have a significant role in the system.

using models to make predictions and understand climate change, and

Answers will vary but key points should include that past climate can be understood through proxy data (ice and sediment cores and models assist in mapping, understanding, and predicting climate change.

predict what changes could occur in Kansas.

Answers will vary but likely responses will include a discussion of rising temperatures, changing in rain patterns and impacts on agriculture.

Appendix E - GIS-Climate Module Activity 4: Climate Change in Kansas and the Great Plains

Activity 4: Climate Change in Kansas and the Great Plains

Activity Overview

Students will be able to identify and engage in a locally relevant examination of projected climate change events and impacts in Kansas and the Great Plains.

Materials

Internet access and device for connection (multiple websites visited)

Teacher instruction, student instructions with questions, and answer key

Objectives	Learner Assumptions
<p>After completing this activity, a student is able to do the following:</p> <p>Identify and understand an example of climate change in Kansas and the Great Plains and Engage in a locally relevant analysis and scientific communication about these projected events.</p>	<p>In order to complete this activity, students should already have the following:</p> <p>map reading skills, can describe weather, climate, climate classifications, climate controls, and explain a weather report and a climatology report, can describe past and present trends of the Earth’s changing climate, and use models to make predictions about climate change.</p>

Day 1: Student Tasks 1 and 2

Engagement

As the evaluation activity for Activity 3: Examination of Global Climate Change, students were asked to write a three-part summary statement of what they learned about 1) the Earth’s changing climate, 2) using models to make predictions and understand climate change, and 3) predict what changes could occur in Kansas. To begin this activity, have students work briefly in

groups to share their responses and then generate a class list of possible changes that they hypothesize could occur in Kansas.

Exploration

In the first task, students are going to be introduced to research that explains how climate change is likely to drastically decrease wheat production, which would certainly be a climate change related problem for Kansas. The article can be viewed from either of the following websites:

<http://www.sciencedaily.com/releases/2015/02/150219112438.htm> and

<http://www.k-state.edu/media/newsreleases/feb15/climatewheat21815.html>.

(A possible teacher modification to this reading activity would be the addition of a think-pair-share or guided reading sheet.)

Follow-up reading materials to consider for use to build understanding of climate change impacts on agriculture in Kansas are:

Environmental Protection Agency climate change assessment of the Great Plains region

(<http://www.epa.gov/climatechange/impacts-adaptation/greatplains.html>)

Legislative document on assessing the economic cost of climate change in Kansas

(<http://cier.umd.edu/climateadaptation/Climate%20change--KANSAS.pdf>)

National Association of Wheat Growers wheat info: Fast facts

(<http://www.wheatworld.org/wheat-info/fast-facts/>)

Topeka Capitol Journal article on impacted labor productivity

(<http://cjonline.com/news/business/2014-07-05/kansas-less-impacted-climate-change-some-states>)

Explanation

With the news story in mind, student will review a web map and write four hypotheses.

Navigate to <http://arcg.is/1Bs6QgU>. Take a few minutes to let your students become acquainted with the map and its features. In this activity, students will be working with three data layers: 1) roads, 2) boundaries and cities, and 3) wheat production, year 2000. The purpose of this map is for reference and to show patterns of wheat production around the world.

After becoming familiar with the web map and with the wheat impacts research in mind, students will write four hypotheses about how they think the Kansas wheat production projections will impact them, the Great Plains region, the state, and the nation.

Day 2: Student Task 3

Elaboration

For this part of the activity, the students work in five groups to investigate key concepts from the 2014 National Climate Assessment (<http://nca2014.globalchange.gov/>). The National Climate Assessment “summarizes the impacts of climate change on the United States, now and in the future” and it is a collaborative research effort involving over 300 scientists. After introducing the website to the students, give the students about 10 minutes to explore highlights about the Great Plains region and become comfortable navigating the website. Then during the next 10 minutes, assign each group use the graphic organizer provided to read and summarize one of the five key messages. Finally, take 15 minutes (3 minutes/group) and have each group report their findings.

Evaluation

When the class has finished the activity, lead a short discussion that summarizes the conclusions the students reached. Be sure to highlight patterns and relationships that they discovered. Close the activity by having the students re-visit the four hypotheses they wrote about how they think the Kansas wheat production projections will impact them, the Great Plains region, the state, and the nation. Instruct the students to revise or justify why they still agree or now disagree with each of their hypotheses.

Activity 4: Climate Change in Kansas and the Great Plains

In this activity, you will be introduced to and engage in a locally relevant examination of projected climate change events and impacts in Kansas and the Great Plains.

At the start of class, you were asked to share your three-part summary statement from Activity 3: Examination of Global Climate Change, on 1) the Earth's changing climate, 2) using models to make predictions and understand climate change, and 3) predict what changes could occur in Kansas. Now you are going to apply this knowledge to the following scenario and data.

Task 1: In this task, you are going to be read a recent article about a climate change related problem in Kansas. This research that indicates that climate change is likely to drastically impact the quantity of Kansas wheat production. The article can be viewed and read from the following websites:

<http://www.sciencedaily.com/releases/2015/02/150219112438.htm> and
<http://www.k-state.edu/media/newsreleases/feb15/climatewheat21815.html>.

Q1) Summarize specific parts of the research article:

What data was collected?

What conclusion was reached?

Why is this a problem for Kansas?

Why is this a problem for the world?

Task 2: You will be using a GIS map for reference during the next part of this lesson. Navigate to <http://arcg.is/1Bs6QgU>.

Take a few minutes to become familiar with the map. Try zooming, measuring, viewing the legend, and clicking for pop-ups.

You will be working with three map layers:

Roads

Boundaries and cities

Wheat production, Year 2000

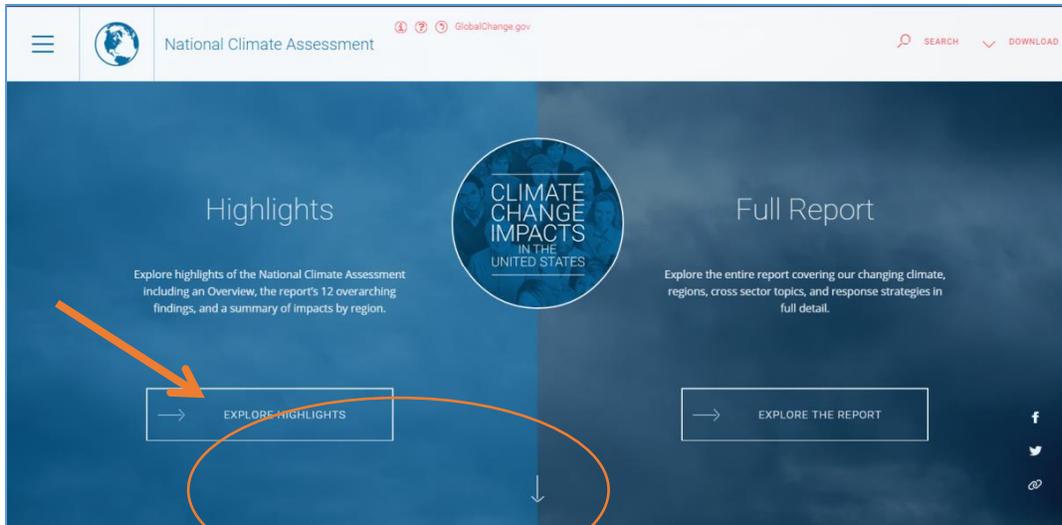
After reviewing the map, specifically viewing it from all the bookmarked points, Q2) Describe the distribution of wheat grown around the world. (Distribution refers to the way something is spread out or placed over a geographic area).

Q3) Identify three countries with the very high wheat production in 2000.

Using the “Bookmarks” button, select “Great Plains” to answer the following question, Q4) explain any connections you recognize between where wheat is grown and where roads are. Explain this connection. (You may need to go to the ‘Contents’ and turn data layers on and off or change the transparency to be able to see the information you need.)

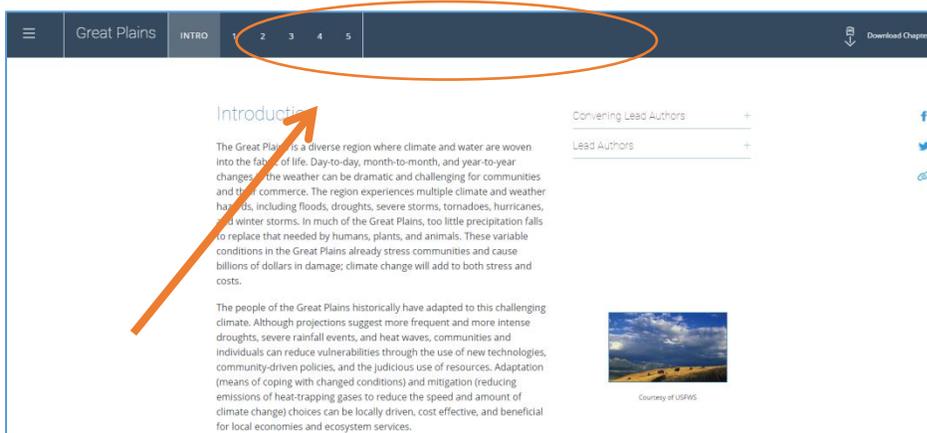
State your hypothesis for how the projected impact on wheat production in Kansas will impact the following four areas (give specific examples):	
Q4) You as part of your community.	Q6) The state of Kansas.
Q5) The Great Plains region.	Q7) The United States of America.

Task 3: During this task, you will be investigating and sharing key messages of climate change from the 2014 National Climate Assessment. Go to: <http://nca2014.globalchange.gov/>. Your screen should appear as:



First, click on “Explore Highlights” on the bottom left part of your screen. Take time and explore the “Highlights” section of the website, which includes the Overview, Report Findings, and Regions.

Next, go back to the home page (<http://nca2014.globalchange.gov/>) or click on the  on the top bar to return to the home page. Click on “Explore the Report” on the bottom right part of your screen and on the following page click on “Regions.” The “Regions” section has the  icon, select “Explore Regions,” and then choose the “Great Plains.” After clicking the downward pointing arrow on the Great Plain homepage you are presented with an introduction and five sections. Your screen should appear as:



After reading the introduction (which includes the maps), click on the corresponding number on the top row of the website to the key message you have been assigned as a group. Answer the

following questions about your section. Be prepared to report your findings using your responses to these questions.

Q9) What key message title were you assigned?

Q10) List the three most important points of this key message.

Q11) What is the overall take-home message of your key message?

Q12) Write a hypothesis about how this information will affect you.

Q13) Write a hypothesis about how this information will affect others who live outside of the Great Plains region.

With this new information, re-visit the four hypotheses you wrote (Q5 –Q8). If you think the four hypotheses are still supported, describe how they are supported by the information presented in the 2014 National Climate Assessment. If you think your hypotheses should be changed, describe the elements of the 2014 National Climate Assessment that lead you to revise your hypotheses

Revise your hypotheses or justify why you still agree with each of their hypotheses (give specific examples).	
Q14) You as part of your community.	Q15) The state of Kansas.

Q16) The Great Plains region.	Q17) The United States of America.

Activity 4: Climate Change in Kansas and the Great Plains

Student Questions Suggested Answer Key

Task 1:

Q1) Summarize specific parts of the research article:

What data was collected?

Wheat production was compared with projected changes in average temperature in a climate model.

What conclusion was reached?

Changes (both increases and decreases) in average temperature will alter the quantity of wheat that will be produced, suggesting that less will be produced than is currently.

Why is this a problem for Kansas?

Answers will vary but is likely to include that this projected scenario could change Kansas economics by negatively impacting the number of wheat related jobs (for production, manufacturing, and transportation), possibly change how much wheat is worth, alter local production, and threaten the livelihoods of many rural communities.

Why is this a problem for the world?

Answers will vary but is likely to include discussion of a reduction in amount of wheat, a key commodity in the food trade, could mean less available food globally, resulting in greater possible starvation and food crisis situations.

Task 2:

Q2) Describe the distribution of wheat grown around the world.

Answers will vary but are likely to include: widespread, on every continent except Antarctica, both centrally located and on coasts, high densities are clustered, and not in mountains, rainforests, or across deserts.

Q3) Identify three countries with the very high wheat production in 2000.

There are several options, but should include three of the following: United States, China, India, Kazakhstan, Canada, Turkey, the United Kingdom/England, and/or Australia.

Q4) Explain any connections you recognize between where wheat is grown and where roads are. Explain this connection.

There tend to be a large network of roads where wheat is grown. This is likely because once harvested, the wheat must be transported to other locations in order to be processed, and delivered to markets.

State your hypothesis for how the projected impact on wheat production in Kansas will impact the following four areas (give specific examples):	
<p>Q5) You as part of your community. Answers will vary, but students are likely to talk about their feelings, their school, their jobs, and personal or family experiences and impacts.</p>	<p>Q6) The state of Kansas. Answers will vary, but students are likely to talk about local jobs and the economy, food availability or prices, and a change in local culture.</p>
<p>Q7) The Great Plains region. Answers will vary, but students are likely to talk about the regional economy, movement of goods, availability of food, and a change in regional culture and reputation.</p>	<p>Q8) The United States of America. Answers will vary, but students are likely to include a discussion of economics, food security, and movement of people.</p>

Task 3:

Q9) What key message title were you assigned?

Answers will be one of the following five: 1) energy, water, and land use, 2) sustaining agriculture, 3) conservation and adaptation, 4) vulnerable communities, and 5) opportunities to build resilience.

Q10) List the three most important points of this key message.

Answers will vary based on key message assigned, but will correspond with the take-home message in Q11.

Q11) What is the overall take-home message of your key message?

Answers will vary based on topic suggested, but likely to include the following by topic (directly from website):

- 1) Energy, water, and land use: Rising temperatures are leading to increased demand for water and energy. In parts of the Great Plains region, this will constrain development, stress natural resources, and increase water competition.
- 2) Sustaining agriculture: Changes to crop growth cycles due to warming winters and alteration in the timing and magnitude of rainfall events have already been observed. As these trends continue, they will require new agriculture and livestock management practices.
- 3) Conservation and adaptation: Landscape fragmentation, which is increasing. A highly fragmented landscape will hinder adaptation of species to a new climate as climate change alters their normal habitat composition.
- 4) Vulnerable communities: Communities that are already most vulnerable to weather and climate extremes will be stressed even further by more frequent extreme events occurring.
- 5) Opportunities to build resilience: The magnitude of expected changes will exceed those experienced in the last century. Existing adaptation and planning efforts are inadequate to respond to these projected impacts.

Q12) Write a hypothesis about how this information will affect you.

Answers will vary but are likely to include a discussion of personal feelings, experience, and habits that would be impacted, for example: spending less time outside because it would be hotter, what they like to eat may become less available, changes to what their town or region landscape looks like, or if they come from a farming family what they produce may change.

Q13) Write a hypothesis about how this information will affect others who live outside of the Great Plains region.

Answers will vary, but should include discussion of possible economic, environmental, and societal impacts such as food scarcity, changes in jobs, movement of people, and changes in the natural environment.

Revise your hypotheses or justify why you still agree with each of their hypotheses (give specific examples).

<p>Answers will vary but are expected to build on prior responses at the appropriate scale (local, state, regional, and nation) and include a greater discussion of how energy, water resources, and local land are used, how they think agriculture and food supply will be impacted, what can be done to conserve, adapt, and protect vulnerable areas, and what that means for local areas to increase their resiliency.</p>	
<p>Q14) You as part of your community. Answers will vary (see above).</p>	<p>Q15) The state of Kansas. Answers will vary (see above).</p>
<p>Q16) The Great Plains region. Answers will vary (see above).</p>	<p>Q17) The United States of America. Answers will vary (see above).</p>

Appendix F - GIS-Climate Module External Review Sheet

Thank you for agreeing to review the GIS-Climate module. This module will be used as part of the ‘Making Climate Change Locally Relevant’ project during the summer and fall 2015 semesters.

The goal of the GIS-Climate module is to introduce students to important climate change concepts, focusing on building content knowledge from understanding climate, to examining global climate change, and finally studying local examples. Please review the four activities for accurate content, sequence, and classroom formatting. The activities within this module are specifically broad and general, so the teachers using this module will adjust and tailor the activities to their own classroom at the middle and high school levels. Teachers will be using this module as part of a climate change unit in the following classes: general science, earth science, agricultural science, biology, and environmental science.

The GIS-Climate module is in the attached files. Please use the following form to provide feedback. It consists of two sections, first is an overall review and second is a specific review of each activity within the module. If you would like to complete the review electronically, please select your response by highlighting or bolding it, otherwise print and complete. If you have any questions or concerns during the process, please contact me, Lisa Tabor, by email at lkt7779@ksu.edu or by phone at (785) 565-8580. Once completed, send your review to me by email at lkt7779@ksu.edu or by mail at Lisa Tabor, Center for Science Education, Kansas State University, 364 Bluemont Hall, Manhattan KS 66503.

Overall Review of the GIS-Climate Module

1. Are the learning objectives clearly stated?
 - a. Yes
 - b. No
 - i. If no, please list which objective(s) and/or activity(ities) are not clearly stated.

2. Do the instructional strategies in each activity build towards mastering the learning objectives?
 - a. Yes
 - b. No
 - i. If no, please explain in what part of the activity(ities) that the instructions are not focused toward the learning objectives.

3. Does each activity build successively upon the next?
 - a. Yes
 - b. No
 - i. If no, please explain where within the module and/or activities there is a disconnect in the progression of content.

4. Do you think the module will be engaging and motivating for students?
 - a. Yes
 - i. If yes, please describe or share specific aspects of the module that engages and motivates.
 - b. No
 - i. If no, what would make the module more engaging and motivating?

5. Will the students be engaged in inquiry, independent thinking, and/or problem solving through this module?
 - a. Yes
 - i. If yes, please describe or share specific aspects of the module that engages and motivates.
 - b. No
 - i. If no, what could be added to the module to better include inquiry and engage students in independent thinking and/or problem solving?

6. Do you think each activity be completed in two class periods (50-minutes each + homework as stated)?
 - a. Yes
 - b. No
 - i. If no, please list which activities you think could not be completed in two class periods and how long you think the activity would take.

7. What is the greatest strength of the GIS-Climate module?

8. Do you feel that the module is complete and ready to use?
 - a. Yes
 - b. No
 - i. If no, please explain what parts of the module would require greater preparation.

9. What is the biggest weakness of the GIS-Climate module?

Activity Specific Review

To answer the following questions there is no format. I would like your thoughts about each activity. Please share with me the good and the bad (e.g. thoughts about the accuracy of the content, appropriateness of the content, specific formatting or sequence questions, things that may seem like they are missing, concerns, confusions, any needed revisions, general thoughts).

10. Please share your overall review of Activity 1.
11. Please share your overall review of Activity 2.
12. Please share your overall review of Activity 3.
13. Please share your overall review of Activity 4.

Appendix G - Student Climate Change Knowledge Assessment

Student Climate Change Knowledge Assessment

Thank you for participation in this survey. Please complete the following questions to the best of your abilities. It is estimated that it will take about 5 minutes to complete. Your responses and anonymity will be protected. Please ask your teacher if you have any questions.

Multiple choice:

1. _____ is the daily conditions of the atmosphere in a place.
 - a. Weather*
 - b. Climate
 - c. Outdoor monitoring
 - d. Trends
2. _____ is a description of long term average conditions for a region.
 - a. Weather
 - b. Climate*
 - c. Outdoor monitoring
 - d. Trends
3. The climate is impacted by and changes in response to both _____ and _____ processes.
 - a. Human and natural*
 - b. Natural and lunar
 - c. Lunar and geological
 - d. All of the above
4. Which two factors are used in determining the basic Koppen climate classification of a region?
 - a. Precipitation and temperature*
 - b. Precipitation and geographic position on the planet
 - c. Temperature and cold ocean currents
 - d. Topography and proximity to water
5. Modeling is used to project future climate change through:

- a. Predicting the future
- b. Reading sunspot patterns and cycles
- c. Observations of the moon
- d. Constructing mathematical simulations of real climate processes*

Check all that apply:

- 6. Which of the following play a role in regulating climate? (Select all that apply).
 - a. Seasons
 - b. Topography*
 - c. Proximity to water*
 - d. Temperature of ocean currents*
 - e. Time of the day
 - f. Geographic position on the planet*

Appendix H - Knowledge of Climate Change across Global Warming's Six Americas

Knowledge of Climate Change across Global Warming's Six Americas

From Maibach, et al., 2011: 15-ITEM SCREENING INSTRUMENT

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.

1. What do you think? Do you think that global warming is happening?

Yes...

- ...and I'm extremely sure (9)
- ...and I'm very sure (8)
- ...and I'm somewhat sure (7)
- ...but I'm not at all sure (6)

No...

- ...and I'm extremely sure (1)
- ...and I'm very sure (2)
- ...and I'm somewhat sure (3)
- ...but I'm not at all sure (4)

Or...

- I don't know (5)

2. Assuming global warming is happening, do you think it is ...

- Caused mostly by human activities
- Caused mostly by natural changes in the environment
- Other
- None of the above because global warming isn't happening

3. How worried are you about global warming?

- Very worried
- Somewhat worried
- Not very worried
- Not at all worried

4. How much do you think global warming will harm you personally?

- Not at all
- Only a little
- A moderate amount
- A great deal
- Don't know

5. When do you think global warming will start to harm people in the United States?

- They are being harmed now
- In 10 years
- In 25 years
- In 50 years
- In 100 years
- Never

6. How much do you think global warming will harm future generations of people?

- Not at all
- Only a little
- A moderate amount
- A great deal
- Don't know

7. How much had you thought about global warming before today?

- A lot
- Some
- A little
- Not at all

8. How important is the issue of global warming to you personally?

- Not at all important
- Not too important
- Somewhat important
- Very important
- Extremely important

9. How much do you agree or disagree with the following statement: "I could easily change my mind about global warming."

- Strongly agree
- Somewhat agree

- Somewhat disagree
- Strongly disagree

10. How many of your friends share your views on global warming?

- None
- A few
- Some
- Most
- All

11. Which of the following statements comes closest to your view?

- Global warming isn't happening.
- Humans can't reduce global warming, even if it is happening.
- Humans could reduce global warming, but people aren't willing to change their behavior so we're not going to.
- Humans could reduce global warming, but it's unclear at this point whether we will do what's needed.
- Humans can reduce global warming, and we are going to do so successfully.

12. Do you think citizens themselves should be doing more or less to address global warming?

- Much less
- Less
- Currently doing the right amount
- More
- Much more

13. Over the past 12 months, how many times have you punished companies that are opposing steps to reduce global warming by NOT buying their products?

- Never
- Once
- A few times (2-3)
- Several times (4-5)
- Many times (6+)
- Don't know

14. Do you think global warming should be a low, medium, high, or very high priority for the President and Congress?

- Low
- Medium
- High

- Very high

15. People disagree whether the United States should reduce greenhouse gas emissions on its own, or make reductions only if other countries do too. Which of the following statements comes closest to your own point of view?

The United States should reduce its greenhouse gas emissions ...

- Regardless of what other countries do
- Only if other industrialized countries (such as England, Germany and Japan) reduce their emissions
- Only if other industrialized countries and developing countries (such as China, India and Brazil) reduce their emissions
- The US should not reduce its emissions
- Don't know

Appendix I - Student Survey of GIS Use

Student Survey of GIS

Thank you for participation in this survey. Your thoughts and feedback about GIS are important to understanding its use in schools. Please complete the following questions to the best of your abilities. It is estimated that it will take about 5 minutes to complete. This is not a graded activity; it's about what you think. Your responses and anonymity will be protected. Please ask your teacher if you have any questions.

1. Please rate how much you liked using GIS on a scale from 1 (the worst) to 10 (the best).

1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10

2. What was the best part about using the GIS? (for example: working with the online map, using local data, studying a local phenomenon)

3. What was the worst part about using the GIS? (for example: the program did not load very quickly, it was hard to move around the online map, I needed more time to learn to use the program)

Appendix J - Teacher Perceptions Survey

Teacher Perceptions Survey

Thank you for participation in this project and taking the time to complete this survey. Your thoughts and feedback are a critical component to the project. The following survey should take about 15 minutes to complete and your answers and anonymity will be protected.

Workshop

1. Did the workshop prepare you to implement the GIS-climate module?
 - Yes
 - No

2. Did the workshop enhance your ability to teach climate and climate change content?
 - Yes
 - No

3. Did the workshop prepare you to teach with GIS?
 - Yes
 - No

4. Do you consider your workshop experience to be positive?
 - Yes
 - If yes, please explain: _____
 - No
 - If no, please explain: _____

5. Was your follow-up support positive?
 - Yes
 - If yes, please explain: _____
 - No
 - If no, please explain: _____

GIS

6. Do you plan to continue to use of GIS in your classroom in the future?

- Yes
- No
 - If no, please explain: _____

7. Do you plan to expand your use of GIS in your classroom in the future?

- Yes
- No

8. Did you find the use of GIS to be helpful for teaching the climate change content?

- Yes
- No

9. Do you plan to use GIS to teach climate change again?

- Yes
- No
 - If no, please explain: _____

10. Please share any challenges to using GIS in the classroom:

11. Please share your successes while using GIS in the classroom (e.g. student engagement, student learning, ease of teaching, etc.):

GIS-Climate Module

Please rate the classroom usability of each module activity based on your expert knowledge and classroom implementation by selecting the appropriate box:

12. Did you use Activity 1: Understanding Climate and Weather?

a. If so, please rate the following:

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Teaches the content successfully					
Easy to use					
Receives positive student response					
I would use this activity again in the future					

13. Did you use Activity 2: Identification of Climate Patterns?

a. If so, please rate the following:

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Teaches the content successfully					
Easy to use					
Receives positive student response					
I would use this activity					

again in the future					
---------------------	--	--	--	--	--

14. Did you use Activity 3: Examination of Global Climate Change>

a. If so, please rate the following:

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Teaches the content successfully					
Easy to use					
Receives positive student response					
I would use this activity again in the future					

15. Did you use Activity 4: Climate Change in Kansas and the Great Plains?

a. If so, please rate the following:

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Teaches the content successfully					
Easy to use					
Receives positive student response					
I would use this activity again in the future					

Activity 5: Local Inquiry Activity

16. Please use the following scale of difficult to easy to rate the creation and implementation of the locally relevant inquiry activity:

	Very Difficult	Difficult	Undecided	Easy	Very Easy
Creation					
Implementation					

17. Did you find the use of local data to be motivating in teaching the content?

- Yes
- No
 - If no, please explain: _____

18. Did you find the use of inquiry to be engaging and illustrating in teaching the content?

- Yes
- No
 - If no, please explain: _____

Climate Change Content

19. Do you plan to continue teaching about climate change in your classroom in the future?

- Yes
- No

20. Would you use this specific pedagogical mix (GIS-local data-inquiry) to teach climate change again?

- Yes
- No
 - If no, please explain: _____

21. Please share any challenges to teaching climate change content:

22. Please share your successes to teaching climate change content:

Other

23. Is there anything else about this project and/or your participation that you would like to share?

Appendix K - Teacher Semi-Structured Protocol

Teacher Semi-Structured Interview Protocol

I have scheduled a series of interviews as part of the overall evaluation of my dissertation research. Given that you attended the summer workshop and implemented the GIS-climate module in your classroom, your insights and perspectives are vital in documenting the successes, challenges, and outcomes of this research.

The primary purpose of this interview is to collect your feedback and experiences through participation in this research. Your responses will be kept in the strictest confidence. You will not be identified by name on any reports. However, some of your responses may be included in the final dissertation and used in professional presentations or journal articles.

Your participation in this interview is voluntary. You may withdraw at any time or you may elect to refrain from responding to any question. The following questions will be used to guide the discussion. Thank you for your time and all your hard work!

Question 1: In three words, please share your overall thoughts about this project.

Question 2: Tell me about your post-workshop experience.

- What were the most beneficial parts?
- What aspects were difficult and/or needed improvement?
- What did you find you needed after the fact?

Question 3: What challenges did you face using GIS in your classroom?

Question 4: What great moments did you have in teaching with GIS?

Question 5: Overall, how would you characterize your students' response to the use of GIS?

Question 6: Would you use GIS again?

- How do you plan to use it?
- Why wouldn't you use it again?

Question 7: In general, how did your students respond to the climate change content?

Question 8: Did you find the use of local data to be helpful? Why or why not?

Question 9: Tell me about the activity you created (Activity 5). How did the process go?

- How did you come up with the idea?
- How did the activity fit into your existing curriculum?
- Describe the classroom implementation from your perspective.
- Describe how your students responded to the classroom implementation.
- Is it an activity you will use again?

Question 10: Is there anything else you would like to share that we have not covered in this discussion?

Appendix L - Classroom Observational Protocol

Classroom Observational Protocol

(Modified Reformed Teaching Observation Protocol (RTOP))

- I. Background Information
 - a. Name of teacher -
 - b. Location of class (district, school, room) -
 - c. Subject observed -
 - d. Grade level -
 - e. Date of observation –
 - f. Start time –
 - g. End time –

- II. Contextual Background and Activities (In the space provided below please give a brief description of the lesson observed, the classroom setting in which the lesson took place (space, seating arrangements, etc.), and any relevant details about the students (number, gender) and teacher that you think are important. Use diagrams if they seem appropriate.)

- III. Record here events that may help in documenting the ratings.

Time	Description of Events

--	--

IV. Lesson Design and Implementation

		0 Never Occurred	1	2	3	4 Very Descriptive	Non- Applicable
1	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.						
2	The lesson was designed to engage students as members of a learning community.						
3	In this lesson, student exploration preceded formal presentation.						
4	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.						

V. Content

		0 Never Occurred	1	2	3	4 Very Descriptive	Non- Applicable
1	The lesson involved fundamental concepts of the subject.						
2	The lesson promoted strongly coherent conceptual understanding.						
3	The teacher had a solid grasp of the subject matter content inherent in the lesson.						
4	Connections with real world phenomena were explored and valued.						
5	Students used GIS to represent phenomena.						
6	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.						
7	Students were reflective about their learning.						

VI. Communicative Interactions

		0 Never Occurred	1	2	3	4 Very Descriptive	Non- Applicable
1	Students were involved in the						

	communication of their ideas to others using a variety of means and media.						
2	The teacher's questions triggered divergent modes of thinking.						
3	There was a climate of respect for what others had to say.						
4	Active participation of students was encouraged and valued.						
5	Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.						
6	The teacher acted as a resource person, working to support and enhance student investigations.						

VII. Final Notes, Thoughts, and Observations

Appendix M - Rubric for Analysis of Inquiry Activities

Rubric for Analysis of Inquiry Activities

Rubric for Analysis of Inquiry Activities			
	Beginning	Developed	Accomplished
Aligned with GIS-Climate Module	Alignment is not clear or vaguely identified in this activity.	Alignment is evident but not clearly addressed in the activity.	Alignment is evident and clearly addressed in the activity.
Use of 5E Model	Some of the 5E Model components are used.	Most of the 5E Model components are used.	The complete 5E Model is used.
Type and Use of Local Data	One type and small set of data was used.	Two to three data sources of any size were used and compared with other data.	Two to three data sources of any size were used and compared with other data that the students also identified to be used.
Use of GIS	The GIS is used for referencing content.	The GIS is used for referencing and manipulating data.	The GIS is used for reference, manipulating, and analyzing data.
Question Posed	The question was very specific and leads to one right answer.	The question was specific but allowed for student exploration of several possible answers.	The question was specific but allowed for student exploration and interpretation of multiple possible answers.
Student Investigation	Students led the	Students led the	Students led the

	investigation with a lot to some help from the teacher.	investigation with some to little help from the teacher.	investigation with little to no help from the teacher.
Student/Class Sharing/Reporting	Students informally shared or presented their findings.	Students presented formal presentations of findings.	Students presented formal presentations of findings followed by in-discussions with peer feedback.

What was the guiding question?

What local issue was focused on?

What climate change content was emphasized?

How was the GIS used?

Appendix N - Instrumentation External Review Sheet

Thank you for agreeing to review the instrumentation for the ‘Making Climate Change Locally Relevant’ project.

The data to be gathered from these instruments are from the classroom implementation of the GIS-Climate module in Fall 2015. This module seeks to introduce students to important climate change concepts, focusing on building content knowledge from understanding climate, to examining global climate change, and finally studying local examples. The research questions being explored are:

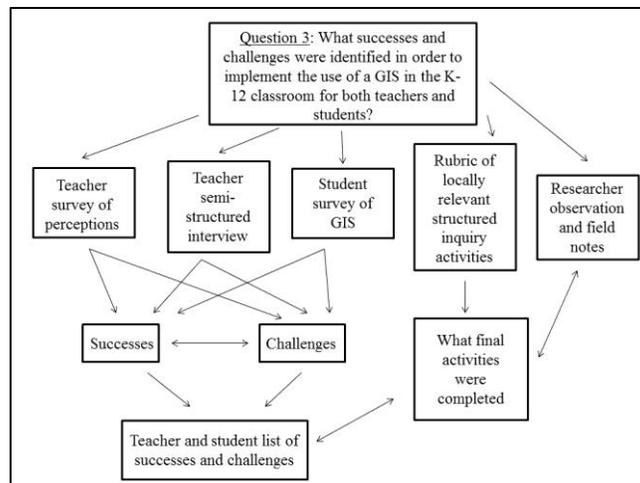
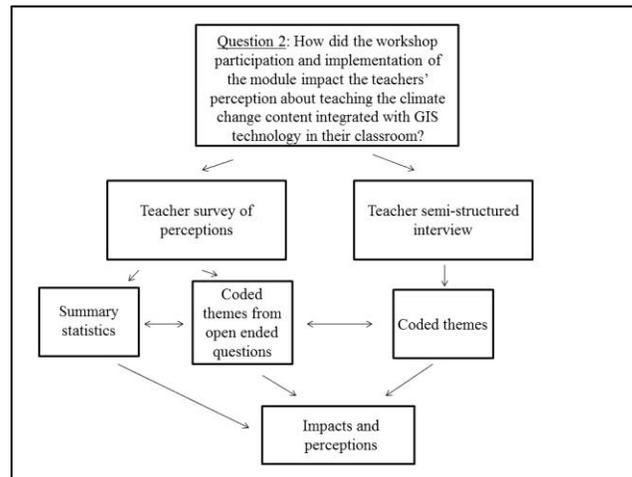
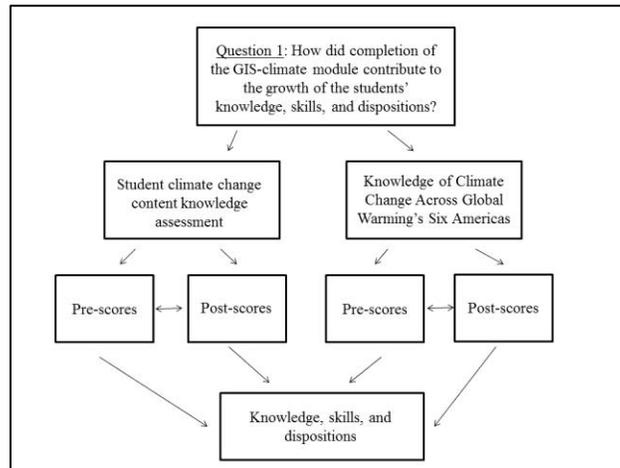
1. Did completion of the climate change module contribute to the growth of the students’ knowledge, skills, and dispositions about climate change?
2. How did the workshop participation and implementation of the module impact the teachers’ perception about teaching the climate change content integrated with GIS technology within their classroom?
3. What successes and challenges were identified in order to implement the use of a GIS in the K-12 classroom for both teachers and students?

The figures below show how the data gathered with the instruments and from the different sources will be synthesized in answering the research questions.

Please review the six instruments (1-Student Knowledge Assessment, 2-Student GIS Survey, 3-Teacher Perception Survey, 4-Teacher Semi-Structured Interview Protocol, 5-Inquiry Activity Rubric, and 6-Observation Protocol) for accurate content, general consistency and readily identifiable interconnections between instruments, and classroom usability in middle and high school science classrooms. Teachers will be using this module as part of a climate change unit in the following classes: general science, earth science, agricultural science, biology, and environmental science.

The instrumentation is in the attached files. Please use the following form to provide feedback. It consists of four sections: content, cohesion, usability, and overall review. If you would like to complete the review electronically, please select your response by highlighting or bolding it, otherwise print and complete. If you have any questions or concerns during the process, please contact me, Lisa Tabor, by email at lkt7779@ksu.edu or by phone at (785) 565-8580. Once completed, send your review to me by email at lkt7779@ksu.edu or by mail at Lisa Tabor, Center for Science Education, Kansas State University, 364 Bluemont Hall, Manhattan KS 66503.

Connecting the research questions and instrumentation for data analysis



Content: Student Knowledge Assessment Only

1. Is the climate content accurate on the student knowledge assessment?
 - a. Yes
 - b. No
 - i. If no, please identify the errors.

2. Does the student knowledge assessment align with the Essential Principles of Climate Literacy (http://oceanservice.noaa.gov/education/literacy/climate_literacy.pdf)?
 - a. Yes
 - b. No
 - i. If no, please identify which principle(s) are not being addressed.

Cohesion

3. Is there general consistency and readily identifiable interconnections between instruments between instruments?
 - a. Yes
 - b. No
 - i. If no, please explain what and where lacks cohesion.

4. Do you think the data gathered with these instruments will answer the research questions as planned?
 - c. Yes
 - d. No
 - i. If no, please explain why not and/or identify where any issues are.

Usability

5. Are the student instruments appropriate for use with middle school and high school students?
 - a. Yes
 - b. No
 - i. If no, please explain what seems inappropriate or not feasible

6. Do you think the student instruments would be easiest to use in the classroom if they were computerized or on paper?
 - a. Computerized online survey
 - i. If so, please explain why.
 - b. Paper survey

- i. If so, please explain why.
7. Do the time estimations on the instruments seem reasonable?
- a. Yes
 - b. No
 - i. If no, please explain which instrument seems to have an inaccurate time estimate.

Instrument Specific Review

To answer the following questions there is no format. I would like your thoughts about each instrument. Please share with me the good and the bad (e.g. thoughts about content, specific formatting or sequence questions, strengths, weaknesses, things that may seem like they are missing, concerns, confusions, any needed revisions, general thoughts, or a simple “ready to go”).

- 8. Please share your overall review of the Student Knowledge Assessment
- 9. Please share your overall review of the Student GIS Survey.
- 10. Please share your overall review of the Teacher Perception Survey.
- 11. Please share your overall review of the Teacher Semi-Structured Interview Protocol.
- 12. Please share your overall review of the Inquiry Activity Rubric.
- 13. Please share your overall review of the Observation Protocol.

Appendix O - Student Dispositions Response Data

Table 38 - Student Dispositions Response Data Pre and Post

Student Response Data by Question from <i>Knowledge across Global Warming's Six Americas</i>					
Question	Response Options	Pre		Post	
		Total	%	Total	%
Do you think that global warming is happening? (Pre N=488; Post N=402)	Yes	345	70.7%	296	73.6%
	No	46	9.4%	39	9.7%
	I don't know	97	19.9%	67	16.7%
How sure are you that global warming is happening? (Pre N=488; Post N=402)	Extremely sure	72	14.8%	103	25.6%
	Very sure	110	22.5%	99	24.6%
	Somewhat sure	167	34.2%	107	26.6%
	Not at all sure	70	14.3%	44	10.9%
	I don't know	69	14.1%	49	48.0%
How sure are you that global warming isn't happening? (Pre N=488; Post N=402)	Extremely sure	26	5.3%	30	7.5%
	Very sure	32	6.6%	30	6.1%
	Somewhat sure	87	17.8%	67	16.7%
	Not at all sure	198	40.6%	170	42.3%
	Don't know	145	29.7%	105	26.0%
Assuming global warming is happening, do you think it is... (Pre N=516; Post N=402)	Caused mostly by human activities	228	44.2%	227	56.5%
	Caused mostly by natural changes in the environment	142	27.5%	108	26.9%
	Other	48	9.3%	34	8.5%
	None of the above because global warming isn't happening	98	19.0%	33	8.2%
How worried are you about global warming? (Pre N=488; Post N=402)	Very worried	74	15.2%	66	16.4%
	Somewhat worried	184	37.7%	157	39.1%
	Not very worried	147	30.1%	113	28.1%
	Not at all worried	83	17.0%	66	16.4%

How much do you think global warming will harm you personally? (Pre N=488; Post N=402)	Not at all	77	15.8%	68	16.9%
	Only a little	104	21.3%	90	22.4%
	A moderate amount	130	26.6%	129	32.1%
	A great deal	63	12.9%	55	13.7%
	Don't know	114	23.4%	60	14.9%
When do you think global warming will start to harm people in the United States? (Pre N=488; Post N=402)	They are being harmed now	83	17.0%	68	16.9%
	In 10 years	90	18.4%	58	14.4%
	In 25 years	84	17.2%	84	20.9%
	In 50 years	84	17.2%	75	18.7%
	In 75 years	75	15.4%	65	16.2%
	Never	72	14.8%	52	12.9%
How much do you think global warming will harm future generations of people? (Pre N=488; Post N=402)	Not at all	29	5.1%	29	7.2%
	Only a little	54	11.1%	48	11.9%
	A moderate amount	138	28.3%	124	30.8%
	A great deal	169	34.6%	152	37.8%
	Don't know	98	20.1%	49	12.2%
How much had you thought about global warming before today? (Pre N=488; Post N=402)	A lot	159	32.6%	107	26.6%
	Some	164	33.6%	141	35.1%
	A little	135	27.7%	118	29.4%
	Not at all	30	6.1%	36	8.9%
How important is the issue of global warming to you personally? (Pre N=488; Post N=402)	Not at all important	86	17.6%	66	16.4%
	Not too important	146	29.9%	96	23.9%
	Somewhat important	175	35.9%	151	37.6%
	Very important	55	11.3%	65	16.2%
	Extremely important	26	5.3%	24	6.0%
How much do you agree or disagree with the following statement: "I could easily change my mind about global warming." (Pre N=488; Post N=402)	Strongly agree	55	11.3%	39	9.7%
	Somewhat agree	209	42.8%	161	40.0%
	Somewhat disagree	144	30.0%	126	31.3%
	Strongly disagree	80	16.4%	76	19.0%

How many of your friends share your views on global warming? (Pre N=483; Post N=402)	None	206	42.7%	135	33.6%
	A few	132	27.3%	109	27.1%
	Some	78	16.1%	97	24.1%
	Most	52	10.8%	42	10.4%
	All	15	3.1%	19	4.7%
Which of the following statements comes closest to your view? (Pre N=488; Post N=402)	Global warming isn't happening	59	12.1%	49	12.2%
	Humans can't reduce global warming, even if it is happening	80	16.4%	55	13.7%
	Humans could reduce global warming, but people aren't willing to change their behavior so we're not going to	199	40.8%	180	44.8%
	Humans could reduce global warming, but it's unclear at this point whether we will do what's needed	130	26.6%	105	26.1%
	Humans can reduce global warming, and we are going to do so successfully	20	4.1%	13	2.7%
Do you think citizens themselves should be doing more or less to address global warming? (Pre N=402; Post N=397)	Much less	24	6.0%	284	71.5%
	Less	49	12.2%	23	5.8%
	Currently doing the right amount	92	22.9%	59	14.9%
	More	152	37.8%	24	6.0%
	Much more	85	21.1%	7	1.8%
Over the past 12 months, how many times have you punished companies that are opposing steps to reduce global warming by NOT buying their products? (Pre N=488; Post N=402)	Never	284	58.2%	208	51.7%
	Once	23	4.7%	40	10.0%
	A few times (2-3 times)	59	12.1%	54	13.4%
	Several times (4-5 times)	24	5.0%	29	7.2%
	Many times (6+)	7	1.4%	8	2.0%
	Don't know	91	18.6%	63	15.7%
Do you think global warming should be a low, medium, high, or very high priority for the President and Congress? (Pre N=488; Post	Low	106	21.7%	77	19.2%
	Medium	210	43.0%	165	41.0%
	High	111	22.7%	98	24.4%
	Very high	61	12.6%	62	15.4%

N=402)					
People disagree whether the United States should reduce greenhouse gas emissions on its own, or make reductions only if other countries do too. Which of the following statements comes closest to your own point of view? The United States should reduce its greenhouse gas emissions... (Pre N=488; Post N=402)	Regardless of what other countries do	215	44.1%	183	45.5%
	Only if other industrialized countries (such as England, Germany and Japan) reduce their emissions	38	7.8%	40	9.9%
	Only if other industrialized countries and developing countries (such as China, India and Brazil) reduce their emissions	56	11.5%	55	13.7%
	The US should not reduce its emissions	20	4.0%	24	6.0%
	Don't know	159	32.6%	100	24.9%

Appendix P - Teacher Ratings of GIS-Climate Module Activities

Table 39 - Teacher Rating of Activity One

Teacher Ratings of Activity 1: Understanding Climate and Weather (N=11)							
Question	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Mean	SD
Teaches the content successfully	0	0	1	8	2	4.1	0.5
Easy to use	0	1	1	5	4	4.1	0.9
Receives positive student response	0	1	3	5	2	3.7	0.9
I would use this activity again in the future	0	1	0	5	5	4.3	0.9
Average Overall Rating for Activity 1						4.1	

Table 40 - Teacher Rating of Activity Two

Teacher Ratings of Activity 2: Identification of Climate Patterns (N=7)							
Question	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Mean	SD
Teaches the content successfully	0	0	1	4	2	4.1	0.7
Easy to use	0	0	3	2	2	3.8	0.9
Receives positive student response	0	1	2	2	2	3.7	1.1
I would use this activity again in the future	0	1	0	3	3	4.1	1.1
Average Overall Rating for Activity 2						4.0	

Table 41 - Teacher Rating of Activity Three

Teacher Ratings of Activity 3: Examination of Global Change (N=6)							
Question	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Mean	SD
Teaches the content successfully	0	0	2	3	1	3.8	0.6
Easy to use	0	1	2	2	1	3.5	1.1
Receives positive student response	0	2	1	2	1	3.3	1.2
I would use this activity again in the future	0	1	1	3	1	3.7	1.0
Average Overall Rating for Activity 3						3.6	

Table 42 - Teacher Rating of Activity Four

Teacher Ratings of Activity 4: Climate Change in Kansas and the Great Plains (N=5)							
Question	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Mean	SD
Teaches the content successfully	0	0	1	2	2	4.2	0.8
Easy to use	0	1	2	0	2	3.6	1.3
Receives positive student response	0	1	2	1	1	3.4	1.1
I would use this activity again in the future	0	0	3	1	1	3.6	0.9
Average Overall Rating for Activity 4						3.7	

Appendix Q - Activity Five Lesson Compilation by Teacher

Teacher C

Making Climate Change Local

Standards: Science

MS-ESS3-2.	Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects
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Social Studies: Physical Geography: Physical Features

Students should be able to analyze the characteristics of physical geography and apply this analysis to their world. Climate factors of weather and climate, major climate zones, climate change within regions, plant and animal life

Activity Overview:

Students will analyze tree rings and relate the information to past weather patterns. Students will also conduct first person interviews of senior citizens to gather information about past weather conditions in that person's childhood.

Materials:

GPS

Camera

Tree Corer

Permission Forms from Landowners

Paper Straws for each Sample-Storage

Collection Bags for Core Samples

Collection Bags for Leaves

Phone Books to Press Leaves

Permanent Markers for Labeling

Sandpaper-60, 220, 400 grit

Glue

Dissecting Scopes

Access to past weather data for Lyon County Kansas

Objectives:

After completing this activity, a student will be able to do the following:

- *Learn how scientists gather information about the Earth's past weather and climate.
- *Learn that tree ring patterns can be used to study weather and climate in the past.
- *Learn how to locate, assess, and compare different types of data.
- *Use the data to help understand what climate was like in a particular location in the past.

Day 1-3: Student Tasks

Engagement:

Discuss why it is important to know about Earth's past climate.

What ways do you know of that scientists collect data about Earth's past climate.

Introduce dendrochronology, the study of tree rings.

<http://www.nps.gov/webrangers/activities/dendrochronology/?id=04>

Review how trees grow.

Electronic copy of "Can You Read a

Tree?" <http://bookbuilder.cast.org/view.php?op=view&book=47834&page=1>

Interactive website for tree rings.

http://www.classzone.com/books/earth_science/terc/content/investigations/es2905/es2905page01.cfm?chapter_no=29

Exploration:

Working in pairs students will use the sample tree cross sections to find the age of the tree.

Discussion points:

Count the dark and light rings. Each set of light and dark is in ring.

Width of rings indicates the quality of growing conditions during the season. Narrower rings indicate stress. What conditions might cause stress in a plant?

2. Count rings to determine the age of the tree starting at the outside and working into the center.

Outermost dark green layer represents late season wood, light layers just inside spring growth.

To determine the age, subtract number of dark rings from year tree was cut or bored.

(Suggestion: start at the outside and count back by years. ie-2015, 2014, 2014, etc.

3. Students will use metric rulers to measure the width of tree rings.

4. Students will describe and share differences and similarities between the rings on the tree.

Explanation:

Variation in year to year growth in based on sensitivity.

Definition of a tree ring.

Elaboration:

Students will share findings.

Evaluation:

A class discussion will be held to summarize conclusions the students reached discussing patterns and possible causes. Review engagement questions-Why is it important to know about Earth's past climate? How do trees fit into ways that scientists collect information about Earth's past climate? Compare tree rings to ice and sediment cores. Looking at pollen tells about the environment.-Uniformitarianism.

Day 4-10: Student Tasks

Engagement: (Due to the fact that samples have to be dried, I may complete this during the summer.) (Find person at ESU or Arborists to demonstrate the sampling for the students.)

Students will use a GPS to record the location of each tree that is sampled.

Students will take pictures of each tree sampled.

Students will collect leaf samples for identification.

Students will measure and record the circumference of the tree.

Twelve to 15 core samples will be collected on several different varieties within the same area.

(Oak, Ash, Walnut, Elm)

Exploration:

Students will create an Excel csv comma delimited file for each sample and upload into Americus Community ArcGIS map.

Pictures will be uploaded into a file and shared.

Pictures for each tree location will also be uploaded to the map.

Students will begin collecting core sample data on a specific genus.

Select one ring that seems to reflect below-average precipitation for the growing season based on width.

Determine corresponding year by counting the rings starting with the outside ring.

Repeat with one ring that seems to reflect above-average precipitation.

Use weather data to record information for the ring selected.

Identify tree genus for core samples.

Research information about the genus of the tree selected.

Add information to ArcGIS map about genus of tree.

Explanation:

Students will apply prior knowledge to substantiate claims about the weather during the time frame for the trees. Students will interview a senior citizen to find out about weather during their lifetime. They will compare their tree rings to the interview persons stories.

Students will explain whether dry years are increasing in frequency. How many years are marked as dry.

Create a skeletal plot of the information. Compare to the tree rings.

Elaboration:

Students will look at five rings before and after the below and above average precipitation to explain what the climate was like during the 10 year period. This information will be used to describe the history of the tree.

Evaluation:

The final product will be the presentation.

Works Cited

Agency, United States Environmental Protection. Tree Rings: Living Records of Climate. n.d.
<http://epa.gov/climatechange/kids/documents/tree-rings.pdf>. 18 June 2015.

McDougal Littell.

http://www.classzone.com/books/earth_science/terc/content/investigations/es2905/es2905page01.cfm?chapter_no=29

National Park Service.

<http://www.nps.gov/webrangers/activities/dendrochronology/?id=04>

Ohio State University.

<http://beyondweather.ehe.osu.edu/issue/earths-climate-changes/can-you-read-a-tree>
Yale Forestry School. Tree Ring Collecting and Analysis Methods. 1999.
<http://www.yale.edu/fes519b/saltonstall/trmethods.htm>. 18 June 2015.

Tree Rings Climate Records

Name _____

Partner's Name _____

Tree Ring Analysis

1. Core Location _____

Latitude

Longitude

2. Type of tree _____

3. Number of Dark Rings _____

4. Age of Tree (show math work) _____

5. Graph skeletal plot vs. precipitation. Graph skeletal plot vs. temperature.

6. Create a graph of precipitation for each year for your tree.

7. Compare the tree graph to the precipitation graph. List similarities and differences.

8. Ring selected for below-average precipitation _____

Age of Tree _____

b. Precipitation Record for that year _____

- c. Temperature Record for that year _____
- d. Did a local person mention it? _____

9. Ring selected for above-average precipitation _____

Age of Tree _____

- b. Precipitation Record for that year _____
- c. Temperature Record for that year _____
- d. Did a local person mention it? _____

10. Write a paragraph based on the rings you selected for questions 8 and 9. Be sure to discuss how weather affected your tree for that specific time period. What was happening outside of these extreme years?

11. Compare your tree core to another group's data. How were the the cores similar? How were the cores different? Did you have the same species of tree? Were your trees the same age?

12. What factors other than precipitation might affect the growth of a tree? Create an age vs. diameter of tree ring graph.

13. Research Information

Scientific Name of Tree _____

Common Name of Tree _____

Description of Tree (Height/Trunk Size/Crown Distance) _____

Leaf Description _____

Life Span _____

Habitat _____

Fruit/Seed _____

Uses _____

Pests _____

14. Make an ArcGIS map of an Excel csv comma delimited file for each sample and upload into Americas Community ArcGIS map.

15. Upload pictures for each tree location to your map under notes.

16. Add scientific name and common name to each tree note.

17. Make a Story Map or presentation in ArcGIS.

18. Extension: Find the tree ring that corresponds to the year you were born. Based upon the tree ring, describe the weather for that year. Check the weather data. How accurate were you?

Works Cited

Agency, United States Environmental Protection. Tree Rings: Living Records of Climate. n.d. <http://epa.gov/climatechange/kids/documents/tree-rings.pdf>. 18 June 2015.

Yale Forestry School. Tree Ring Collecting and Analysis Methods. 1999. <http://www.yale.edu/fes519b/saltonstall/trmethods.htm>. 18 June 2015.

Teachers D and E

Name _____ Hour _____

You will be working with a partner on this assignment.

Introduction: Aquifers are an important source of water in Western Kansas. However, with the increase in human populations and the corresponding increase in agriculture we are seeing a dramatic reduction in the amount of water available in aquifers around the world. In addition to the effects of agriculture we are also seeing a worldwide shift in climate regions. These shifts are attributed to climate change. In this unit we will learn about the Ogallala aquifer and its importance in Kansas agriculture, the effect of agriculture on the depth of the aquifer and the

importance of climate change on climate regions. We will be using on-line reading materials as well as ArcGIS (a geographic information system program).

Begin by opening the following website to learn more about aquifers.

<http://plainshumanities.unl.edu/encyclopedia/doc/egp.wat.018>

Describe the structure of an Aquifer:

Describe the Ogallala Aquifer:

Why is it so important to have underground sources of water?

Open the following website, the USGS site for water management in the High Plains

<http://ne.water.usgs.gov/ogw/hpwlms/physsett.html>

The Ogallala Aquifer is critical to life in Western Kansas, but is located under other states as well. How big is the aquifer and what other states rely on the water stored there?

Interpret the information in Figure 2. What is the range of annual precipitation in Western Kansas between 1980 and 1997?

Farming has been an important industry in the plains since the 1800's. How has water use changed from the 1800's until today?

Look at graph 1, the amount of irrigated acres in the plains. Farmers irrigate (water) areas of their land that do not receive enough rainfall to grow their crops. Click on the graph to enlarge it so that you can see the values. How many acres of land were irrigated in Kansas in 1949?

Describe the trend in irrigation in Kansas between 1949 and 2002.

Look at the data from other states. Which state showed the greatest change? (explain)

Which state showed the least change over the same time period? (explain)

Why do you think we could have such differences between states?

Enlarge the image for graph 2 so that you can read the values. What is the data used for this graph (and what are the units)?

Compare the values in this graph to those of graph #1. Explain how these two graphs are related.

Human populations in the plains region have increased since the 1900 from 0.9 to 2.3 million people. Where do the majority of people live and how might that impact the Ogallala Aquifer?

Of the land associated with the Ogallala Aquifer, 40.9% is agricultural. How much of that irrigates using water from the aquifer?

For this activity we will be using ArcGIS. This is a powerful tool that allows you to overlay information onto maps. We will be targeting the assignment on the plains region of the United States, relating to the Ogallala Aquifer.

Follow this link, it will open a map. Remember the tools we used in the activities when we learned about ArcGIS. (you may want to review your notes)

<http://arcg.is/1MS6t6C>

To begin with only the following layers should be clicked on: Kansas Counties, World Boundaries and Sat. Thickness (thickness of the aquifer).

Click on the bookmark for the United States. Bring up the legend for the thickness (in feet) of the aquifer.

Where is the aquifer the deepest (over 700 feet deep). _____

What is the range of depths in the state of Kansas? (Use the bookmark for Kansas or zoom in).

Use the bookmark for Garden City. Here you can easily see the gradation of depths. The deepest part seems to be south of Garden City. How deep is this? _____

Zoom out to view all of Kansas. Where else in the state do we see the same depths recorded?

Now click on the layer which shows Aquifer Change between 2000 and 2009. This shows how much the depth has changed (measured in meters). Where, and how much, is the greatest change in Kansas as shown on the map? _____

explain the relationship between change of depth to the recorded depth (see answers for 19 and 20).

Turn off the layer for 'aquifer change' and click on the layer for 'useable lifetime'. This layer represents how long we can get water from the areas of the aquifer. Zoom in on Gray County (East of Garden City). Describe the predictions for Gray County.

Turn on the layer for the Koppen -Geiger climate regions. Adjust the transparency so that you can see the aquifer data below the climate regions. How does the location of the aquifer relate to the climate regions (what regions are over the aquifer and what regions aren't) during the time period 1900-1920?

Make sure to have observed and scenario B2 checked for the Koppen-Geiger predictions. Describe what happened to the climate regions between 1980 and 2000. Give a reasonable explanation as to why that might have happened.

Now toggle through from 2020 to 2100. Describe what is happening to the climate regions in the western half of the state.

Give a reasonable explanation relating the predicted level of the Ogallala to the climate regions in the year 2100.

Finally, click on the temperature and precipitation predictions. Look at western Kansas and describe what is predicted to happen in this region in 2050.

With this additional information, give a reasonable explanation as to the depletion of water in the Ogallala Aquifer. (tie human actions to predicted climate change)

Follow up (Elaboration):

Read the article: <http://www.washingtonpost.com/blogs/wonkblog/wp/2013/09/12/how-long-before-the-midwest-runs-out-of-water/>

The article quotes sources as saying that the aquifer is losing 2 feet of water per year in some counties. Does this agree or disagree with the data from our arcGIS activity? (explain)

List some of the ways that farmers have been changing their practices in an effort to conserve the aquifer.

The problem, however, isn't isolated to aquifers in the United States. Read the following article it describes the results of a study, published by researchers at McGill and Utrecht University in the Netherlands, in the science journal Nature. Read through the article and be sure to examine the map. There is a lot of information on the map, but the key to understanding the map is that the blue areas get more rain than is being used while the red doesn't get enough to make up for human use.

<http://www.washingtonpost.com/blogs/wonkblog/wp/2012/08/10/where-the-worlds-running-out-of-water-in-one-map/>

Are all the aquifers in the world drying up? Explain your answer using the information from the map and use specific examples.

Although we have multiple aquifers in the United States, what percentage of U.S. irrigated farmland depends upon the Ogallala. _____

Personal opinion, to be written on another piece of paper and attached. You have read a lot of information over the past few days, and interpreted a lot of data from different sources. Now it is time for you to put it together. Predict what will happen in the next 100 years, relate your prediction to the data presented as well as what you think will happen with human populations and human behavior around the world. Must be 50 words or more, and include specific examples and predictions. (8 points)

Teachers F and G

Name: _____

Block: _____

Evolution of Skin Color

Research Questions:

Do only light skinned people get skin cancer?

What are the causes of skin cancer?

Why are light skinned populations more at risk of skin cancer than other populations?

At what age does skin cancer typically occur? Is the incidence of skin cancer greater in youth or old age?

The story map for this investigation can be viewed from the following website:

<http://arcg.is/1esHADX>

1 World UV Index

Does the amount of UV light reaching the Earth vary in a predictable manner? If so, describe the pattern you observe.

What latitude receives the greatest amount of UV light? The least?

2 Melanin: Natural Sunscreen

Based on these data, where might you expect to find the most lightly pigmented and most darkly pigmented people on the planet? Be as specific as you can.

Provide a rationale to your answer above (i.e., why did you think that more darkly pigmented people would be concentrated at a given location?)

3 Skin Tone and UV Reflectance

Consider the graph from this section:

Is skin reflectance related to the amount of melanin produced by the given skin type?

Is skin reflectance randomly distributed throughout the globe? If not, how would you describe the pattern?

Does it appear that the amount of melanin in the skin is related to the UV index of the given area?

How closely do these findings match your original prediction?

Based on the trends you have observed, what factor appears to determine skin color of a population?

Think It Through:

Based on the information provided so far, it seems reasonable to hypothesize that darker skin evolved to protect against the harmful effects of UV light. In particular, individuals who lacked optimal pigmentation for tropical latitudes had a greater risk of skin cancer and death. Until fairly recently, this was the leading hypothesis about the evolution of skin color. However, there is a problem with this hypothesis.

Evolution is a change in the gene pool of a population of organisms from generation to generation. Natural selection is one of several mechanisms by which evolution can take place. Through natural selection, populations evolve and become adapted to their specific environment. Natural selection will occur if the following three conditions are present:

Variation: The organisms in the population vary with regard to a trait.

Heredity: Variation in the trait has a genetic component transmissible to offspring.

Selective Pressure & Differential Reproductive Success: Some traits increase the odds of surviving to reproductive age and successfully producing and rearing offspring in a given environment.

Some traits are more adaptive. Those organisms having the better adapted trait leave more offspring behind—they are “naturally selected.” In the next generation, this adaptive (and inherited) trait will increase in frequency and will be represented in a greater proportion of the population. At this point, the genetic makeup of the population is different from that of the starting population: the population has evolved. Evolution is really a “number’s game”: the organisms that reproduce the most “win” because their traits will be disproportionately represented in the next generation. Note also that individuals do not evolve. They either breed more effectively or less effectively, depending on already existing differences in their traits. Only populations evolve or change over time.

Review your answer to Research Question 3. Keeping your answer in mind, how strong a selective pressure do you expect skin cancer (UV-induced mutations) to exert on reproductive success?

Based on this information, does it seem likely that skin cancer is the selective pressure responsible?

How does skin color fail to meet the three requirements of natural selection outlined above?

3 UV Light and Folate

Does folate appear to be linked to natural selection?

All other things being equal, which skin tone would you expect to be correlated with higher levels of folate?

Based on this new information, what would happen to the reproductive success of a:

A light-skinned person living in the tropics?

A light-skinned person living in the polar region?

A dark-skinned person living in the tropics?

A dark-skinned person living in the polar region?

Predict the skin tones expected at different latitudes, taking folate needs into consideration. Use the world map (Figure 4) to indicate the skin tone expected at each latitude (shade the areas where populations are darkly pigmented).

4 Vitamin D Deficiency

Does vitamin D appear to be linked to natural selection?

Taking only vitamin D into consideration, what would happen to the reproductive success of a:

A light-skinned person living in the tropics?

A light-skinned person living in the polar region?

A dark-skinned person living in the tropics?

A dark-skinned person living in the polar region?

5 Climate Change and Changing UV Levels

What effect would depletion of the ozone layer have on the types and amounts of radiation reaching Earth's surface?

How would this change in radiation reaching Earth affect skin cancer rates?

6 Climate Change and Skin Cancer

How does climate change relate to increased UV radiation reaching the Earth?

If global temperatures are increasing, how might that affect rates of skin cancer?

Final Analysis:

Are UV light, vitamin D or folate needs sufficient individually to explain the current world distribution of skin color?

Consider your own skin tone. What would you need to survive and reproduce(food, vitamin supplements, clothing, sunscreen, etc.) in each of the following locations:

An equatorial region

A polar region

How might you explain that Inuits, living at northern latitudes, are relatively dark-skinned (much more so than expected for their latitude)?

How might you explain the fact that Northern Europeans are slightly lighter-skinned than expected for their latitude?

Teacher I

Activity 4: Impacts of Mining and Climate Change in Kansas and other states in the U.S.

Activity Overview

Students will:

Create a profile presentation of the element/mineral they were assigned to research using GIS

Identify and locate mining locations and engage in a locally relevant examination of projected climate change events and impacts in Kansas and other states in the U.S.

Learn how climate change impacts mining and adaptation in the mining sector due to climate change.

Materials

Internet access and device for connection (multiple websites visited)

Teacher instruction, student instructions with questions, and answer key

Objectives	Learner Assumptions
<p>After completing this activity, a student is able to do the following:</p> <p>Create a profile presentation of the element/mineral assigned to research.</p> <p>Identify and understand an example of climate change in Kansas and other states in U.S. related to mining.</p> <p>Engage in a locally relevant analysis and scientific communication about these projected events.</p>	<p>In order to complete this activity, students should already have the following:</p> <p>Atomic structure and properties of the element/mineral</p> <p>map reading skills,</p> <p>can describe weather, climate, climate classifications, climate controls, and explain a weather report and a climatology report,</p> <p>can describe past and present trends of the Earth's changing climate, and</p> <p>Use models to make predictions about climate change.</p>

Day 1: Student Tasks 1 and 2

Engagement

As the evaluation activity for Activity 3: Examination of Global Climate Change, students were asked to write a three-part summary statement of what they learned about 1) the Earth's changing climate, 2) using models to make predictions and understand climate change, and 3) predict what changes could occur in Kansas. To begin this activity, have students work briefly in groups to share their responses and then generate a class list of possible changes that they hypothesize could occur in Kansas.

Exploration

In the first task, students will be introduced on the outcome expectations on minimum information required in making a profile presentations of the element/ mineral they were assigned to research. The following websites will be helpful and recommended:

<http://www.ptable.com>

<http://www.destiny.com>

<http://www.easybib.com/cite/form/website> (citation website)

Then, students will be required to research on climate change impacts and adaptation in the mining sector and how mining also contributes or impacts to the climate change in Kansas and other states in the U.S. The article can be viewed from either of the following websites:
<http://www.greenpeace.org/international/en/campaigns/climate-change/coal/Mining-impacts/> and
<http://www.landlearnsw.org.au/sustainability/climate-change/minerals/impacts>
<http://www.dpi.nsw.gov.au/research/topics/climate-change/mining>

Follow-up reading materials to consider for use to build understanding of climate change impacts on mining in Kansas are:

Environmental Protection Agency climate change assessment of the Great Plains region
(<http://www.epa.gov/climatechange/impacts-adaptation/greatplains.html>)

Legislative document on assessing the economic cost of climate change in Kansas
(<http://cier.umd.edu/climateadaptation/Climate%20change--KANSAS.pdf>)

National Mining Association of United States: <http://www.nma.org>

Topeka Capitol Journal article on impacted labor productivity
(<http://cjonline.com/news/business/2014-07-05/kansas-less-impacted-climate-change-some-states>)

Explanation

With the news story in mind, student will review a web map and write four hypotheses.

Navigate to <http://arcg.is/1K1PvDu>. Take a few minutes to let your students become acquainted with the map and its features. In this activity, students will be working with five data layers: 1) world mineral deposits, 2) Koppen -Geiger Observed and Predicted Climate Shifts, 3) Alaska Gold Mining, 4) Coal Mines in Illinois and 5) USDOE EIA Top 100 Gassy Coal Mines in the U.S. The purpose of this map is for reference and to show climate change patterns and impacts on mining sector in the U.S. The map will show the past climate before mining and the current climate after mining and predicted future climate changes.

After becoming familiar with the web map, students will write four hypotheses about how they think U.S. mining production projections will impact them, the state, and the nation.

Day 2: Student Task 3

Elaboration

For this part of the activity, the students work in five groups to investigate key concepts from the 2014 National Climate Assessment (<http://nca2014.globalchange.gov/>). The National Climate Assessment “summarizes the impacts of climate change on the United States, now and in the future” and it is a collaborative research effort involving over 300 scientists. After introducing the website to the students, give the students about 10 minutes to explore highlights about the Great Plains region and become comfortable navigating the website. Then during the next 10 minutes, assign each group to use the graphic organizer provided to read and summarize one of the five key messages. Finally, take 15 minutes (3 minutes/group) and have each group report their findings.

Evaluation

Students will be present their profile presentation on the element/ mineral to the class using the smart board. Their presentation should include the use of Arc GIS online maps showing the location of the mining site and projected impacts on climate change over the region. It should also include discussions on how climate change impacts mining and adaptations of the mining sector of the state due to climate change effects.

When the class has finished the activity, lead a short discussion that summarizes the conclusions the students reached. Be sure to highlight patterns and relationships that they discovered. Close the activity by having the students re-visit the four hypotheses they wrote about how they think U.S. mining production projections will impact them, the state, and the nation. Instruct the students to revise or justify why they still agree or now disagree with each of their hypotheses.

Teacher J

Biomes Mapping Comparison

Name _____

Period _____

AcrGIS is a system of using interactive maps to compare information. You will log in to the following website and use the prepared map to answer the following questions about the biomes in both South east Kansas and the similar biome in Nigeria, Africa.

Web address: _____

Open map: Notice that several maps are opened on the left side of the screen. The maps can be turned off on by clicking (check-marking) the boxes to the left of the map name.

For the first exercise make sure that the only map marked in the Koppen-Geiger. This will allow you to see all of the biomes on the globe. You can zoom in and out with the function buttons in the left corner of the map. You can also click on the time line at the bottom of the map and set the map into motion.

Move to the top of the map and click on book marks. Go to Kansas.

What is the biome in SE Kansas? _____ (set the map in motion)

From bookmarks, click on Nigeria. What is the Biome? _____ (set the map in motion)

Now unmark the Koppen-Geiger map and mark the Annual Precipitation map. Use your book marks to record the annual precipitation levels for both locations.

SE Kansas _____ Nigeria _____

Now un-book mark the Annual Precipitation map and mark Change in Precipitation 2050 map

What are the predicted changes in precipitation for both of the book marked locations?

SE Kansas _____ Nigeria _____

Which location has the greatest change? _____ Why do you think this location had a greater change? Hint* local topography

According to you Koppen Is the change in precipitation enough to change the biome? _____

Compare your finding to the results of your plant growth lab. Is the total rainfall the only factor that effects how the Biome works? Explain.

function? _____

What other factors would influence the plant /animal life in the biome? _____

Based on this information what misconception could someone make about Global Climate change? _____

How would you correct the misconception? How would you explain the process to someone who did not believe that Climate change is an issue? _____

Teacher K

Activity: Kansas Climate Change Impact on Population

Activity Overview

Students will be able to identify and explain Kansas changing climate, use models to explain how precipitation relates to climate change, and use models make predictions about future climate change and its impact on population.

Materials

Internet access and device for connection (multiple websites visited)

Teacher instruction, student instructions with questions, and answer key

Objectives	Learner Assumptions
<p>After completing this activity, a student is able to do the following:</p> <ul style="list-style-type: none"> Identify and explain past and present trends of Kansas changing climate, Use models to explain how precipitation relates to climate change, and Use models to make predictions about climate change and its impact on population. 	<p>In order to complete this activity, students should already have the following:</p> <ul style="list-style-type: none"> map reading skills, graph reading skills, and can describe weather, climate, climate classifications, climate controls, and explain a weather report and a climatology report.

Day 1: Student Task 1

Engagement

Connect the students back to the last activity and the discussion of westward movement and where people settled based on suitable environment. Bridge that conversation into the question, “can climate impact the decision to live in a certain location?” Share with your students that

they are going to explore how Kansas climate is changing and what evidence of systems-based interactions there is to support this conclusion.

Exploration

In this task, students will be completing the Kansas Climate Change Impact on Population, accessible at the following website:

<http://www.arcgis.com/home/item.html?id=567e3c06f6554af9ab50adbc1dde531f>. This online activity walks students through recorded climate data for the past 100 years and encourages them to observe, analyze, and engage with the climate materials through interactive maps, graphs, and images. The task culminates with a discussion and prediction of the future climate of Kansas.

Explanation

The module Kansas Climate Change Impact on Population students will interpret a Kansas map of climate with an interactive change from 1890 through 2040. The students will then compare the climate map with a precipitation map and relate the impact of precipitation on the existing climate. A third map containing population density for the various climactic regions will be used to identify preferred environment choices.

Day 2: Student Tasks 2 and 3

Elaboration

In this task, students will be completing the Kansas Climate Change Impact on Population activity, Using Models to Make Predictions, accessible at the following website:

http://authoring.concord.org/sequences/47/activities/282?show_index=true. This online activity uses models to explore and explain how Earth's systems work together to cause climate change. The same report option is available as with the first module to be used if preferred.

Evaluation

When the class has finished the activity, lead a short discussion that summarizes the conclusions the students reached, based on the Elaboration activity. Use the following link

<http://nca2014.globalchange.gov/report/sectors/agriculture - graphic-16670>As homework, have students write a three-part summary statement of what they learned about 1) the Earth's changing

climate, 2) using models to make and understand climate change, and 3) predict what changes could occur in Kansas. (This three-part summary statement will be used in the engagement activity of Activity 4: Climate Change in Kansas and the Great Plains).