

2017-01-01

Active learning effect on the public's perception of anthropogenic global climate change

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ACTIVE LEARNING EFFECT ON THE PUBLIC'S
PERCEPTION OF ANTHROPOGENIC
GLOBAL CLIMATE CHANGE
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Master's Program in Environmental Science

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Dedication

I would like to dedicate this to my loving husband who not only encouraged me to pursue a Master's degree, but also supported me throughout the journey. His motivation and belief in me led to this accomplishment. I also would like to dedicate this to my dad and mom who have always supported my dreams by teaching me to believe in myself and accomplishing any goal despite the obstacles I faced.

ACTIVE LEARNING EFFECT ON THE PUBLIC'S
PERCEPTION OF ANTHROPOGENIC
GLOBAL CLIMATE CHANGE

by

IVY GISSELLE TREVIZO, BS

THESIS

Presented to the Faculty of the Graduate School of
The University of Texas at El Paso
in Partial Fulfillment
of the Requirements
for the Degree

MASTER OF SCIENCE

Department of Geological Sciences
THE UNIVERSITY OF TEXAS AT EL PASO
December 2017

Acknowledgements

The support and knowledge of Dr. Deana Pennington, Dr. Laura Serpa, and Dr. William Robertson is greatly acknowledged. I would like to especially thank Dr. Pennington for her time, knowledge and resources. I gratefully acknowledge the assistance of Oscar Ricaud and Luis Chavira in creating the online interface and the use of Lifemapper. This material is based upon work supported by the National Science Foundation under Grant No. DBI- 1356707 for the Transforming Biodiversity Analysis with Landscapes, Automation, and Provenance project. I would also like to acknowledge the Diana Natalicio Environmental Education Endowment.

Abstract

Anthropogenic, or human-caused global climate change has been debated for many years among the public despite the growing evidence that there is scientific consensus on this topic. A gap has been discovered between scientific evidence of increasing temperatures and the public's perception on climate change. This gap has been hypothesized to come from the method in which the scientific community represents scientific evidence. The goal of this study was to determine if active learning techniques around local and regional climate change and climate change impacts changes the awareness, perception, and behavioral intentions of different segments of the public. The study used a quantitative component involving online active learning bounded by pre- and post-surveys. A pre-survey was given to all participants, which included questions on their initial awareness, perceptions, and behavioral intentions regarding global climate change. After individuals explored climate data they were prompted to fill out a post-survey, which revealed how these activities had changed their perception on anthropogenic global climate change. Results were consistent throughout in that there was no statistically significant change in the post-activity scores when providing local climate change impacts in the form of a hands-on activity. No statistically significant correlation was found between the independent variables (gender, ethnicity, political view, and education level) and participants' change in concern from the pre- and post-activity results. The study found that although there was no statistically significant change in concern level for participants based on their political views, participants who associated as conservative had a higher increase in level of concern (36.8%), becoming more alarmed, than liberals who became more alarmed (13.3%). In contrast, more liberals had a decrease in concern (33.3%), becoming less alarmed, than conservatives who became less concerned (21.1%). These results indicate that this curriculum (looking at data for themselves) was useful for increasing concern of AGW of conservatives while decreasing concern of liberals. This method of communicating to the public caused individuals to move away from the extremes of their political view.

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Chapter 1: Introduction

Anthropogenic or human-caused global climate change remains a topic of great debate among the public even though there exists a scientific consensus that the Earth's global average temperature has increased, and that much of this increase is due to increased emissions of greenhouse gases such as carbon caused by burning of fossil fuels (Bedford, 2010; Bedford & Cook, 2013; USGCRP, 2017; Wuebbles et al., 2017). The Intergovernmental Panel on Climate Change (IPCC) and U.S. Global Change Research Program (USGCRP) emphasized that climate change is predominantly anthropogenic and that the damage caused by global warming will most likely be irreversible if no action is taken globally (IPCC, 2013; Shi et al, 2015; USGCRP, 2017; Wuebbles et al., 2017). Since the beginning of the twentieth century there has been an increase in temperatures of 1.3 °F to 1.9 °F and temperatures in the United States are predicted to increase by 7 °F to 9 °F by 2100 (Melillo et al., 2014; Egan & Mullin, 2017). Hence, it is imperative that the public be convinced of the reality and consequences of anthropogenic global warming.

Several terms have been interchangeably used to describe the changing climate. Climate change is a term used to describe any change in Earth's climate over time including warming, cooling, or getting wetter or drier (IPCC, 2007; Bedford, 2010). Climate change involves more than warming, has no spatial reference, and can refer to events that are global, regional or local in extent (Bedford, 2010). Global warming, on the other hand, explicitly involves a global scale, refers to increasing average temperatures while not considering other climate changes, and does not identify a particular cause of these changes. Another term commonly used is anthropogenic global warming (AGW), which refers to an increase in temperature that is human-caused (Bedford, 2010). Although AGW is an increase of average temperature at a global scale, not all

places on Earth experience the same change. Therefore, some places on Earth will experience cooling and others may become wetter. This study focuses on public perception of AGW.

A wide variety of scientific observations provide evidence that global temperatures are rising. Analysis of global, long-term temperature observations have found that 2014 was the warmest year on record and the last three years have been the warmest years recorded globally (USGCRP, 2017 p 10; 13). Findings show that sixteen of the warmest years that have been recorded globally occurred in the last seventeen years, excluding 1988 (USGCRP, 2017, p 13). The temperature of the sea surface has increased (IPCC, 2014 p 40), resulting in bleaching of coral reefs worldwide (IPCC, 2014 p 51); more than a quarter of the CO₂ emitted into the atmosphere has been absorbed by the ocean making it more acidic (USGCRP, 2017 p 28). Glaciers are receding (IPCC, 2014 p 42) and the polar ice caps are melting (IPCC, 2014 p 42) causing coastal flooding as the ocean rises (USGCRP, 2017 p 27). Global sea level has risen by 7 inches since the 1900s and is expected to continue rising by 1-4 feet by 2100 (USGCR, 2017 p 10). Heavy rainfall is expected to increase in intensity and frequency; heatwaves have become more frequent since 1960; and temperatures will rise by 2.5° F over the next few decades (2021-2050) (USGCR, 2017, p 10-11). In a more recent study by Hsiang et al. (2017) it was found that rising temperatures will have detrimental effect on the country's economics and there will be a rise in energy costs and death tolls related to heat waves. Already extreme events have cost the United States more than \$1.1 trillion since 1980 (USGCRP, 2017; Wuebbles et al., 2017). Warming will be occurring throughout the United States, but the southern states will suffer more due to the rising temperatures, including Texas (Plumer & Popovich, 2017; Hsiang et al., 2017).

The increase in temperature is correlated with increases in atmospheric carbon dioxide. Carbon dioxide concentrations of no more than 300 parts per million have been recorded from

420, 000-year-old ice cores (Weber & Stern, 2011). In 1959, the observatory in Mauna Loa, Hawaii measured atmospheric carbon dioxide at high levels of 315 parts per million and by the end of the 1970s carbon dioxide levels reached 335 parts per million (Hecht & Tirpak, 1995; Weber & Stern, 2011). More recently the USGCRP, (2017) has found that global atmospheric carbon dioxide concentration has now exceeded 400 parts per million. This discovery in 1970 led Congress to pass the Global Climate Act in 1987 to combat global warming and in 1990 a national research program was established by the Global Change Research Act to study global environmental change, its effects, and possible responses (Weber & Stern, 2011). Since then, scientists have increased their understanding of climate change over the past 150 years by accumulating observational data, testing and refining hypotheses, construction of theories and models to synthesize knowledge, and testing of these theories and models (National Research Council, 2010; Weber & Stern, 2011).

In addition, an analysis by Oreskes (2004) of 928 abstracts from peer-reviewed scientific articles (published between 1993 and 2003) found strong agreement among the scientific community that warming is occurring largely due to anthropogenic emissions of greenhouse gases, which include carbon dioxide and methane, as well as the burning of fossil fuels and land-cover changes. Oreskes (2004) also found that among all the authors there were no disagreement with the consensus and none of the abstracts argued that current climate change is natural. The study also reported that major scientific bodies such as the IPCC, National Academy of Sciences, American Meteorological Society and the American Geophysical Union had recently issued statements that agreed on the evidence that human activity is enhancing climate change (Oreskes, 2004). Recently the USGCRP 2017 assessment, based on extensive evidence, concluded that human activity (human contribution of 93% to 123%) is the dominant (with a high confidence)

and extremely likely cause of warming; observed warming is especially due to emissions of greenhouse gases (USGCRP, 2017 p 10; 114). Another study (Weber & Stern, 2011), used an IPCC assessment report from 2007 and various independent assessments and found that 97%-98% of active and prominent climate scientists who were signatories of major public statements were endorsers of climate change. Cook et al. (2013) reviewed abstracts from 1991 to 2001 that used words “global climate change” and “global warming” and found that 97% of the papers recognized that the Earth’s average temperature is increasing due to greenhouse gas emissions. In a recent synthesis of findings from six independent studies of the scientific literature on climate change, Cook et al. (2016) reported a 97% consensus among climate science experts that the dominant cause of observed warming is human activities, and that the National Academies of Science from 80 countries have issued statements endorsing this position. Hence, strong consensus among scientists regarding human-induced climate change has existed for at least a decade.

Although it is possible to find peer-reviewed publications that reject this scientific consensus among the scientific community, these only represent a small portion of the human-induced climate change publications (Cook et al., 2013). Several of the studies that published papers that claim the scientific consensus is not real have been strongly challenged and found to be flawed (Cook & Jacobs, 2014; Abraham et al., 2014).

1.1 Statement of Problem

The public understanding of this issue is inconsistent with the scientific consensus; a misconception by the public is that there is disagreement on the reality and causes of climate change among scientists. This gap has been termed the “consensus gap” which leads to a lower

belief on the reality of climate change and results in a lack of support for the policies to mitigate the change (Cook et al., 2013; Cook & Jacobs, 2014). A survey by Kohut et al. (2009) revealed that three-quarters of people (76%) think climate change is anthropogenic and believe most scientists agree. Of those who believe warming is due to anthropogenic atmospheric changes, 41% think there is no scientific consensus. More recently, Leiserowitz et al. (2014) found a misunderstanding of scientific consensus among American adults: only 42% believe that most of the scientific community thought global warming is occurring, 33% voiced that there is much disagreement among the scientific community whether global warming is occurring, 20% perceived themselves to not be educated enough to respond, and 6% believe that most of the scientific community does not think global warming is occurring.

Awareness has steadily increased over the years with 4 in 5 Americans professing that they understand the issue when it comes to climate change (Bowman et al., 2016; Egan & Mullin, 2017). Although there has been an increase in awareness by the public this has not yet translated into factual knowledge as less than half of Americans do not acknowledge that scientists agree that climate change is occurring (Egan & Mullin, 2017).

1.2 Objective

The aforementioned studies focused on tailoring messaging and content to different types of audiences in surveys. This study tried to address the issue of lack of knowledge by providing an active learning activity, in hopes that giving the public an opportunity to interact with climate data themselves would change their concern about AGW. There are many opportunities for outreach that involve direct engagement with the public and hands-on activities. Such activities are referred to as “active learning.” Active learning can be defined generally as any kind of

instructional method that is used to engage the students in the learning process (Prince, 2004). In other words, active learning requires the student to accomplish meaningful activities and to think about what they are learning (Bonwell & Eison, 1991; Prince, 2004). Active learning characteristics include: 1) the student is involved in more than just listening, 2) more emphasis is placed on developing of a students' skills, 3) students are involved in higher-ordered thinking which include analysis, synthesis and evaluation, 4) emphasis is placed on the exploration of the students' attitudes and values (Bonwell & Eison, 1991).

A study by Redish et al. (1991) showed that improvement in learning gains was attributed to the nature of active engagement and not due to the extra time spent on a given topic. Prince (2004) disclosed that Redish et al. (1991), along with other studies, (Hake *et al.* 1998; Laws *et al.* 1999) when taken together provided significant support for active engagement techniques. These methods particularly support addressing students' fundamental misconceptions.

Constructivism is a theory which is defined by Naylor & Keogh (1999) as learning that involves an active process where learners can construct meaning by connecting the new ideas they have learned to their existing knowledge (Jones & Araje, 2002). A known philosopher, Ernst von Glaserfeld stated, regarding radical constructivism, that constructivism can be a set of beliefs that provides a model of cognition which in turn leads to a method of teaching and allows the students to become an active learner (von Glaserfeld, 1994; Aulls & Shore, 2008).

Constructivism informs the student about learning and gives them no choice but to interpret reality. This theory also allows students to be active participants in creating meaning from what they are learning and to perceive learning as initiated by understanding (Aulls & Shore, 2008).

Jerome Bruner, throughout his studies also found that “learners are responsible for the

construction of their own knowledge and understanding to an unanticipated degree” (Olson & Bailey, 2014).

One model based on constructivism is the “5 E's” approach which capitalizes on hands-on activities and was therefore used for this study (Carr *et al.*, 2007). The 5 E's of the model are engage, explore, explain, elaborate and evaluate. In the engage stage the instructor uses an engagement activity that connects past and present learning experiences which helps the learner participate in their own learning process (Carr *et al.*, 2007). The instructor’s role in this stage is to create interest, raise a question, and generate curiosity. A very important part of engagement is the opportunity for the instructor to identify any misconceptions the learner may have. The explore and explain stages both involve the guidance of the instructor. In explore stage the learners investigate a phenomenon and “arrive at a common understanding of certain concepts, process or skills” and the instructor provides time for the learner to work through some problems. In the explain stage, learners begin to demonstrate conceptual understanding or behaviors by listening and trying to comprehend the explanations given by the instructor (Carr *et al.*, 2007). In this stage, the learner begins to not only organize the evidence-based statements, but they also start to use academic language of science (Carr *et al.*, 2007). The elaborate stage consists of the instructor monitoring and facilitating discussions that will challenge the learner and the evaluate phase is where learners are assessed by the teacher or by themselves throughout the other stages (Carr *et al.*, 2007).

The goal of this study was to determine if active learning based on the 5Es model employed around local and regional climate change impacts, changes the awareness, perception, and behavioral intentions of different segments of the public. This research involved developing an interactive activity that allowed adults to use scientific inquiry to interpret data that displayed

how climate change is expected to affect local and regional temperature and precipitation, and how those changes may impact water in the region, as well as local and regional species and ecosystems.

1.3 Hypotheses

Based on past studies, predictions were made that results would vary considerably by:

- Age, with older participants more likely to be dismissive;
- Gender, with women more likely to be alarmed;
- Race, with Hispanics more likely to be alarmed;
- Political View, with Liberals more likely to be alarmed.

Other predictions made included changes between the pre- and post-surveys would be more pronounced for those who were classified initially as dismissive or uncommitted, and less pronounced for those who were classified initially as alarmed. The project collected and analyzed data regarding how the perception of the public on anthropogenic global climate change had changed during the active learning activity using a pre-survey and post-survey.

Chapter 2: Background

2.1 Studies of worldview and beliefs about climate change

Although some articles that are related to this study have already been discussed in the preceding section, a brief review of other related research is necessary. While the focus of this study is to determine if active learning has an impact on individuals and their awareness of climate change other studies have focused on an individuals' worldview and preconceptions of climate change. This literature review will cover three sections: first, the importance of an individuals' preconception of the scientific consensus on climate change; second, how the knowledge of scientific education affects the individuals' worldview; and third, what attempts have been made to close the gap between a persons' worldview and adopting accurate scientific mental models.

In two studies by Lewandowsky et al. (2013), the authors examined how the perception of scientific consensus interacts with a persons' worldview, which has been found to be the primary obstacle to acceptance of AGW, and in turn leads to a decline in the public concern. The first study focused on whether scientific consensus contributes to the acceptance of diverse scientific facts- from HIV/AIDs to AGW. This study found that perceived consensus was related to the acceptance of scientific fact, but found the relationship was not unique to AGW but rather was the same for other scientific issues. The second study included two groups, a control group and a test group that was provided information highlighting a 97% consensus among climate scientists. Participants in the latter group were more willing to attribute long-term climate change to human-causes and accept that human carbon dioxide emissions were the cause when consensus among the scientific community was emphasized. In addition, Schuldt & Pearson (2016) ran a logistic regression analysis on race differences and found that Whites perceived a

higher scientific consensus than non-Whites, but overall, along with recent studies, found that perceived scientific consensus was a strong predictor (both non-Whites and Whites) for mitigation efforts (Ding et al., 2015; van der Linden et al., 2015).

Research in science education shows that an individuals' preconception that conflicts with their scientific understanding makes it difficult to create new mental models that are scientifically accurate (National Research Council, 2005; Werner & Stern, 2011). The conflict of misconception may be caused in part by agnotology which was coined by science historian Robert Proctor (Proctor, 2008; Bedford, 2010). Agnotology is culturally induced ignorance or doubt, sometimes brought about through inaccurate or misleading data, document suppression, or other forms of misinformation in the popular media. Studies have found that misconceptions are very difficult to remove, but one effective way to combat this is through refutations, which were found to explicitly address climate misconceptions and climate misinformation to improve a persons' climate literacy (Muller et al., 2008; Kowalski & Taylor, 2009; Tippet, 2010; Cook et al., 2014). The study found that using a two-channel science communication that combined information content and cultural meanings was effective for public outreach (Cook et al., 2014).

In another study, Shi et al. (2015) conducted a mail survey in Switzerland that was used to examine what impact climate-change-relevant knowledge had on the publics' concern for climate change when controlling for cultural worldviews. The study focused on the question of whether scientific knowledge is significant for explaining the concern people have for climate change, including their worldview. The authors focused on four subscales of climate-change-related knowledge: physical knowledge, such as, "burning oil, among other things, produces CO₂"; causal knowledge, such as, "climate change is mainly caused by human activities"; action-related knowledge, for example, "a large part of the CO₂ emission in Switzerland is

caused by the transport sector”; and result-related knowledge, such as, “for the next few decades, the majority of climate scientists expect a cooling down of the climate” (Shi et al., 2015).

The results suggested that an individual is motivated to change behavior if they have more knowledge about climate-friendly behaviors and less likely to change behaviors with knowledge about negative consequences of climate change. Shi et al. (2015) concluded that risk communication should focus on causal knowledge (which was positively related to a concern for climate change), emphasizing consequences that are more related to individual lifestyles rather than communicating uncontrollable consequences.

Hine et al. (2016) studied public response to different types of messaging about climate change and found that public perceptions and concerns could be organized into three distinct segments including dismissive, uncommitted and alarmed. Results indicated that participants who were dismissive were more prone to change their beliefs and actions towards climate adaptation when climate change messaging emphasized local impacts. All three segments of participants showed increased motivation for climate change adaptation when content provided specific advice for adaptation.

In a related study, Evans & Lawrence (2014) found that participants had a stronger will to take part in climate change mitigation when they were given a scenario that focused on adaptation measures based on local climate effects rather than those that were more general climate effects. Evans & Lawrence (2014) focused on how to deliver the correct data to the public and find a way that would communicate this data with the most impact.

In a recent study, Akerlof et al. (2015), found that vulnerable groups are more concerned about climate risks and feel more threatened by climate change, including people of color. Hispanics have been found to be the most concerned for climate change and willing to say that

the government should regulate greenhouse gas emissions, according to the Washington Post-ABC News Poll from 2014. Non-Whites are more prone to care about the environment because often time they are more “directly affected by the negative effects of climate change” (Schuldt & Pearson, 2016, p 500). Schuldt & Pearson (2016) also found that political association is a stronger predictor for personal existence belief, likelihood of perceiving a scientific consensus, and support for policy aimed at reducing greenhouse gas emissions among Whites than non-Whites. When it comes to White conservative males, McCright & Dunlap (2011) found that this group has a higher level of denial of climate change than other groups of adults.

In another study, Marquart-Pyatt et al. (2011) found that adults who associate as a liberal or Democrat have a positive concern for climate change with higher education attainment. The opposite was found with adults who associate as conservative or Republican, they have a negative concern for climate change with higher education attainment (Marquart-Pyatt et al., 2011; Egan & Mullin, 2017). In a related study, Unsworth & Fielding (2014) found that adults whose political association was salient provided momentarily less support for climate change policies and their own stance on this issue was aligned more with their political identity.

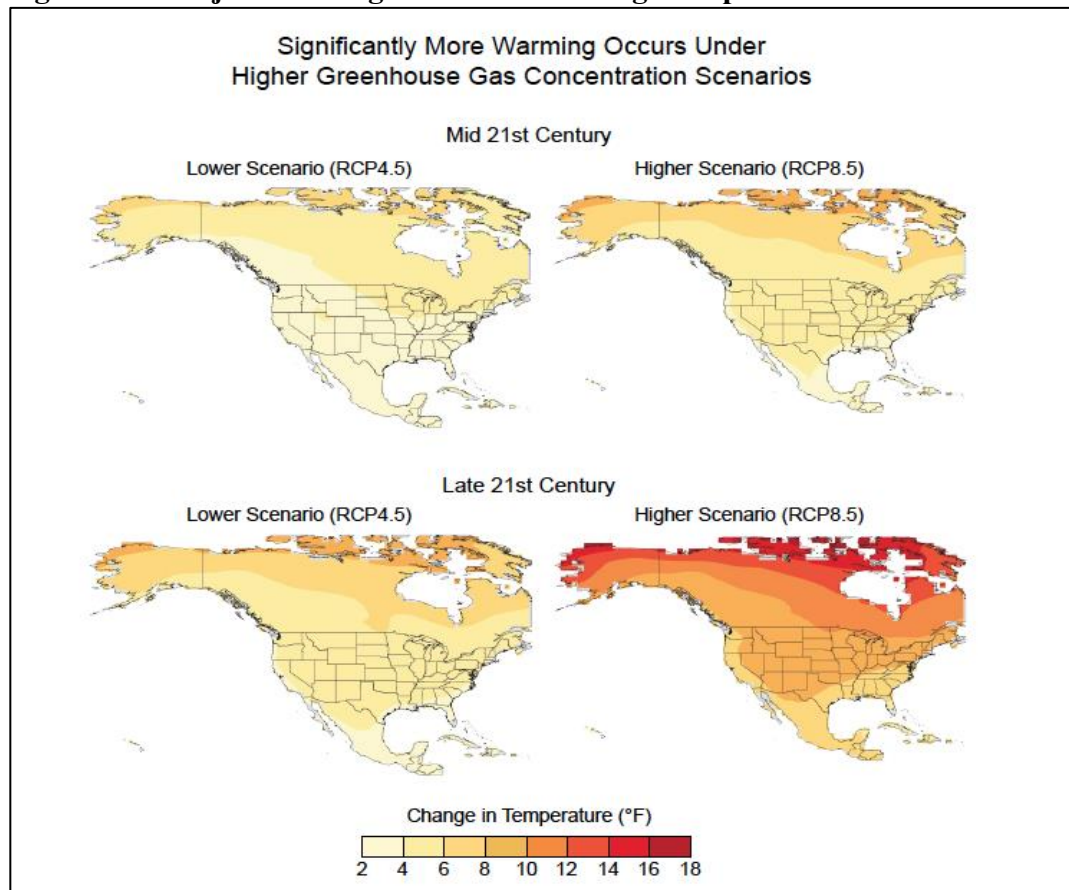
Scientific consensus on climate change has been established extensively through several studies and shown to influence the publics’ perception of AGW. The studies previously described are related to this proposal because they provide details on the most effective way to change the publics’ awareness, perception and behavior on AGW, which is the focus of this study.

2.2 Climate change reconstructions and projections

The USGCRP was established in 1989 by the Presidential Initiative to “assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change” (About USGCRP, n.d.). In constitution with the White House officials and the Subcommittee on Global Change Research, the USGCRP Executive Director “ensure that the Program meets all mandated requirements” (About USGCRP, n.d.). The USGCRP comprises of 13 agencies that conduct research on global change and its impacts on society (About USGCRP, n.d.). The primary vehicles for implementing and coordinating global change research activities are Interagency Working Groups, who address “major components of the Earth’s environmental and human systems” (About USGCRP, n.d.).

The USGCRP Fourth National Climate Assessment recently reported that the period between 1901-2016 has been the warmest in history with record-breaking and climate-related weather extremes in the last few years. Human-activity is the cause for this observed warming since the mid-20th century and in addition to warming, “other aspects of global climate are changing” (USGCRP, 2017 p 10). Examples of these changes have been documented by many studies conducted by researchers and include changes in surface temperatures, atmospheric temperatures and oceanic temperatures; melting glaciers; shrinking sea ice and snow cover; rising sea levels (risen 7-8 inches since 1900); and ocean acidification (USGCRP, 2017).

Figure 2.1: Projected changes in annual average temperatures



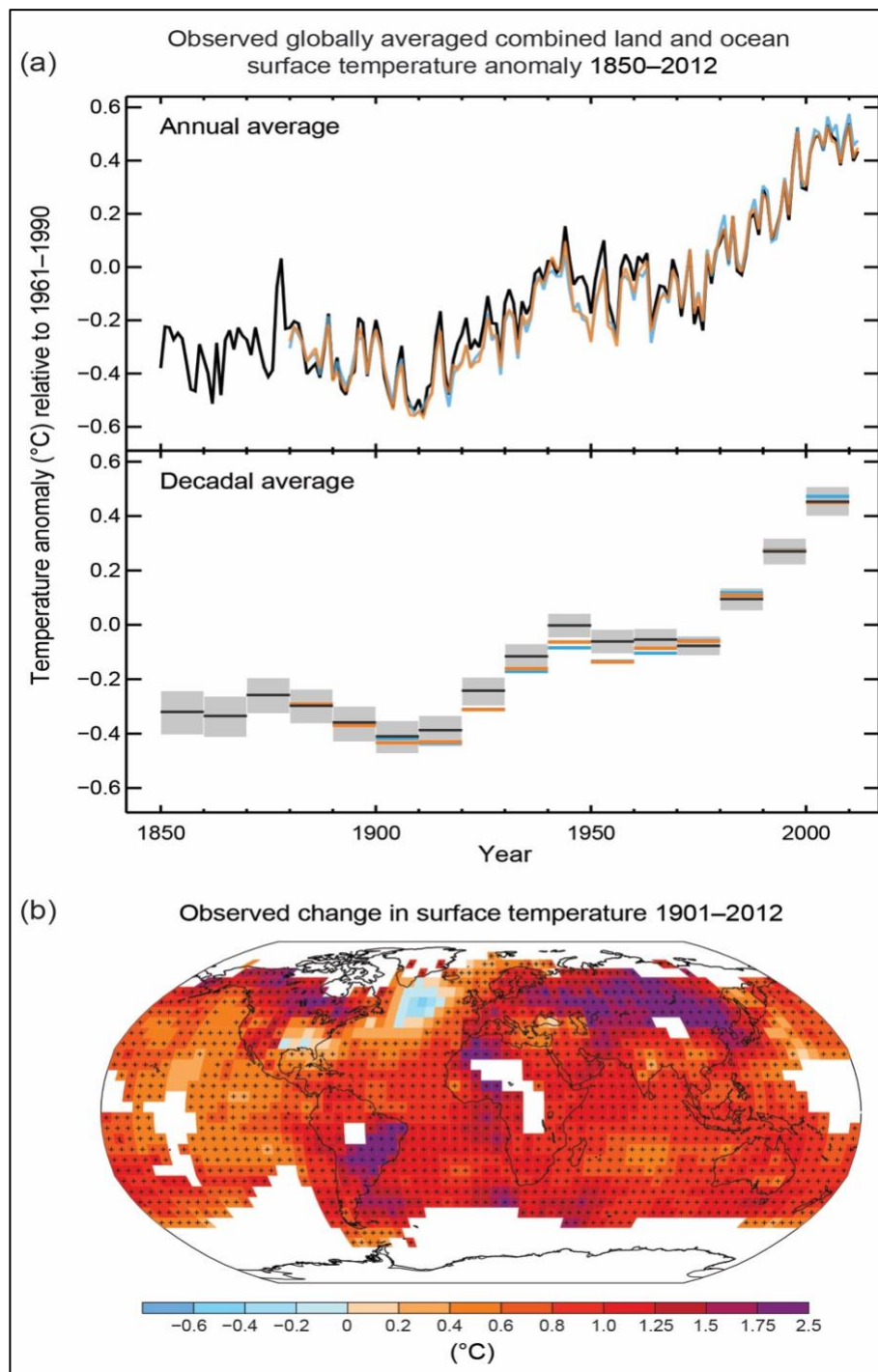
Maps showing projected changes in annual average temperatures for two future pathways for mid and late 21st century. The changes in the maps are the differences between the average projected temperatures for the two scenarios (mid-century (2036-2065) and late-century (2070-2099)) and the average projected temperatures observed for the near-present (1976-2005). (Figure ES.4 in USGCRP Fourth National Climate Assessment, Volume I, p 18).

The IPCC is a leading international body that assesses the most recent scientific information that is produced worldwide relevant to the understanding on the topic of climate change (IPCC, 2013). The IPCC does not conduct any research or monitor climate related data but rather focuses on the review of this scientific information as an essential part that allows for an objective and complete assessment. The IPCC also reflects a range of views and thousands of scientists from all over the world who contribute to this work (IPCC, 2013).

The IPCC's Fifth Assessment Report in 2015 reported observed changes in the climate system as follows: "human influence on the climate system is clear, and recent anthropogenic emissions of green-house gases are highest in history" (IPCC, 2014 p 2). These changes on the climate system have led to an impact on not only humans, but also on natural systems. The last three decades have been found to be successively warmer than any decades since 1850 leading to the warmest 30-year period (1983–2012) in the last 1400 years in the Northern Hemisphere. Figure 1 shows that over the period of 1880 to 2012, the globally averaged combined land and ocean surface temperature data (calculated with a linear trend) shows a warming of 0.82 °C (0.65 to 1.06 °C) (IPCC, 2014).

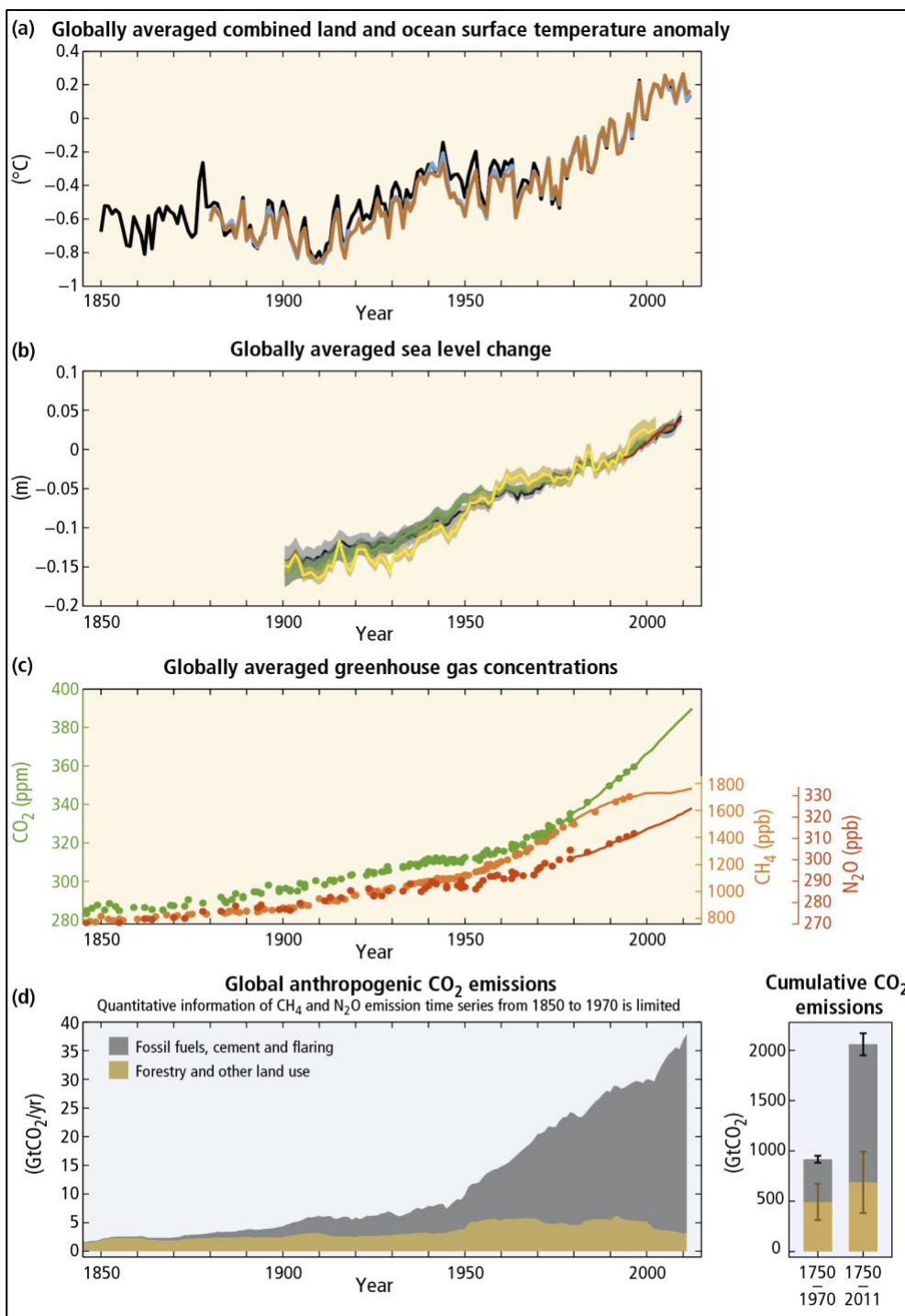
The causes of climate change indicate anthropogenic greenhouse gas emissions are higher than ever, have increased since the pre-industrial era, and have been driven largely by population and economic growth. Figure 2 shows the increase of global anthropogenic CO₂ emissions since 1970. Cumulative CO₂ emissions have tripled from fossil fuel combustion, cement production and flaring and have increased by 40% from forestry and other land use. Cumulative anthropogenic CO₂ emissions were 2040 ± 310 gigatonnes of CO₂ (GtCO₂) between 1750-2011; 40% of CO₂ emissions have remained in the atmosphere (880 ± 35 Gt CO₂) while 30% have been absorbed by the ocean. The IPCC reports with high confidence that half of the anthropogenic CO₂ emissions occurred in the last 40 years.

Figure 2.2 Observed globally averaged land and ocean surface temperature anomalies



(a) Observed globally averaged land and ocean surface temperatures anomalies combined along with decadal uncertainty for one data set in lower half of graph (shaded in grey). (Figure 1.1a of IPCC Fifth Assessment Report 2015. Working Group 1 Figure SPM.1, p 4, IPCC, Switzerland).

Figure 2.3 Annual global anthropogenic carbon dioxide (CO₂) emissions



(d) Annual global anthropogenic carbon dioxide (CO₂) emissions (gigatonne of CO₂- equivalent per year) from 1750 to 2011. Cumulative emissions are shown on the right side as bars and whiskers with uncertainties (IPCC Fifth Assessment Report 2015, Synthesis Report, Figure SPM.1, p 3, IPCC, Switzerland)

2.3 Local and regional climate change impacts

As temperatures increase due to climate change, there will be many changes that are foreseen for the Southwestern US. A study by Routson et al. (2011) suggested that severe drought conditions with a warmer and drier future can be anticipated. This suggestion was based off a new tree-ring record that was collected from a living bristlecone pine (*Pinus aristata*) that was from the headwaters region in the Rio Grande River. In this record, they found unusual dryness in a multi-century period from 1 to 400 AD including a megadrought from the 2nd century that lasted almost five decades. The drought was more severe than during the medieval period megadroughts known in this region. Their findings suggested the Southwest should anticipate similar drought conditions (Routson et al., 2011).

Ault et al. (2012) suggested that global climate models underestimate the risk for future drought because they do not account for hydroclimatic fluctuations that instrumental and paleoclimate data indicate are multidecadal to multicentury. To assess the risk of persistent droughts, Ault et al. (2012) developed methods that combined paleoclimate information with climate model projections and found the risk for megadroughts in the Southwestern U.S. to be at least 80% and higher than 90% in certain areas.

2.4 Species distribution modeling

Expected changes in drought and water availability have profound implications for an array of human and environmental processes, including the distribution of species native to the area. Species distribution models (SDM) are an analytical technique used to estimate the environmental conditions where there are known occurrences of a species and compare those conditions at other sites where that species could potentially exist (Hijmans & Elith 2016).

SDMs can be used to predict the location of plant and animal species in geographic space that is based on a mathematical representation of the specie's requirements. SDMs can determine the habitat of species that are rare or threatened and can model the potential spread of an invasive species (Hollander, 2013). The SDMs are also useful for creating predictions of suitable habitat for species under future climate conditions, supposing that a specie's habitat will migrate in geographic space due to the change in climate (Hollander, 2013). There are several steps that are taken to create an SDM: 1) collecting the locations where species are known to occur; 2) obtaining environmental variables from spatial databases based on the selected locations; 3) fitting environmental variables to a model at each occurrence point; and 4) predicting the variable of interest across the chosen region under current, past or future climate conditions (Hijmans & Elith, 2016). This approach, therefore, can be used to analyze potential changes in local and regional flora and fauna as a result of changing climate and water resources.

A notable SDM software called Lifemapper (<http://lifemapper.org>), has been developed by the University of Kansas. Lifemapper combines climate change data with species occurrence data derived from natural museum specimens around the world, and generates data sets of the past, present, and future distribution of species. The model is run automatically each month for every species with sufficient information and the results are cached. More accurate analyses can be conducted as needed. This model is available through a web portal that can be accessed by any user and allows them to browse, download, and manipulate the data and models. An interface to the Lifemapper cache was created that accessed the data for species native to the Middle Rio Grande region. This was embedded in an online curriculum that allowed users to participate in a hands-on activity using the cache of information. Users had the opportunity to

browse the maps created by Lifemapper for whichever local and regional species they were interested in.

This project was built on prior educational research conducted by the SPECIES (Students Predicting the Effects of Climate In Ecosystems) project, created by the University of Michigan in collaboration with the Lifemapper project. The SPECIES interface consisted of a fourteen-day curricular unit aimed for middle and high school students that focused on climate change impacts on biodiversity and ecosystems. This online workbook allowed students to have a hands-on educational experience with climate change including how it may impact species. This project incorporated an interface similar to SPECIES that had a different set of questions and was used in a slightly different way.

Chapter 3: Methods

3.1 Approach

The study used a quantitative component involving online active learning bounded by pre- and post-surveys. The online, active learning-based curriculum was created for the general public, exposing participants to climate change and species distribution data, highlighting potential changes in the El Paso region. Adult participants were recruited to complete the curriculum at eleven public events. A pre- and post-survey assessed to what degree this curriculum changed their awareness, perceptions and behavioral intentions towards climate change.

3.2 Participants and site location

This research utilized an online survey of general climate data and attitudes towards anthropogenic global climate change and was administered from the months of May to September 2017 to the public at eleven events. Pilot testing occurred during the month of April to obtain feedback on the web interface, curricula and surveys. After the pilot study was completed the curricula, surveys and website were finalized. Consenting adults 18 years and older were the target population for this study and were randomly recruited at events where people were spending leisure time around the El Paso region. Internal Review Board (IRB) approval was obtained prior to collecting any information from the participants, and all participants were required to sign a consent form indicating that they were aware that data was collected for research purposes, that their participation was voluntary, and that they could decline

to participate at any time. In total, 97 individuals were recruited to participate in the online survey from eleven events (Table 3.1).

Table 3.1 Events where survey participants were recruited

Event and date where survey participants were recruited. Number of surveys collected refers to participants who filled out the survey on site at the event. Post-event surveys refer to participants who were recruited at an event but filled out the survey after the event.

Event Name	Date	Number of Surveys Collected	Post Event Surveys
7th Annual ESD's Earth Day Celebration	22-Apr	2	2
Arts and Farmers Market	13-May	8	6
El Paso Public Library	15-May	7	
Farmers Market at Ardovino's Desert Crossing	10-Jun	3	6
Sunland Park Mall	24-Jun	1	
El Paso Ice Cream Festival	2-Jul	11	
Fourth of July 5K Run	4-Jul	11	
Alameda Auto Electric's Second Annual Car Show	30-Jul	7	
6 th Annual Big Latch	5-Aug	12	1
Cadlelighters Walk for Hope	23-Sep	10	
12th Annual Chihuahuan Desert Fiesta	30-Sep		10

To motivate individuals to participate in the survey an iPad raffle was advertised at each event. Each person who participated in the survey was entered in the raffle and one participant was chosen to win the iPad. After an explanation was given of what should be expected while participating in the survey the participant was logged on to a University of Texas at El Paso (UTEP) laptop from where they completed the survey. Some individuals choose to spend their time at the event rather than fill out the survey. These participants signed a consent form at the event stating that they were committing to take the survey and were handed a business card with the survey website link and password in order to take the survey at their convenience. Participants were then asked to email an acknowledgement of completion once they had completed the survey in order to be entered in the iPad raffle. Each participant had four hours to complete the survey

once they had begun; the survey would then close after four hours from the start time despite where they were participating from.

3.3 Survey development

The online, active learning-based curriculum was created for the general public exposing participants to climate change, species distribution data, and water source data, highlighting potential changes in the El Paso region identified from the data. The online curriculum was completed in approximately fifteen minutes, depending on participant choices. After providing demographic information, a pre-survey was given to participants asking questions on initial thoughts on climate change and to assess to what degree this curriculum changed their awareness, perceptions and behavioral intentions towards climate change. The survey was developed on software called Qualtrics which is a web-based survey tool that can be used by anyone to create surveys, online data collection and analysis.

The curriculum was comprised of five activities and participants were initially asked to answer several questions during and after each activity. These questions would have been used to evaluate the degree to which participants learned targeted concepts from the activities in each section. The questions after each activity were removed half way through the study to shorten the survey because the length became a deterrent for participation. These questions were removed from the data analysis for participants who had answered these questions.

In the first activity, participants watched one of five videos on how carbon dioxide warming works that ranged from one to five minutes in length. The second activity asked participants to explore climate data from the past to see for themselves what historical records suggest about climate change, at both global and regional scales. The third activity consisted of a

short video educating the participant on how climate models worked and allowed them to explore future climate data themselves, again at the global and regional scales. The next step enabled participants to explore the expected impacts of climate change on distributions of fauna in the El Paso region. The curriculum was created online, accessing climate change and species distribution data through the internet. The curriculum was based on the species that have been documented over many years in the El Paso region and consisted of lists of species and maps of their distribution in and around the Franklin Mountains. The aim was to use species the El Paso locals are familiar with and that are native to the region to peak the public's interest, as was shown in the study by Evans & Lawrence (2014). The last activity allowed participants to view water supply information and how water sources in the El Paso region would be affected by climate change. Evaluation of changes in beliefs, perceptions, and behavioral intentions followed at the end of the interface when individuals were asked to participate in a post-survey.

Questions in the pre-survey attempted to elicit participant views that would enable categorization as dismissive, uncommitted, concerned or alarmed, following the typology of Hine et al. (2016). The pre-survey consisted of 17 questions and the post-survey consisted of 16 questions, answer choices were on a one to seven Likert scale with most of the answer choices ranging from 'Strongly Agree' to Strongly Disagree'. Examples of questions found in the pre-survey have been included below in Table 3.2.

Table 3.2 Example of survey questions

Question examples with answer choices from the pre-survey on a 7-point Likert scale. A complete list of survey questions can be found in Appendix A.

How important is the issue of climate change?		To what degree are you aware of potential local impacts of climate change on biodiversity?		How concerned are you that local animal and plant species may be threatened to become extinct?		I believe climate change will affect me personally.	
Very important	7	Extremely aware	7	Very concerned	7	Strongly agree	7
Important	6	Moderately aware	6	Moderately concerned	6	Agree	6
Moderately important	5	Somewhat aware	5	Somewhat concerned	5	Somewhat agree	5
Not sure	4	Unsure	4	Unsure	4	Unsure	4
Moderately unimportant	3	Somewhat unaware	3	Somewhat unconcerned	3	Somewhat disagree	3
Of little importance	2	Moderately unaware	2	Moderately unconcerned	2	Disagree	2
Unimportant	1	Unaware	1	Unconcerned	1	Strongly disagree	1

The curriculum activity followed the 5 Es Instructional Model which is represented by a recursive cycle of cognitive stages that focuses on inquiry-based learning as explained in Carr et al. (2007). The 5 Es of the model are engage, explore, explain, elaborate, and evaluate. To engage, the activity created interest by raising a question and a problem and allowing participants to voice their perception and current awareness on global climate change. Part of this was facilitated by a pre-survey to obtain quantitative information. In the explore phase, participants had an opportunity to investigate global climate change further by watching several videos and visiting websites with climate data that allowed them to reach a common understanding in this concept. Participants had an opportunity to think critically about the information they were viewing and test the predictions they initially had formed within the limits of the activity. The active learning activity led participants to stimulate their curiosity which

would lead them to discover new insights, confirm their prior assumptions or challenge their prior perceptions.

An explanation of the impacts of anthropogenic global climate change was facilitated through the climate data, Lifemapper data, and water source information they examined. At this step participants had a chance to explain their conceptual understanding and contrast what they had learned with their previous misconceptions. Participants were further able to elaborate what they had learned as they made the connection between how global warming occurs and the impacts it has on temperature, fauna, and water sources. After making these connections, participants had a chance to use previous information from the curriculum to ask questions and make decisions on the concept of climate change. Throughout the activity, participants were given the chance to draw reasonable conclusions from the evidence they were viewing.

Participants then had an opportunity to evaluate their previous misconceptions and what they had learned through the post-survey as they answered questions that voiced how their perception and awareness had changed. The investigator was also able to evaluate each participant with the post-survey to determine if initial perception and awareness on human-caused climate change had indeed changed.

3.4 Data analysis

After survey responses had been collected, answers were reverse coded for items that had been phrased from a “positive” to a “negative” scale to be consistent with the “negative” to “positive” form of the majority of the questions. The data were then exported from Qualtrics into a Microsoft Excel worksheet. Participants were removed from the analysis if their responses

were missing answers in the pre-survey, post-survey or demographic section. The sample size after removal of incomplete responses was 76 survey participants.

Participant answers on the pre- and post- surveys were summed with a higher total meaning a greater degree of concern about climate change (1 to 7 scale, where 7 = *greater concern*). Participants were then categorized into four groups, ‘Alarmed’, ‘Concerned’, ‘Uncommitted’, and ‘Dismissive’ using the total score of their responses for each survey as follows: Alarmed = 4, Concerned = 3, Uncommitted = 2, and Dismissive = 1. The change in level of concern pre- and post- learning activity for each participant was then identified as ‘Increase’, a ‘Decrease’ or ‘No Change’ in concern (Table 3.3).

Table 3.3 Change of concern level based on score difference

Participants categorized based on their score difference from the pre- and post-survey.

Difference	Change
Pre-survey = Post-Survey	No Change
Pre-survey < Post-Survey	Increase in Concern Level
Pre-survey > Post-Survey	Decrease in Concern Level

Results were statistically analyzed using SPSS and Minitab. Pre- and post-survey results were statistically analyzed, including basic summary statistics to determine if post-activity responses differed significantly from pre-activity responses. The Likert items for the pre-survey were added up to derive a Likert scale that could later be used to run parametric tests on the data and the same was done for the post-survey. A Cronbach’s alpha was run to analyze pre- and post-survey results independently. Cronbach’s alpha was used because it is a measure of internal consistency of the data and a measure of scale reliability. The pre-survey questionnaire consisted of 17 items, and had Cronbach’s alpha of 0.87 indicating a high level of internal consistency. The post-survey questionnaire consisted of 16 items and had a high level of internal consistency with a Cronbach’s alpha of 0.80. The mean for each of the participants’ responses was calculated

in Excel and then using Minitab a paired t-test was run on the pre-and post-survey mean score difference. A paired t-test is used to compare the means of two sample sets when the observations in one sample can be paired with observations in the other sample and therefore was used to find change in concern.

Demographic information was used to find correlations between each demographic variable and the change in degree of concern. Non-parametric tests were used to analyze the relationship between demographics and change in concern because the data were not continuous and included ordinal data. Non-parametric tests included Spearman's and Point-Biserial correlations. A Spearman Rho correlation is a non-parametric test that can be used to measure the degree of association between two variables. A Spearman's correlation was used to find if there was a statistically significant relationship between education level and change in concern. Education level was analyzed using a Spearman's correlation because this variable was considered ordinal even though change in concern was continuous. Point-Biserial correlation measures the strength of association between a continuous variable and a dichotomous variable. A Point-Biserial test was used for gender and ethnicity because they were both binary variables. Gender was measured with two choices, 'Male' and 'Female' making it a dichotomous variable. Ethnicity of participants was categorized into two groups, 'Hispanic' or 'Non-Hispanic' making the data dichotomous.

One demographic variable that did not require a non-parametric test was age group and concern change. A Pearson's correlation is used to assess the strength of association between two continuous variables and was used to assess if there was a statistically significant relationship between age group and change in concern. A Pearson's correlation test was used for these variables because both variables were continuous data.

Chapter 4: Results

4.1 Overall results

Change in participants' concern level was highest for the 'No Change' category (51%) followed by the 'Increase' (26%) and 'Decrease' (23%) change categories (Figure 4.1). Parametric tests used to compare pre- and post-survey results included Cronbach's alpha and a paired t-test. A normality test was run on the 'Score Difference' (change in concern) of the pre- and post-survey and found that the data was normally distributed (Mean = -0.09; Standard deviation = 0.73; P-value = 0.10). Results show that the mean post-activity scores were lower (5.22 ± 0.82) than pre-survey scores (5.32 ± 0.94), a decrease of 0.1 (95% CI, -0.27, 0.07) in the mean level of concern after engaging in the learning activity (Figure 4.2). This difference was not statistically significant (T-value = -1.17, P-value = 0.24, $\alpha = 0.05$).

Figure 4.1 Percentage of change in concern level

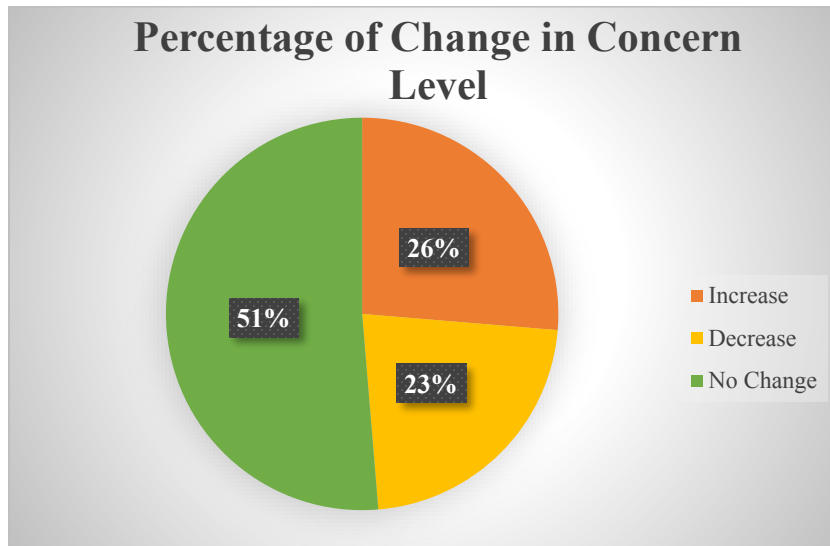
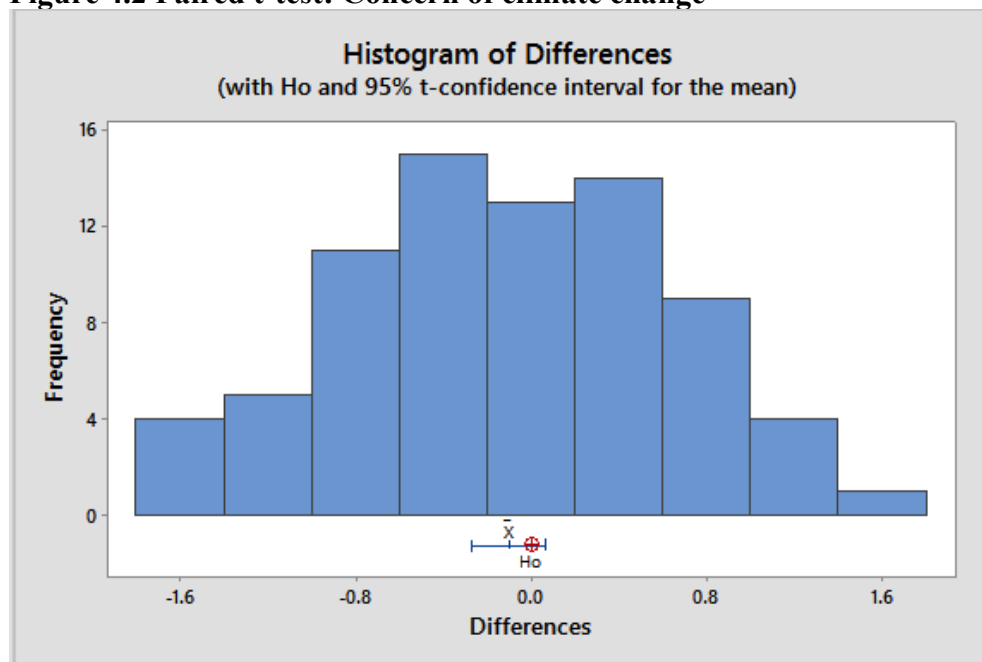


Figure 4.1 Change of concern level showing percentage of participant's who had 'No Change', 'Increase' in concern, or 'Decrease' in concern (n=76).

Figure 4.2 Paired t-test: Concern of climate change



Initial concern of climate change compared to post-activity concern for each participant using a Paired t-test.

4.2 Non-parametric tests on demographic data

Results were disaggregated by age, gender, race, and political view. Percentage of participants for age groups were as follows: 18-29 (44.7%), 30-39 (19.7%), 40-49 (15.8%), 50-59 (13.3%), 60-69 (5.3%) and Over 70 (1.3%). The majority of participants were initially concerned about climate change, with younger participants (50-59) being the most concerned initially (60.0%) (Table 4.1). Overall, the highest level for initial concern level for participants was ‘Concerned’ (51.3%). Younger adults (18-29) had a larger ‘Increase’ in concern (38.2%) and adults (40-59) had predominantly ‘No Change’ in concern (66.7%-70.0%) (Figure 4.3).

Table 4.1 Initial climate change belief of participants by age

Initial Climate Change Belief of participants disaggregated by Age. Missing Values indicate no responses were recorded for the level of concern in that age group.

Initial Climate Change Belief						
Age	18-29	30-39	40-49	50-59	60-69	Over 70
Alarmed	23.5%	40.0%	41.7%	20.0%	75.0%	
Concerned	50.0%	53.3%	50.0%	60.0%	25.0%	100.0%
Uncommitted	20.6%	6.7%	8.3%	10.0%		
Dismissive	5.9%			10.0%		

Figure 4.3 Change in concern level by age group

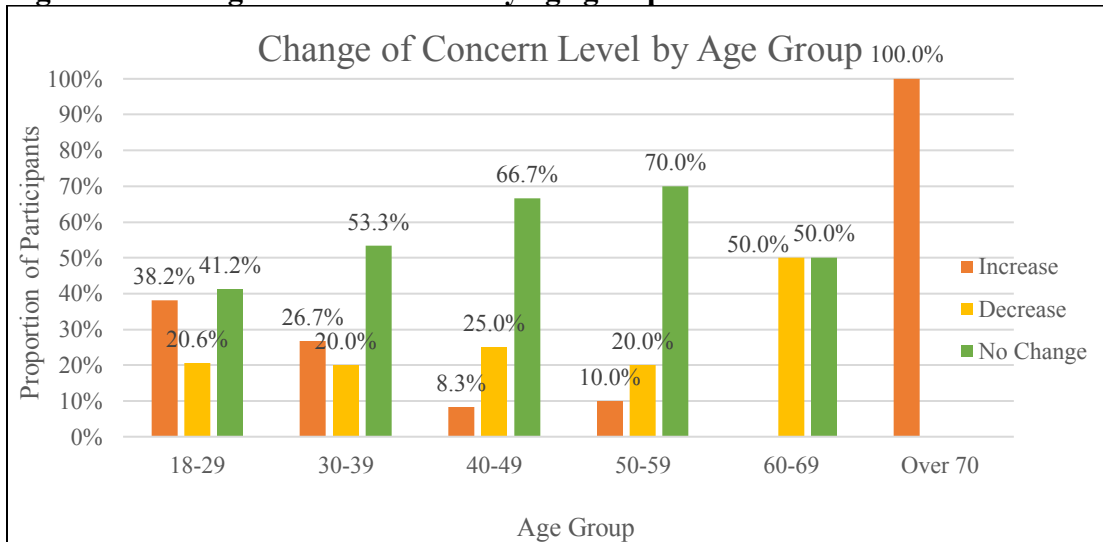
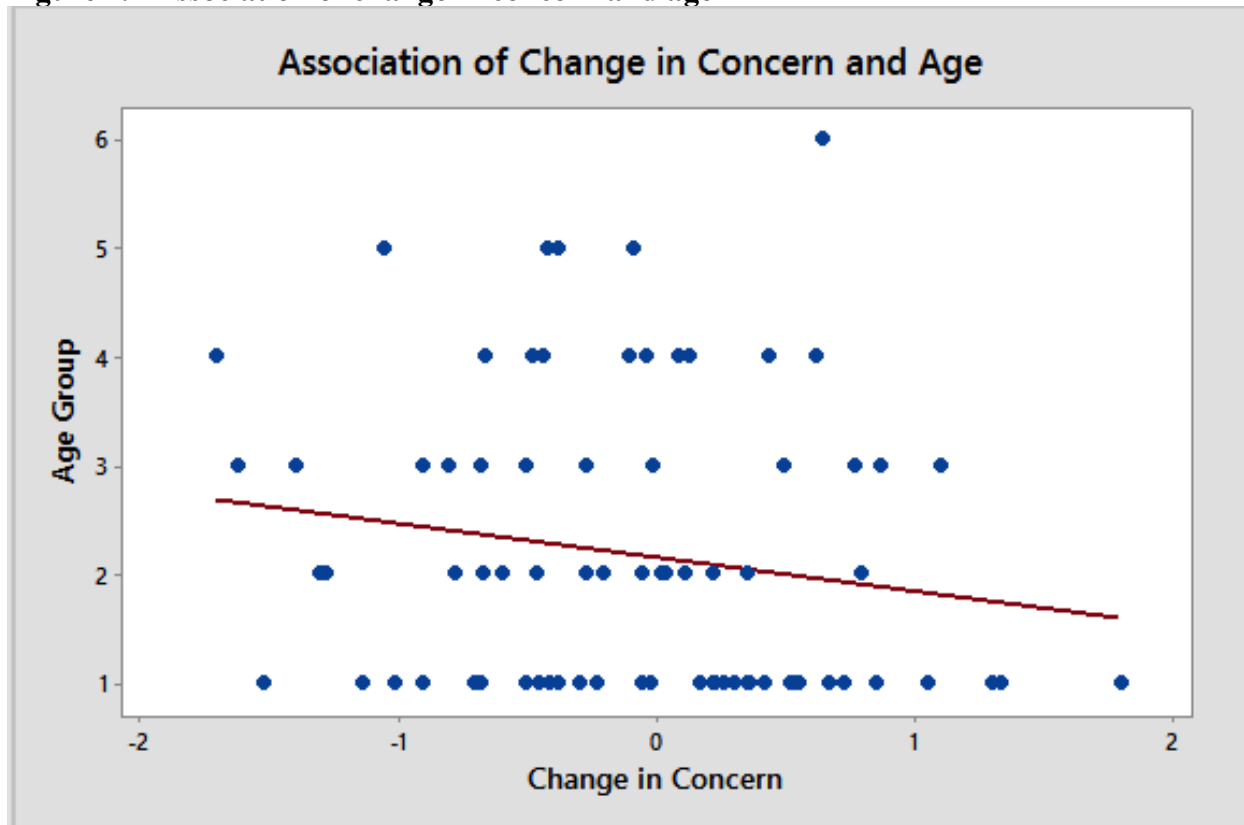


Figure 4.3 Change in concern level and participant age given in percentages. Missing concern levels indicate there were no participants in that category for that age group (n=76).

A Pearson's Correlation was used to determine whether there was a statistically significant association between age group of a participant and change in concern. There was a weak negative correlation, signifying there was a decrease in concern, between the two variables that was not statistically significant ($r(74) = -0.172$, $p = 0.138$) (Figure 4.4).

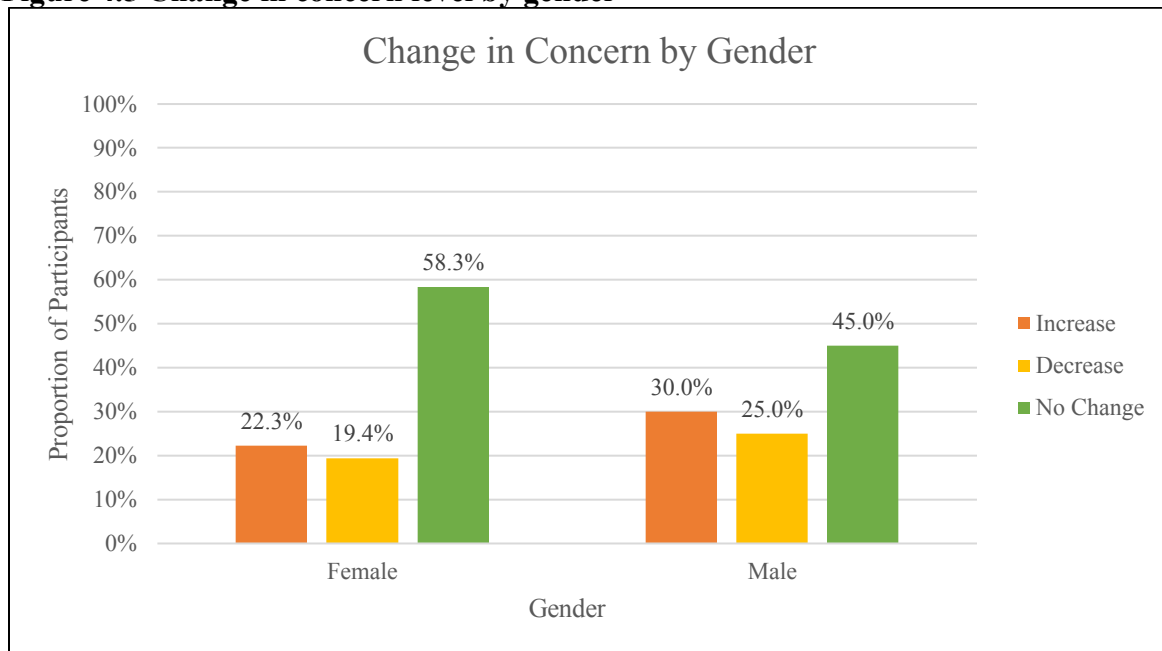
Figure 4.4 Association of change in concern and age



Association between age group of participants and change in concern of pre-and post-survey. Participant age was categorized into groups and recoded as follows: 1 = 18-29, 2 = 30-39, 3 = 40-49, 4 = 50-59, 5 = 60-69, 6 = 70 and over.

Of the 76 respondents, 48% were male and 52% were female. Of the females, 22.3% increased in concern, 19.4% decreased in concern and 58.3% had no change in concern level for climate change. For males, 30.0% increased in concern, 25.0% decreased in concern and 45.0% had no change in concern for climate change. Overall, men had a higher 'Increase' in concern level (30.0%) and women had a high percentage of 'No Change' in concern level (58.3%) (Figure 4.5).

Figure 4.5 Change in concern level by gender

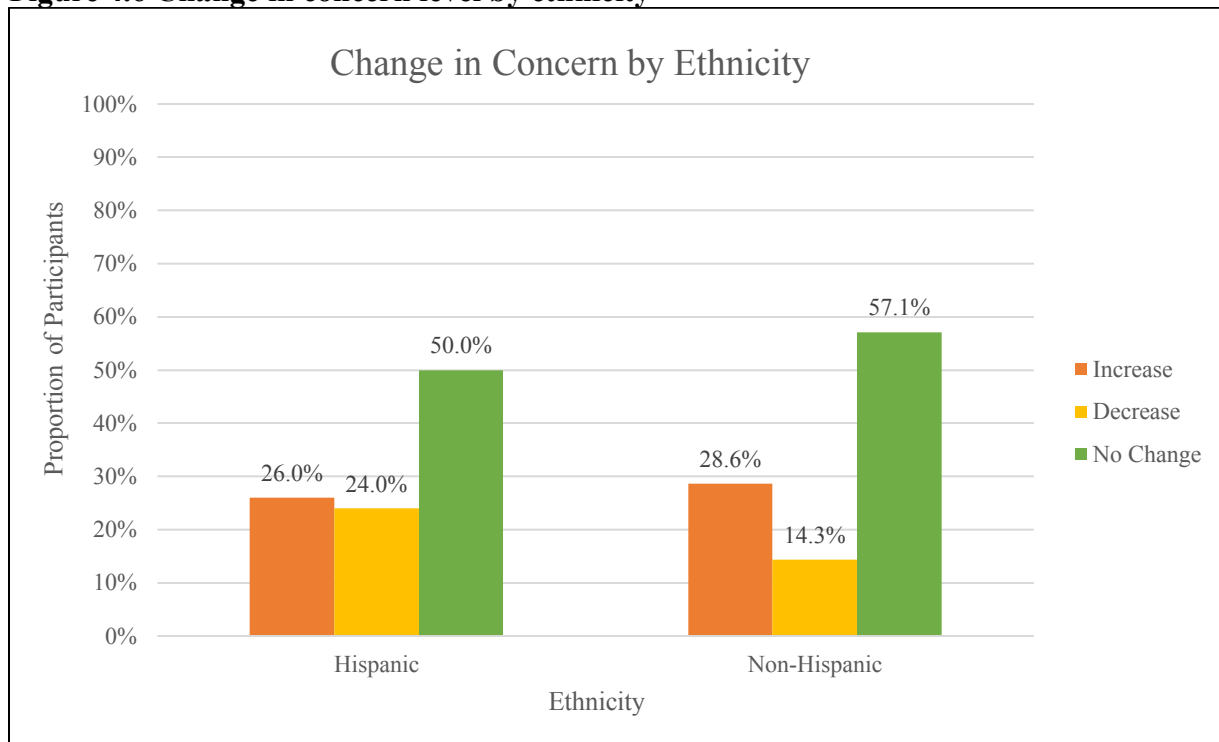


Change of concern level of participants and gender given as number of participants (n= 76).

Association of gender with change in concern was statistically analyzed using a Point-Biserial correlation. No association was found between the participants' gender and change in concern ($r_{pb} = 0.081$, $p = 0.488$) which make the correlation not statistically significant, but there was a positive slope.

Ethnicity of participants were grouped into 'Hispanic' or 'Non-Hispanic' and 70% of participants were Hispanic while 30% were non-Hispanic. Of the 76 participants, six participants did not answer the question about their ethnicity (n= 71). Of the Hispanic 26.0% had an increase in concern, 24.0% had a decrease in concern and 50.0% had no change in concern level. Non-Hispanics had an increase of 28.6% increase in concern, 14.3% decrease in concern and 57.1% no change in concern level. Hispanic participants had a higher percentage of 'Decrease' in concern level and had a lower 'Increase' in concern level (Figure 9). Non-Hispanics had a higher percentage of 'No Change' in concern level although there 'Increase' in concern level was higher than Hispanics.

Figure 4.6 Change in concern level by ethnicity

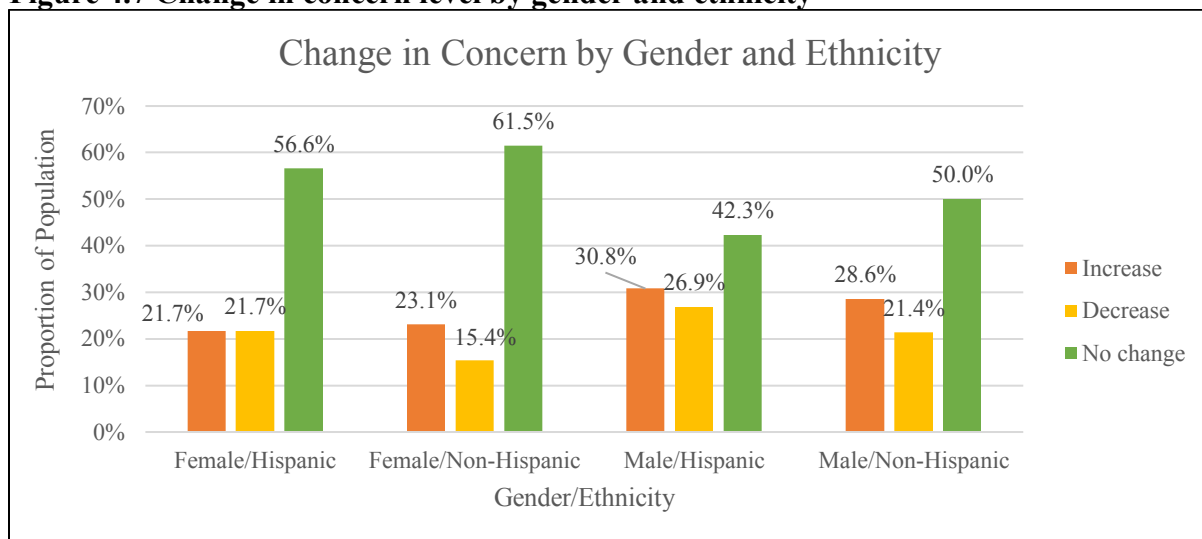


Change in concern level and education level of participants shown in percentages (n= 71).

A small negative association between ethnicity and change in concern was found using a Point-Biserial correlation. This correlation was not found to be statistically significant ($r_{pb} = -0.105$, $p = 0.388$), with a negative slope.

When looking at gender and ethnicity, Hispanic women had a high percentage of 'No Change' in concern level (56.5% - 61.5%) in the post-activity. Women who were non-Hispanic had a higher percentage of an 'Increase' in concern level (23.1%). Men who were Hispanic had a higher percentage in an 'Increase' concern level (30.8%) compared to non-Hispanic males and women (Figure 4.7).

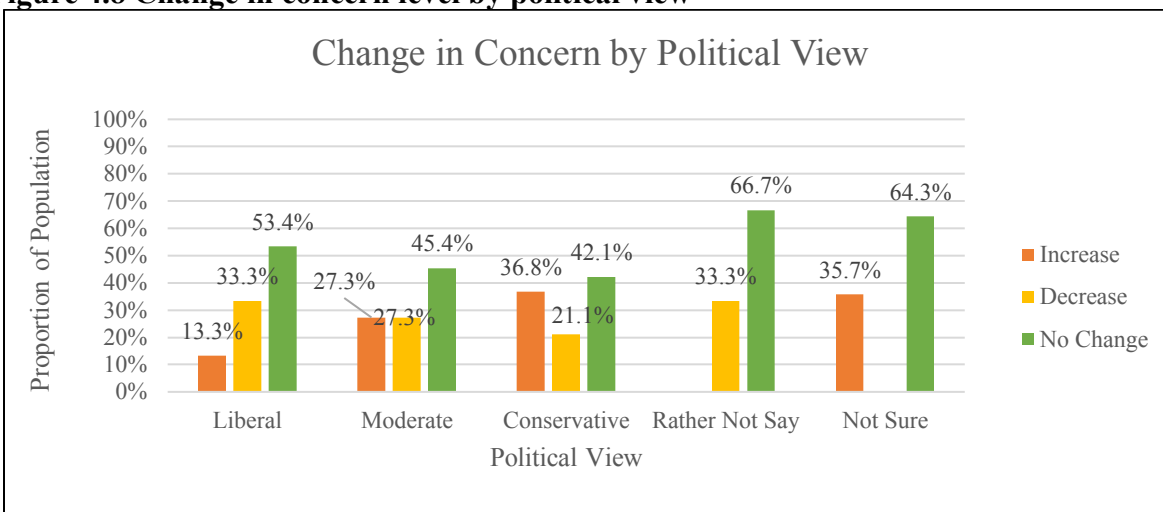
Figure 4.7 Change in concern level by gender and ethnicity



Change in concern level disaggregated by gender and ethnicity given in percentages (n= 76).

Political view was divided in groups as follows: Liberal (19.7%), Moderate (28.9%), Conservative (25.0%), Rather not say (7.9%), and Not sure (18.4%). Participants who associated as conservative had the highest percentage of 'Increase' in concern level (36.8%) than the other views. Participants who chose not to associate with a political view (66.7%) or those who were unsure (64.3%) had the highest percentage of 'No Change' in concern level. Participants who associated as conservative had a smaller percentage (42.1%) of 'No Change' when compared to participants who associated as liberal (53.4%); liberals (13.3%) had a smaller percentage of 'Increase' in concern than conservatives (36.8%) (Figure 4.8).

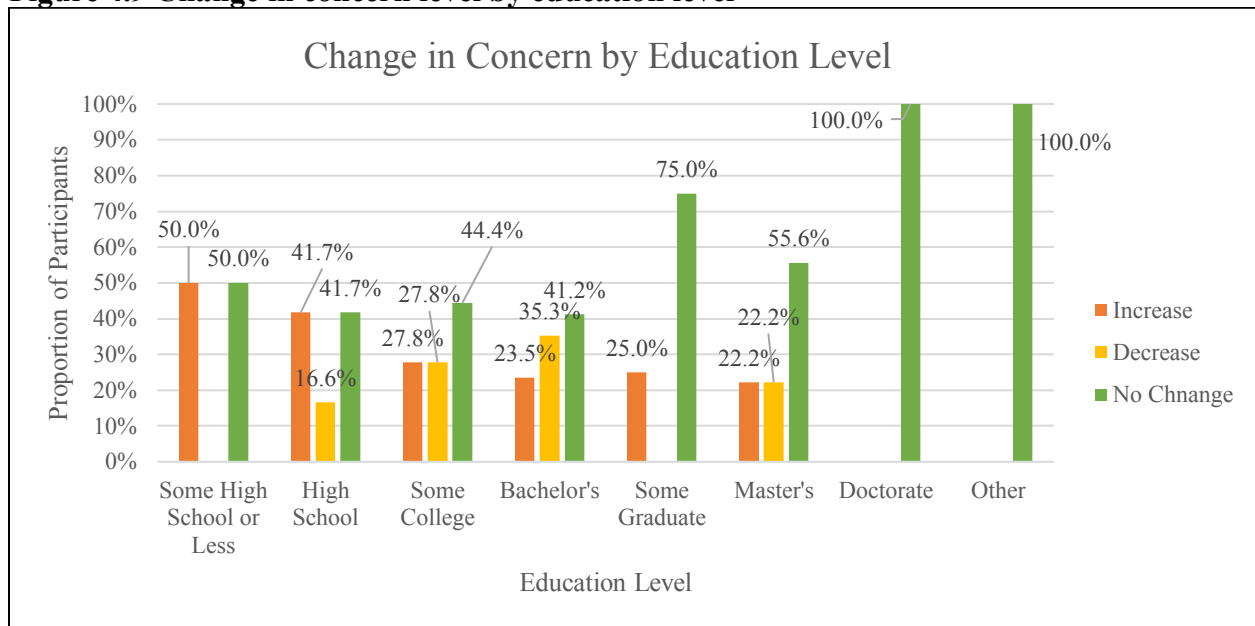
Figure 4.8 Change in concern level by political view



Change in concern level and political view given in percentages. Missing concern levels indicate there were no participants for that political view (n= 76).

Participant education level percentage were as follows: some High School or less (2.6%), High school graduate (15.8%), Some College (23.7%), Bachelors (22.4%), Some graduate (5.3%), Masters (23.7%), Doctorate (2.6%), and Other (3.9%). The percentage of participants with 'No Change' was high throughout the education levels. Participants who had any college education had the highest 'No Change' in concern level (Figure 4.9).

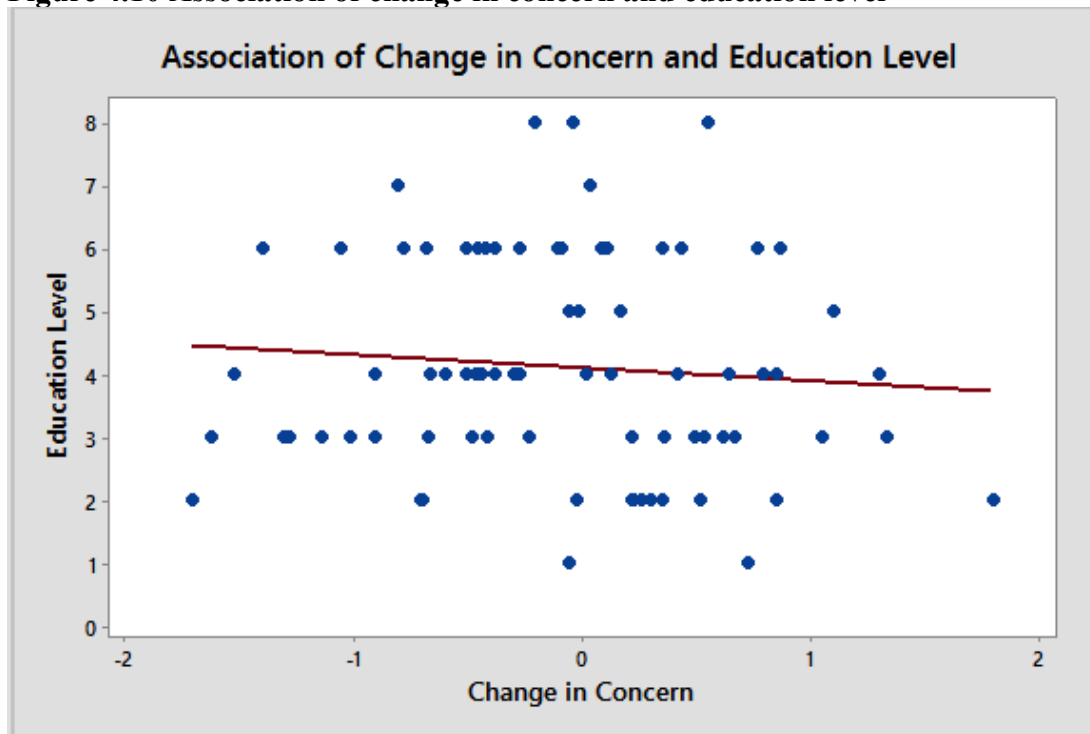
Figure 4.9 Change in concern level by education level



Change of concern level and education level shown in percentages. missing concern levels indicate there were no participants for that education level (n= 76).

The Spearman's correlation revealed a weak negative association between education level and change in level of concern (Figure 4.10), which was not statistically significant ($r_s = -0.12$, $p = 0.35$, $\alpha = 0.05$).

Figure 4.10 Association of change in concern and education level



Association between Education level of participant and the score difference from the pre-survey and post-survey. Participant responses were recoded as follows: 1 = Some High School or Less, 2 = High School Diploma, 3 = Some College, 4 = Bachelors, 5 = Some Graduate School, 6 = Masters, 7 = Doctorate, and 8 = Other.

Chapter 5: Discussion and conclusions

This study targeted the general public's concern on climate change (adults 18 years and older) and if this concern would change when given local climate change impacts with an active learning activity (hands-on). Data analysis compared a pre-survey given before the active learning activity to a post-survey that was given after the activity. This study sought to determine if a hands-on activity would change the concern of individuals based on the categorization of 'Alarmed', 'Concerned', 'Uncommitted', or 'Dismissive', hypothesizing that participants' concern who were Dismissive and Uncommitted would be more pronounced. Disaggregation of demographic data was also analyzed and correlations between gender, ethnicity, political view, and education level were made.

Political views have been the strongest predictor of environmental beliefs and a literature review completed by McCright et al. (2016) found that 67 to 69 surveys they reviewed showed that people who associated with the political left have a stronger pro-climate view than those who associate with the political right (Tjernström et al., 2008; Tranter et al., 2011; Clements et al., 2012; Engels et al., 2013; Hornsey et al., 2016). McCright et al. (2016) also found that two of the surveys that did not adhere to this consistent pattern were geographically limited samples and relatively small studies. The study found that although there was no statistically significant change in concern level for participants based on their political views, participants who associated as conservative had a higher increase in level of concern (36.8%), becoming more alarmed, than liberals who became more alarmed (13.3%). In contrast, more liberals had a decrease in concern (33.3%), becoming less alarmed, than conservatives who became less alarmed (21.1%). These results indicate that this curriculum (looking at data for themselves) was useful for increasing concern of AGW of conservatives while decreasing concern of liberals.

This method of communicating to the public caused individuals to move away from the extremes of their political view.

Results were consistent throughout in that there was no statistically significant change in the post-activity scores when providing local climate change impacts in the form of a hands-on activity. The data analysis indicated that 51% of participants showed no change in their concern for climate change, 26% increased in their concern and 23% decreased in concern of AGW resulting in a negative score differences from the pre- to post-activity. No statistically significant correlation was found between the independent variables (gender, ethnicity, political view, and education level) and participants' mean score difference from the pre- and post-activity results. The demographic variables all had a weak correlation in concern change.

Furthermore, results from the post-survey showed that 51% of adults had initially been concerned that climate change was occurring. The high number of already concerned adults may have led to the low number of changes in concern this study found. To interpret the results further, a summary is given below.

In many other studies, findings have shown that women have stronger pro-climate views than men (Brody et al., 2008; Tjernström et al., 2008; McCright, 2010; Kvaløy et al., 2012; Leviston, 2012; McCright et al., 2016). Although this study did not find that women had a higher increase in concern level, it could be that many women in this region are already aware of climate change impacts and that is why the study found that women had the largest no change in concern level.

Many studies have concluded that younger people have more concern for the environment and therefore have a higher concern for climate change impacts (Hornsey et al., 2016; Aldy et al., 2012, McCright, Dunlap, and Pyatt, 2016, McCright et al., 2016). This study is

consistent with these results in that younger adults (18-29) had a larger increase in concern for AGW than the other ages. Furthermore, older adults (40-59) had the highest no change in concern level for AGW.

In a recent study, Shi et al. (2016) found that there are different dimensions of knowledge and that these shape peoples' concern of climate change and therefore knowledge continuous to be an important driver of concern (Tobler et al., 2012). Through a literature review, Shi et al. (2016) found that many studies who do not find a correlation between knowledge and concern level believe concern is linked to values instead of knowledge. Yet, through the study, Shi et al. (2016) concluded that the different dimensions of knowledge are not all important for public concern on climate change and helps to better understand why some studies do not find significant relationship between knowledge and public concern level. Results for the study found that knowledge of 'physical characteristics' of climate change tends to have a negative effect on a person's concern (or no significant effect) while knowledge of 'causes of climate change' leads to a higher concern (Shi et., 2016, p 759). The results for the study at hand found that there was no significant change in participants' concern and are similar to the results found by Shi et al., (2016) when comparing the kind of information about climate change that was given to participants. This study focused more on providing physical characteristics of climate change.

There is still much uncertainty among Americans as recently as of 2011. The Global Warming Six America's has divided the public into several categories that are similar to the ones used in this study (Leiserowitz et al., 2011). The study reported that 39% of Americans fall into the groups Alarmed and Concerned and a quarter of Americans fall under Dismissive and Doubtful. Leiserowitz et al. (2011, p 5) found that a third of Americans stated, "they could easily change their minds about global warming", which included the Disengaged (73%) and Cautious

(58%) segments. Based on the on this study, it is important for climate change communication to continue to sway those in the Disengaged and Cautious groups into Concerned or Alarmed level of concern. Four of the Six Americas stated, “if given the chance to talk to an expert on the issue” they would ask nine out of the 13 questions given in the study (Leiserowitz et al., 2011, p 6). It seems the American people are seeking for the information, but have not been successful in obtaining it.

In a study by Sterman (2011), they argue how communication of technical reports and information can be improved by providing different kinds of communication rather than simply providing additional information in hopes that it will automatically change people’s concern. A widening gap and low scientific literacy makes climate change messaging even more challenging (Sterman, 2011). According to Sterman (2011, p 7), “people generally do not reason in accordance with the principles of scientific method” and more concerning, other studies have found that people’s belief in global warming is affected by daily temperature (Egan & Mullin, 2010; Sterman, 2011; Li et al, 2011). Sterman (2011) also suggests that scientific communication reports should be written in plain language and with minimal technical jargon to encourage better scientific literacy and inquiry skills. Furthermore, Sterman, (2011 p 15) suggests that “effective risk communication must catalyze learning at a level deep enough to change entrenched mental models” and that “mere transition of information is not sufficient” (Weber & Stern, 2011).

5.1 Implications

Although Shi et al. (2016) states that studies who find no significant relationship among knowledge and public concern tend to tie values to concern of the public, further investigation needs to be done if a hands-on activity would have a greater impact on public concern of climate

change when it includes the public's values and worldview (Kellstedt et al., 2008; Kahun et al., 2012). Measuring the results in a better way also leads to better understanding of what really impacts the public's concern on AGW. Shi et al. (2016) suggests that using an objective measure is more qualified than using a subjective measure and that public education is not a lost cause. Focusing on carefully developed messages and material while accounting for the public's values, may lead to a greater success in changing the public's concern on climate change (Shi et al., 2016) and for this study may be beneficial to try some of these suggestions along with the online curriculum.

5.2 Suggestions for future research

This research was preliminary and exploratory in nature, and as such, explored a wide range of potentially mediating factors using a variety of statistical tests. Future work will include engaging a statistician to assist with analyzing the data on the impact of political view on change in level of concern. This will facilitate design of more nuanced approaches to assessing potential significance of the existing results, and better framing subsequent data collection and analysis.

An issue that arose with the survey curriculum were two items that did not load properly during the distribution of the survey. In several events, it was found that the species distribution model, Lifemapper, and the climate data websites did not display the climate information due to loading issues. Online based surveys can provide a great mode to distributing online information, but can have several issues as well. The online glitches would have been remedied with proper Wi-Fi connection and distribution of the survey would have reached a larger number of participants if it had been sent out digitally with a consensus form embedded to the survey web link. For an online survey the best method of distribution is through email and other online

sources. To target a larger audience a consent form can be included in the interface prior to sending out the survey. This would allow for participants to take the survey at their own convenience allowing participants to complete the survey and would also help with longer survey time. The questions that had initially been asked after each section (CO₂ mechanism, climate data, climate models, Lifemapper, and water source) would have been useful to evaluate the degree to which participants learned targeted concepts from the activities in each section and allowing this study to better understand the changes that occurred and if results were indeed due to a high initial concern of climate change.

Although this study was conducted in an informal setting future work may include the transferring of this active learning activity into a formal setting and creating a lengthier curriculum. One way that this can be done is through the enhancing of each activity so that each section can be a lesson given to students in the span of a week or longer. Each lesson can focus on one of the five sections in more detail and with added hands-on activities. One unit with five modules for each activity can be created for this curriculum and several hands-on activities can then be incorporated into each of the modules. Activities can vary depending on the information the teacher wishes to cover and can include websites, graphic organizers, concept maps, worksheets, group research projects, tests and quizzes, role playing and writing in class such as keeping journals (Bonewall & Eison, 1991; Bellanca, 2009).

The previous activities are instructional tactics that engage a student's mind which enables them to transform from a passive learning state to an "active state where they are generators of knowledge" (Bellanca, 2009, p 7). Another important tactic for incorporating an active learning approach into the classroom includes discussion between students which can be facilitated by the teacher by pausing ten to twenty minutes during a lecture (Bonewell & Eison,

1991). The pauses during the lecture allow students to discuss and rework their notes with their peers leading to a better comprehension of the subject (Bonewell & Eison, 1991). The curriculum can be used in college courses as well as for high school and middle schools. Although the curriculum seems to be advanced for younger students, Bruner (1966), a known constructivist author stated that “any subject can be taught effectively in some intellectually honest form to any child at any stage of development” (p 33).

It is important to try and convince the public of human caused climate change and the impacts it will have if no action is taken. It may be more important to begin educating the younger generations in this concept as they are the future of the world.

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Appendix A. Complete list of survey questions.

Pre-Survey		
Question Number	Question	Answer Choices
1	How important is the issue of climate change to you?	7- Very important, 6- Important, 5- Moderately important, 4- Not sure, 3- Moderately unimportant, 2- Of little importance, 1- Unimportant
2	To what degree are you aware of potential local impacts of climate change on biodiversity?	7- Extremely aware, 6- Moderately aware, 5- Somewhat aware, 4- Unsure, 3- Somewhat unaware, 2- Moderately unaware, 1- Extremely unaware
3	How concerned are you that local animal and plant species may be threatened to become extinct	7- Very concerned, 6- Moderately concerned, 5- Somewhat concerned, 4- Unsure, 3- Somewhat unconcerned, 2- Moderately unconcerned, 1- Not at all concerned
4	How concerned are you that your outdoor activities may be threatened by climate change?	7- Very concerned, 6- Moderately concerned, 5- Somewhat concerned, 4- Unsure, 3- Somewhat unconcerned, 2- Moderately unconcerned, 1- Not at all concerned
5	I am uncertain that climate change is occurring	1- Strongly agree, 2- Agree, 3- Somewhat agree, 4- Neither agree nor disagree, 5- Somewhat disagree, 6- Disagree, 7- Strongly disagree
6	I believe that there is still plenty of time to prepare for climate change	1- Strongly agree, 2- Agree, 3- Somewhat agree, 4- Neither agree nor disagree, 5- Somewhat disagree, 6- Disagree, 7- Strongly disagree
7	The effects of global climate change have not yet begun	1- Strongly agree, 2- Agree, 3- Somewhat agree, 4- Neither agree nor disagree, 5- Somewhat disagree, 6- Disagree, 7- Strongly disagree
8	I believe climate change will affect me personally	7- Strongly agree, 6- Agree, 5- Somewhat agree, 4- Neither agree nor disagree, 3- Somewhat disagree, 2- Disagree, 1- Strongly disagree
9	I am not concerned about water supply in the region I live in	1- Strongly agree, 2- Agree, 3- Somewhat agree, 4- Neither agree nor disagree, 5- Somewhat disagree, 6- Disagree, 7- Strongly disagree
10	Human-induced global climate change is widely accepted by most of the scientific community	7- Strongly agree, 6- Agree, 5- Somewhat agree, 4- Neither agree nor disagree, 3- Somewhat disagree, 2- Disagree, 1- Strongly disagree
11	I believe the effects of climate change have already begun	7- Strongly agree, 6- Agree, 5- Somewhat agree, 4- Neither agree nor disagree, 3- Somewhat disagree, 2- Disagree, 1- Strongly disagree
12	I believe the majority of global climate change is occurring by human activities	7- Strongly agree, 6- Agree, 5- Somewhat agree, 4- Neither agree nor disagree, 3- Somewhat disagree, 2- Disagree, 1- Strongly disagree

13	I believe there is not enough time to prepare for climate change	7- Strongly agree, 6- Agree, 5- Somewhat agree, 4- Neither agree nor disagree, 3- Somewhat disagree, 2- Disagree, 1- Strongly disagree
14	Climate change will not affect me personally	1- Strongly agree, 2- Agree, 3- Somewhat agree, 4- Neither agree nor disagree, 5- Somewhat disagree, 6- Disagree, 7- Strongly disagree
15	I am concerned about water supply and availability in my region	7- Strongly agree, 6- Agree, 5- Somewhat agree, 4- Neither agree nor disagree, 3- Somewhat disagree, 2- Disagree, 1- Strongly disagree
16	I believe the majority of global climate change is occurring by natural changes in the environment	1- Strongly agree, 2- Agree, 3- Somewhat agree, 4- Neither agree nor disagree, 5- Somewhat disagree, 6- Disagree, 7- Strongly disagree
17	The seriousness of climate change is exaggerated	1- Strongly agree, 2- Agree, 3- Somewhat agree, 4- Neither agree nor disagree, 5- Somewhat disagree, 6- Disagree, 7- Strongly disagree

Post-Survey		
Question Number	Question	Answer Choices
1	I am more alarmed about climate change than when I started this activity	7- Strongly agree, 6- Agree, 5- Somewhat agree, 4- Neither agree nor disagree, 3- Somewhat disagree, 2- Disagree, 1- Strongly disagree
2	Climate change will pose a threat to me or my way of life in my lifetime	7- Strongly agree, 6- Agree, 5- Somewhat agree, 4- Neither agree nor disagree, 3- Somewhat disagree, 2- Disagree, 1- Strongly disagree
3	I am not concerned about water supply in my region	1- Strongly agree, 2- Agree, 3- Somewhat agree, 4- Neither agree nor disagree, 5- Somewhat disagree, 6- Disagree, 7- Strongly disagree
4	I believe the majority of global climate change is occurring by natural changes in the environment	1- Strongly agree, 2- Agree, 3- Somewhat agree, 4- Neither agree nor disagree, 5- Somewhat disagree, 6- Disagree, 7- Strongly disagree
5	Climate change will not pose a threat to me or my way of life in my lifetime	1- Strongly agree, 2- Agree, 3- Somewhat agree, 4- Neither agree nor disagree, 5- Somewhat disagree, 6- Disagree, 7- Strongly disagree
6	I believe the majority of global climate change is occurring by human activities	7- Strongly agree, 6- Agree, 5- Somewhat agree, 4- Neither agree nor disagree, 3- Somewhat disagree, 2- Disagree, 1- Strongly disagree
7	The seriousness of climate change is exaggerated	1- Strongly agree, 2- Agree, 3- Somewhat agree, 4- Neither agree nor disagree, 5- Somewhat disagree, 6- Disagree, 7- Strongly disagree
8	I am more concerned about water supply and availability in my region.	7- Strongly agree, 6- Agree, 5- Somewhat agree, 4- Neither agree nor disagree, 3- Somewhat disagree, 2- Disagree, 1- Strongly disagree
9	I am more aware of how climate change will affect me personally	7- Strongly agree, 6- Agree, 5- Somewhat agree, 4- Neither agree nor disagree, 3- Somewhat disagree, 2- Disagree, 1- Strongly disagree
10	I am concerned about how global climate change will affect my outdoor activities	7- Strongly agree, 6- Agree, 5- Somewhat agree, 4- Neither agree nor disagree, 3- Somewhat disagree, 2- Disagree, 1- Strongly disagree
11	To what degree are you now aware of potential local impacts of climate change on biodiversity?	7- Extremely aware, 6- Moderately aware, 5- Somewhat aware, 4- Unsure, 3- Somewhat unaware, 2- Moderately unaware, 1- Extremely unaware
12	In general, do you think that a rise in the world's temperature caused by the "greenhouse effect"	7- Extremely dangerous, 6- Very dangerous, 5- Somewhat dangerous 4- Unsure, 3- Somewhat not dangerous, 2- Not very dangerous, 1- Not at all dangerous

	is dangerous to the environment?	
13	To what extent are you willing to take personal action to reduce your own carbon emissions?	1- Extremely unwilling, 2- Moderately unwilling, 3- Somewhat unwilling, 4- Neither unwilling nor willing, 3- Somewhat willing, 2- Moderately willing, 1- Extremely willing
14	How convinced are you that climate change is actually happening- would say that you are	7- Was already convinced, 6- Completely convinced, 5- Mostly convinced, 4- Unsure, 3- Mostly unconvinced, 2- Completely unconvinced, 1- Not convinced at all
15	When it comes to the issue of global climate change, how well do you feel you understand this	7- Understood it very well, 6- Understood most of it, 5- Moderately well, 4- Not sure, 3- Understood a little, 2- Not very well, 1- Did not understand

Appendix B. Tables for demographic variables.

Table 4.2. Change in concern level and gender given in percentages

Gender	Increase	Decrease	No Change
Female	22.3%	19.4%	58.3%
Male	30.0%	25.0%	45.0%

Table 4.3. Change in concern and ethnicity given in percentages

Ethnicity	Increase	Decrease	No Change
Hispanic	26.5%	24.5%	49.0%
Non-Hispanic	28.6%	14.3%	57.1%

Table 4.4. Change in climate change concern level disaggregated by gender and ethnicity

Gender/Ethnicity	Increase	Decrease	No change
Female/Hispanic	21.7%	21.7%	56.6%
Female/Non-Hispanic	23.1%	15.4%	61.5%
Male/Hispanic	30.8%	26.9%	42.3%
Male/Non-Hispanic	28.6%	21.4%	50.0%

Table 4.5. Change in concern and political view. Missing values indicate there was no participants for that political view

Political View	Increase	Decrease	No Change
Liberal	13.3%	33.3%	53.4%
Moderate	27.3%	27.3%	45.4%
Conservative	36.8%	21.1%	42.1%
Rather Not Say		33.3%	66.7%
Not Sure	35.7%		64.3%

Table 4.6. Concern level and education level. Missing values indicate there were no participants of that age group or concern level

Education Level	Increase	Decrease	No Change
Some High School or Less	50.0%		50.0%
High School	41.7%	16.6%	41.7%
Some College	27.8%	27.8%	44.4%
Bachelor's	23.5%	35.3%	41.2%
Some Graduate	25.0%		75.0%
Master's	22.2%	22.2%	55.6%
Doctorate			100.0%
Other			100.0%

Vita

My name is Ivy Gisselle Trevizo and I attended Wayland Baptist University where I received a Bachelor's of Science in 2011. As an undergraduate student, I worked on a research project titled Experimental test of the Function of Rock Wren Nest Pavement. In 2012, I participated in an internship at Au Sable Institute of Environmental Studies where I was an Environmental Education Intern and taught Natural Science and Michigan History to K-12 grade students. In 2015, I participated in Upward Bound Summer Camp where I helped lead a UTEP Earth Tech summer camp for high school students. This program is a part of a year-round college preparatory program for students from low-income families. I helped lead science programs such as water sampling and testing, mapping and led field trips to Hueco Tanks and the Water Treatment plant. I also participated in the Diana Natalicio internship at the USDA-Southwest Climate Hub in Summer of 2017. I was tasked with creating a presentation on the mistakes scientists make when communicating climate change. I also worked on a Climate Masters project with a goal of creating a volunteer culture of Climate Masters to increase climate literacy and support both adaptation and mitigation activities. I have held the job of a substitute teacher since 2014 at the Socorro Independent School District where I provide classroom instruction for K-8th grade students. I am also a volunteer at the Franklin Mountain State Park and help lead hikes.

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This thesis/dissertation was typed by Ivy G. Trevizo