The Effect of a Climate Change Learning Cycle on Pre-Service Teachers' Perceived Knowledge, Beliefs, Concerns, and Sense of Environmental Responsibility

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Abstract

Background: Climate change is recognized as one of the world's most pressing challenges. As domestic and global environmental events become more frequent and severe devastating multifaceted consequences ensue for humans and the environment. In order to reduce the implications of climate change, positive environmental actions are required by human societies. Pre-service science teachers play an important role in educating students about climate change concepts, their behaviors and empowering them as future citizens to adopt pro-environmental behaviors that may reduce implications of climate change. Teachers' environmental knowledge, beliefs, and concerns about climate change have been found to significantly impact their personal pro-environmental behaviors which may then be adopted by their students. **Purpose:** This research study investigated pre-service teachers' perceived environmental knowledge, beliefs, concerns, and sense of responsibility about domestic and global catastrophic environmental events before and after a pre-service climate change learning cycle. Findings may inform climate change pedagogical approaches and content in elementary science education programs. The research questions were as follows: (1) What was the effect of climate change instruction on pre-service teachers' perceived environmental knowledge? (2) What was the effect of climate change instruction on pre-service teachers' level of environmental concerns? (3) What was the effect of climate change instruction on pre-service teachers' sense of environmental responsibility? (4) What was the effect of climate change instruction on pre-service teachers' pro-environmental beliefs? **Methods:** This intervention study used a single-group pretest and posttest design to collect and analyze quantitative data regarding pre-service teachers' perceived environmental knowledge, level of environmental concerns, pro-environmental beliefs, and sense of environmental responsibility before and after a climate change learning cycle. The study was part of a science content unit taught using online modes of instruction to 47 pre-service teachers by an experienced science educator in their science methods course. Archival survey data obtained before and after the climate change lesson were used for data interpretation. Paired sample *t*-tests were used to compare the pretest and posttest scores to determine the treatment effects on pre-service teachers' environmental knowledge, concerns, beliefs, and sense of environmental responsibility. **Results:** The findings indicated that the intervention climate change learning cycle significantly improved pre-service teachers' perceived environmental knowledge, level of concerns, and sense of environmental responsibility. No significant pre-post gains were found for pre-service teachers' level of pro-environmental beliefs. **Conclusion:** The findings indicate that a short-term online intervention using an online climate change learning cycle can positively affect future science educators' perceived knowledge, levels of concern about climate change, and sense of responsibility regarding the environment. These teachers may, in turn, pass these beliefs on to students. Follow-up studies are needed to assess participants' implementation of climate science education in their elementary school classrooms and examine the status of their elementary students' environmental beliefs, attitude, concerns, and sense of responsibility regarding environmental and climate topics.

Keywords: climate, teachers, environment, responsibility, cycle

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Chapter I

Introduction

Climate change is a local and global environmental hazard and major issue of the 21st century. According to Orr (2009), the effects of climate change cannot be removed or reversed, and consequently can only be contained. Vast bodies of literature and scientific evidence have emerged shedding light on how human activity has significantly impacted the world's climate systems. A series of local, regional, national, and global disasters have occurred linked to climate change that have resulted in huge social, environmental, and economic consequences.

A sequence of extreme flooding events inflicted devastation on coastal Texas in the past years, including Tropical Storm Allison (2001), Hurricane Ike (2008), Memorial Day Flood (2015), and Tax Day Flood (2016) (Satija et al., 2016). In 2017, Hurricane Harvey struck landfall and became the wettest tropical cyclone on record in the United States, leaving a trail of destruction and having been responsible for at least 68 direct deaths in Texas (Blake & Zelinsky, 2018). Studies have found that the increased chances of observed precipitation that accumulated during Hurricane Harvey are likely a result of human-influenced climate change (Risser & Wehner, 2017; Trenberth et al., 2018). Northern California experienced the most extreme fire season on record in 2018, having 22,000 structures destroyed, 600,000 hectares burned, and 95 fatalities (Brown et al., 2019). 2018 was also California State's costliest wildfire season, having experienced the most destructive wildfire and largest wildfire to date (Brown et al., 2019). These observed wildfires in California are also linked to anthropogenic climate change (Williams et al., 2019).

The global world has also experienced environmental events that have inflicted considerable destruction to environments and people. The Amazon rainforest, the world’s largest rainforest with the planet's largest river system containing millions of plant and animal species, experienced over 80,000 fires in 2019 (National Institute for Space Research, 2019). It is estimated that the fires inflicted losses on over 906,000 hectares of land in an ecological system that provides services to local and world populations (Antonelli et al., 2018). The abundant and vast plant ecosystem in the Amazon absorbs numerous amounts of the world’s carbon dioxide gas yearly, and these ecological losses due to fires reduces the absorption impacts.

As significant climate issues occur throughout the world, citizens and governments need to be informed and play important roles in order to control and reduce climate change. Through all the destruction and devastations occurring, researchers have pushed for educational efforts with the ultimate goal of promoting environmentally responsible behavior (Huber, 2018; Savitz-Romber et al., 2015; Wolff & Booth, 2017). Educational efforts have focused on developing the attitudes, knowledge, and skills of students in order to encourage pro-environmental behaviors and environmental stewardship in their lives. Research has shown that driving behavior change through accumulating knowledge alone about content is insufficient, and other variables must be considered in support of actions (Ajzen, 2001; Heberlien, 2012). Scholarship has shown that attitudes are among the most significant determinants of behavior and behavioral change, with studies showing strong correlations between positive attitudes and pro-environmental behaviors (Garrison, 1995; Kraus, 1995; Mohai, 1992; Weaver, 1996).

Research Problem

The National Center for Science Education (NCSE) investigated in their national study in what ways climate change was taught in America's public schools and found that a significant portion of teachers had limited to inadequate formal instruction in climate science in their teacher preparation programs in college (Pultzer et al., 2016a). The national study indicated in its report that many science teachers lacked appropriate scientific knowledge and understandings about climate change, with many of them being unaware of the extent of scientific agreement about climate change.

Teachers can play an essential role in influencing their students' lives through enabling them to become scientifically informed citizens who can significantly control and reduce effects of climate change through pro-environmental behaviors (Skamp et al., 2012). The relationships and connections between environmental knowledge and environmental attitudes in helping promote pro-environmental behavior and responsibility have been investigated by many research studies (Liobikiene & Poskus, 2019; Slavoljub et al., 2015). Likewise, studies have also researched the relationship between environmental concerns and the effects, significance, and influence on environmental attitudes (Clark et al., 2003). Additionally, researchers have explored the connection and impact of environmental concerns on guiding learners' environmentally related behaviors (Arisal & Atalar, 2016; Chen & Tung, 2014; Li et al., 2019). As researchers investigate variables that can transform behaviors, recent research has sought to investigate the impact of domestic and global environmental concerns on the connection between environmental knowledge and beliefs and that of environmental responsibility on pre-service teachers (Janmaimool & Chudech, 2020). Janmaimool and

Chudech (2020) found that understanding the relations between these different variables could translate into better communications of global climate change issues that can support changes in behaviors towards pro-environmental actions. Their results showed that local and international disastrous environmental incidents could increase students' level of concern for the environment and heighten their sense of moral accountability to safeguard the environment. Further research on this topic can translate into better curriculum development and instruction for pre-service teachers that can promote pro-environmental behaviors for them and their students.

Purpose of Research Study

Adequate preparation of science teachers requires development of pre-service teacher education programs that focus on teachers' knowledge of basic climate change concepts as well as understanding of climate change models and how climate systems works (Herman et al., 2017; Wise, 2010). These programs are essential in enhancing teachers' content knowledge on climate change and addressing misunderstandings about the research on climate change. The purpose of this study was to examine the effect of a climate change learning cycle on preservice teachers' perceived knowledge, beliefs about climate change, levels of concern about climate change, and sense of responsibility related to the environment, in order to inform future implementation of climate change instruction within science methods courses for pre-service teachers.

Research Questions

The study addressed the following research questions:

1. What was the effect of climate change instruction on pre-service teachers' perceived environmental knowledge (PEK)?

2. What was the effect of climate change instruction on pre-service teachers' level of environmental concerns (EC)?
3. What was the effect of climate change instruction on pre-service teachers' sense of environmental responsibility (ER)?
4. What was the effect of climate change instruction on pre-service teachers' pro-environmental beliefs (EB)?

Hypothesis

The research questions posted in the preceding section of the study were the foundation for the subsequent null hypothesis:

1. There was no statistically significant difference in pre-service teachers' perceived environmental knowledge prior to participating in climate change instruction and the environmental knowledge of those pre-service teachers after participating in the instruction.
2. There was no statistically significant difference in pre-service teachers' level of environmental concerns prior to participating in climate change instruction and the level of environmental concern of those pre-service teachers after participating in the instruction.
3. There was no statistically significant difference in pre-service teachers' sense of environmental responsibility prior to participating in climate change instruction and the sense of environmental responsibility of those pre-service teachers after participating in the instruction.
4. There was no statistically significant difference in the level of pre-service teachers' pro-environmental beliefs prior to participating in climate change

instruction and the level of pro-environmental beliefs of those pre-service teachers after participating in the instruction.

Definition of Terms

Perceived Environmental Knowledge (PEK): One's subjective knowledge about what they perceive they know about nature, environments, and relevant issues.

Environmental Knowledge (EK): One's comprehension of the nature, environments, and related concerns, such as existing environmental conditions, the origins of environmental problems and potential impacts (Chan & Lau, 2000).

Environmental Concern (EC): The extent to which humans are concerned about the environmental challenges which include both local and international environmental challenges (Janmaimool & Chudech, 2020).

Environmental Responsibility (ER): It describes a sense of personal accountability toward the environment or sense of obligation to take action to prevent detrimental effects on the environment (Janmaimool & Chudech, 2020).

Environmental Beliefs (EB): It describes the notions of an individual relationship to the natural environment (Lee & Hae, 2017).

Environmental Attitude (EA): It refers to peoples' common beliefs about the connections between human and environment, also called environmental worldview (Janmaimool & Chudech, 2020).

Digital Interactive Science Notebook (DISN): It provides students an online space that can be utilized to organize digital content.

Intergovernmental Panel on Climate Change (IPCC) Reports: The IPCC prepares thorough Assessment Reports about understandings on climate change, its origins, potential influences and response decisions (IPCC, 2014).

Next Generation Science Standards (NGSS): National science standards that were created based on the recommendations of the Framework for K-12 Science Education developed by the National Research Council (NGSS, 2013).

One-Group Pretest-Posttest Design: A type of research design in which all participants are subjected to identical conditions. A pre-test is administered on the dependent variable, followed by implementation of a treatment, and concluding with the administration of a post-test on the dependent variable again (Gall et al., 2003).

EdPuzzle: It is a free evaluation-centered platform that allows teachers and students to design and construct interactive online videos by inserting open-ended or multiple-choice questions, audio notes, audio tracks, or commentaries on a video (Edwards, 2021).

Padlet: It is an educational technology company that provides a cloud-based software-as-a-service, presenting a real-time collaborative web platform in which users can upload, manage, and distribute content to online bulletin boards called “padlets.” (Perez, 2015)

Pre-service teachers: In this study, pre-service teachers were college students enrolled in a teacher education program specifically designed for training future early childhood to sixth grade teachers.

Pro-Environmental Behaviors: They are behaviors and actions that seeks to minimize the negative impact on the environment (Steg & Vlek, 2009).

Texas Essential Knowledge and Skills (TEKS): A curriculum developed by the State Board of Education in Texas that identify what students should learn and be able to achieve at each grade level (TEA, 2019).

Chapter II

Literature Review

This chapter consists of major pieces of literature on the subject of climate change, teacher's beliefs, knowledge, and attitudes about climate change, and an analysis of the variables grounding the primary elements of this research. This study investigates and reports on preservice teachers' concerns about domestic and global catastrophic environmental events. It also examines how climate change instruction effects these concerns in addition to analyzing perceived environmental knowledge, beliefs, and sense of environmental responsibility of preservice teachers. This chapter begins with a general summary of climate change and the scientific discussions surrounding it. An analysis of the relation between teacher knowledge and attitudes towards climate change follows. A brief analysis of the literature on variables that develop the theoretical framework for this study follows. The final sections of this chapter discuss literature related to instructional design.

What is Climate Change?

The United Nations (2015) states that climate change is one of the most important environmental difficulties in the present-day that is global in scope and unprecedented in scale. Climate change refers to any considerable change in the Earth's climate and may include significant changes in temperature, precipitation, or wind patterns over long periods of time (EPA, 2017). In recent years, the term "climate change" has been accepted by scientific community instead of "global warming" to describe the increased heat presence in the atmosphere (Benjamin et al., 2016). This phenomenon refers to the continuing increase in global average temperature near the surface of the earth caused by increasing concentrations of atmospheric greenhouse gases (EPA, 2017; NRC, 2017). This semantic shift in terminology allows a range of climate occurrences to be linked to the changes in earth's climate besides the increases in global temperature. These include changes in ecosystems and wildlife, rising sea levels, extreme cold weather, while also taking into account a variety of sources that have caused or influenced changes in earth's climate including human activity and natural happenings (Seroussi et al., 2019). Benjamin et al. (2016) argues however, that using the term climate change instead of global warming weakens the link between changes to earth's climate to clear-cut origins in the human responsibility.

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as "a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or variability of its properties and the persists for an extended period, typically decades or longer" (p. 120). The EPA (2017) states that greenhouse gases occur naturally in the atmosphere and act as a blanket around the Earth, absorbing heat produced from the sun and energy in the atmosphere, and providing Earth with a natural warming effect, called the "greenhouse effect." The main greenhouse gases include carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4), whereas others include water vapor (H_2O), tropospheric ozone (O_3), and chlorofluorocarbons (CFCs). Major sources of these greenhouse gases include coal burning power plants, industrial processes, automobiles, and some agricultural applications (EPA, 2017; IPCC, 2014).

Carbon dioxide is the major greenhouse gas absorbed and produced naturally as part of the carbon cycle that is greatly causing climate change (EPA, 2017; NRC, 2017). With the start of the industrial revolution in the mid 1700's, human actions have contributed to huge amounts of carbon dioxide and other heat-absorbing gases into the atmosphere. As a consequence of these actions, such as burning fossil fuels, great quantities of these gasses are being released into the atmosphere, causing carbon dioxide concentrations in the atmosphere to increase (EPA, 2017; NRC, 2017). These greenhouse gases, sequentially, have caused the Earth's atmosphere to absorb and trap more heat than normal, resulting in higher temperatures on Earth (EPA, 2017; NRC, 2017). These human activities have been the most significant factor contributing to environmental changes (Vitousek et al., 1997).

Change in temperature in the atmosphere have led to what has come to be known as climate change, which are changes in Earth's climate and weather patterns. Parts of the world have seen abnormal heavy rain, floods, or droughts, as well as numerous and extreme heat waves. Earth's glaciers have melted significantly causing changes in oceans, including increased acidity levels in oceans and rise in sea levels. Consequently, these changes in weather patterns are expected to produce more challenges to the life of humans and the environment (EPA, 2017; NASA, 2014; NRC, 2017).

Scientists are calling the human influence and impact on the Earth system the Age of Humans, or the geological age of Anthropocene (Crutzen, 2006; Lewis & Maslin, 2015). Human influences have included land-utilization changes like deforestation, pollution through variety of ways including consumption of fossil fuels, and threatening biodiversity of different ecosystems (Walther et al., 2002). Environmental systems are connected globally, and human activities have impacted many of these environmental systems (Stevens & Wedding, 2005). Implications of climate change will be discussed next.

Implications of Climate Change

Climate change has become a significant environmental concern with important implications all over the world (IPCC, 2014). A warming climate negatively effects environmental systems, including human life and health, ecological stability, water supplies, power and transportation systems, agriculture, aquatic and terrestrial ecosystems, and economy of many countries (EPA, 2017; NRC, 2017). A rise in global temperature leads to increases in vector-borne diseases (VBD), infectious diseases, morbidity and mortality due to heat waves, and food and water-borne illness caused by contamination including protozoa, parasites, amoebas, and algae (Chalecki, 2002; Batterman et al., 2009). Global warming has led to the extinction of many species in rainforests across the globe, causing problems with various species that could eventually affect humans in the future as well as ecosystems (Williams et al., 2003; UNEP, 2014). Schreiber (2011) revealed how wolf populations in Yellowstone have significantly and negatively been impacted by climate change due to decreases in wolf's prey. Vegetations consumed by wolf's prey have decreased due to its inabilities to adapt to increased temperatures, causing lower prey populations.

The effects of climate change will be different globally as certain areas may experience draughts while others experience acid rains (Chalecki, 2002). Increased temperatures and changes in the climate lead to additional natural disasters, including increases in tornadoes, flooding, and hurricanes (Chalecki, 2002). Globally, the implications of climate change will affect different areas more negatively than others, as different parts of the world experience issues including rising sea levels, heavy flooding, increased temperatures, or extended periods of draught (Diamon-Smith et al., 2011).

Rises in sea levels will destroy homes and infrastructures in coastal communities in addition to possibly contaminating potable water wells with saltwater (Ammon et al., 2009; Leurig & Dlugolecki, 2013).

According to the National Aeronautics and Space Administration (NASA), climate change, in addition to increasing global average surface temperature, will also impact changes in the atmospheric air circulation of the globe, leading to stronger polar winds where certain parts of the world would face colder than average winters and winter storms (2017). Tropical storms and hurricanes are projected to increase in intensity as the increase in temperatures feeds these systems and could lead to greater economic ramifications for those residing in the pathways of these storms (Knutson et al., 2010).

Increases in wind shear and humidity have also impacted the intensity of thunderstorms, causing lightning strikes that have led to increases in wildfires effecting habitats, homes, air quality, and lives (Kunkel et al., 2013). Places like Africa and Asia will face increased number of climate change related deaths as those regions will be challenge by malnutrition, and malaria, diarrheal diseases (Diamond-Smith et al., 2011). International borders will be challenged by human migration as vulnerable populations who have impacted minimally to the global gas discharges will more than likely be negatively impacted the most (Nema et al., 2012).

Scientific Evidence and Consensus of Climate Change

An overwhelming number of scientists (97 percent), scientific research, and scientific evidence argue and place responsibility on human activities as the main reason behind climate change (Anderegg, 2010; Cook et al., 2016; Doran & Zimmerman, 2009; EPA, 2017; NASA, 2017). This argument is supported by many of the US scientific organization and majority of global organizations, including the U.S. National Academy of Sciences, American Chemical Society, The National Research Council (NRC), American Association of the Advancement of Science, Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), and Geological Society of America (EPA, 2017; NASA, 2017; NRC, 2017).

Reports from the Intergovernmental Panel on Climate Change (IPCC) as well as other studies have shown that Earth's average temperature has increased by 1.5 degrees Fahrenheit due to increases in carbon dioxide gas in the atmosphere, and future increases in temperature are likely (Cook et al, 2016; EPA, 2017; IPCC, 2014; NOAA, 2017). Multiple IPCC reports also show that during the past 50 years, daily minimum temperatures have increased beyond average and maximum temperatures of the 1970s (Stocker et al., 2013). Kunkel et al. (2013) discovered that the number of days higher than 95 degrees Fahrenheit and nights higher than 75 degrees Fahrenheit have increased significantly, in addition to decreases in the number of cooler days.

Furthermore, substantial scientific evidence, including climate models have supported that natural and meteorological causes, like volcanic eruptions, solar cycles linked to La Nina, and variations in planet Earth's orbit around the sun, are minor contributors to the increases in greenhouse gases and climate change (EPA, 2017; NOAA, 2017; NRC, 2017). In addition to climate models, climate simulations have also supported arguments that without human activities, the Earth would have experienced insignificant warming throughout the 20th century (NRC, 2017). Two years of research done by Charles David Keeling beginning in 1958 found that atmospheric carbon dioxide concentrations in the atmosphere were steadily increasing (Powell, 2011). In 2017, the

National Oceanic and Atmospheric Administration (NOAA) confirmed that atmospheric carbon dioxide concentrations had increased by over 40 percent since the industrial revolution. Multiple IPCC reports have stated that human actions have produced more than 30 billion tons of carbon dioxide into the atmosphere per year, with the U.S. Geological Survey (USGS) arguing that human actions releases 135 times more carbon dioxide than volcanoes globally release in a year (EPA, 2017; Powell, 2011).

A major local concern of climate change has been heavy flooding in the Houston area. Multiple IPCC reports have shown that trends in precipitation occurring, where incidences of flooding and draught in different regions have increased considerably during the past three decades (IPCC, 2007).

Views Opposing Climate Change

Although there exist substantial and abundant research studies and scientific evidence supporting climate change, there are still scientists and others in the world who question the legitimacy of climate change (Cook et al., 2016; Powell, 2011). These scientists, who comprise of less than five percent of the scientific community, argue that natural variations in solar radiation can be attributed to rising temperatures (American Association of Petroleum Geologists, 2007; Anderegg, 2010; Oreskes, 2004). Svensmark (2007) theorized that the sun's impact on cosmic rays explains hotter climate. He argued that cosmic rays coming into the atmosphere help form aerosols and cloud that reflect sunlight. The earth's elevated solar magnetic activity over the previous decades has safeguarded Earth from cosmic rays and permitted extraordinary heating. However, the sun's recent lack of magnetic activity caused less cloud formation, which has resulted in hotter climates (Svensmark, 2007).

Starting in the 1990s, conservative movements begin to block attempts at climate change programs by teaming up with certain industries in order to deny and dissuade the realities and significance of climate change (Brulle, 2013; Dunlap & McCright, 2015). Conservatives and certain industries with brands in danger of the climate change science introduced the “manufacturing uncertainty” term to the public as a challenge to scientific evidences supporting climate change, through questioning such evidences as invalid or unreliable (Dunlap & McCright, 2015; McCright & Dunlap, 2011). As years passed, valid scientific evidence in the public became known as controversies, where people began to believe that a significant percentage of scientists disagreed on the realities of anthropogenic climate change (Dunlap & McCright, 2015).

In a letter written by Climate Intelligence Foundation (CLINTEL) addressed to the European Union in 2019, 400 signatories made arguments of there being no climate emergency (Collett-White, 2019). Of these 400 signatories, only a minority were found to have any experience in climate science, with many others being authors, geologists, and engineers who had no obvious expertise in the subject of climate change. The letter argued that no scientific link between anthropogenic carbon dioxide emissions and causes of global warming exists; that climate change is a natural cycle that is to be expected; that climate policies are based on models that have many shortcomings; and that there is a lack of scientific evidence linking intensities of natural disasters (e.g., hurricanes, floods, draught, etc.) to higher carbon dioxide levels (Collett-White, 2019). However, as already stated in the section before, many studies, models, and simulations have contradicted such notions, with the tremendous consensus in the scientific community placing blame on human actions for continued climate change and global warming issues (NASA, 2017; NRC, 2017).

Scientific support for warming of the climate system is indisputable (IPCC, 2014). In their research, Cook et al. (2019) found that fossil fuel industry had purposefully misled the public about climate change, with documents showing that they had known about the reality climate changes due to human-activity for years. As the scientific consensus on climate change emerged and strengthened, the fossil fuel industry exaggerated the uncertainties and criticized the consensus, similar tactics used by the tobacco industry for delaying tobacco control (Cook et al., 2019). As the fossil fuel industry failed to offer any reliable alternative explanation for why the climate was transforming, their current debates have now centered on solutions to changing climate.

Climate Change Standards

Early overconsumption practices of European colonists differed from those of Native Americans who practiced sustainable living, leading to pervasive land degradation (Christensen, 2016). As colonies expanded westward, so did people's modification and degradation of lands and environments, leading to environmental problems that continue till today (Ahuti, 2015). Industrialization led to deforestation practices as well as habitat destruction, climate change, and acid rain (Ahuti, 2015). These adverse impacts begin environmental movements in the 1800s focused on practical resource conservation and habitat preservation (Bodzin et al., 2010). By the 1960s, series of pro-environmental amendments were accepted in the U.S. including the Clean Air Act of 1963, Wilderness Act of 1964, Wild and Scenic River Act of 1968, and the National Environmental Policy Act (NEPA) of 1969 (Dunlap & Mertig, 2014). NEPA encouraged federal efforts in preventing and eliminating damage to the ecosystem, becoming the first policy with comprehensive frameworks in protecting the environment (Dongoske et al., 2015). In 1970 the Environmental Protection Agency (EPA) was formed under the presidency of Richard Nixon, who stressed the significance of environmental literacy through every point in the education process (Dunlap & Mertig, 2014; Nixon, 1970).

In seeking to accelerate environmental literacy, civic engagement, and providing resources and research for environmental educators, the North American Association for Environmental Education (NAAEE) was established in 1970 (Carter & Simmons, 2010). The United Nations (UN), due to global environmental concerns, began to also lead a series of international conferences to address public concerns, which led to the formation of the International Program in Environmental Education (IEEP) seeking to promote awareness for the necessity of environmental education (Dunlap & Mertig, 2014). In the decades that passed, environmental education experienced highs and lows of importance as other issues like No Child Left Behind Act of 2001 reduced the priorities of environmental education (Gruenewald & Manteaw, 2007). Nevertheless, in 2015 President Barack Obama signed into law Every Student Succeeds Act, which provided the first federal funds ever for environmental education (Bodor, 2015). Environmental education has been influenced through political, social, national, and international movements, while further research is a necessity as climate change continues to impact lives globally.

Climate Change and Climate Justice

The World Health Organization (2011) assessed that climate change is accountable for approximately 150,000 deaths each year; a more recent report by the

Climate Vulnerability Monitor estimated this quantity at more than 400,000 annual deaths, in addition to thousands of displacements (Climate Vulnerability Forum, 2012). Global inequality in environmental inequality has led to “environmental unequal exchange,” a concept developed by Stephen Bunker (1985) in which raw natural resources found all around the world become more and more concentrated in the more affluent countries, while developing and poorer countries have to tolerate majority of the environmental impacts of extricating them. Recently, this concept has been applied to climate change issues in bringing consideration to the reality that rich and industrialized countries are contributing the greatest to concentration levels of atmospheric greenhouse gas (GHG) that impact climate change; while it is the struggling, less wealthier countries with inferior adaptive abilities that are dealing with the first and worst detrimental effects of climate change (Parks & Roberts, 2006). Concerning the societal divisions of climate impacts, the needy, females, and people of color globally are excessively troubled and susceptible (Bullard & Wright, 2009; IPCC, 2007; Hoerner & Robinson, 2008; Norgaard, 2012; Parks & Roberts, 2006; Sweetman, 2009).

Climate change’s damaging consequences exist both within and between countries. Within the United States, an example of class and race disparities in climate change occurred among African American residents of New Orleans during Hurricane Katrina (Pastor et al., 2006). Racial and economic discrimination unfavorably influenced recovery and resiliency in the months after the storm. Hoerner and Robinson (2008) documented the disproportionate increased burden African American households, whose mean per capita emissions are about 20 percent lower than non-Hispanic white households, could face when dealing with effects of projected climate change and emissions reductions policies. This reflects the global climate justice struggles linked with climate change where responsibility, impacts, costs, and benefits of activities that impact greenhouse gases in the atmosphere are unequally distributed. Over the ensuing decades, billions of people, especially those in developing territories, will face water scarcities, food insecurities, and increased health dangers as a consequence of climate change (UNFCCC, 2007). The absence of climate change education disconnects people to realities of these injustices and inequalities.

Climate Change and Education

In order to motivate and empower students to become future scientifically and environmentally literate citizens, teachers have an essential role in educating and molding students (Skamp et al., 2012). With the crucial goal of promoting environmentally responsible behavior, many environmental and natural resources education efforts have focused on helping develop the knowledge, skills, and attitudes of students (Huber, 2018; Wolff & Booth, 2017). The National Research Council (NRC) in 1996 published the National Science Education Standards (NSES) which supported developing students' scientific knowledge in dealing with social decisions by providing a method to comprehend and tackle personal and social issues (NRC, 1996). As climate change and environmental issues become perilous pressing issues in our world, it is imperative that students become well-informed citizens before making decisions that could impact the environment through political and social spheres (AAAS, 2009).

Findings from Plutzer et al. (2016) paint a challenging picture of environmental education as three quarters of teachers nationwide were found to only allocate about one hour of environmental and climate change instruction throughout the school year. Even more perplexing is the misconceptions and contradictory information that teachers who do teach and emphasize climate change were found to include in their instruction, where only 30 percent taught climate change as a natural phenomenon, while 31 percent stressed contradictory information, stating that climate change was both a human result and caused by natural happenings (Pultzer et al., 2016).

In 1978, UNESCO published the *Tbilisi Declaration*, in which it described environmental education as an interdisciplinary, holistic, and life-long process where it fosters attitudes, motivations, and commitments of people in order for them to take responsible actions (UNESCO, 1978). Two decades later the North American Association for Environmental Education (NAAEE) led environmental literacy programs in the U.S. through publishing a set of guidelines to help guide teachers in evaluating materials. Additionally, it established educational environmental literacy materials (Carter & Simmons, 2010; NAAEE, 2014). In 2013, with the publication of the Next Generation Science Standards (NGSS) climate change became a construct for the first time in U.S. public schools, where students were recommended to learn that climate change due partially to human activity is actually taking place (Ludden, 2013; NGSS, 2013). The NGSS standards include effects on climate due to increases in carbon dioxide concentrations caused by human activity, something absent from previously created national science standards (NGSS, 2013; Revkin, 2012; Smith, 2012).

With changes in standards and curriculum efforts in empowering environmental education, future movements must begin with students at young ages in their homes and communities in order to help create behavioral changes towards a more sustainable future. (NRC, 2012).

Climate Change Education: The Obstacles

Although some scientists refute the idea of climate change, 97 percent of the world's scientists endorse the notion that climate change is transpiring without a doubt (IPCC, 2014; EPA, 2017). Unfortunately, there are teachers who have presented climate change as a controversial theory even with abundant scientific evidence and scientifically published research (Plutzer et al., 2016a). As climate change has become a controversial subject matter in the U.S., teachers have come under pressure from climate change deniers to not teach climate content in their classrooms (Public School Review, 2017). Skamp et al. (2012) also found that teachers may evade teaching climate change due to their own negative perceptions of the topic.

Political debates and controversy in relation to climate change have caused it to become a challenging issue for teachers trying to teach it in schools (Humes, 2012). In addition to pressures from climate change deniers, issues with how climate change education should be taught in schools have become obstacles in trying to teach the content in schools (Ludden, 2013). Political divides have fallen on party lines, with democrats and liberals more probable to accept scientific evidences and research regarding climate change and the human impact, while Republicans and conservatives are significantly less likely to accept any notion of climate change, supporting their claims by referring to arguments made by the less than five percent scientists who satisfy their beliefs (Bolsen el al., 2015). Such political divides and polarization in society can be attributed to why NGSS standards that include climate change have not been adopted by legislators in all states (Bidwell, 2014).

Mansour's (2013) research found that teachers' beliefs significantly influence what and how they teach in a classroom, meaning that political ideology of teachers are powerful indicators of their instructional approach to topics (Plutzer et al., 2016a). As anti-climate activists fund disinformation campaigns, and misconceptions and deceptive research are propagated by the media, populations who lack proper environmental literacy continue to become ever confused on climate change and the indisputable evidence supporting it (Bunten & Dawson, 2014; Lambert & Bleicher, 2013; Somerville & Hassol, 2011). Without proper environmental and climate change literacy, students and adults will easily be susceptible to misconstrued and false statements put forth by the media, politics, or disinformation campaigns that are apparent in society today (Bunten & Dawson, 2014; Lambert & Bleicher, 2013).

Teachers' Knowledge, Beliefs, and Attitudes about Climate Change

Lambert & Bleicher (2013) found that many teachers reported never receiving any formal education in climate change, which reveals that much confusion among educators is due to inadequate scientific knowledge. As skepticism and polarization in the U.S. about climate change increases, reliable and valid scientific evidence about climate change is endangering science education in public schools (Banerjee, 2012). Common misconceptions and major gaps in knowledge about climate change have been found in adults, with many people believing that anthropogenic climate change is farfetched (Leiserowitz et al., 2011; Lombardi et al., 2013). In a recent research known as the *Yale Program on Climate Change Communication*, educators and respondents were found to have limited knowledge about realities of climate change, where only 13 percent of them knew that 97 percent of scientists believed climate change to be real and due to human actions (2017). Similar climate change misconceptions have been prevalent in different studies including science teachers (Herman et al., 2017; Plutzer et al., 2016a; Wise, 2010) and pre-service teachers (Groves & Pugh, 1999; Lambert & Bleicher, 2013; Matkins & Bell, 2007).

Other studies have found that educators are teaching climate change through ideas and claims that are counter to scientific evidence and consensus (Carter & Wiles, 2014; McCaffrey, 2015; Plutzer et al., 2016a; Wise, 2010). In order to help students in constructing attitudes and beliefs that are in support of climate literacy, teachers' instruction in schools is highly significant and important (Ekborg & Areskoug, 2006; Schreiner et al., 2005). Teachers with strong content knowledge about climate change have been successful in helping students with constructing these attitudes and beliefs (McNeal et al., 2017; Sadler et al., 2006). Stevenson et al. (2016) found in their research of middle school students that beliefs teachers have about climate change does not significantly impact their students' beliefs. These findings suggest that students interpret scientific information relatively independently of their teacher's beliefs, and teachers can provide accurate instructions on climate change no matter their personal beliefs on the issue.

Recent research has found improvements in gaps of knowledge and misconceptions of pre-service teachers over the past 20 years. However, weaknesses still exist (Herman et al., 2017; Hermans, 2016; Karami et al., 2017; McNeal et al., 2014; Plutzer & Hannah, 2018; Seow & Ho, 2016; Wise, 2010). Liu et al. (2015) in their research of in-service teachers' knowledge of the greenhouse effect found that misconceptions still existed about the causes and consequences of the climate change.

Other studies have found that the most confusing misconceptions that pre-service teachers hold are the differences between global warming and the greenhouse effect (Arslan et al., 2012; McNeal et al., 2014; Herman et al., 2017). In recent years, teachers' knowledge and comprehension of climate change has seen improvement. However, gaps exist in their understanding of the consequences and remedies for the environmental issue (Dawson, 2012; McNeal et al., 2014). Incorrectly accrediting effects of global warming to the diminution of the ozone layer is one common misunderstanding that research has shown still exists in teachers and pre-service teachers (Arslan et al., 2012; Cordero et al., 2008; Hansen, 2010; Kerr & Walz, 2007; Khalid, 2003; Herman et al., 2017; Lambert et al., 2011). Climate education obstacles still exist where teachers are still avoiding teaching the subject, while other teachers teach climate change from a skeptical perspective (Dawson, 2012; Hodson, 2013; Plutzer & Hannah, 2018; Seow & Ho, 2016).

Although greater than 97 percent of scientists argue the legitimacy of anthropogenic climate change, many studies still find that pre-service and in-service teachers believe that humans are not responsible for climate change (Hestness et al., 2014; Plutzer & Hannah, 2018; Wise, 2010). In their study of Turkish pre-service teachers, Higde et al. (2017) found that, although most of their respondents believed climate change is happening, some pre-service teachers ignored climate change altogether. Research on pre-service and in-service teachers have also found that many of them have misconceptions about methods to remediate the in-depth consequences of climate change, believing that every environmental friendly action can help reduce the impacts of climate change (Groves & Pugh, 1999; Ikonomidis et al., 2012; Shea et al., 2016). Other authors have criticized that there is a lack of pro-environmental behaviors in numerous teachers and the attitudes displayed in respect to the environment (Ambusaidi et al., 2012; Karami et al., 2017).

The Effect of Academic Courses on Teacher's Knowledge and Beliefs

Adult populations in societies make decisions and judgements regarding science or technology related policies that can significantly and directly impact their lives, therefore highlighting the importance of becoming science literate (Miller, 2016). As teachers teach in schools, the NGSS requires that science courses teach scientific literacy skills and climate change content throughout the curriculum in order to help prepare students to become science literate. However, many teachers lack the content and resources to be successful (Boon, 2016; Dawson, 2012; Plutzer et al., 2016c).

Consequently, due to gaps in teacher knowledge and climate change misconceptions, effective mental models, professional development workshops, and providing proper resources to teachers are recommended for teachers to overcome these circumstances (McCaffrey & Buhr, 2009). Unfortunately, instruction currently received in many teacher preparation programs fail to advance aspiring teachers' knowledge and attitudes about climate change (Boone, 2016). Effective environmental education courses for teachers have been found to be successful in helping teachers integrate, create, and design appropriate environmental contents for their classrooms (Ekborg & Areskoug, 2006; Shepardson & Niyogi, 2012; Sondergeld et al., 2014). Shea et al. (2016) argued that effective environmental education courses with teachers should include three essential elements, including science content, pedagogical practices, and the use of local environments by going outdoor. In creating a hybrid program, Shea and colleagues recruited twenty-seven participants for a weeklong summer institute. The study found participants were successful in integrating workshop content into their classrooms, while also remaining concerned on strategies in integrating climate change content into their own curriculums at school (Shea et al., 2016).

Likewise, the Stanford Project designed a professional development program that provided teachers with direction on instruction, resources, and guidance in leading students through discourses on climate change and emphasizing the importance of student talk (Holthuis et al., 2014). Findings from this workshop revealed that students were able to develop higher-order thinking skills through opportunities for discourse provided by the teachers. Additionally, increased critical thinking skills developed for both students and teachers (Holthuis et al., 2014). Furthermore, Mason and Santi (1998) found that through social discourse, students were able to attach meaning to scientific concepts which allowed “anchoring” new knowledge into prior knowledge. A few other studies on pre-service teachers’ climate change knowledge and understanding found that pre-service teachers’ understanding of climate change increased along with their ability to implement newly acquired knowledge. Moreover, they were able to make thoughtful and informed decisions about climate change issues (Bell et al., 2011; Hasturk & Dogan, 2016; Lambert & Bleicher, 2013; Matkins & Bell, 2007). Lambert and Bleicher (2013) found that pre-service teachers’ perceptions and understanding of the scientific evidences of climate change, their understanding of climate change implications, and corrections to misconceptions held about the consensus of scientists about climate change changed significantly through providing a unit on climate change in a science methods course. Lombardi and Sinatra (2012) found that even short courses can significantly increase pre-service teachers’ knowledge and understanding of climate change.

In consideration of the abundant research on teachers' and pre-service teachers' knowledge and misconceptions, the need for research supported courses and programs for training and educating teachers and pre-service teachers in climate change education is of high priority for the purpose of significantly changing teachers' knowledge and attitudes about climate change (Gulamhussein, 2013). Effective professional development, curriculum, and workshops for climate change education are required in order to help promote teachers' views and their roles and responsibilities for teaching about climate change (McGinnis et al., 2015). Providing climate change education in institutions of teachers' preparation programs can significantly impact teachers' attitudes, lifestyles, and involvement in ways that can help them oppose climate change (Avissar et al., 2017). In the absence of such effective programs, students and teachers are susceptible to misleading information and disinformation put forth by the media, politics, and anti-climate campaigns (Bell et al., 2011; Bunten & Dawson, 2014; Lambert & Bleicher, 2013). Hodson (2003) argues that education should enable students to critically analyze society's values, and the lack of not addressing climate change issues disempowers students.

Environmental Responsibility

In this study, environmental responsibility (ER) is defined as the dimension of thinking of learners about personal obligations about the environment or their sense of accountability to do something to help alleviate unwanted effects on the environment. Studies have provided insight into learners' ideas about actions that should be taken (and by whom), actions learners are personally willing to take, and actions learners do take to mitigate climate change (Boyes et al., 2008; Boyes & Stanisstreet, 2012; Chhokar et al., 2011; Lester et al., 2006). Research on pro-environmental beliefs have found that people with world views are more inclined to participate in pro-environmental behaviors than people who are human-centered (Dunlap et al., 2000). Likewise, studies have shown that adults have positive attitudes and ideals concerning the environment when provided outdoor, nature experiences (Chawla, 1998; Ewert et al., 2005; Palmer et al., 1999).

Additionally, many research studies have found that ER contributes in a significant way to learner's readiness to engage in pro-environmental behaviors (Liobikiene & Juknys, 2016; Wang et al., 2014; Zareie & Navimipour, 2016). Lester et al. (2006) utilized an instructional intervention on fifth graders, having them develop their own radio announcements related to climate change. In analyzing the students' ideas about reducing the production of greenhouse gases, they found that learners were more likely to support behaviors grounded in recognized scientific thinking after the instruction. Clark et al. (2003), analyzed internal and external influences on pro-environmental behaviors and argued that ER empowers individuals to act for the protection of the environment. Other research also found that differing levels of learner's perceived responsibility can meaningfully impact a learner's intents of conservation (Zhu et al., 2019).

Researchers have also examined learners' ideas and attitudes about pro-environmental behaviors. Boyes et al. (2008) found that many Chinese high school students thought of climate action as a collective responsibility between individuals, government, and businesses. However, Sternang & Lundholm (2011) noted in their study that participants felt others should act in favor of climate action while excluding themselves as an individual with equivalent responsibility.

In some studies, researchers examined participants' personal willingness to take behavioral action on what they believed to be essential in order to address climate change issues (Boyes et al., 2008; Boyes & Stanisstreet, 2012; Chhokar et al., 2011). It was found that learners were willing to engage in actions involving less cost or personal effort (e.g., switching off electronics) instead of those behaviors and actions involving great sacrifice or potential inconvenience to themselves (e.g., taking public transportation). Barr (2003) asserts individuals and instructions may indirectly alter their daily practices and minimize negative impacts to the environment as ER could potentially persuade them to accept responsibility for having caused environmental problems due to their behaviors.

Environmental Belief and Attitude

Attitude is defined as a person's evaluative judgment about a particular thing that a person can consistently approve or disapprove (Eagly & Chaiken, 1993). Environmental attitude (EA) is defined as person's general beliefs about the interactions amongst human and nature, also termed environmental worldview (Janmaimool & Chudech, 2020). Since climate change is linked to practical behavioral actions, EA can be measured as people's positive or negative beliefs about the natural environment that are used to make judgements (Masud et al., 2017). For the purpose of this study, the term environmental belief (EB) will be used, in order to measure people's endorsement of a pro-ecological worldview and the overall relationship between humans and the natural environment. In studying ecotourism, Lee and Choi (2017) conceptualized environmental attitudes into three characteristics, namely environmental beliefs, environmental value, and environmental sensitivity. Environmental beliefs describes the notions of an individual relationship to the natural environment, environmental value describes an individual’s perceived values in relation to environmental problems, while environmental sensitivity is the recognition of individuals to the seriousness and significance of environmental issues and accepting the influence of human activities on environmental problems (Lee & Choi, 2017).

Research studies have found mixed results when analyzing the effects of EA on pro-environmental behaviors. Some have found positive correlations between the two variables (Mohai, 1992; Weaver, 1996), while other studies found weak relations between the two variables (Olli et al., 2001; Paco & Lavrado, 2017). It is theorized that people with positive EAs should be able to acknowledge the harmful environmental outcomes of particular actions and behaviors, consequently leading to the creation of pro-environmental behaviors in these individuals (Janmaimool & Chudech, 2020).

Environmental Knowledge

According to Laroche et al. (2014), environmental knowledge (EK) is defined as an individual’s ability to recognize the signs, conceptions, and behavioral patterns associated to the safeguards and preservation of the environment according to established environmental information. EK is also defined as the knowledge and understanding of individuals about the environment and pertinent environmental issues, including environmental problems, causes, and implications (Chan & Lau, 2000). Studies have shown that individuals with greater EK are most likely to demonstrate pro-environmental behaviors, meaning that EK could enhance environmental awareness (Lee, 2010; Mostafa, 2007; Oguz et al., 2010; Slavoljub et al., 2015; Unal et al., 2017). In addition, a study of purchasing cars, Flamm (2019) found that those engaged in energy-efficient cars had higher EK levels. Likewise, Mostafa (2009) and Sang and Bekhet (2015) found that higher levels of EK significantly impacted attitudes of consumers in green behaviors, including purchasing green products.

Environmental Concern

Environmental concern (EC) is defined as the degree to which people are concerned about the environment, including devastations, disruptions, conservation, and dangers to earth's different ecosystems (Dunlap & Jones, 2002; Hartmann & Apaolaza-Ibanez, 2012). Likewise, Singh and Bansal (2012) argued that EC is the consciousness of learners as they gravitate towards environmental and ecological issues, including perceptions for necessary problem-solving actions to help alleviate environmental issues. Weigel and Weigel (1978) believed that EC and people's awareness to environmental issues were related to one another. Threatening regional and international environmental events that created imbalances between people and nature appear to positively affect people's ecological and EC (Abdul-Muhmin, 2007). Additionally, environmental behaviors, including pro-environmental behaviors, can be predicted through understanding peoples' EC (Wu et al., 2019). Climate change implications may significantly contribute to people's levels of concern as environmental events arise and cause significant problems throughout the world. Janmaimool and Chudech (2020) noted in their study that increased EC could support transforming environmental knowledge and attitudes into environmental responsibility.

Teacher Preparation in Science Education

A growing number of researchers widely recognize that science education of teachers is a critical component of making real change in making meaningful science learning for all children, and in turn, securing lasting reforms in the classrooms (Gess-

Newsome et al., 2004; NRC, 1996; Stuart & Thurlow, 2000; Weld & Funk, 2005). Teacher education research literature indicates that elementary teachers are not comfortable teaching science and resist teaching it (Luera & Otto, 2005). Elementary teachers are found to possess low levels of conceptual knowledge and inadequate skills in science (Stevens & Wenner, 1996).

Researchers have made efforts to develop teacher education programs that successfully lead preservice teachers to positive experiences and motivation toward science teaching. Considerable evidence from research supports the proposition that specifically designed science courses with inquiry-oriented pedagogy influence preservice teachers' overall attitudes and/or beliefs about teaching science (Bohning & Hale, 1998; Brown, 2000; Eiriksson, 1997; Key & Bryan, 2001; Luera & Otto, 2005; Weld & Funk, 2005; Windschitl, 2002; Zoller, 2000). Findings indicate that exposure to inquiry-based elementary teacher education courses strengthen preservice teachers' beliefs and confidence to teach science, in addition to increasing their science content knowledge.

Learning Cycle

The learning cycle is an instructional method developed by Robert Karplus and his colleagues as a conceptual framework for the selection, organization, and presentation of subject matters in science classrooms (Eakin & Karplus, 1976). Additionally, it approaches instructions through a Piagetian theory of cognitive development and incorporates Piaget's views on how hands-on experiences, social interactions, and physical maturation are processes that children follow in a series of states (Eakin & Karplus, 1976). Many studies have found that the combination of inquiry investigations, hands-on strategies, and reflective exercises significantly impact adult and student learning in science courses (Marek & Methven, 1991; Miechtry, 1995).

In developing the climate change instructional lesson for this study, the author collaborated with the science education department head and the faculty member whose courses implemented the instructional lesson for this study. The faculty member's course teaches pre-service teachers through the 5E learning cycle. The course educates students by incorporating the 5E learning cycle as the most proven and effective method to teach science and environmental education (Bybee et al., 2006; Jacobson et al., 2015; Karpudewan et al., 2014). The 5E learning cycle was developed through the Biological Sciences Curriculum Study (BSCS) program and includes five phases in a research and inquiry-based model that has been around for more than two decades (Bybee, 2014). These phases were used in order to create the intervention lesson for this study, and include these five phases: engagement, exploration, explanation, elaboration, and evaluation (Bybee, 2014). Each phase has a unique purpose in guiding students in the learning process. The engagement phase begins the lesson by trying to gain students' attention through demonstrations or other discrepant form of activities. The exploration usually provides students some form of hands-on activity that allows learners to engage in discovering pieces of the scientific concept. The explanation phase incorporates different forms of media for the instructor to help guide students through explaining the science content of the lesson. The elaboration phase typically extends the lesson's ideas and challenges students to new situations where they can apply concepts learned throughout the first three Es. The final phase, the evaluation phase, typically includes some form of assessment where students provide the instructor evidence of their learning through the learning cycle (Bybee, 2014). The different parts of the climate change instructional lesson will be discussed in the methodology chapter.

Online Learning

Globally, the Covid-19 pandemic disrupted learning in schools for 70 percent of students worldwide (UNESCO, 2019). This led to school closures and many schools shifting to online instruction models, which on its own creates unique challenges and decisions for educators. This includes faculty and staff lacking the technology solutions, software, and tools to facilitate online learning (Gordon et al., 2010). The researcher and instructor developed the climate change instructional lesson using different ideas to continue teaching science content through effective methods.

A meta-analytical review of 86 studies indicates that online learning is a viable alternative to face to face settings (Stodel et al., 2006). Miller and Knuth (2004) found no statistical differences in student teaching measures between students involved in field experiences while taking an online course and students taking courses on campus. In a comparison of an online course and face-to-face science education course, Harlen and Altobello's (2003) results showed better learning outcomes online. The quality of the course content and design, and the nature of the interactions with the instructor are more important determinants of learning than whether the course is taught face-to-face, online, or some blend of both (Koory, 2003). Research indicates that collaboration and interactivity within a situated environment might be the strongest aspect of designing with virtual worlds (Dickey, 2003; Dickey, 2005; Petrakou, 2010). Incorporating e-pedagogy designs and knowledge, the instructor and researcher were committed in utilizing and learning how to implement inquiry-based methods into online teaching as they designed the intervention lesson. This ensured that course objectives were met even as the instruction was to occur in a virtual setting.

Chapter III

Methodology

The purpose of this study was to examine the effect of a climate change learning cycle on preservice teachers' perceived knowledge, beliefs, concerns, and perceived responsibilities related to the environment. This chapter describes the research design, population and sample, instrumentation, data collection procedures, data analysis procedures, and time frame of the study.

Research Questions

The four research questions for this study are as follows:

1. What was the effect of climate change instruction on pre-service teachers' perceived environmental knowledge (PEK)?
2. What was the effect of climate change instruction on pre-service teachers' level of environmental concerns (EC)?
3. What was the effect of climate change instruction on pre-service teachers' sense of environmental responsibility (ER)?
4. What was the effect of climate change instruction on pre-service teachers' pro-environmental beliefs (EB)?

Overview of the Research Study

In order to answer the research questions, the author utilized a single-group pretest and posttest design to collect and analyze the effects of instructions in an elementary science course using a climate science curriculum. The climate science curriculum was designed using a learning cycle model by the researcher with input given by the science instructor of record and researcher's faculty advisor. The climate science intervention learning cycle was taught by an experienced and established science educator who was not the researcher and instructor of record for the course. Data from a pilot study was gathered in the Fall of 2020 with 33 participants that helped in creating and modifying different aspects of the climate science intervention learning cycle. In the Spring of 2021, 47 students from two elementary science methods courses were instructed using the new climate science curriculum, that consisted of six instructional hours split into two days of two consecutive weeks. A survey instrument was used before and after the two weeks of instruction to collect pretest and posttest data. Specific details about the research setting and climate science intervention learning cycle will be described in subsequent parts.

Overview of the Research Setting

This study took place at a large, urban university in a south-central region in the United States. The Teacher Education Program is housed in the College of Education's Curriculum and Instruction Department at the university. With over 400 new teachers completing the Teacher Education Program yearly, the university's alumni are a major source of local influence in education.

The Teacher Education Program prepares teachers for different certification levels and is organized into four semesters described as Pre-Teaching, Developing Teaching, Student Teaching 1, and Student Teaching 2. This study focuses on a part of the curriculum in the EC-6 Science Methods course that begins in Student Teaching 1 semester. The title of the methods course is Elementary Science Methods 2.

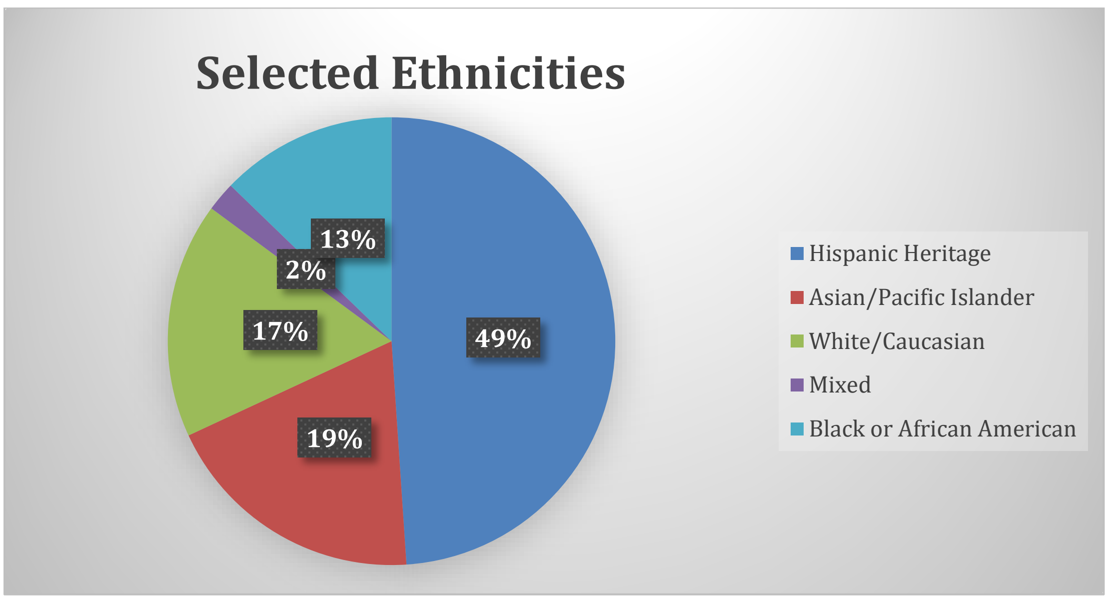
In the Fall of 2020, a pilot study was conducted in order to help design the activities and timing of the different aspects of the intervention learning cycle. In this study, 33 pre-service teachers were instructed on an inquiry-based climate lesson. The information gathered from this study was utilized to improve and refine the design of the climate intervention learning cycle, including helping gather data on transition times, videos, and the use of online platforms that were most constructive for the goals of the lessons. First, a documentary video with information on climate change and climate science that was utilized in the engage was removed due to time constrictions. Secondly, the university's system for discussion forums was shifted to Padlet on the recommendation of the pre-service teachers. Padlet is an online platform that easily allows students to post answers to discussion questions or share thoughts that are available to view immediately. Third, the use of digital interactive science notebook (DISN) received positive feedback from students, allowing for the structure of the intervention learning cycle to have a framework that was organized during the online sessions. These areas of refinement informed the intervention learning cycle design for the second iteration that occurred in the Spring of 2021.

Participants

The participants for this study consisted of 47 pre-service students enrolled in one of two different sections of the same course in the Spring of 2021. Forty-four of the participants were female and the remaining three were male. As shown in Figure 1 on page 40, majority of participants identified themselves as Hispanic. All students were enrolled in the second of two sections of an elementary science methods course and were working towards their bachelor's degree in Teaching and Learning with certification for teaching early childhood through sixth grade. All teacher preparation courses occurred in a virtual setting in the Spring semester of 2021. Participants were enrolled in four 3-hour courses that met once a week. Each of the science methods courses met in the afternoon for three hours during the scheduled day of the week, for thirteen weeks of the Spring 2021 semester. All 47 participants were enrolled in a three-hour morning class prior to the science methods course, and two more classes that met on a different day of the week. During a normal year, students would have spent two days at the university taking four classes, while gaining field experience the other three days of the week. However, in the Fall of 2020 and Spring of 2021, all experiences in school had gone virtual.

Figure 1

Survey Item on Participant's Ethnicity



Research Design

The purpose of this study was to examine the effect of a climate change learning cycle on preservice teachers' perceived knowledge, levels of concern, beliefs, and perceived sense of responsibility related to the environment. The researcher utilized a single-group pretest and posttest design to collect and analyze quantitative data regarding pre-service teachers' environmental knowledge, level of environmental concerns, pro-environmental beliefs, and sense of environmental responsibility before and after climate change instructional cycle.

Setting. The study was conducted at a large, urban university in a south-central region in the United States in the Spring of 2021. The participants were in two sections of the same course that met on two different days with same instructor using Zoom, an online meeting platform. The course consisted of a regular term schedule, where students met for 14 weeks of instruction. It is a mandatory course for students seeking to become EC-6 certified teachers. The course curriculum has been designed through collaboration of the science education faculty at the university and consists of teaching pre-service teachers inquiry and direct instruction models for delivering science instruction to pre-kindergarten to sixth grade. The science methods courses are aligned with the content objectives defined in the Next Generation Science Standards (NGSS) and Texas Essentials Knowledge and Skills (TEKS). Along with explorations of life science, physical science, and engineering, the climate change curriculum featured heavily in the earth and space science portion of the science methods class. The course curriculum design included climate-related content taught during two weeks of the course. This learning cycle was used as the intervention for the current study. The NGSS standards on climate and climate change include 5-ESS3.C, MS-ESS3.C, and MS-ESS3.D, which are fifth and sixth grade standards detailed in Table 1 on page 42.

Table 1

NGSS standards on climate and climate change.

5-ESS3.C	**Human Impacts on Earth Systems** • Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.
MS-ESS3.C	**Human Impacts on Earth Systems** • Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. • Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.
MS-ESS3.D	**Global Climate Change** • 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.

Intervention learning cycle. The researcher for the current study designed the climate intervention learning cycle with the assistance of two members of the Science Education faculty who taught the course in the past. In addition, the researcher had taught the same course for seven years. The researcher intended for the original intervention lesson to be taught during face-to-face class settings using constructivist approaches such as the 5E Instructional Model (Bybee, 2014) and best practices in science education aligned with the TEKS (TEA, 2019), and NGSS as outlined in the National Research Council (NRC, 2012). In the Spring of 2020, however, the COVID-19 pandemic prompted the university to move all instruction online. This change required the researcher to redesign the intervention plan to be taught fully online in two weeks.

The next sections describe the learning cycle in detail.

Week one. Figure 2 on the next page provides a summary of the climate instruction that occurred in the first week of the intervention. Week one's lesson focused on content over differences between climate and weather. During the Engage phase, students were pulled into breakout rooms and were required to observe and compare, using a T-chart in their digital interactive science notebook (DISN), weather maps and climate maps. Students discussed the similarities and differences they observed within their groups and as a whole class later. The purpose of the Engage phase was to provide information to the instructor about student's prior knowledge about climate and weather. During the Explore phase, students watched and analyzed a weather forecast of their choosing through an online website, answered questions about their analysis, and then watched a video that explored differences between climate and weather. The activities in the Explore phase allowed students to self-discover and self-assess their current understanding of terminology for weather and climate. For the Explanation phase, students shared their definitions that they came up with from the Explore phase to the whole class. They then completed guided notes in their DISN as the instructor summarized differences between weather and climate. To formatively assess if students could explain the differences between climate and weather, the instructor then facilitated the completion of a digital Venn diagram by dragging and dropping phrases into the appropriate location of the diagram through student communication. The Elaborate phase required students to utilize a KWL chart and Think-Pair-Share strategy to discuss and complete the first two columns on what they knew and wanted to learn about climate change. Students then explored a website provided by NASA and completed the last column and shared as a class what they had learned. This phase provided students with an opportunity to discover and share their current understanding of the term climate change. The Evaluation phase of week one provided students with statements that they had to read and determine if each statement referred to weather or climate. Answers were then discussed within groups. These statements were designed for the pre-service teachers to reflect on and discussed what they had learned during the first week's lesson.

Figure 2

Summary of Week One's Learning Cycle Content, Activities, and Purpose

Week ONE	Content	Activities	Purpose
ENGAGE	Climate & Weather	Weather Map vs. Climate Map Graphic Organizer (T-Chart) Students share their observations	Activating & assessing Students' Prior-Knowledge
EXPLORE	Climate & Weather	Watch a Weather Forecast Answer critical thinking questions Watch video exploring Weather & Climate	Self-discovery, self-assessing of climate & weather terminology
EXPLAIN	Climate & Weather	Students share definitions Instructor summarizes differences Venn Diagram on characteristics of Weather & Climate	Students will be able to explain the difference between climate and weather
ELABORATE	Climate	Know-Wonder-Learned (KWL) Think-Pair-Share Explore climate website on nasa.gov	Self-awareness & sharing on what students know about term: "climate change"
EVALUATE	Climate & Weather	Drag & Drop in DISN – read statements and determine if it is referring to climate or weather	Assessing students' knowledge on climate & weather

Week two. Figure 3 on page 46 provides a summary of the description of week two's climate instruction. The content of week's two lesson focused on global climate change and human impacts on Earth's systems. In the Engage phase, students utilized their DISN and clicked on a picture that took them to Padlet, an online forum that allowed students to share their thoughts. Students reflected on what they had heard and/or believed about climate change and shared their thoughts by posting on the Padlet website. Students then discussed their thoughts as they read posts made by their peers. The activity activated and engaged students on their prior knowledge and beliefs about climate change. The Explore phase placed students into breakout rooms, where they were part of one of six different teams. Teams were given 10 minutes to explore an assigned video that differed from other teams that ranged from three to six minutes long, and then answered questions in their DISN and then discussed the significance of the video. After 10 minutes, all teams returned to the main meeting room, where each team presented what they had observed and learned in their videos. The video in each team consisted of a classroom demonstration that allowed students to discover a piece of the science behind climate change. During whole class discussion, the objective was to create a complete understanding of the science behind climate change based on each team's presentation. This phase allowed students to discover collaboratively the science on how Earth's temperature is rising. During the Explain phase, EdPuzzle's online platform was utilized, where students answered questions that pop up on their personal laptop or digital screens as a video was played. The students watched *The Lorax*, with questions focused on making connections to the real world. After the video, each student completed questions in their DISN pertaining to climate change and the video, followed by a whole class discussion. Ending the explain, Greta Thunberg was introduced to the class, and a class discussion ensued on how Greta is considered a modern-day Lorax. The Elaborate phase is reminiscent of the Explore phase, where students returned to their teams and breakout rooms, were given a video to watch and answered questions on, then returned to the whole class for sharing and discussion. Each video consisted of one major domestic or global impact of greenhouse and climate change. The activity allowed students to observe, share, and learn from each other the major impacts climate change is having on both a domestic and global scale. In the final phase, the Evaluate phase, students worked together to complete blanks in paragraphs using word banks found on their DISN. This provided the instructor with data on students' knowledge on climate change.

Figure 3

Summary of Week Two's Learning Cycle Content, Activities, and Purpose

Week TWO	Content	Activities	Purpose
ENGAGE	Climate Change	Complete Padlet with thoughts, beliefs on Climate Change	Activating & assessing Students' Prior-Knowledge
EXPLORE	Climate Change	Breakout rooms/Create 6 Teams 6 different demo videos: each team watches 1 Teams must answer questions, be ready to present their discovery to class during Explain	Explore climate change science (each video is a piece of science on whole picture on how Earth's temperature is rising
EXPLAIN	Climate Change	Each team presents their demo video content EdPuzzle – the Lorax book with questions Greta Thunberg discussion – is she modern day Lorax?	Students piece together presentations & get complete picture of science of climate change Lorax: Make real life connections, continuing societal problems
ELABORATE	Climate Change	Breakout rooms/same teams as Explore Jig-saw: 6 different videos on 'major impacts' of climate change – each team watches One Teams comeback and present their observations/understanding form videos	Students will be able to learn and share the major impacts that climate change is having both domestically and/or globally.
EVALUATE	Climate Change	Fill in the Blank completed in DISN – read statements and determine correct words that fit into blanks	Assessing students' knowledge on climate change

Appendix B contains the recording sheets and information accompanied during day one of the climate change instruction. Appendix C contains the recording sheets and information accompanied during day two of the climate change lesson.

Protection of Human Subjects

Pre-tests (questionnaire) and post-tests (questionnaire) were administered online by the instructor of record for the course for her to assess the effectiveness of the lesson. Therefore, the data were treated as archival. The researcher received approval to obtain archival data from the University of Houston's Committee for the Protection of Human Subjects as the instructor of record for the science methods course. The letter from the University of Houston Committee for the Protection of Human Subjects can be found in Appendix D.

Instrumentation

Janmaimool and Chudech (2020) developed the instrument that was modified for use in the current study. The researcher examined potential instruments for the current study, located the Janmaimool and Chudech survey, and modified it to meet the current study's specific research questions. The researcher examined for validity by evaluating its face validity. The survey was slightly modified in one construct in order to provide examples of domestic concerns about the environment that are relevant to participants in the study. The original survey consisted of measures of Perceived Environmental Knowledge (PEK), Environmental Behaviors (EB), Environmental Concerns (EC), and Environmental Responsibility (ER) (Janmaimool & Chudech, 2020). Janmaimool and Chudech's (2020) confirmed the reliability of the survey items by analyzing the data of 30 undergraduate students who were given the survey. Cronbach's alpha was calculated in order to measure the internal consistency of this survey instrument. The value of Cronbach's alpha for each survey variable was measured to be above 0.70, meaning that the created and developed survey items and scale were reliable for measuring each variable (Nunnally, 1978). The modified Janmaimool and Chudech survey utilized for this study can be found in Appendix A.

Instrument development. Janmaimool and Chudech developed each section of the survey by adapting other research instruments that will be described in detail below.

In order to measure perceived environmental knowledge (PEK), the survey measured participants' perceived PEK by employing self-reporting techniques. As shown in Figure 4 on page 49, the survey contained a five-item scale that was originally developed by Zhu (2015) utilizing Hsu's (1997) relevant scales that had a similar purpose. Zhu (2015) conducted pilot studies and utilized validity panelists to evaluate and ensure validity and reliability of the scale and items. Relatively high internal validity consistency was found for the perceived knowledge scale and items (Cronbach's alpha value of 0.821) on the instrument (Zhu, 2015). Janmaimool and Chudech's adaptation of the instrument utilized scores on the Likert scale that ranged from "not at all" to "very well." The researcher modified the wording on the last PEK item on the survey that was local to participants in the original survey in order to gauge current participants' opinions about local issues related to PEK.

As shown in Figure 5 on page 49, the study instrument included two subsections for environmental concern (EC)—domestic environmental concerns (items 6 to 9) and global environmental concerns (items 10 to 14). In order to measure these variables, a five-point Likert scale ranging from "not at all" to "very much concerned" was established on the instrument based on a Gallup poll environmental concern questions (Dunlap et al., 1993). The Gallup's poll validity was supported in Neumayer's (2002) analysis of examining the Gallup poll's cross-national differences in environmental surveys with theoretical hypotheses. Validity checks need to utilize hypotheses for which strong a priori expectations from theoretical reasoning exists and systemic data should be utilized instead of casual observations, questions that the Gallup study appropriately asks (Neumayer, 2002).

Figure 4

Survey Items for Perceived Environmental Knowledge (PEK)

CIRCLE YOUR RESPONSE FOR EACH QUESTION	Not at All				Very Well
1. How much do you know about climate change situations?	1	2	3	4	5
2. How much do you know about causes of global warming?	1	2	3	4	5
3. How much do you know about impacts of global warming?	1	2	3	4	5
4. How much do you know about characteristics of ecosystems and natural resources?	1	2	3	4	5
5. How much do you know about causes of flooding in Houston, Texas?	1	2	3	4	5

Figure 5

Survey Items for Environmental Concern (EC)

Domestic Environmental Concerns	6. How concerned are you about flooding in Houston, Texas?	1	2	3	4	5
	7. How concerned are you about shorter winter period in the U.S.?	1	2	3	4	5
	8. How concerned are you about severe hurricanes impacting Houston, Texas during hurricane season?	1	2	3	4	5
	9. How concerned are you about heavy floods occurring in the Houston area?	1	2	3	4	5
Global Environmental Concerns	10. How concerned are you about fires in the Amazon rainforest?	1	2	3	4	5
	11. How concerned are you about the death of aquatic animals due to waste in the oceans?	1	2	3	4	5
	12. How concerned are you about rising global average temperatures?	1	2	3	4	5
	13. How concerned are you about the dramatic decline of polar bears at the North Pole?	1	2	3	4	5
	14. How concerned are you about sea level rise?	1	2	3	4	5

For measuring sense of environmental responsibility (ER), Janmaimool and Chudech developed a five-point Likert scale by utilizing the application of questions created by Kaiser and Shimoda (1999). In their research study, Kaiser and Shimoda (1999) utilized a questionnaire consisting of a Social Desirability Scale, a General Ecological Behavior measure, an adapted Guilt Scale, and six scales related to theoretical differentiation of responsibility concepts. The questionnaire was given to 445 participants of two Swiss transportation associations, and results indicated that if people feel guilty for what they do or fail to do, they also feel morally responsible for the environment. Kaiser and Shimoda (1999) argued that ecological behavior should be justified on a probabilistic measurement methodology that takes the important features of ecological behavior into consideration, something their developed questionnaire accomplished. Reliability, internal consistency, and validity scores in their research indicated that a probabilistic measurement approach can assess general environmental behavior accurately (Kaiser, 1998, Kaiser & Shimoda, 1999). In this instrument, the five-point Likert scale consisted of scores ranging from “completely disagree” to “completely agree.” Figure 6 on the next page provides the survey items found on the instrument.

Figure 6

Survey Items for Environmental Responsibility (ER)

	Completely Disagree				Completely Agree
15. I am aware of environmental impacts before deciding to do something.	1	2	3	4	5
16. I am willing to purchase green products even though I have to pay more.	1	2	3	4	5
17. I am willing to act environmentally even though I do not feel comfortable, such as using public transportation, using stairs instead of an elevator, etc.	1	2	3	4	5
18. It is my responsibility to protect the environment.	1	2	3	4	5
19. I have tried to use things more efficiently in order to save natural resources, such as energy saving behaviors, reuse and recycling behaviors, etc.	1	2	3	4	5

Finally, for measuring environmental beliefs (EB), the study used direct self-reporting methods by utilizing the scale of the new environmental paradigm (NEP) aimed at measuring people's environmental worldview, beliefs, or attitudes (Dunlap et al., 2000) Previous studies and meta-analyses have provided a strong support of the NEP scale as a research instrument (Hawcroft & Milfont, 2010; Lundmark, 2007). Janmaimool and Chudech revised the NEP scale used in the survey and utilized six of the 15 items on the original questionnaire in order to ensure the reliability of the collected data. As shown in Figure 7 on page 52, questions on EB used a five-point Likert scale with scores ranging from "completely disagree" to "completely agree."

Figure 7

Survey Items for Environmental Beliefs (EB)

20. Ecosystems are vulnerable, and they can be easily deteriorated.	1	2	3	4	5
21. Nature is strong, and it can cope with consequences of human development activities.	1	2	3	4	5
22. Naturally, the existence of plants and animals is for human utilization.	1	2	3	4	5
23. The earth is like a spaceship with finite room and resources.	1	2	3	4	5
24. If things continue on their present course, we will soon experience a major ecological catastrophe.	1	2	3	4	5
25. Humans have the right to modify the natural environment to suit their needs.	1	2	3	4	5

Figure 8 below provides overview of the survey domains and adaptation information discussed above.

Figure 8

Variables, Questions, and Explanations for Data Collection

Domain: Variable	Instrument Questions	Adapted From
1: Perceived Environmental Knowledge - PEK	1 – 5	Zhu, 2015
2: Environmental Concern – EC	6 - 14	Gallup Poll – Global Environmental Concern, 1993
3: Environmental Responsibility - ER	15 - 19	Kaiser & Shimoda, 1999
4: Environmental Beliefs – EB	20 - 25	New Environmental Paradigm (NEP) Scale Dunlap, Van Liere, Mertig, & Jones, 2000

Data Collection Procedures

The current study took place at a large, urban preservice teacher education program in the south-central United States during the Spring 2021 semester. The study follows a pretest/posttest design. Data collection of the survey was carried out before and after the implementation of a two-week learning cycle on climate change. To assess the previous knowledge, attitude, concerns and unbiased opinions of the pre-service teachers prior to the intervention, the researcher gathered pre-test data. The pretest (survey) was distributed to students through a Google form link a week before the participants were instructed on the two-week intervention—the learning cycle on climate change. The link was both emailed and shared during the course meeting time. To measure the acquired knowledge, attitudes, and concerns of students after the climate change lesson, the researcher administered the same survey as a posttest. The posttest (survey) was given to students immediately following the climate intervention lesson via Google form link. The link was emailed and embedded in their digital interactive science notebooks (DISN). To safeguard student information and confidentiality, students were required to only enter their first and last initials for the completion of the pretest and posttest. Each initial in the pretest was given a number and matched to a corresponding posttest initial. These data were only shared with the researcher in order to further safeguard student information and confidentiality. The collected data were treated as archival. The researcher received approval to obtain archival data from the University of Houston's Committee for the Protection of Human Subjects as the instructor of record for the science methods course.

Data Analysis Procedures

Data from the pretest and posttest surveys were analyzed after final exams were completed by the pre-service teachers in the spring of 2021. The data analysis of the pretest and posttest data was performed upon transferring all data to the SPSS 27 (IBM) software. The raw scale scores of each item on the questionnaire were assigned to the appropriate domain and totaled for 47 pre-service teachers who were enrolled and completed the intervention lesson as well as the pretest and posttest survey. There were no missing data and absences during these two weeks from enrolled participants. The average scores of PEK, EC, ER, and EB were calculated separately for the pretest and posttest survey. Items 21, 22, and 25 were reversed scored with 5 changing to 1, 4 changing to 2, 3 staying 3, 2 changing to 4, and 1 changing to 5. The higher the score for PEK, the stronger the individual's perception of comprehension about the nature and environment. The higher the score of EC, the higher are individuals' level of concerns about catastrophic environmental problems. The higher the score of ER, the stronger are the individuals' feeling of moral responsibility towards the environment. The higher the score of EB, the stronger the perception, or belief about, the connection between humans and the environment.

The Paired Sample *t*-test is a parametric statistical method used to determine whether the difference in the means between two sets of observations, such as pre-test and post-test, is significant. In order to determine statistical significance, the ninety-five percent confidence level ($p < .05$) was used as the criterion level.

Limitations of the Study

There were several limitations associated with the study. First, a convenience sample was used rather than a random sample. Also, the number of responses (N=47) could affect generalization of the survey population. Second, the results of the study included individual beliefs; therefore, individual misinterpretation of the statements form the instrument was possible (Schober & Conrad, 1997; Schober, Corad, & Fricker, 2004). There is also the possibility that individuals may not respond truthfully for a variety of reasons. Third, a one-group pretest-posttest design was used in this study. The lack of a control group in a single group design posed a threat to the internal validity of the study (Patten, 2004). The researcher used the one-group pretest-posttest design because the research environment did not permit the establishment of a control group due to the problematic conditions created by the COVID-19 pandemic and the limited number of courses available that could implement the climate change lesson cycle. Fourth, the study lacks longitudinal perspective. The study was based on a two-week intervention lesson with the post-test occurring immediately following the final day of the lesson. With the post-test measurement only occurring one time, it was not possible to ascertain whether the two-week instruction had a lasting impact on the attitudes and beliefs of pre-service teachers regarding climate related issues. Fifth, the brevity of the instruction in this study represents a limitation. Change is complex and time-consuming and in education, according to the Concerns-Based Adoption Model, any implementation within classrooms would require three to five years (Hall & Hord, 2001). Six hours of instruction in two days split between two weeks may not be sufficient time to enable any modifications in future classrooms even if pre-service teacher attitudes changed at the end of the instruction. Lastly, extraneous variables could exist in this study. While the relatively short time in which the instructional lesson occurred may have reduced the effect of extraneous variables, it was not possible to assess whether differences in pretest and posttest results were due to the intervention lesson or to outside factors or extraneous variables.

Summary

This chapter has introduced the design and procedures adopted for the study as well as the methods that were used in data collection and data analysis. The chapter also introduced the setting for the study which occurs in a large urban university in the south-central United States, during two sessions of an elementary science methods course. A quantitative research method was used to test the effectiveness of a guided inquiry instruction about climate-related disasters on the perceived environmental knowledge, beliefs, concerns, and responsibility of pre-service teachers. A one-group pretest-posttest design was employed, and the means of pretest and posttest scores were compared to check for any statistically significant difference. In the data analysis section, the statistical methods used to compare pretest and posttest scores were discussed. The next chapter presents the statistical analysis and results of the study.

Chapter IV

Results and Analysis

The purpose of this study was to examine the effect of a climate change learning cycle on preservice teachers' perceived knowledge, beliefs, concerns, and perceived responsibilities related to the environment. The study utilized a *t*-test for paired samples in order to test the directional research hypothesis. Data were gathered through a survey that consisted of four domains determined by the authors of the instrument: (1) perceived environmental knowledge (PEK), (2) environmental concerns (EC), (3) environmental responsibility (ER), and (4) environmental beliefs (EB). The research questions addressed by this study were as follows:

Research Question One. What was the effect of climate change instruction on pre-service teachers' perceived environmental knowledge (PEK)?

Research Question Two. What was the effect of climate change instruction on pre-service teachers' level of environmental concerns (EC)?

Research Question Three. What was the effect of climate change instruction on pre-service teachers' sense of environmental responsibility (ER)?

Research Question Four. What was the effect of climate change instruction on pre-service teachers' pro-environmental beliefs (EB)?

In order to address the research questions, the following directional research hypothesis were tested:

Research Hypothesis One. The perceived environmental knowledge of pre-service teachers after participating in climate change instruction was statistically significantly higher than the perceived environmental knowledge of pre-service teachers prior to participating in the instruction.

Research Hypothesis Two. The level of environmental concerns of pre-service teachers after participating in climate change instruction was statistically significantly higher than the levels of environmental concerns of pre-service teachers prior to participating in the instruction.

Research Hypothesis Three. The sense of environmental responsibility of pre-service teachers after participating in climate change instruction was statistically significantly higher than the sense of environmental responsibility of pre-service teacher prior to participating in the instruction.

Research Hypothesis Four. The level of pro-environmental beliefs of pre-service teachers after participating in climate change instruction was statistically significantly higher than the level of pro-environmental beliefs of pre-service teachers prior to participating in the instruction.

Results Obtained for Research Hypothesis One

The following is the first of four research questions addressed by this study: What was the effect of climate change instruction on pre-service teachers' perceived environmental knowledge? In addressing this research question, the study tested the following directional research hypothesis: The perceived environmental knowledge of pre-service teachers after participating in climate change instruction was statistically significantly higher than the perceived environmental knowledge of pre-service teachers prior to participating in climate change instruction. To determine whether pre-service teachers' perceived environmental knowledge was statistically significantly more positive after they participated in climate change instruction than pre-service teachers' perceived environmental knowledge before they participated in climate change instruction, a *t*-test for paired samples was utilized. Table 2 below presents the results obtained relevant to Research Hypothesis One.

Table 2

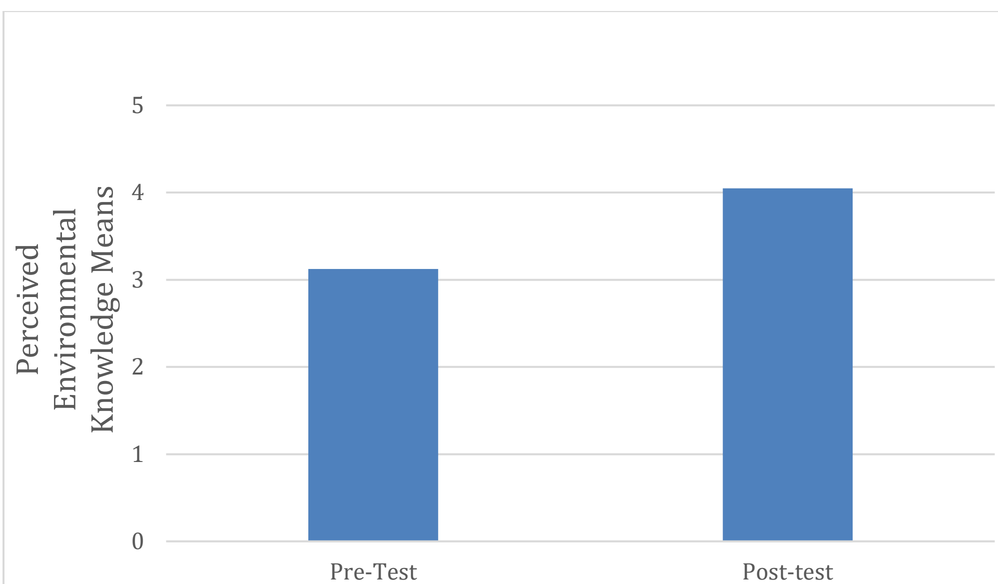
Paired Samples t-test Results Comparing the Pretest and Posttest Scores of EK

Test	*N*	Mean	Std. Dev.	Mean Difference	*t*	df	Sig. (*p*)	*d*
Pre-	47	3.12	.806	.923	9.05	46	<.001	+1.24
Post-	47	4.05	.675					

As presented on Table 2, the *t*-test for paired samples yielded a *t* of 9.05 which was statistically significant ($p < .001$) and a very large effect size ($d = +1.24$) was also educationally meaningful. Figure 9 below shows the results in graphic form.

Figure 9

Bar Graph of Results Obtained for Research Hypothesis One



Results Obtained for Research Hypothesis Two

The following is the second of four research questions addressed by this study: What was the effect of climate change instruction on pre-service teachers' environmental concerns? In addressing this research question, the study tested the following directional research hypothesis: The level of environmental concerns of pre-service teachers after participating in the climate change instruction was statistically significantly higher than the level environmental concerns of pre-service teachers prior to participating in the instruction. To determine whether pre-service teachers' level of environmental concerns were statistically significantly more positive after they participated in climate change instruction than pre-service teachers' level of environmental concerns before they participated in climate change instruction, a *t*-test for paired samples was utilized. Table 3 below presents the results obtained relevant to Research Hypothesis Two.

Table 3

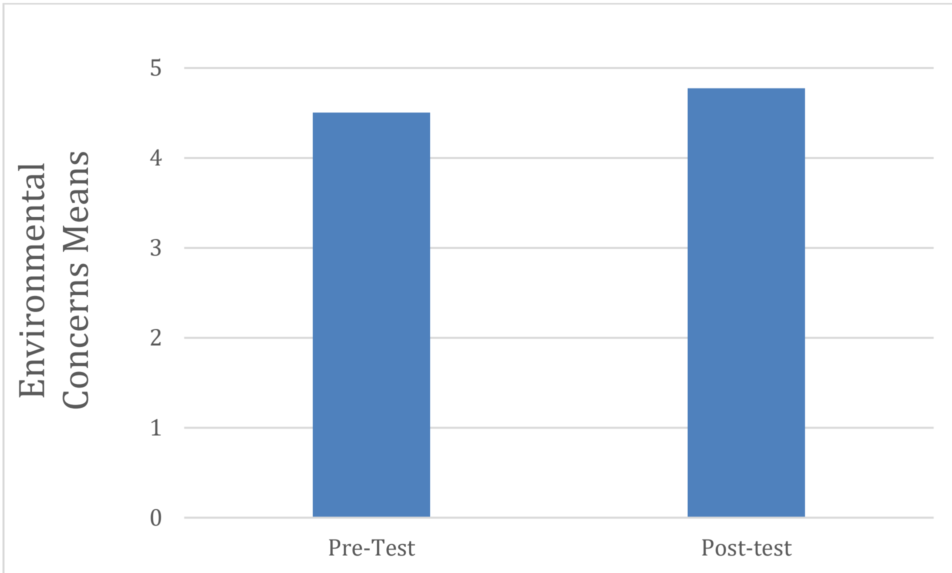
Paired Samples t-test Results Comparing the Pretest and Posttest Scores of EC

Test	*N*	Mean	Std. Dev.	Mean Difference	*t*	df	Sig. (*p*)	*d*
Pre-	47	4.50	.567	.272	4.45	46	<.001	+0.52
Post-	47	4.78	.475					

As presented on Table 3, the *t*-test for paired samples yielded a *t* of 4.45 which was statistically significant ($p < .001$) and an effect size ($d = +0.52$) was also educationally meaningful. Figure 10 on page 61 shows the results in graphic form.

Figure 10

Bar Graph of Results Obtained for Research Hypothesis Two



Results Obtained for Research Hypothesis Three

The following is the third of four research questions addressed by this study: What was the effect of climate change instruction on pre-service teachers' sense of environmental responsibility? In addressing this research question, the study tested the following directional research hypothesis: The sense of environmental responsibility of pre-service teachers after participating in climate change instruction was statistically significantly higher than the sense of environmental responsibility of pre-service teachers prior to participating in the instruction. To determine whether pre-service teachers' sense of environmental responsibility were statistically significantly more positive after they participated in climate change instruction than pre-service teachers' sense of environmental responsibility before they participated in climate change instruction, a *t*-test for paired samples was utilized. Table 4 on page 62 presents the results obtained relevant to Research Hypothesis Three.

Table 4

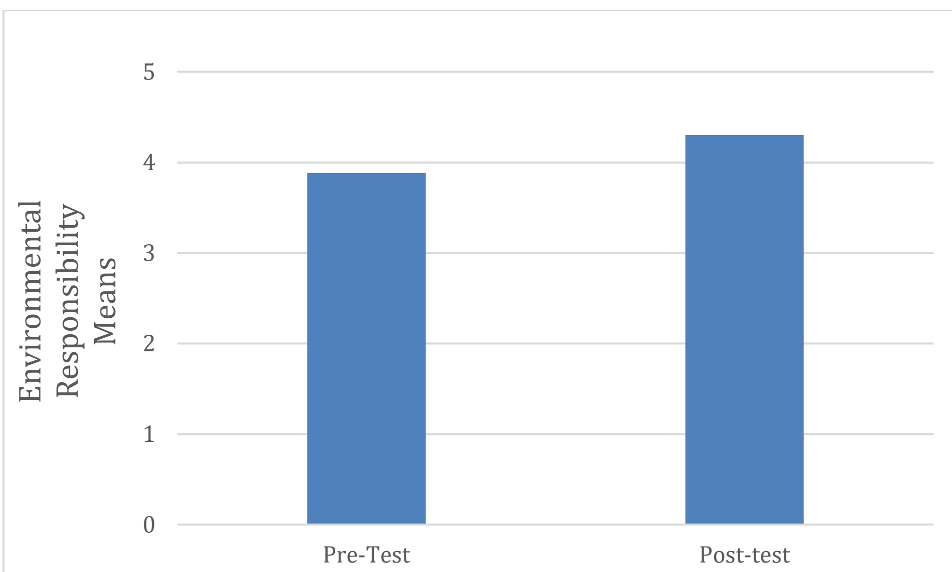
Paired Samples t-test Results Comparing the Pretest and Posttest Scores of ER

Test	*N*	Mean	Std. Dev.	Mean Difference	*t*	df	Sig. (*p*)	*d*
Pre-	47	3.88	.807	.421	4.40	46	<.001	+0.54
Post-	47	4.30	.765					

As presented on Table 4, the *t*-test for paired samples yielded a *t* of 4.40 which was statistically significant ($p < .001$) and an effect size ($d = +0.54$) was also educationally meaningful. Figure 11 below shows the results in graphic form.

Figure 11

Bar Graph of Results Obtained for Research Hypothesis Three



Results Obtained for Research Hypothesis Four

The following is the fourth of four research questions addressed by this study: What was the effect of climate change instruction on pre-service teachers' pro-environmental beliefs? In addressing this research question, the study tested the following directional research hypothesis: The level of pro-environmental beliefs of pre-service teachers after participating in climate change instruction was statistically significantly higher than the level of pro-environmental beliefs of pre-service teachers prior to participating in the instruction. To determine whether pre-service teachers' level of pro-environmental beliefs was statistically significantly more positive after they participated in climate change instruction than pre-service teachers' level of pro-environmental beliefs before they participated in climate change instruction, a *t*-test for paired samples was utilized. Table 5 below presents the results obtained relevant to Research Hypothesis Four.

Table 5

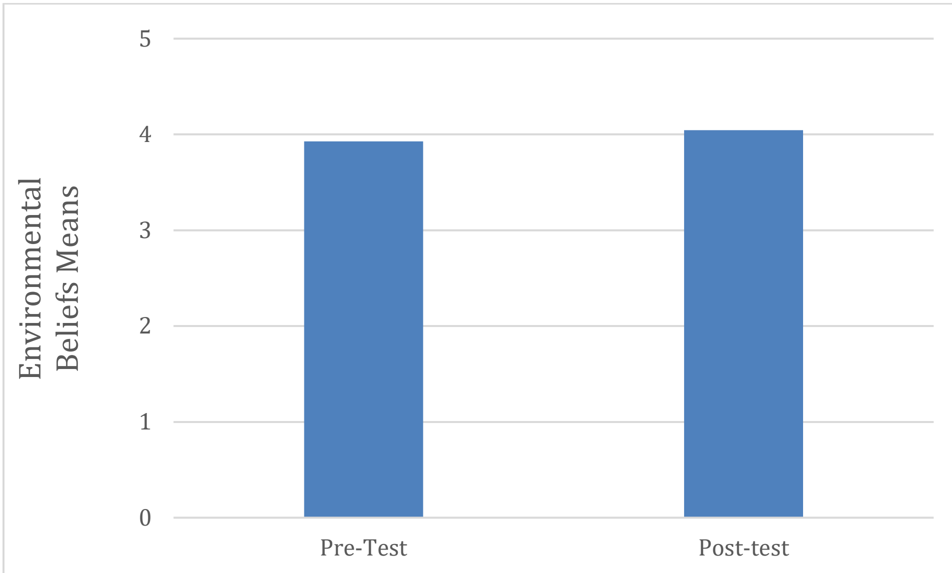
Paired Samples t-test Results Comparing the Pre-test and Post-test Scores of EB

Test	*N*	Mean	Std. Dev.	Mean Difference	*t*	df	Sig. (*p*)	*d*
Pre-	47	3.93	.692	.117	1.69	46	.098	+0.18
Post-	47	4.05	.596					

As presented on Table 5, the *t*-test for paired samples yielded a *t* of 1.69 which was not statistically significant ($p = .098$) and an effect size ($d = +0.18$) that was not educationally meaningful. Figure 12 on page 64 shows the results in graphic form.

Figure 12

Bar Graph of Results Obtained for Research Hypothesis Four



Summary

Forty-seven pre-service teachers participated in the climate change instruction and completed the pretest and posttest survey. The results of the survey were used to compare perceived environmental knowledge, level of environmental concerns, level of pro-environmental beliefs, and sense of environmental responsibility of pre-service teachers before they received climate change instruction and the perceived environmental knowledge, level of environmental concerns, level of pro-environmental beliefs, and sense of environmental responsibility after they received climate change instruction. This chapter presented the results obtained from the analysis relevant to research question one through four and the hypotheses set forth in this study. Statistically significant differences were found regarding research question one, two, and three; in each case, these differences were also viewed to be educationally meaningful. No statistically significant relationship was found regarding research question four. The next chapter present the study's conclusions and interpretations for each of the four research questions, as well as implications and recommendations for further research.

Chapter V

Conclusion

Introduction

The purpose of this study was to examine the effect of a climate change learning cycle on preservice teachers' perceived knowledge, beliefs, concerns, and perceived responsibilities related to the environment. The study examined four research questions. Chapter Three reported the methods and procedures that were utilized to achieve this purpose. Chapter Four presented the results of series of *t*-tests examining each of the four research questions. This chapter further discusses and interprets those findings and establishes connections between the results and the research questions defined for the current study. The researcher will also explore possible implications of the study and how it may inform the field of science teacher preparation. The chapter concludes with recommendations for areas of future research.

Conclusion and Interpretation for Research Question One

The first research question compared pre-service teachers' environmental knowledge before participating in climate change instruction with their environmental knowledge after participating in the instruction. For this study, environmental knowledge was evaluated using self-reporting methods yielding results deemed perceived environmental knowledge (Janmaimool & Chudech, 2020). Environmental knowledge is defined as understanding of the nature, environments, and relevant issues, such as existing environmental conditions, the reasons of environmental challenges and possible effects (Chan & Lau, 2000). The first research question asked: What was the effect of climate change instruction on pre-service teachers' environmental knowledge? In addressing this research question, the study tested the following directional research hypothesis: The environmental knowledge of pre-service teachers after participating in climate change instruction is statistically significantly higher than the environmental knowledge of pre-service teachers prior to participating in the instruction. The results presented in Table 2 on page 59 indicate that there was a statistically significant difference ($p < .001$) between the mean obtained for pre-service teachers before they participated in climate change instruction (3.12) and the mean obtained after they participated in climate change instruction (4.05). Therefore, the directional research hypothesis is accepted.

Given this conclusion, this study suggests the following interpretation: There is a statistically significant difference in pre-service teachers' perceived environmental knowledge after participating in climate change instruction than pre-service teachers' perceived environmental knowledge before participating in a climate change instruction. Furthermore, Table 2 indicated the obtained effect size (*d*) of +1.24 was obtained. Gall, Borg, and Gall (1996) argue that an effect size greater than 0.33 is educationally meaningful, therefore differences in pre-service teachers' environmental knowledge on pretest and posttest yields a significant effect size, indicating that the climate change learning cycle was successful in improving pre-service teachers' environmental knowledge as measured by the survey.

Conclusion and Interpretation for Research Question Two

The second research question compared pre-service teachers' level of environmental concerns before participating in climate change instruction with their level of environmental concerns after participating in the instruction. Environmental concern helps explain individuals' attitudes towards the environment and environmental behaviors. For this study, environmental concern is defined as the level to which people are alarmed about the environmental troubles found globally and domestically (Janmaimool & Chudech, 2020). The second question asked: What was the effect of climate change instruction on pre-service teachers' level of environmental concerns? In addressing this research question, the study tested the following directional research hypothesis: The pre-service teachers' level of concerns about catastrophic environmental problems after participating in climate change instruction is statistically significantly more than the pre-service teachers' level of concerns about catastrophic environmental problems prior to participating in the instruction.

With regard to pre-service teachers' environmental concerns analyzed during the study, the results present in Table 3 on page 60 indicate that there was a statistically significant difference ($p < .001$) between the mean obtained for pre-service teachers before they participated in climate change instruction (3.12) and the mean obtained after they participated in climate change instruction (4.05). Therefore, the directional research hypothesis is accepted.

Given this conclusion, this study suggests the following interpretation: There is a statistically significant difference in pre-service teachers' level of concerns about catastrophic environmental problems after participating in climate change instruction than pre-service teachers' level of concerns about catastrophic environmental problems before participating in a climate change instruction. Furthermore, Table 3 indicated the obtained effect size (d) of +0.52 was obtained. This signifies that the pretest and posttest difference corresponds to a large effect size and indicates that the climate change instruction was successful in improving the overall pre-service teachers' level of concern about catastrophic environmental problems as measured by the survey. Additionally, it can be argued that the positive difference in pre-service teachers' level of environmental concern is also educationally meaningful.

Conclusion and Interpretation for Research Question Three

The third research question compared pre-service teachers' sense of environmental responsibility before participating in climate change instruction with their sense of environmental responsibility after participating in the instruction. For this study, environmental responsibility refers to a sense of personal obligation towards the environment or sense of responsibility to take action to avoid undesirable impacts on the environment (Janmaimool & Chudech, 2020). The fourth question stated: What was the effect of climate change instruction on pre-service teachers' sense of environmental responsibility? In addressing this research question, the study tested the following directional research hypothesis: The sense of environmental responsibility of pre-service teachers after participating in climate change instruction is statistically significantly stronger than the sense of environmental responsibility of pre-service teachers prior to participating in the instruction.

With regard to pre-service teachers' sense of environmental responsibility analyzed during the study, the results present in Table 4 on page 62 indicate that there was a statistically significant difference ($p < .001$) between the mean obtained for pre-service teachers before they participated in climate change instruction (3.88) and the mean obtained after they participated in climate change instruction (4.30). Therefore, the directional research hypothesis is accepted.

Given this conclusion, this study suggests the following interpretation: There is a statistically significant difference in pre-service teachers' sense of environmental responsibility after participating in climate change instruction than pre-service teachers' sense of environmental responsibility before participating in a climate change instruction. Furthermore, Table 4 indicated the obtained effect size (*d*) of +0.54 was obtained. This signifies that the pretest and posttest difference corresponds to a large effect size and indicates that the climate change instruction was successful in improving the overall pre-service teachers' sense of environmental responsibility as measured by the survey. Additionally, it can be argued that the positive difference in pre-service teachers' sense of environmental responsibility is also educationally meaningful.

Conclusion and Interpretation for Research Question Four

The fourth research question compared pre-service teachers' pro-environmental beliefs before participating in climate change instruction with their pro-environmental beliefs after participating in the instruction. For this study, environmental belief refers to individuals' general beliefs about the relationships between human and nature, also called environmental worldview or general environmental attitude (Janmaimool & Chudech, 2020). The fourth question stated: What was the effect of climate change instruction on pre-service teachers' pro-environmental beliefs? In addressing this research question, the study tested the following directional research hypothesis: The pro-environmental beliefs of pre-service teachers after participating in climate change instruction is statistically significantly stronger than the pro-environmental beliefs of pre-service teachers prior to participating in the instruction.

With regard to pre-service teachers' pro-environmental beliefs analyzed during the study, the results present in Table 5 on page 63 indicate that there was no statistically significant difference ($p < .098$) between the mean obtained for pre-service teachers before they participated in climate change instruction (3.93) and the mean obtained after they participated in climate change instruction (4.05). Therefore, the directional research hypothesis is not accepted.

Given this conclusion, this study suggests the following interpretation: There is not a statistically significant difference in per-service teachers' pro-environmental beliefs after participating in climate change instruction than pre-service teachers' pro-environmental beliefs before participating in a climate change instruction. Furthermore, Table 5 indicated the obtained effect size (d) of +0.18 is less than one-third of a standard deviation. This signifies that the pretest and posttest difference corresponds to a small effect size and indicates that the climate change instruction was not successful in improving the overall pre-service teachers' pro-environmental beliefs as measured by the survey. Additionally, it can be argued that the difference in pre-service teachers' pro-environmental beliefs is not educationally meaningful.

Implications

This study sought to extend the knowledge base concerning the effect of climate change instruction on pre-service teachers' perceived environmental knowledge, attitudes, concerns, and affective dispositions of environmental responsibility by looking at pre-assessment and post-assessment results from a survey instrument. This study provides implications for future work with pre-service teachers and future integration of climate change instruction within current elementary science methods courses. Though this study is not meant to be generalized to all teacher preparation programs, aspects of the findings can inform science teacher educators who are preparing pre-service teachers for adopting an environmentally responsible stance.

This study examines the perceived environmental knowledge, beliefs, concerns, and sense of environmental responsibility of pre-service teachers before and after climate change instruction during a science methods course designed to prepare early childhood through sixth grade pre-service teachers to teach science to students. The results suggest that participation in a climate change learning cycle affected pre-service teachers' beliefs about perceived environmental knowledge, level of concerns, and sense of responsibility for environmental issues. These findings align with previous studies that found similar significant increases in environmental knowledge, interest, and understanding (Arslan et al., 2012; Lambert et al., 2012; Lombardi & Sinatra, 2012). These findings appear to indicate that a two-day climate change instruction significantly improves pre-service teachers' environmental knowledge, concerns, and sense of environmental responsibility.

Despite the positive findings for EK, EC, and ER, the results did not yield statistically significant or educationally meaningful findings for EB. This is contrary to findings of previous studies that found short term environmental instruction can lead to shifts in environmental attitudes and beliefs of undergraduate students (Packer, 2009; Rideout, 2005). However, previous studies have shown that female students demonstrate more positive environmental beliefs and attitudes compared to males (Anderson et al., 2007; Tikka et al., 2000; Zelezny et al., 2000). One of the reasons that might explain why the current study differed from past studies is the ratio of male to female student participants. Forty-four of the 47 pre-service students selected female as their gender on the surveys. Kuo and Jackson's (2014) reported that females started their environmental research course with stronger environmental attitudes and completed the course with a positive shift in attitude that was not statistically significant. Similarly, the mean of this study's pretest score on pro-environmental beliefs was initially high (3.93 of a possible 5), indicating that the pre-service teachers already had a high pro-environmental beliefs prior to climate change instruction. A future study that can include a balanced number of gender participants could provide better environmental belief data.

Figure 5 below shows a summary of the movement upward or downward for each domain. The arrows with dashed lines indicate a movement either up or down that was not statistically significant and solid filled arrows indicate a statistically significant move. Solid filled up arrows also indicate statistically significant effect size, and dashed, up and down arrows indicate not statistically significant effect size. This figure provides a summary review of the changes in the domains after completing the climate change instruction.

Figure 13

A Summary View of the Survey Questionnaire

Domain	Statistical Significance	Effect Size
1. Environmental Knowledge	$p < .001$	$d = +1.24$
2. Environmental Concern	$p < .001$	$d = +0.52$
3. Environmental Responsibility	$p < .001$	$d = +0.54$
4. Environmental Attitudes	$p = .098$	$d = +0.18$

Note. A summary view of the movement of domain 1-4 of the survey instrument, solid filled arrows indicating statistically significant ($p < .05$) or educationally meaningful movement (Cohen's $d > 0.33$).

The Next Generation Science Standards (NGSS) suggest integrating climate literacy into science curricula, identifying climate change, energy, human impacts on earth systems and sustainability as key ideas in both life and earth sciences. As humans witness changes in the global climate and the communities around them, pre-service teacher development programs play a guiding role in leading our next generation of students on this path towards a sustainable future. Hence, climate change curriculum and instruction opportunities are critically needed to develop required knowledge base, concern, attitudes and sense of responsibility among school-age students. There is broader impact on society as the gap grows between the science and the public's understanding of science (Sterman, 2011). Baram-Tsabari and Osborne (2015) challenge science educators to teach students to be able to make informed choices. The results of this study suggest that two days of climate change instruction is educationally effective and is one example on how to address this challenge posed to the science education community (Berry et al., 2008). Research by McNeal et al. (2017) found that teaching climate change gives teachers a sense of hope as they impact the future through their students. Through climate change instruction, pre-service teachers are given the tools that can better help them with their instruction in schools, that has been found to be highly significant and important in helping students construct attitudes and beliefs that are in support of climate literacy (Ekborg & Areskoug, 2006; McNeal et al., 2017; Schreiner et al., 2005)

Stevenson et al. (2016) found that teacher beliefs about global warming and student climate change knowledge were the strongest predictors of student belief that global warming is happening, and human caused. Stevenson et al. (2016) also found that student climate change knowledge was a strong, positive predictor of students' belief that global warming is happening, and human caused. By providing pre-service teachers in teacher preparation programs climate change instruction, their future students can assemble the basic climate change background information and connect human causes to climate (Stevenson et al., 2016).

Suggestions for Future Research

The findings of this study indicated statistically significant increases in pre-service teachers' environmental knowledge, concerns, and sense of environmental responsibility after the climate change instruction. he results of this study diverged from past studies that reported statistically significant positive changes in participants' environmental attitudes. The high disproportionate number of female students may explain this finding since females demonstrate more positive environmental attitudes than males (Anderson et al., 2007; Tikka et al., 2000). Future studies with more proportionate female and male participants may illuminate this finding further. This finding also brings gender differences in environmental attitudes to the forefront, indicating that future research should examine any possible effects of climate change instruction on school-age males and females.

Another avenue for future research could be adding a qualitative aspect to the current research design. It would be particularly helpful to investigate participants' prior level of experience with environmental activities that impact any of the four domains. Interviewing the participants over time through a longitudinal study would also help the researcher gather information regarding the climate change instruction and its effect over time. Participants can be interviewed when they enter the teacher education program about responsible environmental behaviors and interviewed again at the conclusion of the program in order to investigate changes in their beliefs, concerns, and knowledge about the environment. A longitudinal study that tracks participants throughout the program can also help assess the survey instrument based on data collected in order to further ensure validity and reliability of the instrument.

Additionally, a follow-up study is needed to assess these participants' implementation of climate science education in their classrooms over time and to examine the status of their students' environmental beliefs, attitude, concerns, and responsibilities regarding environmental and climate topics. This will help investigate climate change instruction on long-term outcomes in the classroom. As students become active participants in their communities and countries, for example by voting, they will become part of the political society where their decisions could have significant impacts and influence on climate-related issues, and global climate decisions that will impact their own country and the ecosystems all over the globe.

In addition, the current online design of the intervention lesson could be compared to both face-to-face and hybrid lessons. A study that can compare the strengths and effectiveness of these three different platforms for instruction can add to the body of knowledge for effectiveness of different modes of instruction. As parents and educators are making significant decisions about students' educational futures, the strengths of different modes of instruction can inform and help educators as they plan diverse effective instructional lessons for students.

The current research study and intervention lesson measured perceived knowledge and responsibilities of participants and did not measure responsible environmental behaviors. The current study focused on expository interventions and future research on this topic can incorporate problem-solving or project-based environmental activities that could encourage pre-service teachers to take pro-environmental action on their own and help develop ownership which can promote pro-environmental behaviors for them and their future students. Bandura (1997) argued that efficacy beliefs are strong motivating and guiding influences on behavior. Research in a variety of settings has shown that efficacy is a crucial factor in the commencement, preservation, and outcome of behavior (Bandura, 1986). Due to the limitations of time and the online instruction, participants were provided a foundation based on knowledge instruction for climate change, however the instruction did not make issues personal to the participants where pro-environmental behaviors could be promoted and measured.

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Appendix A

Climate Change: A Survey for Pre-Service Science Teachers

Directions: This survey is about Climate Change education. Please answer each question the best you can. Thank you!

1. What is your age: ______

2. Sex: Male ___________ Female ___________ Other (please fill in): ________

3. Ethnicity (Check all that apply):

   ________ Caucasion ________ Black or African American

   ________ American Indian ________ Hispanic

   ________ Asian _________ Native Hawaiian or Pacific Islander

   Other: _________________________

4. What best describes your religious identity?

5. Politically, I usually identify myself as: ____________________

6. Your father's highest level of education:

   High school or below ___ Some college or Associates ___ Bachelor's Degree ___

   Master's Degree ___ Ph.D. or Above ___ I don't know ___

7. Your mother's highest level of education:

   High school or below ___ Some college or Associates ___ Bachelor's Degree ___

   Master's Degree ___ Ph.D. or Above ___ I don't know ___

8. Are you the first person in your family to go to college? Yes ______ No ______

9. Have you ever taken an environmental science course? Yes ______ No ______

10. Have you taken college or university courses that discussed the topics relating to Climate Change education? _______ Yes _______ No

11. Have you attended workshops or training that discussed topics relating to Climate Change education? ______ Yes _______ No

12. What is your main source of environmental information?

Directions: The following questions relate to how climate change has impacted your sense of responsibility towards the environment. The survey will take 10-15 minutes to complete. As a reminder, your responses will be anyonymous.

CIRCLE YOUR RESPONSE FOR EACH QUESTION	Not at All				Very Well
1. How much do you know about climate change situations?	1	2	3	4	5
2. How much do you know about causes of global warming?	1	2	3	4	5
3. How much do you know about impacts of global warming?	1	2	3	4	5
4. How much do you know about characteristics of ecosystems and natural resources?	1	2	3	4	5
5. How much do you know about causes of flooding in Houston, Texas?	1	2	3	4	5
6. How concerned are you about flooding in Houston, Texas?	1	2	3	4	5
7. How concerned are you about shorter winter period in the U.S.?	1	2	3	4	5
8. How concerned are you about severe hurricanes impacting Houston, Texas during hurricane season?	1	2	3	4	5
9. How concerned are you about heavy floods occurring in the Houston area?	1	2	3	4	5
10. How concerned are you about fires in the Amazon rainforest?	1	2	3	4	5

11. How concerned are you about the death of aquatic animals due to waste in the oceans?	1	2	3	4	5
12. How concerned are you about rising global average temperatures?	1	2	3	4	5
13. How concerned are you about the dramatic decline of polar bears at the North Pole?	1	2	3	4	5
14. How concerned are you about sea level rise?	1	2	3	4	5

CIRCLE YOUR RESPONSE FOR EACH QUESTION

	Completely Disagree				Completely Agree
15. I am aware of environmental impacts before deciding to do something.	1	2	3	4	5
16. I am willing to purchase green products even though I have to pay more.	1	2	3	4	5
17. I am willing to act environmentally even though I do not feel comfortable, such as using public transportation, using stairs instead of an elevator, etc.	1	2	3	4	5
18. It is my responsibility to protect the environment.	1	2	3	4	5
19. I have tried to use things more efficiently in order to save natural resources, such as energy saving behaviors, reuse and recycling behaviors, etc.	1	2	3	4	5
20. Ecosystems are vulnerable, and they can be easily deteriorated.	1	2	3	4	5
21. Nature is strong, and it can cope with consequences of human development activities.	1	2	3	4	5
22. Naturally, the existence of plants and animals is for human utilization.	1	2	3	4	5

23. The earth is like a spaceship with finite room and resources.	1	2	3	4	5
24. If things continue on their present course, we will soon experience a major ecological catastrophe.	1	2	3	4	5
25. Humans have the right to modify the natural environment to suit their needs.	1	2	3	4	5

Appendix B

Climate Change Instruction Part 1

Part 1 – Climate Change Instruction

Teacher's Name:
Strand: Earth and Space

Lesson Name: Weather and Climate
Science Topic: Weather and Climate

Basic Lesson Components	
Grade Level: 5 **Time Estimate:** **Science Content:** Weather is the state of the atmosphere at any time, including things such as temperature, precipitation, air pressure, humidity and cloud cover. Daily changes in the weather are due to winds and storms. Seasonal changes are due to the Earth revolving around the sun. Climate is the average weather usually taken over a 30-year time period for a particular region and time period. **TEKS:** 5.8 (A) differentiate between weather and climate; **Content Objective(s):** The student will be able to differentiate between weather and climate. **ELPS:** **Listening:** 2.C Learn new language structures, expressions, and basic and academic vocabulary heard during classroom instruction and interactions **Speaking** 2.E Share information in cooperative learning interactions **Reading** 4.E Read linguistically accommodated content area material with a decreasing need for linguistic accommodations as more English is learned Writing 5B Write using newly acquired basic vocabulary and content-based grade-level vocabulary **Language Objective (s):** I can listen and learn science vocabulary. I can share with my ideas with my group during a group activity. I can read information about climate change on a website. I can write what I learned using science vocabulary	
Vocabulary:	**Definition:**
Weather	The state of the atmosphere at any time.
Climate	The average weather usually taken over a 30-year time period for a particular region and time period.
Temperature	A measure of the warmth or coldness of an object or substance
Misconceptions:	
Rain falls out of the sky when the clouds evaporate Clouds are mostly smoke, made of cotton or wool, or they are bags of water	

Materials/Resources/Technology Needs:			
Materials: DISN, Access to internet			
Book: "WOW! Weather!" by Paul Deanno and Toby Mikle			
Technology: computer, Zoom			
Safety:			
none - virtual lesson			
5E Instructional Procedures			
	Activity	**ELL Strategy**	**Vocabulary**
Engage	• In breakout rooms students observe and compare a weather map and climate maps. • Students complete a T-chart comparing the information they observe on the two types of maps. • Students state the similarities and differences that they observe	Graphic Organizer	Weather Climate Temperature
Explore	• Students watch a video exploring the differences between climate and weather. • Students answer questions about the video. • Students Analyze a Weather Forecast by using the website http://teacher.scholastic.com/activities/wwatch/analyze/ • Students take a screenshot of the forecast and paste it in their DISN.	Video	Weather Climate Temperature
Explain	• As the teacher summarizes the difference between weather and climate, the students type in the answers to a fill in the blank. • Students and teacher complete a Venn Diagram about the characteristics of weather and climate by dragging and dropping phrases.	Graphic Organizer	Weather Climate Temperature
Elaborate	• Students use a KWL with Think-Pair-Share and explore the website • https://climatekids.nasa.gov/climate-change-meaning/ • Students share what they learned with the class.		Weather Climate Temperature
Evaluate	Weather vs. Climate statements. Student read statements and determine if it is referring to Weather or Climate		Weather Climate Temperature

ELED 4312
Unit 2 Earth Science
Lesson 4
Fall 2020

Weather and Climate
Writing Content Objectives

Name:

Engage

Explore

Explain

Elaborate

Evaluate

Writing Content Objectives

Information for Today

Questions/Homework

4 Week of 2/15	**Earth Science** Weather and Climate • Writing Content Objectives • TEAM Time	• Cruising the Climate with Spreadsheets (Krall) • Weather Watchers - Teaching through Trade Books (Christine Royce)	**Due by class on 2/22** ➢ **Unit Test 1** ➢ **Journal 1** ➢ Quiz 4 ➢ DISN Output 4

At the end of today's lesson, I will put you into breakout rooms with your Teams.

Today's Science Topic

Earth Science - Weather and Climate

Today's TEKS

(8) Earth and Space. The student knows that there are recognizable patterns in the natural world and among the Sun, Earth, and Moon system. The student is expected to:

(A) differentiate between weather and climate;

Engage

Explore

Explain

Elaborate

Evaluate

Writing Content Objectives

Comparing Weather and Climate Maps

Directions: Look at the Weather Map to the left and Climate Maps to the right of this page. In the T-Chart below make a list of what you observe in each map.

Weather Map	Climate Map

What similarities do you see?

What differences do you see?

Engage

Explore

Explain

Elaborate

Evaluate

Writing Content Objectives

Exploring Climate and Weather

Directions for video exploration:

1. Read through the questions.
2. Watch the video just to enjoy the pictures and information without answering the questions.
3. Read through the questions again, then watch the video and answer the questions by dragging and dropping the answers as the video plays.

1. What is climate?

2. How many climate zones are there on the Earth?

3. What is weather?

4. Why are accurate weather forecasts important?

5. Name 4 technologies that help meteorologists forecast the weather.

Engage
Explore
Explain
Elaborate
Evaluate
Writing Content Objectives

Directions:

1. Visit the Scholastic "Analyze a Weather Forecast" page by clicking on the picture.
2. Choose the weather related topic you would like to analyze - Hurricanes, Winter Storm, Tornado or Drought.
3. Answer the questions and make the forecast. Take a screenshot of the forecast and paste it below.

How does this help you distinguish weather from climate?

Engage
Explore
Explain
Elaborate
Evaluate
Writing Content Objectives

Weather vs. Climate

Directions: Fill in the blanks as your teacher summarizes. Then using what you have learned about weather and climate place the boxes in the correct portion of the Venn Diagram below.

Weather is what the____________is doing right now. Examples are is it sunny, __________, cold_______. Climate is the_________of what the weather_________. It's the average weather - typically over ________ years. It shows long term_________.

Weather

Both

Climate

Wind speed

What to wear on a day

Certain place thought of as wet or dry

Short time frame

Short term changes in the atmosphere

Rainfall

Changes in atmosphere from min. to min

Humidity

Sunshine

2 main things- temperature and rainfall

Temperature

Average of 30 years

Decide what to buy next season

Expected on a daily basis

KWL with TPS

Topic: Climate Change

Understanding Climate

Before we start this activity let's find out what you know about climate change. Click on the box to the right and take a brief survey.

Directions: Complete the first two columns below as your teacher directs. Then read the information and watch the animations by clicking on the picture. Then complete the last column as your teacher directs.

What I **Know**	What I **Wonder**	What I **Learned**

Engage
Explore
Explain
Elaborate
Evaluate
Writing Content Objectives

Combining K-W-L with Think-Pair-Share

What Is K-W-L?

K-W-L is a 3-column chart that helps capture the Before, During, and After components of reading a text selection.

- **K** stands for **Know**
  What do I already know about this topic?
- **W** stands for **Wonder**
  What do I wonder about this topic?
- **L** stands for **Learned**
  What have I learned about this topic?

What is Think-Pair-Share?

1. Announce a discussion topic or problem to solve.
2. Give students at least 10-15 seconds of think time to **THINK** of their own answer.
3. Ask the students to **PAIR** with their partner to discuss the topic or solution.
4. Finally, randomly call or a few students to **SHARE** their ideas with the class.

How Does KWL with TPS Work?

1. On students' individual clean sheets, three columns should be drawn.

2. Label Column 1 **K**, Column 2 **W**, Column 3 **L**.

3. Before reading, students fill in the Know column with 3 things they already know about the topic. This helps generate their background knowledge. *Then have students draw a wavy line under their writing.*

3a. Have students share with a partner the information they already know and write down anything new from their partner under the wavy line.

4. Then have students wonder what they might learn about the topic, which might follow a quick glance at the topic headings, pictures, and charts that are found in the reading.

Have them write down two ideas. *Then have students draw a wavy line under their writing.*

4a. Have students share with a partner the information they wonder about the topic and write down anything new from their partner under the wavy line.

5. Have students read the selection. After reading, students should fill in their new knowledge gained from reading the content in the Learned column. *Then have students draw a wavy line under their writing.*
5a. Have students share with a partner the information they learned about the topic and write down anything new from their partner under the wavy line.

Engage

Explore

Explain

Elaborate

Evaluate

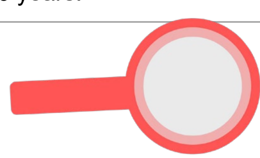
Writing Content Objectives

Output 4

Directions: Read each statement below and identify whether it is referring to weather (W) or Climate (C). Place the W or C in the left column. Use the magnifying glass at the bottom of the page to check your answers in the right column.

	1. Usually it is sunny in Texas.	
	2. This can change from day to day.	
	3. This can remain about the same over a number of years.	
	4. Conditions outside on a daily basis.	
	5. The typical or usual condition for an area.	
	6. Yesterday it was sunny but today we have storms.	
	7. Every year we have mild winters and it rarely snows.	
	8. It is normal for New York to have a lot of snow each year.	
	9. Florida is a popular vacation spot because of consistent sunny days and warm temperatures.	
	10. Our state is on a tornado watch today.	
	11. We should wear a coat today.	
	12. Phoenix, Arizona is a desert.	
	13. What to bring to Los Angeles when we travel there next May.	
	14. We need to bring an umbrella tomorrow.	
	15. Earth has been experiencing increasing temperatures for the last 30 years.	

Click and drag from the handle.



Click and drag the magnifying glass over the blue square to reveal the correct answer.

Engage
Explore
Explain
Elaborate
Evaluate
Writing Content Objectives

Content Objective	*Content Objectives sometimes called* ❖ ❖ *Content Objectives are:* • • • •
TEKS Verb	*Steps for writing content objectives* 1. Identify_______________, ____________________ and______________________from TEKS. 2. Identify________________in Student Expectation
TSWBAT:	3. Typically use_____________verb in each C.O. *Other Tips* Begin each C.O. with ___________________ Use the verb from the ___________________ Plan lesson____________writing the C.O.

Implications for the Science Classroom:

Engage

Explore

Explain

Elaborate

Evaluate

Writing Content Objectives

Writing Content Objectives Practice

Directions:
1. Highlight the Strand in red, the Knowledge statement in blue and the Student Expectation in green.
2. Answer the questions.
3. Use the Student Expectation to write the Content Objective.

5.8 Earth and space. The student knows that there are recognizable patterns in the natural world and among the Sun, Earth, and Moon system. The student is expected to:

(A) differentiate between weather and climate;

1. What is the student expectation in this TEKS?

2. What is the verb in this Student Expectation?

3. What does it mean?

4. If you were observing a classroom in which the teacher was teaching this TEKS what would you expect to see the students doing?

5. Write the content objective for the TEKS in the space below.

Engage

Explore

Explain

Elaborate

Evaluate

Writing Content Objectives

What happens in the TEKS has 2 verbs in it? If the students are to use the verbs with the same content such as “measure and record” weather patterns you may write just one content objective for that TEKS. If the students are to use the verbs with different content, then you should write two separate content objectives.

Directions:
1. Highlight the Strand in red, the Knowledge statement in blue and the Student Expectation in green.
2. Answer the questions.
3. Use the Student Expectation to write the Content Objectives.

2.8 Earth and space. The student knows that there are recognizable patterns in the natural world and among objects in the sky. The student is expected to:

(A) measure, record, and graph weather information, including temperature, wind conditions, precipitation, and cloud coverage, in order to identify patterns in the data;

1. What are the verbs in the Student Expectation above?

2. What content should the students measure, record and graph?

3. What content should the students identify?

4. Write 2 content objectives for the TEKS above in the space below.

Engage

Explore

Explain

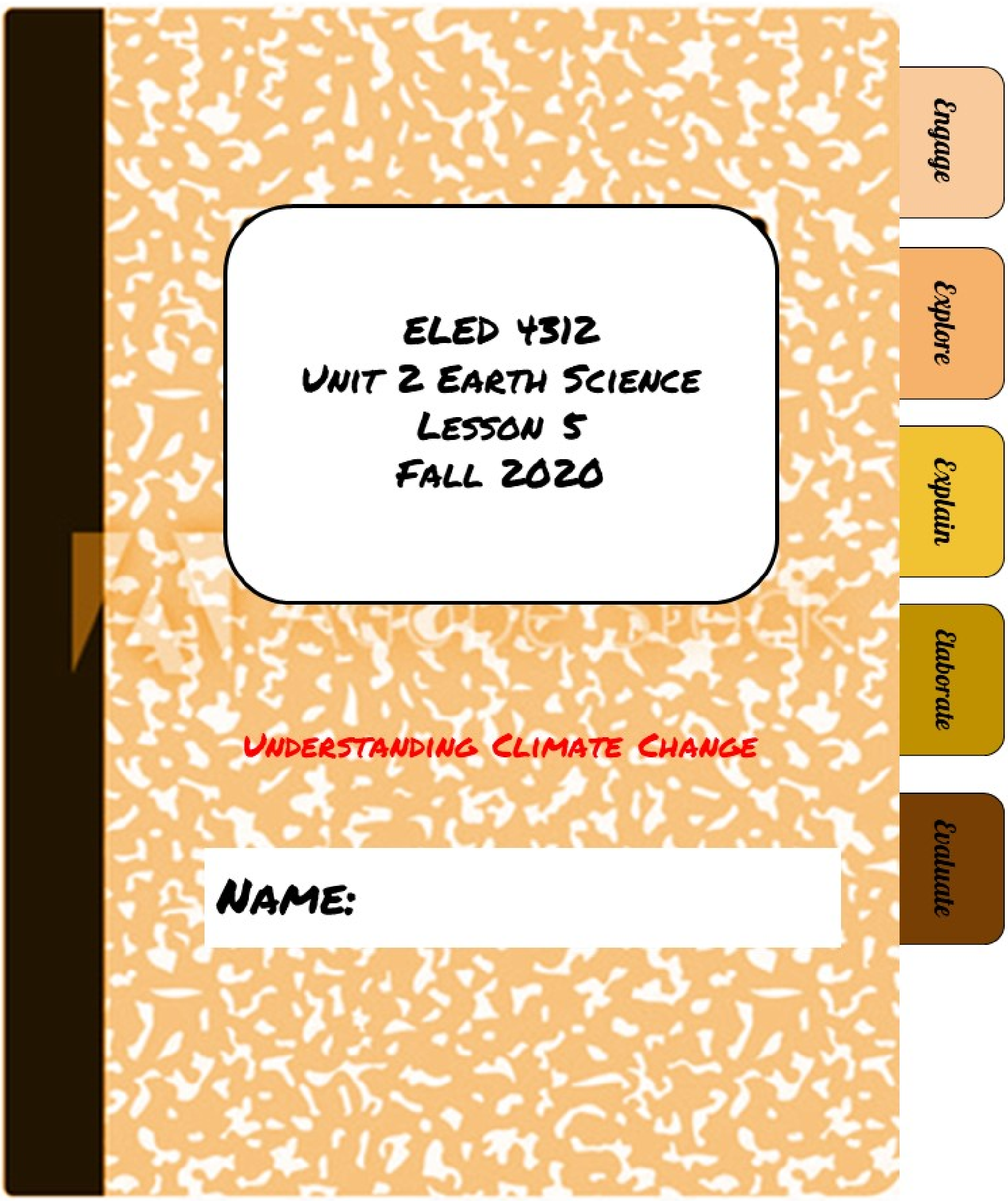
Elaborate

Evaluate

Writing Content Objectives

Appendix C

Climate Change Instruction Part 2


ELED 4312
Unit 2 Earth Science
Lesson 5
Fall 2020
Understanding Climate Change
Name:
Engage
Explore
Explain
Elaborate
Evaluate

Information for Today

Questions/Homework

5 Week of 2/22	**Earth Science** • Weathering and formation of soils • ELPS	• Weathering and Soil Formation (In Blackboard) • How does Mechanical Weathering Change Rocks? (Wardrip and Tobey)	**Due by class on 3/1** ➢ Quiz 5 ➢ DISN Output 5

6 Week of 3/1	**Earth Science** • Properties of soils • Misconceptions	• Second-Grade Soil Scientists (Gibb) • Soil Science in the Digital Age (Vance High and Laura Van Horn) • The Science Beliefs Quiz (Stein, Barman, Haley and Miller)	**Due by class on 3/8** ➢ **Journal 2** ➢ **5ELessonDraft1** ➢ Quiz 6 ➢ DISN Output 6

Today's Science Topic

Earth Science - Weather and Climate

Today's TEKS

(8) Earth and Space. The student knows that there are recognizable patterns in the natural world and among the Sun, Earth, and Moon system. The student is expected to:

(A) differentiate between weather and climate;

Engage

Explore

Explain

Elaborate

Evaluate

Thoughts on Climate Change

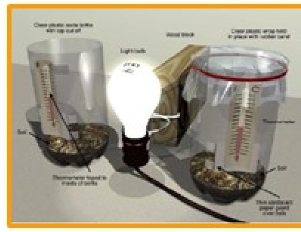
Directions:
1. Click on the picture for the link that will take you to our Padlet.
2. Think about what you know, heard or believe about climate change
3. Click on the pink circle at the bottom of the Padlet and enter your answer to the following question:

What are your thoughts about Climate Change?

When the discussion has finished, take a screenshot of the Padlet and paste it below.

Exploring the Science Behind Climate Change

Team 1: Greenhouse Lab



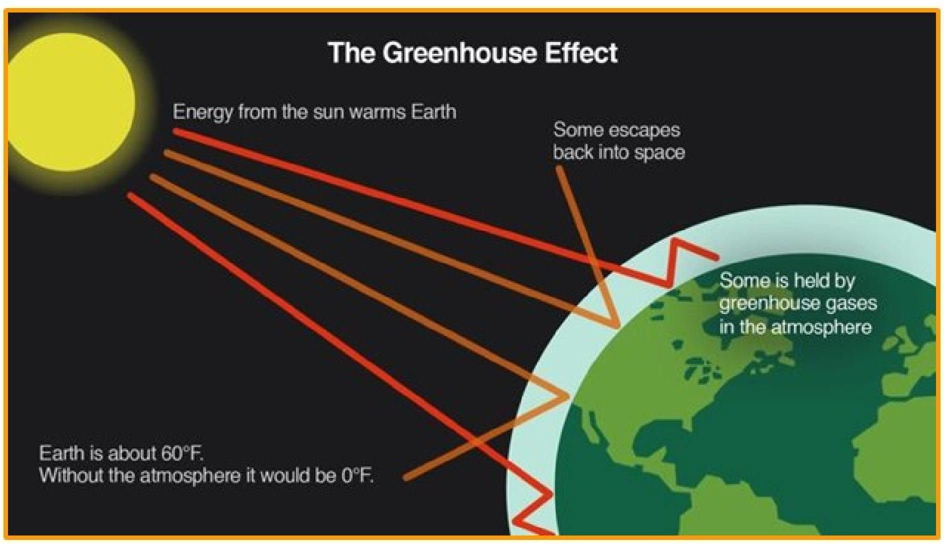
Directions:
1. Watch the video by clicking on the picture.
2. After watching the video, discuss what you observed.
3. Answer the questions below.
4. Be prepared to share the "main" content the experiment is teaching with the class.
5. Use the picture below to help illustrate what you are sharing.

1. Which container had an increase in temperature?

2. What does the saran (plastic) wrap represent in the experiment?

T

3. What would happen to Earth if there was no atmosphere?



Engage
Explore
Explain
Elaborate
Evaluate

Exploring the Science Behind Climate Change

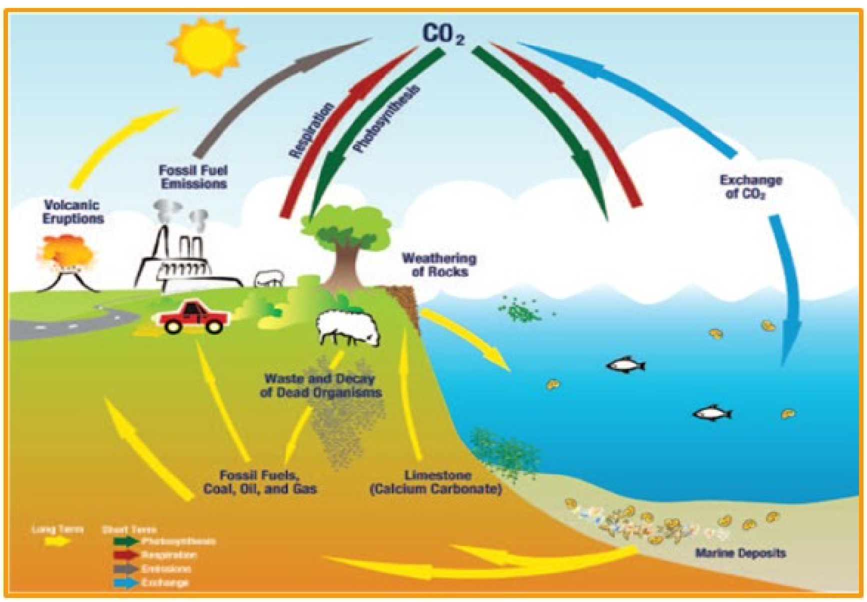
Team 2: What Happens if CO2 Levels Increase?

Directions:
1. Watch the video by clicking on the picture.
2. After watching the video, discuss what you observed.
3. Answer the questions below.
4. Be prepared to share the “main” content the experiment is teaching with the class.
5. Use the picture below to help illustrate what you are sharing.

1. What is the difference between each container?

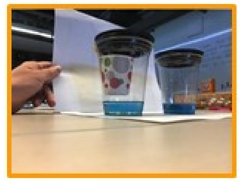
2. How does CO2 impact the temperature in the container?

3. What would happen to Earth if CO2 levels continue to increase?



Exploring the Science Behind Climate Change

Team 3: CO2's in the Ocean?



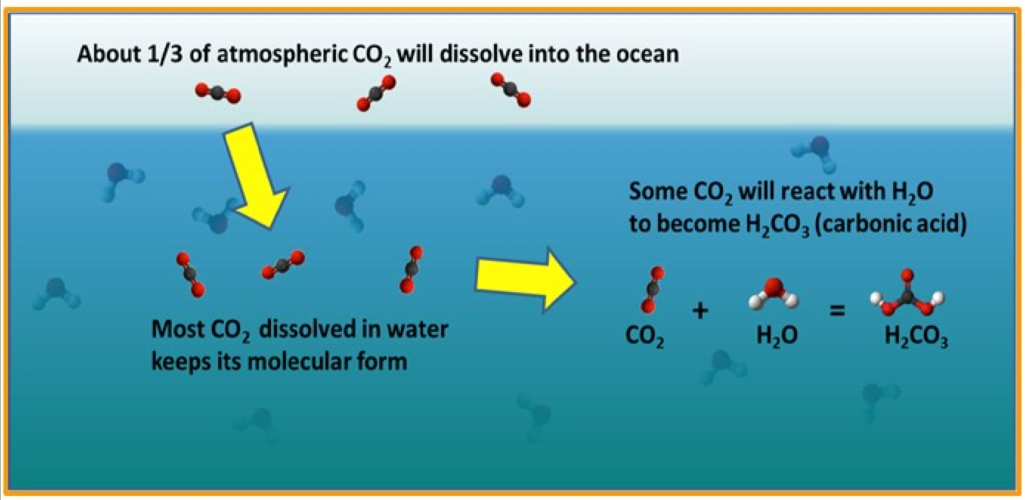
Directions:

1. Watch the 2 videos by clicking on the pictures. On the second video watch only the first 2 min. 9 seconds.
2. After watching the videos, discuss what you observed.
3. Answer the questions below.
4. Be prepared to share the "main" content the experiment is teaching with the class.
5. Use the picture below to help illustrate what you are sharing

1. What gas does mixing vinegar and baking soda release?

2. How does the gas change the liquid in the cup?

3. What would happen to ocean water if CO2 levels in the atmosphere continue to increase?



Engage
Explore
Explain
Elaborate
Evaluate

Exploring the Science Behind Climate Change

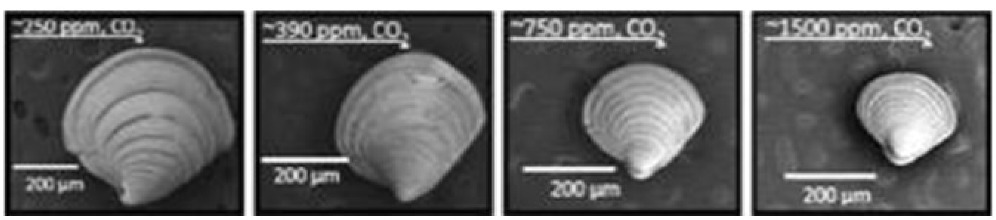
Team 4: What if CO2 Levels in Oceans Increase?

Directions:
1. Watch the video by clicking on the picture.
2. Stop the video after 4 min and 57 seconds.
3. After watching the video, discuss what you observed.
4. Answer the questions below.
5. Be prepared to share the “main” content the experiment is teaching with the class.
6. Use the picture below to help illustrate what you are sharing.

1. What’s the difference between each container?

2. What did the acid do the eggshells (seashells)?

3. What would happen to Earth’s marine creatures if acid levels in oceans continue to increase? (Think about food webs.)



Exploring the Science Behind Climate Change

Team 5: How Does Temperature Affect Oceans?

Directions:
1. Watch the video by clicking on the picture.
2. After watching the video, discuss what you observed.
3. Answer the questions below.
4. Be prepared to share the “main” content the experiment is teaching with the class.
5. Use the picture below to help illustrate what you are sharing.

1. Based on the experiment, what happens to water as it heats up?

2. What happens to water when it cools down?

3. Earth is mostly covered by water. What are some things that are likely to happen as the Earth gets warmer?

Engage

Explore

Explain

Elaborate

Evaluate

Exploring the Science Behind Climate Change

Team 6: How Do Glaciers Affect Sea Levels?

Directions:
1. Watch the 2 videos by clicking on the pictures.
2. After watching the videos, discuss what you observed.
3. Answer the questions below.
4. Be prepared to share the "main" content the experiment is teaching with the class.
5. Use the picture below to help illustrate what you are sharing.

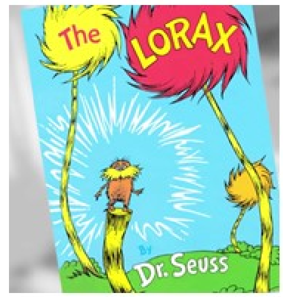
1. What's the difference between each container?

2. Based on the experiment, does ice on land or water have a great effect on water levels?

3. What are somethings that are/can happen as glaciers on land begin to melt?

Engage
Explore
Explain
Elaborate
Evaluate

Climate Change: Real World Connections



Directions:

1. Read through the following questions.
2. Watch the video together as a class.
2. When the questions appear on Edpuzzle your teacher will call on someone to answer.
3. Be ready to discuss your answers to the following questions.

Questions:

1. How could the Once-ler have managed his company to protect natural resources and not run out of trees to manufacture "Thneeds"?

2. The Lorax says he speaks for the trees. What does this mean to you?

3. What did we do as a society when we realized that we were polluting the environment?

4. Now that we have learned we were damaging the environment we must continue to conserve it. What term is used when talking about the avoidance of the depletion of natural resources in order to maintain an ecological balance?

5. What greenhouse/climate change related problems are facing our environment today?

Engage

Explore

Explain

Elaborate

Evaluate

Introducing Greta Thunberg

Greta Thunberg is a 17-year old climate activist from Sweden. A school girl with autism, standing at less than 5ft, she started the 'School Strike for Climate' protests. She has become a global superstar of the climate change movement. Promoting #fridaysforfuture alongside millions of school children (and now adults) across the globe to demand politicians, governments and corporations take action on climate change.

In what ways can we consider Greta our modern day Lorax?

Engage

Explore

Explain

Elaborate

Evaluate

Major Impacts of Greenhouse and Climate Change

Directions:
1. Watch the video in your breakout rooms. If your video is longer than 5 minutes - just watch the first 5 minutes of it.
2. Answer the questions.
3. Be prepared to share with the class the answers to your questions.

Engage

Explore

Explain

Elaborate

Evaluate

TEAM 1

1. Describe what your video is discussing.

2. What did you learn from the video?

3. Have you or someone you know personally experienced the issue the video describes?

TEAM 2

1. Describe what your video is discussing.

2. What did you learn from the video?

3. Have you or someone you know personally experienced the issue the video describes?

Major Impacts of Greenhouse and Climate Change

Engage

Explore

Explain

Elaborate

Evaluate

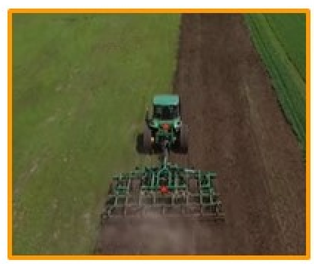
TEAM 3

1. Describe what your video is discussing.

2. What did you learn from the video?

3. Have you or someone you know personally experienced the issue the video describes?

TEAM 4



1. Describe what your video is discussing.

2. What did you learn from the video?

3. Have you or someone you know personally experienced the issue the video describes?

Major Impacts of Greenhouse and Climate Change

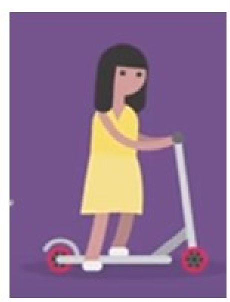
TEAM 5

1. Describe what your video is discussing.

2. What did you learn from the video?

3. Have you or someone you know personally experienced the issue the video describes?

TEAM 6



1. Describe what your video is discussing.

2. What did you learn from the video?

3. Have you or someone you know personally experienced the issue the video describes?

Engage
Explore
Explain
Elaborate
Evaluate

What Did We Learn?

Directions: With your teacher fill in the blanks using the Word Bank. After you have used the word you can highlight it.

Word Bank

flood Sun glaciers rise
greenhouse gases
conserve thermal expansion expand
sustain
temperature acidic
carbonic acid shells

The energy from the __________ warms Earth.

__________ __________, such as CO2, trap the energy inside the atmosphere.

CO2 regulates the _______________ of the Earth.

CO2 dissolves in water and forms ______________.

Carbonic acid causes the ocean to become _________ and dissolves the

___________ of animals.

As the Earth's temperature rises, the ocean's temperature rises which causes the water to _____________ to a greater volume.

__________ __________ contributes to sea level rise.

________________ in the ocean and on the land are melting due to warming temperatures.

As the glaciers on the land melt, the water drains into the sea causing the sea level to ___________.

Sea level rise will cause coastlines to ____________.

Through various laws we have started to ______________ the environment but now we must figure out how to ______________ what we have conserved.

Engage
Explore
Explain
Elaborate
Evaluate

Output 5

Directions:

1. Click on the box to take you to the survey.
2. **Take a screenshot of first page of Survey that has your name on it**
3. Take the survey.
4. Paste the screenshot here for your Output 5.

Understanding Climate

Engage

Explore

Explain

Elaborate

Evaluate

Appendix D

University of Houston IRB Approval Letter

UNIVERSITY of HOUSTON

DIVISION OF RESEARCH
Institutional Review Boards

APPROVAL OF SUBMISSION

January 9, 2021

Yunes Golabbakhsh

ygolabbakhsh@uh.edu

Dear Yunes Golabbakhsh:

On January 9, 2021, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title of Study:	The Effects of a Guided Inquiry Instruction About Climate-Related Disasters on the Environmental Concerns of Pre-Service Teachers
Investigator:	Yunes Golabbakhsh
IRB ID:	STUDY00002769
Funding/ Proposed Funding:	Name: University of Houston, Grant Office ID: None, Funding Source ID: None
Award ID:	None;
Award Title:	
IND, IDE, or HDE:	None
Documents Reviewed:	• Dr. Bailer Letter of Cooperation, Category: Letters of Cooperation / Permission; • HRP-503 Yunes Golabbakhsh.pdf, Category: IRB Protocol;
Review Category:	Exempt
Committee Name:	Not Applicable
IRB Coordinator:	Sandra Arntz

The IRB approved the study on January 9, 2021 ; recruitment and procedures detailed within the approved protocol may now be initiated.

As this study was approved under an exempt or expedited process, recently revised regulatory requirements do not require the submission of annual continuing review documentation. However, it is critical that the following submissions are made to the IRB to ensure continued compliance:

- Modifications to the protocol prior to initiating any changes (for example, the addition of study personnel, updated recruitment materials, change in study design, requests for additional subjects)

UNIVERSITY of HOUSTON
DIVISION OF RESEARCH
Institutional Review Boards

- Reportable New Information/Unanticipated Problems Involving Risks to Subjects or Others
- Study Closure

Unless a waiver has been granted by the IRB, use the stamped consent form approved by the IRB to document consent. The approved version may be downloaded from the documents tab.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system.

Sincerely,

Research Integrity and Oversight (RIO)
Office University of Houston, Division of
Research 713 743 9204
cphs@central.uh.edu
http://www.uh.edu/research/compliance/irb-cphs/