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by

Rana Khalidi

May 2018

CALIFORNIA AND TEXAS SECONDARY SCIENCE TEACHERS' PERCEPTIONS
ABOUT CLIMATE CHANGE

A Dissertation Presented to the
Faculty of the College of Education
University of Houston

In Partial Fulfillment
Of the Requirements for the Degree

Doctor of Education

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Abstract

Background: Science teachers' perceptions about climate change can affect their instruction in the classroom. Teachers' misconceptions about this topic can be problematic since scientifically inaccurate ideas may be transferred to their students. **Purpose:** The aim of the study was to investigate climate change perceptions of secondary science teachers in California and Texas, including their knowledge, teaching approaches, and personal views. The study assessed whether their views were linked to their political and religious affiliations and beliefs. It also examined whether there were any differences between California and Texas teachers. **Methods:** A total of 832 secondary public school science teachers (456 from California and 376 from Texas) responded to an online questionnaire that examined their perceptions about climate change. Both descriptive and inferential statistics were used to determine the differences in strengths and deficiencies between teachers' responses in both states. **Results:** Findings indicate that a significant proportion of California and Texas teachers have misconceptions with regards to basic climate change concepts. A higher proportion of California teachers than Texas teachers emphasize the scientific consensus about climate change causes. More Texas teachers than California teachers are sending mixed messages about climate change causes to students by emphasizing the natural causes as well as the scientific consensus. The study also found a significant association between teachers' political and religious affiliations and beliefs and their views of the scientific consensus and climate change causes. **Conclusion:** Differences between California and Texas teachers in terms of their knowledge, views, and approaches to climate change suggest that climate change is taught differently in the two states. Due to the suboptimal understanding of content knowledge among a significant proportion of science teachers, it is recommended to develop teacher education programs and in-service teacher training that focus on improving teachers' scientific knowledge and teaching approaches to climate change.

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Chapter I

Introduction

Climate change is a controversial topic in the United States. It has important human, social, economic and political implications (Cohen & Waddell, 2009). There is widespread agreement among scientists that climate change is occurring and that it has resulted mainly from human-induced releases of greenhouse gases (Intergovernmental Panel on Climate Change, 2014; United States Environmental Protection Agency, 2017). Even with this consensus among scientists about climate change, this topic, like any other environmental issue, has become a subject of political debate in the US (Gough, N. & Gough, A., 2010; Hamilton, 2011; McCright & Dunlap, 2011). This is mainly due to the polarization in the American society between the right conservative and left liberal segments of the US population. This polarization is reflected on those (mainly Democrats) who agree that climate change is occurring, and those (mainly Republicans) who do not (Pew Research Center, 2016). This controversy has impacted climate change education in schools and has affected the individual classrooms. For example, there are science teachers who deny climate change themselves, while others face pressure not to teach it from climate change deniers in their communities (Public School Review, 2017). In some instances, some science teachers have been intimidated not to teach certain concepts about climate change, and as a result have preferred to avoid discussing this topic in their classrooms (Gough, N. & Gough, A., 2010; Wise, 2010). In other instances, teachers have presented climate change as a controversial theory (Plutzer, Hannah, Rosenau, McCaffrey, Berbeco, & Reid, 2016a).

Education has a key role in promoting scientific literacy about climate change (Plutzer et al., 2016a). Education also plays an important role in changing people's attitudes and behaviors toward the environment. Changing young people's minds is an essential step in order to be able to confront the ongoing environmental issues (Gough, N. & Gough, A., 2010). Therefore, a great obligation falls on public school teachers, who influence a large segment of society.

If teachers are to help their students understand scientific concepts of climate change, they must have a sound understanding of these topics that is good enough to be able to explain them accurately and to teach about them effectively in their classrooms (Bartholomew, Osborne & Ratcliffe, 2004). Studies have shown a relationship between teachers' background characteristics and content preparation on one side, and teaching practices and investigative classroom culture on the other side (Berkman & Plutzer, 2010; Supovitz & Turner, 2000). Hence, it is important that teachers possess the climate change content knowledge necessary, in order to be able to develop appropriate learning classroom practices and teaching strategies.

This study focused on public school science teachers' perceptions about climate change, in order to assess their level of awareness and any misconceptions they may have about this topic. The study included a total of 832 secondary (grades 9-12) science teachers from two of the largest states in the US, namely California and Texas. The objective was to examine whether there were any significant differences in teachers' perceptions about climate change between the two states. Another aim of the study was to assess whether teachers' views about climate change were linked to their political and religious affiliations and beliefs. Chapter one describes the research problem, the purpose

of research study, and the research questions addressed in the study. Chapter two reviews the discourse regarding climate change and the current status of climate change education in the US, including California and Texas. Chapter three describes the methodology used to study and compare secondary science teachers' knowledge, teaching approaches, and personal views about climate change in California and Texas. A detailed description of the study findings, including statistical analysis of questionnaire data, is presented in chapter four. Chapter five discusses the conclusions, including limitations of the study, and implications to science education.

California and Texas have the two largest populations in the US, with California ranking first (~39 million) and Texas ranking second (~28 million) (United States Census Bureau, 2017). California and Texas share several similarities and differences. They are both southwestern states, with a diverse population, including large, Mexican and Hispanic communities, and fast growing economies. They both have heavily populated cities that are located on or near the coast, and are polluted (American Lung Association, 2015; United States Census Bureau, 2017). However, California is considered to be a liberal, eco-friendly, Democratic-leaning, "Blue" state. It has been leading the nation in adopting policies to reduce climate change, and in implementing science standards that support climate change education in public schools (State of California, 2016). Unlike California, Texas is considered to be a conservative, less eco-friendly, Republican-leaning, "Red" state (Kiernan, 2017; Starr, 2014). It is regarded to be one of the states that are skeptical about climate change. Skepticism about climate change in Texas remains a significant obstacle to climate change education (Bagley, 2014). In addition, science education in Texas has a long controversial history (Berdanier, 2017). Teaching

climate change as part of the science curriculum has also been compounded by the fact that Next Generation Science Standards (NGSS) have not and are not likely to be adopted in Texas anytime soon (Smith, 2012).

The public's perception of climate change is greatly affected by the prevailing political views, with Democrats and liberals usually more worried about climate change, and Republicans and conservatives usually less worried about climate change (Hamilton, 2011; McCright & Dunlap, 2011). The public's awareness of the extent of the scientific consensus on climate change is a necessary factor in public support for policies, which aim to reduce climate change (Ding, Maibach, Zhao, Roser-Renouf, & Leiserowitz, 2011). Polarization between Democratic and Republican legislatures in the US congress has grown significantly in the last twenty years (Vox, 2016). Science teachers are part of the polarized American society. Their sound understanding of climate change concepts is related to their acceptance of the scientific validity of climate change, and in turn their beliefs of the necessity of addressing it in their classrooms. Teachers' negative perceptions may cause them to avoid teaching climate change in their classrooms (Skamp, Boyes & Stanisstreet, 2012). Therefore, science teachers' thorough understanding of environmental science topics will help their students develop views about climate change that are consistent with those accepted by the scientific community (Gough, N. & Gough, A., 2010).

Research problem

Science teachers play an important role in educating students about climate change concepts. They also motivate and empower students as future citizens to be actively involved in making scientifically informed decisions about how to control and

reduce climate change (Skamp, Boyes & Stanisstreet, 2012). There have been only a few research studies on teachers' perceptions about climate change, and how these perceptions may be influenced by teachers' scientific knowledge, political affiliations and beliefs, personal views about climate change as well as teaching approaches to climate change in public school science classrooms (Monroe, Oxarat, & Plate, 2013; Plutzer et al., 2016a; Wise, 2010). A major recent study was a report from the National Center for Science Education (NCSE), which examined how climate change is taught in America's public schools (Losh, 2017; Plutzer et al., 2016a). This was a national study, which found out that a significant proportion of science teachers had limited training and lacked formal instruction in climate science when they were in college. Study finding indicated that many science teachers were unaware of the extent of the scientific consensus about climate change, and concluded that teachers' scientific knowledge can hinder effective teaching about climate change.

There are a few studies about science teachers' perceptions of climate change that were limited to specific states, such as Colorado and Florida (Herman, Feldman & Vernaza-Hernandez, 2015; Wise, 2010). No similar published studies from California or Texas have been found in the literature.

Purpose of research study

The objective of the study was to investigate California and Texas secondary science teachers' perceptions about climate change in order to determine how science teachers in California and Texas public schools are dealing with the challenge of teaching about climate change. To achieve this objective, California and Texas secondary science teachers' knowledge, teaching approaches, and personal views about climate change were

assessed. In addition, teachers' personal views about climate change were examined to determine whether their views were linked to their political and religious affiliations and beliefs. California and Texas teachers' responses were also compared to determine whether there were any differences in teachers' perceptions about climate change between the two states.

Research questions

The study addressed the following research questions (RQ):

RQ1. How knowledgeable are secondary science teachers about climate change in California and Texas? Are there any differences in knowledge about climate change between California and Texas teachers?

RQ2. What are secondary science teachers' approaches to climate change instruction? Are there any differences in teaching approaches to climate change between California and Texas teachers?

RQ3. What are secondary science teachers' views about the anthropogenic causes of climate change? Are there any differences in climate change views between California and Texas teachers?

RQ4. Are secondary science teachers' views about the anthropogenic causes of climate change linked to social factors such as their political and religious affiliations and beliefs? Are there any differences in the association between California and Texas teachers?

Chapter II

Review of literature

Climate change is a hotly debated topic that has important economic, social, cultural, educational and political implications. Following is a brief review of recent literature regarding climate change (including arguments for and against) and climate change education in the US, with a focus on California and Texas.

What is climate change?

Climate change refers to any considerable change in the Earth's climate, which takes place over a long period of time. Climate change may include significant changes in temperature, precipitation, or wind patterns (US EPA, 2017). Global warming is causing the changes in climate patterns. It refers to the continuing increase in global average temperature near the surface of the earth, which is caused by the increasing concentrations of atmospheric greenhouse gases, mainly carbon dioxide (National Aeronautic and Space Administration, 2014; National Research Council, 2017; US EPA, 2017).

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" (IPCC, 2014; NRC, 2017; US EPA, 2017). The main greenhouse gases include carbon dioxide (CO₂), nitrous oxide (N₂O), and methane (CH₄). Other greenhouse gases include water vapor (H₂O), tropospheric ozone (O₃), and chlorofluorocarbons (CFCs). Major contributors of greenhouse gas emissions include coal burning power plants and

industrial processes. Other sources of greenhouse gases are also emitted from automobiles, and some agricultural applications (IPCC, 2014; US EPA, 2017).

Carbon dioxide is the major greenhouse gas that is greatly causing climate change (NRC, 2017; US EPA, 2017). Carbon dioxide is absorbed and produced naturally, as part of the carbon cycle, through animal and plant respiration, ocean-atmosphere exchange and volcanic eruptions. As a result of human activities, such as burning of fossil fuels and variations in land usage, great quantities of carbon dioxide are being released into the atmosphere, causing carbon dioxide concentrations in the atmosphere to increase (NRC, 2017; US EPA, 2017).

From the time when the industrial revolution began (about 1750), human actions, mainly the burning of fossil fuels, have emitted huge amounts of carbon dioxide, and more heat-absorbing gases into the atmosphere (US EPA, 2017). As a result, greenhouse gas releases have expanded the greenhouse effect by causing the atmosphere to absorb more heat than it normally does. This has caused the surface temperature of Earth to increase (NRC, 2017; US EPA, 2017).

As a result of this rising of global temperatures, large changes in Earth's climate and weather have occurred. Several areas of the world have undergone changes in rainfall, causing additional heavy rain, floods, or droughts, as well as numerous, severe heat waves. Furthermore, Earth's glaciers and oceans have undergone several major changes. Some changes include warming and increasing the acidity of the oceans, melting of ice caps, and rising of sea levels. These changes will become more evident in the coming years. As a result, these changes in weather patterns are expected to produce

more challenges to the life of humans and the environment (NASA, 2014; NRC, 2017; US EPA, 2017).

Scientific evidence of climate change

Many scientists tried to understand the effects of greenhouse gases on climate. In 1824, Joseph Fourier, was the first scientist to discover that atmospheric gases can absorb heat produced from the sun, and raise the surface temperature of the Earth (NRC, 2017; Powell, 2011). In the 1850s, John Tyndall demonstrated the greenhouse effect by measuring how much atmospheric gases such as nitrogen, oxygen, water vapor, carbon dioxide, and hydrocarbons, can absorb the Earth's radiant heat. Tyndall concluded that if the amounts of atmospheric gases were to change, then the amount of heat absorbed by the atmosphere will change, and as a result the climate may also change (NRC, 2017; Powell, 2011).

In 1896, Svante Arrhenius drew on the work of Tyndall, by investigating the role of carbon dioxide gas in the atmosphere. In 1908, Arrhenius included his findings in his book entitled "Worlds in the Making", which states that if carbon dioxide levels in the atmosphere doubled, then global temperature would increase by 9-11°F (NRC, 2017; Powell, 2011). In the 1930s, Guy Callendar became interested in Arrhenius ideas. In 1938, he used global temperature observations to prove, according to his calculations, that Earth was getting hotter by 0.009 °F per year. He attributed this finding to increased coal burning, which had added about 150,000 million tons of carbon dioxide to the air during the past half century (Powell, 2011). In 1958, Charles David Keeling, measured concentration of atmospheric carbon dioxide at two different research stations, one located at the top of Mauna Loa volcano in Hawaii, and the other in Antarctica. After two

years, the study data proved that atmospheric carbon dioxide concentrations were steadily increasing (NRC, 2017; Powell, 2011).

There is ample supporting scientific evidence that climate change is actually happening and that human activities are largely causing it (NASA, 2017; US EPA, 2017). According to the US Environmental Protection Agency (EPA), human actions in the 20th century have produced large quantities of carbon dioxide and more greenhouse gases into the atmosphere. The National Oceanic and Atmospheric Administration (NOAA), has confirmed that atmospheric carbon dioxide concentrations are higher by over 40% since the beginning of the industrial revolution. Atmospheric carbon dioxide concentrations have increased from about 280 parts per million (ppm) in the 18th century to over 400 ppm in 2016. Since 1959, concentrations have increased by more than 85 ppm (NOAA, 2017). According to NOAA, the existing carbon dioxide concentrations are greater than they used to be in at least 800,000 years (IPCC, 2014; NRC, 2017).

The US Geological Survey (USGS) has stated that human actions currently release over than 135 times as much carbon dioxide as annual volcanoe releases (US EPA, 2017). In 2001, the Intergovernmental Panel on Climate Change (IPCC) indicated that doubling atmospheric carbon dioxide would raise global temperatures 3-8 °F (Powell, 2011). According to an IPCC report published in 2013, human actions presently produce more than 30 billion tons of carbon dioxide into the atmosphere per year (IPCC, 2014).

Studies have shown that, over the previous century, the average temperature of the Earth has increased by 1.5 °F, and is expected to increase by another 0.5 to 8.6 °F within the following 100 years (US EPA, 2017). In addition, scientific research has

shown that natural causes (e.g., solar radiation variations, Earth's orbit shape changes) are very improbable to explain recent climate change (IPCC, 2014; NOAA, 2017; US EPA, 2017).

Opposing views to climate change

Although there is consensus among the scientific community regarding the legitimacy of climate change, there is opposition from climate change disbelievers who question the scientific agreement about climate change (Cook, Oreskes, Doran, Anderegg, Verheggen, Maiback, Carlton, Lewandowsky, Skuce, Green, Nuccitelli, Jacobs, Richardson, Winkler, Painting, & Rice, 2016). Climate change deniers, including some scientists, as well as a wide range of journalists, writers, politicians and non-governmental organizations, are skeptical about whether climate change is actually happening (Powell, 2011). Some of them question how much climate change has occurred and is likely to continue happening. Others believe that climate change is naturally occurring and are not convinced that it is man-made. Skeptics generally deny that climate change will negatively impact humans and their environment (Powell, 2011).

Within the scientific community, climate change deniers comprise less than 5 percent of scientists (Anderegg, 2010; Cook et al., 2016; Doran & Zimmerman, 2009; Oreskes, 2004). Dr. Willie Soon, a Harvard astrophysicist and a famous climate change skeptic, argues that fluctuations in solar geomagnetic variation rather than human activities cause most climate change. According to Soon, the amount of solar energy received changes as Earth revolves around the sun, and also in response to variations in solar radiation from sunspots (Soon, 2003). Dr. Henrik Svensmark is a well-known physicist and climate change denier. According to Svensmark's "cosmoclimatology"

theory, cloud cover changes caused by variations in cosmic rays are a major contributor to climate change rather than man-made carbon dioxide. Therefore, less cosmic rays cause less clouds to form and so the climate becomes hotter (Svensmark, 2007).

Furthermore, the American Association of Petroleum Geologists (AAPG) and other geological organizations hold non-committal positions about the cause of climate change (American Association of Petroleum Geologists, 2007). Scientists in these organizations argue that the data, which proposes that the average Earth temperature is increasing, can be attributed to natural variations in solar radiation. According to their argument, if the climate system is essentially driven by energy from the sun and therefore if the sun's energy production varies, then the climate will vary. Other geologists argue that the significant increase in global temperature is an expected result, since earth is still evolving from the Little Ice Age (13th - 17th century) (AAPG, 2007).

There are numerous corporations and non-governmental organizations that finance efforts to deny climate change, such as Exxon Mobil Foundation, Koch Industries, and the American Petroleum Institute (Simidian, 2017). Heartland Institute, a conservative public policy organization, which conducts work on education reform, is a leading supporter of climate change denial (Idso, Carter & Singer, 2017; Worth, 2017). The institute claims that the scientific consensus on the causes and consequences of climate change is without value. According to Heartland Institute, there is no survey or study showing consensus on any of the most important scientific issues in the climate change debate (Worth, 2017).

The media plays a role in creating grounds for controversy by reporting and discussing climate change denial (Dunlap, 2013). Studies have shown that the US media

has contributed in undermining the strength of the scientific consensus of climate change (Antilla, 2010). Some of the journalists who promote climate change denial include John Tierney, New York Times columnist and science correspondent, and late author Michael Crichton, both of whom claim that there is no evidence of scientific consensus about climate change (Powell, 2011).

Scientific consensus about climate change

There is overwhelming consensus among the scientific community that human actions are causing continuing global warming and climate change (NASA, 2017; NRC, 2017). Several studies have been conducted to quantify the extent of scientific consensus on anthropogenic (human-caused) climate change. These studies reviewed articles about climate change that were published in the peer-reviewed scientific literature (Cook et al., 2016). Results of review studies showed that there is 97 percent consensus among scientists, in published climate change research, that observed climate change is most likely caused by humans (Anderegg, 2010; Cook et al., 2016; Doran & Zimmerman, 2009; Oreskes, 2004).

In 2001, the new Bush administration asked the National Academy of Sciences to assess the evidence for global warming. The Academy confirmed that global warming is real and that greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to increase. Donald Kennedy, former president of Stanford University and former editor of *Science*, which publish dozens of science articles each week, said, "Consensus as strong as the one that has developed around this topic is rare in science". D. James Baker, former head of NOAA, the chief government repository of climate information, stated

that “There’s no better scientific consensus on this than on any issue I know, except maybe Newton’s second law of dynamics”(Powell, 2011). Even the American Association of Petroleum Geologists, whose members depend for their income on fossil fuel combustion, revised its statement in 2007 to read: “expanding scientific climate research into the basic controls on climate” is important and that “they support reducing emissions from fossil fuel use as a worthy goal” (Powell, 2011).

There is wide agreement among the main scientific organizations of the US, including the EPA, NOAA, the National Research Council (NRC), and the National Aeronautic and Space Administration (NASA), the American Association for the Advancement of Science (AAAS), the U.S. National Academy of Sciences, the American Chemical Society (ACS), and the Geological Society of America (GSA), that climate change is taking place and is mainly happening due to excess greenhouse gases from human activities (NASA, 2017; NRC, 2017; US EPA, 2017).

Furthermore, the majority of scientific organizations worldwide, including National Academies of Science from 80 countries, have all issued statements supporting the scientific consensus position on climate change. In addition, IPCC scientific reports confirm that increased carbon dioxide in the atmosphere has resulted in raising the surface temperature of the Earth (Cook et al., 2016).

There is overwhelming scientific evidence, which has shown that natural causes are minor contributors to the current climate change (NOAA, 2017; NRC, 2017; US EPA, 2017). Climate is affected by natural changes that influence how much solar energy reaches Earth. These changes include variations within the sun, fluctuations in Earth’s orbit around the sun that affect the solar energy received by Earth, and changes in the

amount of volcanic aerosols in the atmosphere (NRC, 2017; US EPA, 2017). IPCC argues that although changes in solar energy may continue to influence climate, solar output, over the last 11-year solar cycle, has been lower than it has been since the mid 20th century. However, these natural changes do not explain the recent global warming of Earth's surface (IPCC, 2014). Likewise, changes in the shape of Earth's orbit and the tilt and position of the Earth's axis affect temperature on tens to hundreds of thousands of years, and therefore can not explain the recent global warming (US EPA, 2017). In addition, scientists have been using climate models to illustrate how global temperatures would have changed if only natural factors, such as the sun, and volcanoes, were influencing the climate system. Earth simulations predicted that in the absence of human activities, there would have been negligible warming, or even a slight cooling, over the 20th century (NRC, 2017).

Implications of climate change

Climate change is one of the most important environmental concerns and a serious global air pollution problem. It has important economic, social and political implications (IPCC, 2014). A warming climate brings changes that can negatively impact human life, health and the environment. Climate has an impact on human mortality rates, morbidity and early life development. It results in weakening of trade networks and break up of personal relationships within societal groups (Carleton & Hsiang, 2017). Climate change has a negative impact on water supplies, agriculture, economy, power and transportation systems. It also has a harmful effect on aquatic and terrestrial ecosystems (NRC, 2017; US EPA, 2017).

A major controversial point that may have a significant economic impact is whether any action such as restrictions on using fossil fuels to reduce carbon dioxide emissions should be considered now, or in the future. Climate change advocates feel that immediate action to decrease emissions will help prevent excessive economic expenses in the future and decrease the risk of long-term damage. Climate change opponents argue that those limitations would not have any significant result on the Earth's global temperature (IPCC, 2014).

In the US, climate change has become a partisan political issue. Republicans and Democrats have different opinions and positions on climate change. Republicans are more inclined to resist and fight against actions, which they consider as lacking sufficient scientific evidence. Democrats are more inclined to support actions such as regulating emissions of greenhouse gases, which they think will help decrease and control climate change (McCright & Dunlap, 2011; Pew Research Center, 2016). As a result, the general public has been divided on this environmental issue. Ordinary citizens have taken sides with their political leaders whose ideology they support in their community (Ludden, 2013).

This political debate and controversy have been reflected on climate change education in the science classroom. The political debate has caused climate change to turn into a hot issue in science education and a challenging subject to be taught in the science classroom (Humes, 2012). This is due to the political fight over how climate change education should be discussed in the classroom (Ludden, 2013). In view of that, climate change skepticism is risking the truthfulness and reliability of science education in American public schools (Banerjee, 2012).

Climate change education in the US

Climate change education aims to create an environmentally literate citizenry, empower students with skills and motivate them to take actions to reduce the impacts of climate change (Skamp, Boyes & Stanisstreet, 2012). Climate change education can take place in formal settings, such as traditional schools, and informal settings, such as public places like zoos, parks, aquariums, community centers or media outlets (National Center for Science Education, 2017). Teaching about climate change in US schools usually starts in late elementary and middle school science courses. It is included in secondary school environmental science classes, which are frequently offered as electives. It is also partially covered in biology, chemistry, physics, and earth science classes (Next Generation Science Standards, 2013). This study focuses on climate change education in formal settings.

New national science standards known as the Next Generation Science Standards (NGSS) were released in 2013. NGSS defined academic benchmarks for physical, life, earth and space sciences as well as engineering and technology for grades K-12. The standards were developed by a group of 41-member education experts from 26 states (California Department of Education, 2017a). Several national scientific organizations were also involved in the development of NGSS, including National Research Council (NRC), the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and Carnegie Corporation of New York (NGSS, 2013). For the first time, these standards included a climate change component and recommended that US public school students learn that climate change is actually taking place (Ludden, 2013; NGSS, 2013). The new standards included information

about the human contribution and climate change, which was not mentioned in the national science standards published in 1996 (Smith, 2012). NGSS developers realized that schools are teaching the future generation of scientists and engineers who could help in solving the climate change issue. These standards are also expected to help in guiding the states in developing their own science curricula (Ludden, 2013; Revkin, 2012).

NGSS include middle school standards on climate and weather, and a section for secondary schools on dealing with human environmental influences, including greenhouse-gas emissions (NGSS, 2013). One of the core ideas in NGSS climate and weather standards for middle school is that “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” (NGSS, 2013; Revkin, 2012). The secondary school’s weather and climate standards state that; “changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate” (NGSS, 2013; Revkin, 2012).

So far, adoption of NGSS science standards has happened at a slow pace. Only eighteen states and the District of Columbia (DC) have adopted these standards and are in the process of implementing them in their school districts and schools. Fourteen of these states were lead state partners, which were involved in developing NGSS standards. The 18 states, which adopted the standards, represent over 35% of the students in the U.S. They include Arkansas, California, Connecticut, Delaware, Hawaii, Illinois, Iowa, Kansas, Kentucky, Maryland, Michigan, Nevada, New Hampshire, New Jersey, Oregon, Rhode Island, Vermont and Washington, in addition to DC (National Science Teacher Association, 2017; Schwartz, 2016). Most states that have adopted NGSS have left intact

the sections that deal with climate change and humans' impact on the environment (Jones, 2017). One possible reason legislators in states that have not adopted NGSS standards are still hesitant to adopt these standards is the way the standards describe climate change and evolution (Bidwell, 2014).

Obstacles to climate change education

NCSE is a national organization that defines its mission as defending the integrity of science education against ideological interference. NCSE states that there are obstacles to climate change education, including many conservative groups and organizations, which oppose climate change and have tried to challenge teaching it in public schools.

Attacks against climate change education have occurred at different levels, starting in individual classrooms with teachers denying climate change themselves or facing pressure from other teachers, parents, school administrators and other climate change deniers in their community (Public School Review, 2017). NCSE states that due to the political debate on climate change, many teachers avoid teaching about climate change in their classrooms (Humes, 2012; NCSE, 2012). Science teachers have reported increasing challenges to teaching about human-caused climate change in middle and secondary schools (Banerjee, 2012). In some instances, teachers are forced to present it as a controversial theory, and to teach that climate change is caused by both human activities and natural changes in the environment (Plutzer et al., 2016a). In 2012, 80 percent of teachers polled by the Cooperative Institute for Research in Environmental Sciences (CIRES), a joint mission of the University of Colorado at Boulder and NOAA, indicated that they have faced climate change skepticism from school administrators and parents (Humes, 2012). Conservative think tanks continue to challenge the scientific

consensus on climate change, by trying to confuse teachers and convert the climate change science into a controversy. In early 2017, thousands of science teachers in the US received a booklet titled “Why Scientists Disagree about Global Warming” by mail. The book was published by the Heartland Institute, which planned to send a copy to every public school science teacher in the nation (Worth, 2017).

The attacks have also occurred at state boards of education, school districts and state legislatures, with the introduction of policies, laws, or state education standards specifically intended to undermine climate change education (Banerjee, 2012; NCSE, 2012). Public education standards are set at the state level. This allows instruction of subjects that are especially politically polarized, such as climate change, to differ from state to state (Jackson & Gould, 2017). Conservative politicians in Republican-controlled states, influence climate change education in public schools by introducing “academic freedom bills” legislation. These bills aim to introduce scientific concepts, such as climate change and evolution, as controversial issues rather than as scientific facts. Among the states that have promoted such bills in 2017 are Texas, South Dakota, and Oklahoma (Simidian, 2017). Idaho decided through legislative action to modify their science content standards, and to remove the topic of human actions on climate change (Idaho State Department of Education, 2017). Similar legislative action is taking place in other states (Simidian, 2017). New Mexico, West Virginia and Texas have changed their science standards through their state boards of education, rather than their legislatures (Geiling, 2016; Simidian, 2017). These changes include questioning the rise in global temperatures, and the accuracy of climate change models (Geiling, 2016; Jones, 2017).

Climate change education in California

Climate change is a primary concern in California. The continued changing climate is affecting California, and is likely to further increase the frequency of heat waves, drought, wildfires, decrease in snowpack, and cause additional rise in sea level. Such events are expected to result in negative consequences for human health, air and water quality, agriculture, natural resources, and the economy (State of California, 2016; US EPA, 2016).

California has been leading the nation in adopting policies to reduce climate change. In 2002, California set state standards for the emission of greenhouse gases (GHG) from motor vehicles (State of California, 2016). In 2006, Governor Arnold Schwarzenegger, signed the California Global Warming Solutions Act into law in order to establish a comprehensive program to reduce greenhouse gas emissions from all sources throughout the state (State of California, 2016). In 2015, Governor Edmund G. Brown Jr. signed a legislation, which requires California to reduce greenhouse gas emissions to 1990 levels by 2020 and strengthened this legislation in 2016 by require the state to cut emissions at least 40 percent below 1990 levels by 2030 (State of California, 2016).

California is also leading the nation in implementing science standards that support climate change education. One of the educational priorities in California is to create a generation that would be environmentally literate and would have the critical thinking skills about the environmental issues facing California (California Department of Education, 2017b). In 2003, California Education and the Environment Initiative (EEI) began to formally introduce environmental education into California classrooms.

However, it was not until 2010 that the State Board of Education (SBE) adopted an environmental education curriculum that involved several state agencies, such as California Environmental Protection Agency, and private organizations, like the National Geographic Society. However, implementation of this curriculum was delayed due to funding uncertainties (Jones, 2017). In 2015, in an effort to integrate environmental literacy as part of the K-12 education system for all of California's diverse students, the California State Superintendent of Public Instruction, Tom Torlakson, appointed the Environmental Literacy Task Force (ELTF). As a result, "A Blueprint for Environmental Literacy: Educating Every Student In, About, and For the Environment", was developed and released. The "Blueprint" guidelines provided strategies to achieve environmental literacy for all California students. However, compliance with this document is not mandatory (California Department of Education, 2017b).

California was a lead state partner in the development of the national NGSS in 2011. California guided the national science standards development process and agreed to give serious consideration to adopting the NGSS upon completion (California Department of Education, 2017a). In 2013, after a two-year review process, California SBE voted to adopt the NGSS for California public schools, kindergarten through grade twelve. The California Next Generation Science Standards (CA NGSS) were based on the national NGSS (California Department of Education, 2017a). Moreover, the California NGSS standards differed from the NGSS national standards in that they included a few minor additions to some clarification statements, to better assist teachers with implementation of the NGSS, with no changes made to actual performance expectations (California Department of Education, 2017a).

Climate change education in Texas

Texas is one of the states that are skeptical about climate change, mainly due to the large number of fossil fuel energy companies in the state (Smith, 2012). Former Governor Rick Perry has made very skeptical comments on climate change (Smith, 2012). The current Texas Governor, Greg Abbott, also does not accept man-made climate change, and believes that additional study is still needed to determine the human role in climate change (Price, 2017; Stiehm, 2017). Other officials at state agencies, such as the Texas Commission on Environmental Quality and Texas Railroad Commission, are also openly skeptical about the role of humans in climate change (Price, 2017; Smith, 2012).

Texas State Board of Education (SBOE) is the policy-making body for public schools in Texas. Its role is to set curriculum standards, determine classroom curriculum and select textbooks for Texas public schools from kindergarten through high school (Smith & Burns, 2010). SBOE has a long history of conflicts over science education (Berdanier, 2017; Swaby, 2017). In 2009, SBOE tried to reject science standards on evolution, and was criticized by more than 50 scientific organizations over it (NCSE, 2014). In 2013, SBOE approved new science books for use in classrooms across Texas, but held up one biology text because of claimed factual errors (Hallowell, 2013). In 2017, SBOE members voted to modify the language in high school biology curriculum standards known as Texas Essential Knowledge and Skills (TEKS) that would bring controversial concepts about evolution to its science education standards (Swaby, 2017).

Climate change education has also been a controversial topic in Texas. In 2014, SBOE approved proposed social studies textbooks that lacked accurate information on climate change, in terms of the science behind it and policies needed to reduce use of

fossil fuels. Some of the proposed books questioned the scientific consensus about climate change, its actual occurrence, that it is human-induced and the amount of threat on humans and environment (Bagley, 2014; McGaughly, 2014).

However, there has been a lot of criticism in Texas of the new proposed social studies textbooks. Two education groups, the Texas Freedom Network Education Fund, and NCSE, issued a joint press release in 2014, in which they gave a brief analysis of how the topic of climate change is represented in the proposed Texas social studies textbooks for public schools. In their analysis, they accused the textbooks' authors of misrepresenting climate change facts with regard to the scientific consensus on the phenomenon. An example of these misrepresentations is the inclusion of a comparison of information from the IPCC, the leading international body assessing climate change, with information from the Heartland Institute, an anti-climate change organization, in which both organizations are presented in the textbook as legitimate scientific sources (Bagley, 2014; NCSE, 2014).

Texas is one of the states that have not adopted the NGSS standards. Legislators are refusing to adopt these standards because of the way the standards describe climate change and evolution (Bidwell, 2014). In 2012, Barbara Cargill, the former Republican chairwoman of Texas SBOE indicated that there is a "zero percent chance" that they will adopt the new NGSS (Smith, 2012). Texas SBOE has rejected earlier proposed drafts of the NGSS. Therefore, it is unlikely that these standards will be adopted in Texas classrooms any time soon, despite the fact that four Texas educators were among the 41-member writing committee for the new science standards (Smith, 2012).

Science teachers' perceptions about climate change in the US

Several studies have investigated the American public and teachers' understanding of climate change. These studies assessed their climate change knowledge, beliefs, attitudes, and risk perceptions. Findings have generally indicated a lack of knowledge of the nature of climate change science among the general public. In addition, misconceptions about the causes of climate change are predominant among them (Herman, Feldman & Vernaza-Hernandez, 2015; Roser-Renouf, Maibach, Leiserowitz, & Rosenthal, 2016). Over a third of the US public thinks that scientists disagree about the topic (Curry, Ansolabehere & Herzog, 2007), and that climate change is mainly caused by non-human causes (Roser-Renouf, Maibach, Leiserowitz, & Rosenthal, 2016).

A joint team from Yale Project on Climate Change Communication and George Mason University Center conducted several national surveys, referred to as "Climate Change in the American Mind". From 2008 to 2016, the joint team investigated public understanding of climate change in the US. Study findings revealed an abundance of false beliefs and misunderstandings about climate change in the American society. The study also identified six unique groups within the American public that each responds to climate change in different ways. These groups ranged from the "Alarmed" over climate change, to the "Dismissive" who deny that it exists (Roser-Renouf, Maibach, Leiserowitz, & Rosenthal, 2016).

Similar misconceptions have been documented among school students. In 2011, a study entitled "American Teens' Knowledge of Climate Change" assessed 517 American teens' (aged 13 to 17) understanding of climate change in terms of its causes, consequences and potential solutions. The study provided a baseline assessment and

evaluation tool for climate change educators across the US, to track improvements in climate change literacy among students (Leiserowitz, Smith, & Marlon, 2011). Findings showed that relatively a few American teens in middle and high school have an in-depth understanding of how the climate system works. Fifty four percent of American teens received a failing grade in an assessment test of their knowledge about climate change. Study findings suggested that important misconceptions exist that lead many American teens to misunderstand the causes and potential solutions to climate change. Many teens have confused climate change with the hole in the ozone layer. Some teens believed that the hole in the ozone layer was a large contributor to climate change. Yet, American teens were aware of their limited understanding of the climate change issue, with 70 percent of teens indicating that they needed more information about climate change (Leiserowitz, Smith, & Marlon, 2011).

Review of literature indicates that similar misconceptions with regard to climate change also exist among science teachers (Herman, Feldman & Vernaza-Hernandez, 2015; Plutzer et al., 2016a; Wise, 2010). Some studies focus on pre-service science teachers' ideas about climate change (Groves & Pugh, 1999; Lambert & Bleicher, 2013; Matkins & Bell, 2007). These studies revealed that pre-service teachers hold false ideas about climate change. Lambert & Bleicher (2013) showed that pre-service science teachers had misconceptions about the causes and consequences of climate change.

A few studies examined pre-service teachers' knowledge and understanding of climate change concepts after participation in an elementary science methods course at university, which included a climate change component. Results showed that participants were able to apply their newly acquired concepts to decision making about socio-

scientific issues, such as climate change (Matkins & Bell, 2007). Another similar study indicated that providing a unit on climate change within a science methods college course for pre-service science teachers is an important factor in increasing understanding of climate change (Lambert & Bleicher, 2013). Teachers developed a deeper level of concern about climate change and more interest and confidence to teach about the topic. Teachers' perceptions of evidence for climate change, consensus of scientists, impacts of climate change and influence of politics also changed significantly (Lambert & Bleicher, 2013). McGinnis and Hestness (2014) used drawings of pre-service science teachers enrolled in an elementary science methods course at the University of Maryland to examine their moral reasoning about climate change and how this reflected their ideas about climate change causes and effects. Findings showed that drawings could serve as a useful tool to study teachers' perspectives and self-reflection on socio-scientific issues, such as climate change (McGinnis & Hestness, 2014).

Lombardi and Sinatra (2013) examined relationships among pre-service and in-service science teachers' emotions and plausibility perceptions of climate change in a school district in the southwestern US. Findings suggested that teachers' topic emotions were significant predictors of climate change plausibility perceptions, with more anger and boredom associated with lesser plausibility, and greater fear and hopelessness associated with higher plausibility (Lombardi & Sinatra, 2013). Another study also suggested associations between teachers' background knowledge and beliefs about climate change with plausibility perceptions about climate change (Lambert & Bleicher, 2013).

In another study, McGinnis, McDonald, Hestness & Breslyn (2016) investigated middle and secondary school science teachers' views of the role and responsibility for climate change education after participation in a one-week professional development on climate change education in Maryland. Findings indicated differences in teachers' views of their own roles and responsibilities for teaching about climate change, and recommended designing effective professional development programs for climate change education for science educators (McGinnis, McDonald, Hestness & Breslyn, 2016).

There are other studies that surveyed science teachers' perceptions of climate change, and their classroom practices and needs, that are limited to certain geographic areas of the US (Herman, Feldman & Vernaza-Hernandez, 2015; Monroe, Oxarat & Plate, 2013; Wise, 2010). Wise (2010) conducted a study on climate change instruction, which included 628 secondary science teachers in Colorado public schools. The study results indicated that some misconceptions about climate change existed among teachers, such as that the ozone hole causes global warming, and that there is still considerable disagreement between scientists with regards to climate change causes. Another misconception is the belief that both sides of the controversy over the anthropogenic causes of climate change should be taught to students. Study findings suggested that lack of alignment with the standards and curriculum is the largest barrier for science teachers, followed by the need for more climate change content knowledge.

Monroe, Oxarat & Plate (2013) surveyed 646 secondary science teachers in the southeast US and found that teachers are willing to teach about climate change, despite the challenges associated with state standards and the controversy surrounding it. Teachers viewed climate change education as an opportunity to teach students about the

nature of science, data analysis and critical thinking skills (Monroe, Oxarat & Plate, 2013).

Herman, Feldman & Vernaza-Hernandez (2017) examined 116 secondary science teachers in Florida and Puerto Rico, to determine their conceptions of climate change and climate change instruction. They found out that many secondary science teachers possess misconceptions that are similar to average Americans. Teachers in both groups lacked adequate scientific content knowledge of climate change and ignored essential topics. Findings indicated that nearly all Puerto Rico teachers and more than 70 percent of Florida teachers incorrectly viewed that ozone layer depletion and pesticide use were significant causes of climate change (Herman, Feldman & Vernaza-Hernandez, 2015).

A few research studies have attempted to determine what relevant topics to climate change are taught, and whether teachers are well equipped to teach about it. A national study about teachers' climate change instruction preparation and practices was conducted by Sullivan, Ledley, Lynds & Gold (2014). They analyzed responses of 877 middle and high school science teachers, across 4 different surveys, between 2009 and 2011. Findings indicated that around 70 percent of the teachers spend less than a quarter of their class time teaching climate change, with about 20 percent teaching climate change as a stand-alone topic. The study showed that when teaching climate change, some teachers had misinformation, such as perceiving the human contribution to climate change to be wrong. Other teachers would like to teach climate change as controversial (Herman, Feldman & Vernaza-Hernandez, 2015; Sullivan, Ledley, Lynds & Gold, 2014).

The NCSE and the Pennsylvania State University survey research center conducted a major national study on climate change education during the academic year

2014-2015. The national survey included 1,500 middle and secondary school science teachers from all 50 US states. Study findings showed that teachers' knowledge and beliefs could hinder effective teaching about climate change. Results revealed that teachers were unaware of the extent of scientific consensus about climate change, with less than 50 percent of the teachers indicating limited training and lack of formal instruction in climate science when they were in college. Findings indicated that 70 percent of middle school and 87 percent of high school science teachers allocate at least an hour of teaching to climate change. The study found that 30 percent of teachers believe climate change is due to natural causes. Thirty one percent of teachers taught climate change as a controversial topic. In terms of its causes, only 30 percent of middle school science teachers, and 45 percent of high school teachers agreed with the scientific consensus that global warming is caused mostly by human activities. Another finding in this study was that the political ideology of science teachers was the most powerful predictor of their instructional approach (Plutzer et al., 2016a, 2016b).

There is evidence that teachers' beliefs influence what and how they teach (Mansour, 2013). Teachers' beliefs about teaching and learning are the determining factors in the teachers' decisions about classroom strategies. Previous research on teaching evolution indicates that teachers' personal views can have a significant effect on classroom decisions and teaching approaches (Berkman & Plutzer, 2010). However, other research suggests that teachers' sound understanding of the climate nature of science may only be partially formed by the influence of these beliefs (Waters-Adams, 2007). Stevenson, Peterson & Bradshaw (2016), conducted a study that included 24 middle school science teachers and their 369 students in coastal North Carolina. Study

finding showed that 92 percent of students had teachers who believe that climate change is happening, and 88 percent of students had teachers who believe it is caused by a mixture of natural and human causes. Only 12 percent of students had teachers who acknowledge that climate change is mostly man-made. Thirty percent of students believed that climate change is mostly caused by human activities. These findings suggest that the strongest factor in students' belief in human-caused climate change was their own knowledge of climate science, and that teachers' beliefs may not have a strong relationship with students' beliefs (Stevenson, Peterson & Bradshaw, 2016).

In addition, political ideology has been shown to affect climate change perception. Individuals with liberal ideology are more likely to believe in climate change, and the scientific consensus about it, than those with conservative ideology (Hornsey, Harris, Bain & Fielding, 2016; Hu, Jia, Zhang, Zheng & Zhu, 2017; McCright, 2011). On the other hand, conservatives tend to resist the idea that humans are altering the climate, and hold beliefs about climate change that are less consistent with the scientific consensus. Cook & Lewandowsky believe that while climate change misconceptions are largely due to lack of knowledge, they can also be linked with one's worldview (Cook & Lewandowsky, 2011). It has also been shown that science teachers who believe in a strong government role tend to accept the scientific consensus about climate change, while teachers who believe in a weak government role tend to reject the scientific consensus (Plutzer, 2016a).

Review of literature did not reveal academic studies of science teachers' perceptions about climate change in California and Texas. This study examined how climate change is taught in these two states, and assessed secondary science teachers'

perceptions about climate change and whether these perceptions were influenced by their political and religious affiliations and beliefs.

Chapter III

Methodology

The purpose of this study was to investigate secondary science teachers' perceptions about climate change. This chapter describes the methodology used to conduct the study. This includes detailed description of the research design, sampling strategy, instrumentation, data collection procedures, as well as data analysis procedures performed.

Research design

This is a descriptive study that examined perceptions of California and Texas secondary science teachers about climate change. The study focused on secondary science teachers' knowledge about climate change, and their teaching approaches to climate change controversy. The study also aimed at providing insight whether social factors such as political and religious affiliations and beliefs, influence teachers' views about climate change.

Climate change perceptions of secondary science teachers from California were compared with those from Texas. Secondary science teachers' demographics, knowledge, personal views, and teaching approaches to climate change in California and Texas were examined. One objective was to assess whether there were any significant differences in teachers' knowledge, personal views and teaching approaches to climate change between the two states.

A quantitative approach was used to find answers to the research questions. A survey research design was used to conduct the study. This research design allowed investigation of perceptions of a large sample of secondary science teachers from

California and Texas to be surveyed, through asking a number of questions related to climate change instruction in public schools in the two states. The aim of the study was to get an adequate description of climate change perceptions of secondary science teachers' populations in California and Texas, from what is found in the surveyed sample. The study employed a cross-sectional survey research design, since information was collected from the sample of secondary science teachers at just one point in time. The answers to these questions by the participants constituted the data of the study (Fraenkel & Wallen, 2009).

Study participants were asked to complete an online questionnaire. An online questionnaire is more convenient and inexpensive than a mailed questionnaire, and saves time, as well as human and financial resources. In addition, an online questionnaire offers greater anonymity (Kumar, 2014). However, a major disadvantage to using an online questionnaire is the possibility of receiving a low response rate. Therefore, the online questionnaire was sent out to more than 7,000 secondary science teachers in California and Texas public schools, in order to guarantee that a desired sample size is reached.

Sampling strategy

The sample used in this study was generated, in November 2017, by Market Data Retrieval (MDR), a division of Dunn and Bradstreet, a company that provides commercial data, analytics and insights for business (Market Data Retrieval, 2017). MDR maintains a continuously updated database of 3.9 million K-12 educators in the United States, who are identifiable by type of school, educational sector, as well as name, job title, and contact information (MDR, 2017). MDR provides verified data and research-driven marketing services for a reasonable fee to educators and researchers. The company

helps clients by connecting with highly targeted education professionals through market intelligence, school data, and multi-channel digital communities (MDR, 2017).

MDR staff selected a stratified random sample of 7,060 secondary science teachers from California and Texas from their database, using a formula built into their selection system, which randomly selects the teachers' names. The sample was designed to represent secondary (grade 9-12) science teachers from five science disciplines, which are relevant to climate change (biology, environmental science, chemistry, physics, and earth science) in Texas and California public high schools.

MDR provided 7,060 names and email addresses of secondary school science teachers in California and Texas public schools. These names included 3,494 teachers from California and 3,566 teachers from Texas. For each state, the teachers were stratified by discipline into five groups: about 1,100 biology teachers, 1,100 chemistry teachers, and 500 physics teachers. In addition, a variable number of earth science and environmental science teachers was included from both states. Table 1 shows the numbers of California and Texas secondary science teachers who were invited to participate in the study. Teachers' numbers are distributed by disciplines.

Table 1
Numbers of Secondary Science Teachers Invited to Participate in the Study (N=7,060)

Science discipline	California	Texas
Biology	1,148	1,143
Chemistry	1,139	1,139
Physics	498	573
Earth science	533	256
Environmental Science	176	455
Total	3,494	3,566

The sample of science teachers was representative of all major science disciplines taught in secondary public schools in California and Texas. This was done in order to provide a comprehensive sample that can be generalized to all secondary science teachers in these two states. The numbers of teachers in each discipline were determined by the larger numbers of biology and chemistry high school teachers, as compared to other disciplines. The numbers of teachers in each discipline were also influenced by the smaller numbers of physics, earth science, and environmental science teachers in the MDR database. The selection of numbers of teachers from each discipline also took into consideration the relevance and more likelihood of discussing climate change topics in their classrooms. The advantage of stratified random sampling was to increase the likelihood of representativeness and ensure that key characteristics of individuals in the population were included in the sample (Fraenkel & Wallen, 2009).

Instrumentation

This study used an online questionnaire to investigate secondary science teachers' perceptions about climate change. The questionnaire was designed by the Pennsylvania State Survey Research Center and the National Center for Science Education. It was previously used to conduct a national study entitled "Mixed messages: How climate change is taught in America's public schools", in the 2014-2015 academic year. The original questionnaire included items about topics related to climate change covered in the classroom, possible controversies and potential community pressures, teachers' personal values and attitudes, and teachers' scientific training and educational background (Plutzer et al., 2016a). Most of its items were adapted from previously published work by the researchers and other scholars (Plutzer et al., 2016c; Wise, 2010).

The questionnaire has been revised by the researchers for its content, readability, question order, and formatting (Plutzer et al., 2016c). The questionnaire developers have also validated its construction, psychometric properties, and utility (Plutzer et al., 2016a, 2016c).

The original questionnaire used in the national study had 5 different versions, each aimed at teachers in a specific science discipline including biology, chemistry, physics, earth science, and middle school teachers. Each questionnaire version included 2 questions tailored to that discipline. The questionnaire used in this study was almost identical to that used in the national study. To simplify handling of the survey, the two questions that were directed to a specific discipline were deleted. This allowed one version of the questionnaire to be sent out to all secondary science teachers who were invited to participate in the study, regardless of their science discipline. Four other questions were deleted because they were open-ended, or were not relevant to this study. One question was added regarding whether teachers work in urban, suburban, or rural school districts.

The questionnaire consisted of 30 informational items, which included 6 items on teachers' demographics, 5 items on their educational background and teaching experience, 2 items on school characteristics, 3 knowledge items, 3 items on teaching approaches to climate change, 4 items on teachers' personal views about climate change, 2 items on social factors, as well as 3 items on climate change coverage in the classroom and 2 items on teachers' continuing education. Table 2 shows a brief description of the 30 items included in the questionnaire. Appendix A includes a copy of the online questionnaire used in this study.

Table 2
A Brief Description of Questionnaire Items (N=30)

Item Description	Total	Item
Teachers' Demographics	6	26- Gender, 27- Race, 28- Religious affiliation, 29- Religious beliefs, 30- Political affiliation, 14- Government role.
Education Background and Teaching Experience	5	16- Formal education, 20- Years at school, 21- Teaching experience, 24- Teaching certificate, 25- Certificate type.
School Characteristics	2	22- School district, 23- Graduates go to college.
Teachers' Knowledge	3	7- Essential subtopics, 9- State's science standards, 19- Knowledge of science topics.
Teaching Approaches	3	4-Approach to climate science, 5-Discussing potential solutions, 6-Negotiating the controversy.
Community Pressure	2	8 and 10- Outside pressure.
Teachers' Personal Views	4	11- Climate change causes, 12- Human role, 13- Scientific consensus, 15- Confidence about views.
Climate Change Coverage	3	1, 2 and 3- Topic coverage.
Continuing Education	2	17- Training, 18- Keeping up with knowledge.

Data collection procedures

The online questionnaire was formatted for a Web version through Qualtrics web questionnaire software program, and followed a similar format to the questionnaire used by the national study (Plutzer, 2016a; Qualtrics, 2017). The questionnaire was used to collect data during the academic year of 2017-2018, from January 16 to February 16, 2018. The questionnaire took about 15 minutes to complete. The University of Houston Institutional Review Board (IRB) reviewed all study materials, and determined that the research met the criteria for exempt research, category 2 (IRB study # 1000601, approved October 30, 2017). Appendix B includes a copy of the IRB approval letter.

On January 16, 2018, an email was sent out through Qualtrics website to the compiled lists of (7,060) secondary science teachers in California and Texas. The email included a cover letter explaining the study. The cover letter indicated the purpose of the study, and a request to voluntarily participate in the questionnaire. It also assured participants that respondents will be anonymous. A copy of the cover letter is shown in Appendix C. The email provided a direct link to the online questionnaire. As a follow up, an email reminder was sent out through Qualtrics to non-respondents, a week later, on January 23rd, 2018. A second email reminder was sent on January 31st, 2018, and was followed by a final email reminder on February 7th, 2018, to all remaining California and Texas teachers who did not respond to the questionnaire. Data collection ended on February 16, 2018.

Data analysis procedures

Data analysis included statistical analysis of questionnaire items using the Statistical Package for the Social Sciences (SPSS). For each questionnaire item, both descriptive and inferential statistics were performed. First, a frequency table was generated for each questionnaire item using SPSS to describe and summarize teachers' responses. Each Table included percentages of respondents who chose each alternative answer, and the total size of respondents to each item were reported. Data analysis also included a comparison between science teachers' responses in California and Texas. Inferential statistics using chi-square test for independence and chi-square test for goodness of fit were performed, since all data collected in this study was categorically coded data (Field, 2013; Urdan, 2010). Chi-square test for independence helped determine the differences in strengths and deficiencies between California and Texas

teachers in terms of their knowledge, approaches to teaching climate change, and personal views about climate change.

Therefore, to answer the first research question on teachers' knowledge, descriptive statistics was performed for questionnaire items 7, 9, and 19. This included running frequency tables using SPSS. Next, California and Texas teachers' responses to each questionnaire item were compared using chi-square test for independence. Similarly, to answer the second research question on teachers' approaches to climate change instruction, descriptive statistics was performed for questionnaire items 4, 5, and 6. This included running frequency tables for each questionnaire item. Next, California and Texas teachers' responses to each questionnaire item were compared using chi-square test for independence.

To answer the third research question on teachers' views about climate change, descriptive statistics was performed for questionnaire items 11, 12, 13, and 15. This included running frequency tables. Then, California and Texas teachers' responses to each questionnaire item were compared using chi-square test to compare teachers' responses on each answer choice. For item 13 on scientific consensus and item 11 on climate change causes, chi-square test for independence was performed to compare teachers' responses.

Finally, to answer the fourth research question on whether science teachers' views about climate change were linked to their political and religious affiliations and beliefs, inferential statistics was performed. Chi-square test for independence and chi-square test for goodness of fit were performed to determine whether there was any association between science teachers' political affiliations, views of government role, religious

affiliations, and religious beliefs on one hand, and their personal views of climate change causes on the other hand. Chi-square test goodness of fit allowed comparing teachers' responses within groups such as, within teachers' political party, religious affiliation, views about the role of government and religious beliefs. California and Texas teachers' responses to each questionnaire item were also compared using chi-square test for independence to determine whether there were any significant differences between teachers in the two states.

Chapter IV

Results

This chapter summarizes the questionnaire results of secondary science teachers' perceptions in California and Texas public schools. It includes some of the demographic characteristics of secondary science teachers who responded to the survey, their knowledge about climate change, and their approaches to dealing with the climate change controversy in the science classroom. It also includes teachers' views about climate change, as well as community pressure, and social factors (including political and religious affiliations and beliefs), which may affect climate change instruction. For the purpose of simplification, the data analysis in this chapter focuses on the questionnaire items that are relevant to the research questions addressed in this study. To facilitate data analysis, responses were converted into numerical values and percentages when possible. Descriptive and inferential statistics were conducted using SPSS.

Demographic characteristics

California secondary science teachers' respondents. Six hundred and sixty one out of 3,494 secondary science teachers from California public schools responded to the online questionnaire. Incomplete responses were eliminated from the study. Results were based on responses of 456 California secondary science teachers who answered 80 percent or more of the questions, with a response rate of 13.1 percent. Approximately 72 percent of teachers participating in the questionnaire were white, and were almost equally distributed by gender, with 52 percent females and 48 percent males. Thirty two percent identified themselves as Christians, being either Protestant or Roman Catholic, while about 30 percent identified themselves as atheist or agnostic. Approximately 52 percent

of the teachers described the textual basis of their religion (Bible, Torah, Quran, etc.) as an ancient book of fables recorded by man. About 48 percent of teachers viewed the textual basis of their religion as the inspired or actual word of God, with 7 percent of them believing it to be the actual word of God, to be taken literally word for word. As for their political affiliation, approximately 54 percent of respondents considered themselves as Democrats, while 13 percent were Republicans and 19 percent were independent. Overall, the majority of teachers (83%) agreed with the government role to make laws that keep people from harming themselves. Table 3 shows the demographic characteristics of responding California secondary science teachers.

The vast majority (94%) of participating California science teachers were university graduates, with 34 percent having a master's degree and 9 percent having a doctorate degree. Eighty nine percent of the respondents had more than five years teaching experience, and 36 percent had over 20 years of teaching experience. The majority of teachers obtained their standard secondary certificate through traditional certification program (91%) with over 56 percent having obtained a multiple science field certificate, and 44 percent having obtained a single science field certificate. Table 4 summarizes participating California science teachers' educational background and teaching experience.

All science teachers participating in this questionnaire taught in California public high schools. The majority of these schools were located in a suburban school district (62%), with 25.5 percent located in an urban school district and 12.5 percent located in a rural school district. Approximately 27 percent of teachers indicated that over 75 percent of their high school graduates go to college, while 41 percent of teachers indicated that 50

percent or less of their high school graduates go to college. Table 5 includes some characteristics of the secondary (grade 9-12) public schools of participating California science teachers.

Texas secondary science teachers' respondents. Five hundred and forty nine out of 3,566 secondary science teachers from Texas public schools responded to the online questionnaire. Incomplete responses were eliminated from the study. Results were based on responses of 376 Texas secondary science teachers who answered 80 percent or more of the questions, with a response rate of 10.5 percent. Approximately, 70 percent of teachers participating in the questionnaire were white, with 57 percent females and 43 percent males. Fifty two percent identified themselves as Christians, being either Protestant or Roman Catholic, while 17 percent identified themselves as atheist or agnostic. Twenty nine percent of the teachers described the textual basis of their religion (Bible, Torah, Quran, etc.) as an ancient book of fables recorded by man. About 70 percent of teachers viewed the textual basis of their religion as the inspired or actual word of God, with 55 percent of them believing it to be the inspired word of God, but not everything to be taken literally word for word. As for their political affiliation, approximately 30 percent of respondents considered themselves as Democrats, while 26 percent were Republicans and 26 percent were independent. Overall, the majority of teachers (64%) agreed with the government role to make laws that keep people from harming themselves. Table 3 shows the demographic characteristics of responding Texas secondary science teachers.

The vast majority (95%) of participating Texas science teachers were university graduates, with 35.5 percent having a master's degree and 9 percent having a doctorate

degree. About 85 percent of the respondents had more than five years teaching experience, and 28 percent had over 20 years of teaching experience. Half of teachers obtained their standard secondary certificate through traditional certification program (50%) and the other half obtained their certificate through alternate programs. The majority of teachers (84%) have obtained a multiple science field certificate, while 16 percent of them have obtained a single science field certificate. Table 4 summarizes participating Texas science teachers' educational background and teaching experience.

All science teachers participating in this questionnaire taught in Texas public high schools. About half of these schools were located in a suburban school district (47%), with 27 percent located in an urban school district and 26 percent located in a rural school district. Approximately 20 percent of teachers indicated that over 75 percent of high school graduates go to college, while 47 percent of teachers indicated that 50 percent or less of their high school graduates go to college. Table 5 includes some characteristics of the secondary (grade 9-12) public schools of participating Texas science teachers.

Table 3
Demographic Characteristics of Responding Secondary Science Teachers

Characteristic	California (N=456)	Texas (N=376)
Gender		
Female	52%	57%
Male	48%	43%
Race		
White	72%	70%
Hispanic	8%	13%
Black	2%	4%
Asian	6%	2%
Other ^a	12%	11%
Religion		
Agnostic	13%	9%
Atheist	15%	8%
Protestant	20%	34%
Roman Catholic	12%	18%
Spiritual, but not religious	10%	9%
Other ^b	30%	22%
Religious Beliefs		
Actual word of God	7%	16%
Inspired word of God	41%	55%
Ancient book of fables	52%	29%
Political Affiliation		
Democrat	54%	30%
Republican	13%	26%
Independent	19%	26%
Green party	2%	1%
Libertarian	3%	6%
I choose not to identify	9%	11%
Views on Government Role		
Agree with strong role	83%	64%
Disagree with strong role	12%	26%
Neither Agree/Disagree	5%	10%

Note. ^aIncludes American Indian, Alaska Native, Pacific Islander and teachers who chose not to identify. ^bIncludes Buddhist, Hindu, Jewish, Mormon, Muslim, Greek or Russian Orthodox and teachers who chose not to identify.

Table 4
Responding Teachers' Education Background and Teaching Experience

Background	California (N=456)	Texas (N=376)
Education Level		
Associate Degree	6%	5%
Bachelor of Arts/Science	51%	50.5%
Master's Degree	34%	35.5%
Ed.D./Ph.D.	9%	9%
Teaching at School ^a		
1 to 5	25%	34.5%
6 to 10	16%	29%
11 to 15	23%	15%
16 to 20	16%	9.5%
Over 20	20%	12%
Teaching Experience ^b		
1 to 5	11%	15%
6 to 10	17%	20%
11 to 15	18%	21%
16 to 20	18%	16%
Over 20	36%	28%
Teaching Certificate ^c		
Traditional Program	91%	50%
Alternate Program	9%	50%
Certificate Type		
Single Science Field	44%	16%
Multiple Science Field	56%	84%

Note. ^aTotal years teaching at current school. ^bTotal years teaching. ^cStandard secondary certificate obtained through a traditional or alternate program.

Table 5
School Characteristics of Responding Secondary Science Teachers

Characteristic	California (N=456)	Texas (N=376)
School District		
Urban	25.5%	27%
Suburban	62%	47%
Rural	12.5%	26%
Graduates go to college ^a		
Below 25%	13%	14%
26 to 50%	28%	33%
51 to 75%	32%	33%
Over 75%	27%	20%

Note. ^aPercentages of secondary school students who make it to college after graduation.

Secondary science teachers' knowledge about climate change

Teachers' understanding of the greenhouse effect. Science teachers' knowledge of the greenhouse effect was examined. Questionnaire item 7 asked science teachers to indicate the priority level, which they would give to include a list of subtopics if they were to teach a unit on climate change. Some of these subtopics are necessary to a scientific understanding of the causes of the greenhouse effect. Other subtopics address the consequences of climate change (Plutzer et al., 2016a). The list also included some foil topics or incorrect responses as distractors, which are not relevant to the greenhouse processes, but are relevant to other environmental challenges such as depletion of ozone, use of pesticides, use of aerosol spray cans, and impact of launching rockets into space. Item 7 assumed that teachers who were scientifically well prepared, would be able to identify ozone depletion, pesticide use, aerosol spray cans use, and launching rockets' impact as inappropriate topics for a unit on climate change. Tables 6 and 7 summarize California and Texas science teachers' responses to this questionnaire item.

Table 6
California Teachers' Priority to Include Topics in a Unit on Climate Change (N=465)

Topics	High priority	Medium priority	Not Necessary	Topic should not be covered	No Opinion
Destruction of forests	53%	41%	3%	0.5%	2.5%
Carbon dioxide trapping heat in the atmosphere	87%	12%	0%	0%	1%
Use of aerosol spray cans	10%	50%	30%	5%	5%
People heating and cooling their homes	19%	62%	13%	1%	5%
Depletion of ozone in the upper atmosphere	30%	40%	22%	5%	1%
Use of coal and oil by utility and electric companies	72%	26%	1%	0%	1%
Use of chemicals to destroy insect pests	17%	40%	30%	8%	5%
Incoming shortwave and outgoing longwave energy	44%	33%	12%	2%	9%
Emissions from industry	64%	32.5%	2%	0%	1.5%
The impact of launching rockets into space	3%	27%	48%	10%	12%
Alternative energy sources	79%	19%	1%	0%	1%

Table 7
Texas Teachers' Priority to Include Topics in a Unit on Climate Change (N=376)

Topics	High priority	Medium priority	Not Necessary	Topic should not be covered	No Opinion
Destruction of forests	58%	36%	3%	0%	3%
Carbon dioxide trapping heat in the atmosphere	72%	24%	1%	0%	3%
Use of aerosol spray cans	19%	54%	21%	2%	4%
People heating and cooling their homes	20%	58%	14%	1%	7%
Depletion of ozone in the upper atmosphere	43%	40%	13%	2%	3%
Use of coal and oil by utility and electric companies	60%	33%	4%	0%	3%
Use of chemicals to destroy insect pests	31.5%	40%	20%	3%	5.5%
Incoming shortwave and outgoing longwave energy	22%	42%	16%	3%	17%
Emissions from industry	57%	37%	3%	0%	3%
The impact of launching rockets into space	5%	31%	44%	5%	15%
Alternative energy sources	78%	19%	2%	0%	2%

The questionnaire results indicated that a discussion of carbon dioxide as the main gas trapping heat was considered a high priority among 87 percent of California teachers and 72 percent of Texas teachers. Chi-square test for independence showed a significant association between state and priority category, ($\chi^2(3)=30.020, p<0.001$), suggesting a higher proportion of California teachers considered discussion of carbon dioxide trapping heat as a high priority than Texas teachers. Furthermore, a discussion of the use of coal by utility and electric companies was considered a high priority among 72 percent of California teachers and 60 percent of Texas teachers. Chi-square test for independence

showed a significant association between state and priority category, ($\chi^2(4)=16.570$, $p<0.001$), suggesting a higher proportion of California teachers considered discussion of the use of coal by utility and electric companies as a high priority than Texas teachers. However, the fact that carbon dioxide and other gases trap heat because heat radiated from the Earth's surface has a longer wavelength than absorbed solar radiation energy, was considered a high priority by 44 percent of California teachers and 22 percent of Texas teachers. Chi-square test for independence showed a significant association between state and priority category, ($\chi^2(4)=48.830$, $p<0.001$), suggesting a higher proportion of California teachers considered discussion of incoming shortwave and outgoing longwave energy as a high priority than Texas teachers. Therefore, differences between California and Texas teachers' responses with regards to discussing these topics in a unit on climate change were found to be statistically significant.

On the other hand, a majority of California and Texas teachers gave medium to high priority responses to foil topics, such as depletion of ozone, pesticide use and aerosol spray cans use, to be included in a unit on climate change. Seventy percent of California teachers and 83 percent of Texas teachers gave medium to high priority for depletion of ozone in the upper atmosphere. Chi-square test for independence showed a significant association between state and priority category, ($\chi^2(4)=25.49$, $p<0.001$), suggesting a higher proportion of Texas teachers considered discussion of ozone depletion as a priority topic than California teachers. Also, 57 percent of California teachers and about 72 percent of Texas teachers gave medium to high priority for pesticide use. Chi-square test for independence showed a significant association between state and priority category, ($\chi^2(4)=34.710$, $p<0.001$), suggesting a higher proportion of

Texas teachers considered discussion of pesticide use as a priority topic than California teachers. In addition, 60 percent of California teachers and 73 percent of Texas teachers gave medium to high priority for use of aerosol spray cans. Chi-square test for independence showed a significant association between state and priority category, ($\chi^2(4)=21.600, p<0.001$), suggesting a higher proportion of Texas teachers considered discussion of aerosol spray cans use as a priority topic than California teachers. Therefore, differences between California and Texas teachers' responses with regards to including foil topics in a unit on climate change were found to be statistically significant.

Teachers' knowledge about state's climate change science standards. Table 8 summarizes science teachers' knowledge about their state's science standards' inclusion of climate change anthropogenic causes. Almost two thirds (65%) of California teachers indicated that their science standards included human causes of climate change, as opposed to one third (31.5%) of Texas teachers. A quarter of responding Texas teachers (25%) as opposed to 16 percent of California teachers were not sure whether their state standards included human causes. About 18 percent of Texas teachers and 10 percent of California teachers indicated that their state standards included an expectation that students should be exposed to both sides of the climate change controversy. However, chi-square test for independence showed no significant association between state and knowledge about state's science standards category for these statements (Table 8). On the other hand, 15 percent of Texas teachers and 4 percent of California teachers indicated that their state standards do not expect them to teach about climate change. Chi-square test for independence showed a significant association between state and knowledge about state's science standards category, ($\chi^2(1)=5.442, p=0.020$), suggesting a higher

proportion of Texas teachers than California teachers indicated that their state's science standards had no expectations to teach climate change.

Table 8
Teachers' Knowledge About State's Climate Change Science Standards

State Science Standards	California (N=456)	Texas (N=376)	$\chi^2(1)$	<i>p</i>
Yes, but it does not include human causes.	2%	4%	.416	.519
Yes, it includes human causes.	65%	31.5%	.833	.361
Yes, it includes an expectation that students are exposed to both sides.	10%	17.5%	.795	.373
Yes, but human causes of climate change must be taught as a theory.	2%	5%	1.964	.161
No, but my local school or school district expects me to teach it.	1%	2%	1.418	.234
No, nobody expects me to teach it.	4%	15%	5.442*	.020
I am not sure.	16%	25%	.711	.399

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Teachers' self-ratings of their content knowledge of science topics. Fifty five percent of California science teachers and 44 percent of Texas teachers rated their content knowledge of climate change models as very good or exceptional. Chi-square test for independence showed a significant association between state and content knowledge of science topics category, ($\chi^2(3)=14.232$, $p=0.003$), suggesting a higher proportion of California teachers than Texas teachers rated their content knowledge of climate change models as very good or exceptional. Fifty six percent of California science teachers and 57 percent of Texas teachers rated their content knowledge of ecology as very good or exceptional. In addition, 30 percent of California teachers and 30 percent of Texas teachers rated their content knowledge of weather forecasting models as very good or exceptional. Table 9 summarizes science teachers' self-ratings of their content knowledge of these science topics.

Table 9
Teachers' Self-Ratings of Content Knowledge of Science Topics

Science Topics	California (N=438)	Texas (N=361)	$\chi^2(1)$	<i>p</i>
Ecology			8.335*	.040
Exceptional	16%	16%		
Very Good	40%	41%		
Typical	33%	37%		
Less than Other Teachers	11%	6%		
Climate Change Models			14.232**	.003
Exceptional	10%	6%		
Very Good	45%	38%		
Typical	38%	43%		
Less than Other Teachers	7%	13%		
Weather Forecasting Models			1.078	.782
Exceptional	5%	5%		
Very Good	25%	25%		
Typical	43%	46%		
Less than Other Teachers	27%	24%		

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Science teachers' approaches to teaching climate change

Sending mixed messages. Item 4 of the questionnaire asked science teachers to specify their level of agreement with statements that demonstrate a variety of teaching approaches to climate science, and reflect the climate change controversy. One of the statements asked whether science teachers emphasize that average global temperatures have risen. Another statement asked whether teachers emphasize the scientific consensus that greenhouse gases are the primary causes of climate change. A third statement asked if teachers emphasize that many scientists believe that the increase in average global temperature is most likely due to natural causes. Tables 10 and 11 summarize California and Texas secondary science teachers' responses to these statements.

Overall, California and Texas teachers' responses showed different levels of agreement about the causes of climate change. About 86 percent of responding California teachers (Table 10) emphasized that global temperatures have risen in the last 150 years, with over 50 percent of these teachers agreeing strongly with this statement. A similar proportion (85%) of California teachers emphasized the scientific consensus about the causes of climate change, with 59 percent of these teachers agreeing strongly with the statement. However, 21 percent of California teachers emphasized that many scientists believe that the increases in average global temperature has resulted from natural causes. Out of the 21 percent of teachers emphasizing the natural causes of climate change, 6.5 percent of those teachers agreed strongly with the statement.

Table 10

Proportions of California Science Teachers Agreeing With Approaches to Teaching Climate Change (N=456)

Teaching Approach	Strongly agree	Agree	Disagree	Strongly disagree	Not Applicable
I emphasize that average global temperatures have risen in the last 150 years	56.5%	29%	3.5%	1%	10%
I emphasize that scientific consensus that recent climate change is primarily being caused by human release of greenhouse gases from fossil fuels	59%	26%	4%	2%	9%
I emphasize that many scientists believe that recent increases in temperature is likely due to natural causes	6.5%	14.5%	29%	37%	13%

As for responding Texas secondary science teachers (Table 11), while 67 percent of teachers emphasized that average global temperatures have risen in the last 150 years, about one third (34%) of those teachers agreed strongly with this statement. A similar

proportion of Texas teachers (69%) emphasized the scientific consensus about climate change causes, with 34 percent of them agreeing strongly with the statement. However, 36 percent of responding Texas teachers emphasized that many scientists believe that the increases in average global temperature has resulted from natural causes, with 8 percent of those teachers agreeing strongly with the statement.

Table 11

Proportions of Texas Science Teachers Agreeing With Approaches to Teaching Climate Change (N=376)

Teaching Approach	Strongly agree	Agree	Disagree	Strongly disagree	Not Applicable
I emphasize that average global temperatures have risen in the last 150 years	34%	33%	8%	4%	21%
I emphasize that scientific consensus that recent climate change is primarily being caused by human release of greenhouse gases from fossil fuels	34%	35%	11%	5%	15%
I emphasize that many scientists believe that recent increases in temperature is likely due to natural causes	8%	28%	26%	21%	17%

The above results indicated that a higher percentage of responding Texas teachers (36%), as opposed to 21 percent of responding California teachers, emphasized the natural causes of climate change. Chi-square test for independence showed a significant association between state and agreement category, ($\chi^2(4)=42.364, p<0.001$), suggesting a higher proportion of Texas teachers agreed with emphasizing the natural causes than California teachers. On the other hand, the results also indicated that a higher percentage of California teachers (85%), as opposed to 69 percent of Texas teachers, emphasized the scientific consensus about the causes of climate change. Chi-square test for independence

showed a significant association between state and agreement category, ($\chi^2(4)=61.91$, $p<0.001$), suggesting a higher proportion of California teachers agreed with emphasizing the scientific consensus than Texas teachers. In addition, while a higher percentage of California teachers (85.5%) emphasized that average global temperatures have risen in the last 150 years, a lower percentage of Texas teachers (67%) did that. Chi-square test for independence showed a significant association between state and agreement category, ($\chi^2(4)=56.955$, $p<0.001$), suggesting a higher proportion of California teachers agreed with emphasizing that average global temperatures have risen in the last 150 years than Texas teachers.

Combining “agree” with “strongly agree” responses and “disagree” with “strongly disagree” responses for the two conflicting statements, i.e., emphasizing the scientific consensus versus emphasizing natural causes, generated four groups of teachers (Tables 12 and 13). These groups of teachers included those who were sending mixed messages about climate change causes by emphasizing the scientific consensus and natural causes, those who emphasized the scientific consensus, those who denied climate change by emphasizing natural causes only, and those who avoided climate change discussion in their science classroom (Plutzer et al., 2016a).

Table 12 shows that the majority of responding California teachers (75%) emphasized the scientific consensus, while 19 percent of them were sending mixed messages by emphasizing both points of view. In addition, 5 percent of California teachers supported positions held by climate science deniers and emphasized the position that recent climate change is a natural phenomenon. Only 1 percent of California teachers avoided discussion of climate change.

Table 13 shows that 52 percent of responding Texas teachers emphasized the scientific consensus, while 29 percent of them were sending mixed messages by emphasizing both points of view. Fourteen percent of Texas teachers supported positions held by climate change deniers and emphasized the position that recent climate change is a natural phenomenon. Five percent of Texas teachers avoided discussion of climate change.

Table 12
Some California Teachers Send Contradictory Messages About the Scientific Consensus (N=396)

Emphasize Scientific Consensus	Emphasize Natural Causes	
	Agree or Strongly Agree	Disagree or Strongly Disagree
Agree or Strongly Agree	74 (19%) Mixed Messages	296 (75%) Scientific Consensus
Disagree or Strongly Disagree	21 (5%) Denial	5 (1%) Avoidance

Table 13
Some Texas Teachers Send Contradictory Messages About the Scientific Consensus (N=310)

Emphasize Scientific Consensus	Emphasize Natural Causes	
	Agree or Strongly Agree	Disagree or Strongly Disagree
Agree or Strongly Agree	90 (29%) Mixed Messages	161 (52%) Scientific Consensus
Disagree or Strongly Disagree	44 (14%) Denial	15 (5%) Avoidance

Managing debate about climate change. Questionnaire item 4 also addressed two teaching approaches to climate change that examine how teachers manage debate and inquiry about climate change. One statement asked whether science teachers encourage students to debate the causes of climate change, and another statement asked whether teachers encourage students to come to their own conclusions about its causes. Tables 14 and 15 summarize California and Texas science teachers' responses to these statements.

Overall, higher percentages of Texas teachers than California teachers agreed with the statements. Fifty five percent of California teachers reported that they encourage students to debate the likely causes of climate change, and 61 percent of them encourage students to come to their own conclusions about the causes of climate change (Table 14).

Table 14
California Teachers Managing Debate About Climate Change (N=456)

Managing Debate	Strongly Agree	Agree	Disagree	Strongly Disagree	Not Applicable
I encourage students to debate the likely causes of climate change.	18%	37%	21%	9%	15%
I encourage students to come to their own conclusions about climate change causes.	20%	41%	20%	10%	11%

A higher percentage (67%) of Texas teachers reported that they encourage students to debate the likely causes of climate change, and 69 percent of them agreed that they encourage students to reach to their own conclusions about the causes of climate change (Table 15). Chi-square test for independence showed a significant association between state and agreement category, ($\chi^2(4)=44.640, p<0.001$), suggesting a higher proportion of Texas teachers than California teachers encouraged students to debate the

likely causes of climate change. In addition, chi-square test for independence showed a significant association between state and agreement category, ($\chi^2(4)=31.458, p<0.001$), suggesting a higher proportion of Texas teachers than California teachers encouraged students to reach to their own conclusions.

Table 15

Texas Teachers Managing Debate About Climate Change (N=376)

Managing Debate	Strongly Agree	Agree	Disagree	Strongly Disagree	Not Applicable
I encourage students to debate the likely causes of climate change.	28%	39%	12%	1%	20%
I encourage students to come to their own conclusions about climate change causes.	26%	43%	12%	3%	16%

Discussing potential solutions to climate change. Item 5 of the questionnaire asked science teachers whether they discuss potential steps or solutions people can take to address climate change challenges. Table 16 summarizes California and Texas teachers' responses to item 5. The results indicated that, in general, science teachers included discussions of potential solutions, which government, industry, or students can do themselves to address climate change challenges, as well as potential career opportunities. Overall, higher percentages of secondary science teachers in California than Texas reported that they discuss potential solutions to address climate change. Eighty eight percent of California teachers, and 75 percent of Texas teachers discuss current technologies, such as alternative energy sources and hybrid cars. Eighty three percent of California teachers and 73 percent of Texas teachers discuss personal conservation, such as walking to school. In addition, 72 percent of California teachers

and 63 percent of Texas teachers discuss career opportunities related to new energy technologies, conservation or environmental policy. However, the results also showed that less than half of California teachers (47%) and about one third of Texas teachers (38%) stayed away from more political discussions of policy solutions that address change incentives such as carbon taxes or cap and trade. The above differences between California and Texas teachers' tendency to discuss potential solutions to climate change challenges were found to be statistically significant for all approaches except one. Chi-square test for independence showed a significant association between state and discussion of potential solutions category, suggesting higher proportions of California teachers discussed current technologies, personal conservation, policy solutions and career opportunities than Texas teachers (Table 16). Technologies that mitigate rather than prevent climate change were equally discussed by about half of responding science teachers in both states. Chi-square test for independence showed no significant association between state and discussion of mitigation technologies.

Table 16

Proportions of Science Teachers Discussing Potential Solutions to Climate Change

Potential Solutions	California (N=455)	Texas (N=363)	$\chi^2(1)$	<i>p</i>
Policy Solutions	206 (47%)	135 (38%)	6.045*	.014
Current Technologies	393 (88%)	270 (75%)	22.854***	< .001
Mitigation Technologies	241 (54%)	188 (53%)	0.178	.673
Personal Conservation	369 (83%)	258 (73%)	13.040***	< .001
Career Opportunities	316 (72%)	225 (63%)	6.811**	.009

Note: * $p < .05$, ** $p < .01$, *** $p < .001$

Negotiating climate change controversy. Questionnaire item 6 asked science teachers to report on nine approaches, which teachers may use with their students when

teaching about climate change. The objective was to examine how science teachers deal with the human-caused climate change controversy. To answer this question, teachers had to indicate whether they have done, not done, or would do those approaches if the situation was to arise. Tables 17 and 18 summarize California and Texas teachers' responses to questionnaire item 6.

The most common approach among science teachers in both states was emphasizing the nature of science. Around two thirds of teachers in each state (64% of California teachers and 65% of Texas teaches) reported that they have discussed climate change controversy in the context of nature of science. Chi-square test for independence showed no significant association between state and "have done" category, ($\chi^2(2)=2.749$, $p=0.253$). Another approach was whether teachers would play a neutral role in their classroom by allowing students to discuss the climate change controversy without taking a position. About 75 percent of California teachers, and 87 percent of Texas teachers either have done this in their classes or would consider doing so. Chi-square test for independence showed a significant association between state and "have done" category, ($\chi^2(2)=26.504$, $p<0.001$), suggesting a higher proportion of Texas teachers played a neutral role in their classroom and allowed students to discuss the climate change controversy without taking a position than California teachers.

There was a notable difference between California and Texas teachers' responses in terms of "giving equal time to perspective that raise doubt that humans are mainly causing climate change". While 41 percent of California teachers reported that they would not give equal time to perspective that raise doubt that humans are mainly causing climate change, only 19 percent of Texas teachers indicated that they would not do so.

Chi-square test for independence showed a significant association between state and “have done” category, ($\chi^2(2)=50.424, p<0.001$), suggesting a higher proportion of Texas teachers gave equal time to perspective that raise doubt that humans are mainly causing climate change than California teachers.

Furthermore, avoiding discussion of climate change rarely happened in both states. Only 1 percent of California teachers and 2 percent of Texas teachers have avoided all discussion of climate change. Likewise, only 2 percent of California teachers and 3 percent of Texas teachers have allowed students to opt out of the climate change portions of their class. Similarly, sending or considering to send an explanatory letter to parents rarely happened. Only 1 percent of California teachers and 2 percent of Texas teachers have sent an explanatory letter to parents.

In addition, a large number of teachers reported taking steps to remove conflict from their science classrooms. Thirty eight percent of California teachers and 32 percent of Texas teachers have offered to meet with students outside of their classes to allow them to express their views without the risk of discussion derailing the lesson plan. Almost half of California teachers (50%) and Texas teachers (46%) reported that they might consider doing so. Chi-square test for independence showed a significant association between state and “have done” category, ($\chi^2(2)=16.621, p<0.001$), suggesting a higher proportion of California teachers offered to meet students outside of their classes to allow them to express their views than Texas teachers. On the other hand, chi-square test for independence showed a significant association between state and “have done” category, ($\chi^2(2)=18.946, p<0.001$), suggesting a higher proportion of California teachers than Texas teachers discouraged debate because climate skepticism is not based on sound

science. In addition, chi-square test for independence showed a significant association between state and “have done” category, ($\chi^2(2)=7.143, p=0.028$), suggesting a higher proportion of California teachers than Texas teachers would not adhere strictly to state standards (Tables 17 and 18).

Table 17

California Teachers' Approaches to Addressing Climate Change Controversy (N=456)

Negotiation Approach	I have done	I have not done, but might	I would not do
Give equal time to perspective that raise doubt that humans are causing climate change	25%	34%	41%
Allow students to discuss the controversy without me taking a position	37%	38%	25%
Discuss the controversy in the context of the nature of science	64%	29%	7%
Discourage debate because I believe most climate skepticism is not based on sound science	16%	27%	57%
Offer to meet with students after class	38%	50%	12%
Send an explanatory letter to parents	1%	38.5%	60.5%
Allow students to opt out of portions of the class	2%	17%	81%
Adhere strictly to state standards and not allow discussion that might become controversial	6%	22%	72%
Avoid all discussion of climate change	1%	4%	95%

Table 18
Texas Teachers' Approaches to Addressing Climate Change Controversy (N=376)

Negotiation Approach	I have done	I have not done, but might	I would not do
Give equal time to perspective that raise doubt that humans are causing climate change	40%	41%	19%
Allow students to discuss the controversy without me taking a position	51%	36%	13%
Discuss the controversy in the context of the nature of science	65%	31%	4%
Discourage debate because I believe most climate skepticism is not based on sound science	10%	19%	71%
Offer to meet with students after class	32%	46%	22%
Send an explanatory letter to parents	2%	39%	59%
Allow students to opt out of portions of the class	3%	25%	72%
Adhere strictly to state standards and not allow discussion that might become controversial	8%	29%	63%
Avoid all discussion of climate change	2%	8%	90%

Social factors and teachers' views about climate change

Teachers' views of the scientific consensus on climate change causes. In questionnaire item 13, teachers were asked about the percentage of climate scientists who think that climate change is mostly caused by human actions. Table 19 summarizes California and Texas teachers' responses to this item. Results showed that the majority of responding California teachers (75%) and 48 percent of responding Texas teachers selected the correct answer of "81%-100%" scientific consensus. Chi-square test for independence showed a significant association between state and agreement category, ($\chi^2(1)=54.839, p<0.001$), suggesting a higher proportion of California teachers agreed with 81%-100% scientific consensus than Texas teachers. On the other hand, 25 percent

of Texas teachers, as opposed to 13.5 percent of California teachers, believed that there is “61%-80%” scientific consensus. Chi-square test for independence showed a significant association between state and agreement category ($\chi^2(1)=4.364, p=0.037$), suggesting a higher proportion of Texas teachers agreed with 61%-80% scientific consensus than California teachers. Additionally, 14 percent of Texas teachers, as opposed to 6 percent of California teachers believed that there is only “41%-60%” agreement among climate scientists that climate change is mostly caused by human actions. Chi-square test for independence also showed a significant association between state and agreement category ($\chi^2(1)=4.188, p=0.041$), suggesting a higher proportion of Texas teachers agreed with 41%-60% scientific consensus than California teachers.

Table 19

Science Teachers’ Responses Regarding Scientific Consensus About Climate Change Causes

Scientific Consensus	California (N=399)	Texas (N=310)	$\chi^2(1)$	<i>p</i>
0 to 20%	8 (2%)	19 (6%)	4.481*	.034
21% to 40%	12 (3%)	21 (7%)	2.455	.117
41% to 60%	26 (6.5%)	43 (14%)	4.188*	.041
61% to 80%	54 (13.5%)	78 (25%)	4.364*	.037
81% to 100%	299 (75%)	149 (48%)	54.839***	< .001

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Teachers’ views of human activities as the primary cause of climate change.

In questionnaire item 11, teachers were asked whether they think that climate change is caused mostly by human activities, natural changes in the environment, or both. Table 20 shows responding California and Texas secondary science teachers’ views about climate change causes. Results showed that California teachers were split between those who believed that the recent climate change is caused mostly by human activities (46%)

and those who believed that it is caused by both human activities as well as natural changes in the environment (50%). In contrast, a large majority (65%) of Texas teachers believed that climate change is caused by both human activities and natural changes. Around one quarter (26%) of Texas teachers believed that climate change is caused mostly by human activities. The difference between California (46%) and Texas (26%) teachers' responses who believed that climate change is caused mostly by human activities was found to be statistically significant. Chi-square test for independence showed a significant association between state and climate change causes category ($\chi^2(1)=38.118, p<0.001$), suggesting a higher proportion of California teachers agreed with the anthropogenic causes than Texas teachers. However, the difference between California (50%) and Texas (65%) teachers who believed that climate change is caused by both human activities and natural changes was not found to be statistically significant. Chi-square test for independence showed no significant association between state and climate change causes category ($\chi^2(1)=0.837, p=0.360$).

Table 20
Science Teachers' Views About Climate Change Causes

Climate Change is:	California (N=426)	Texas (N=375)	$\chi^2(1)$	<i>p</i>
Caused mostly by human activities	197 (46%)	98 (26%)	38.118***	<0.001
Caused mostly by natural changes	17 (4%)	25 (7%)	1.524	.217
Caused by both	211 (50%)	244 (65%)	0.837	.360
Not happening	1 (0%)	8 (2%)	5.444*	.020

Note. * $p<.05$, ** $p<.01$, *** $p<.001$

When asked about their confidence level of their beliefs about climate change causes (Table 21), the majority of California teachers (88%) and Texas teachers (76.5%) indicated moderate to extreme confidence levels. Fifty three percent of California teachers as opposed to 43.5 percent of Texas teachers indicated extreme confidence

level. Chi-square test for independence showed a significant association between state and confidence category ($\chi^2(1)=15.842, p<0.001$), suggesting a higher proportion of California teachers indicated highest confidence level in their beliefs about climate change causes than Texas teachers.

Table 21

Science Teachers' Confidence Level in Beliefs About Climate Change Causes

Confidence Level	California (N=453)	Texas (N=376)	$\chi^2(1)$	<i>p</i>
Extremely not confident	10 (2%)	10 (2.5%)	----	----
Moderately not confident	13 (3%)	14 (3.5%)	.037	.847
Slightly not confident	3 (1%)	3 (1%)	-----	----
Neither confident or not	14 (3%)	35 (9%)	9.000**	.003
Slightly confident	13 (3%)	29 (7.5%)	6.095*	.014
Moderately confident	158 (35%)	125 (33%)	3.848	.050
Extremely confident	242 (53%)	160 (43.5%)	15.842	< .001

Note. ---Missing Data, * $p<.05$, ** $p<.01$, *** $p<.001$

Finally, the majority of responding California (79%) and Texas teachers (63%) believed that humans can mitigate climate change, but it is unclear how this could be achieved (Table 22). Chi-square test for independence showed a significant association between state and human role category ($\chi^2(1)=46.035, p<0.001$), suggesting a higher proportion of California teachers than Texas teachers believed that humans can reduce climate change but it is unclear how this could be achieved.

Table 22
Science Teachers' Views About Human Role to Reduce Climate Change

Humans could:	California (N=207)	Texas (N=99)	$\chi^2(1)$	<i>p</i>
Humans could reduce climate change, but people aren't willing ...	35 (17%)	30 (30%)	---	---
Humans could reduce climate change, but it is unclear...	164 (79%)	62 (63%)	46.035***	< .001
Humans can reduce climate change, and we are going to do...	8 (4%)	7 (7%)	.385	.535

Note. ---Missing Data, * $p < .05$, ** $p < .01$, *** $p < .001$

Community pressure. Questionnaire item 8 examined the possibility that science teachers may have received community pressures, to teach or not to teach about climate change anthropogenic causes (Table 23). When asked if no one pressured them, 17 percent of California teachers responded that they were pressured to teach about the anthropogenic causes of climate change, and 14 percent of them were pressured not to teach about it. As for Texas teachers, only 5 percent responded that they were pressured to teach about the anthropogenic causes of climate change, and 8 percent of them were pressured not to teach about it. Pressures came from school administrators, school board members, fellow teachers, parents, local religious or community leaders, or others. In California, the main pressure to teach about the anthropogenic causes of climate change came from fellow teachers (8%), while the main pressure not to teach about it came from parents (4%). The differences between California and Texas teachers' responses were found to be statistically significant for those who indicated that they have received pressure from fellow teachers to teach climate change ($p=0.03$).

Table 23

Proportions of Teachers Who Received Pressure to Teach/Not to Teach About Climate Change Anthropogenic Causes

Pressure from:	Pressure to Teach			Pressure Not to Teach		
	California (N=456)	Texas (N=375)	<i>p</i>	California (N=454)	Texas (N=368)	<i>p</i>
No one	381 (83%)	355 (95%)	.59	390 (86%)	338 (92%)	.44
School administrators	12 (3%)	3 (1%)	.15	7 (2%)	3 (1%)	.20
Community leaders	5 (1%)	1 (0%)	.28	13 (3%)	5 (1%)	.14
Parents	3 (1%)	1 (0%)	.29	18 (4%)	6 (2%)	.05
Fellow teachers	37 (8%)	1 (2%)	.03	9 (2%)	1 (2%)	.40
Others	18 (4%)	7 (2%)	.07	15 (3%)	6 (2%)	.20

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Teachers' views about climate change and association with their political orientation. Responding science teachers' views of climate change and association with their political orientation were examined. Two questionnaire items were studied, namely their responses regarding the scientific consensus about climate change causes and their views of whether climate change is caused mostly by human activities, natural changes in the environment, or both. Secondary science teachers' political affiliations and their views about the government role were analyzed.

Teachers' political affiliations and views of the scientific consensus. As already reported, 75 percent of responding California teachers selected the correct answer that 81% - 100% of climate scientists agree that climate change is caused mostly by human activities, while only 48 percent of responding Texas teachers selected the correct answer of 81%-100% scientific consensus (Table 19). Table 24 shows the proportions of California and Texas teachers from different political affiliations who agreed with the scientific consensus. Sixty one percent of California teachers who agreed with the scientific consensus were Democrats, whereas only 7 percent of them were Republicans.

Similarly, forty three percent of Texas teachers who agreed with the scientific consensus were Democrats, while only 11 percent of them were Republicans. Differences between teachers' political affiliations in both states were found to be statistically significant. Study results indicated significant association between California and Texas teachers' political affiliations and their views of the scientific consensus. Chi-square test for goodness of fit showed a significant association between California teachers' political affiliation and scientific consensus category, ($\chi^2(5)=453.959, p<0.001$), suggesting a higher proportion of California Democrat teachers agreed with the scientific consensus than California Republican teachers. Chi-square test for goodness of fit also showed a significant association between Texas teachers' political affiliation and scientific consensus category, ($\chi^2(5)=90.986, p<0.001$), suggesting a higher proportion of Texas Democrat teachers agreed with the scientific consensus than Texas Republican teachers.

Results also showed a significant difference among science teachers between Democrats and Republicans (Table 25). Seventy four percent of California Democrat teachers and 34 percent of California Republican teachers agreed with the scientific consensus. Similarly, 57 percent of Texas Democrat teachers and 16 percent of Texas Republican teachers agreed with the scientific consensus. Agreement with the scientific consensus was higher among California Democrat teachers (74%) than Texas Democrat teachers (57%). Chi-square test for independence showed a significant association between state and political affiliation category, ($\chi^2(1)=56.333, p<0.001$), suggesting a higher proportion of California Democrat teachers agreed with the scientific consensus than Texas Democrat teachers. Similarly, agreement with the scientific consensus was higher among California Republican teachers (34%) than Texas Republican teachers

(16%). Nevertheless, chi-square test for independence showed no significant association between state and political affiliation category ($\chi^2(1)=0.444$, $p=0.505$).

Table 24

Proportions of Teachers From Different Political Affiliations Agreeing With the Scientific Consensus

Political Affiliation	Teachers agreeing with 81% -100% scientific consensus	
	California (N=299)	Texas (N=149)
Democrat	183 (61%)	64 (43%)
Republican	20 (7%)	16 (11%)
Independent	58 (19%)	52 (35%)
Libertarian	5 (2%)	8 (5%)
Green party	1 (0%)	0 (0%)
I choose not to identify	32 (11%)	9 (6%)

Table 25

Teachers' Proportions of Each Political Affiliation Agreeing With the Scientific Consensus

Political Affiliation	Teachers agreeing with 81% -100% scientific consensus			
	California (N=299)	Texas (N=149)	$\chi^2(1)$	p
Democrat	183/246 (74%)	64/113 (57%)	56.333***	<.001
Republican	20/59 (34%)	16/98 (16%)	.444	.505
Independent	58/87 (67%)	52/98 (53%)	.327	.567
Libertarian	5/14 (36%)	8/23 (35%)	.692	.405
Green party	1/9 (11%)	0/4 (0%)		
I choose not to identify	32/41 (78%)	9/41 (22%)		

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Teachers' views about government role and the scientific consensus. Table 26

shows the relationship between responding California and Texas science teachers' political views about the government role and their views of the scientific consensus.

Results showed that there was a significant difference among science teachers between those who believed and those who did not believe in a strong government role, and their agreement with the scientific consensus. Seventy three percent of California teachers who strongly believed in the government role, agreed with the scientific consensus, whereas only 5 percent of California teachers who do not believe in government role agreed with the scientific consensus. Similarly, 53 percent of Texas teachers who strongly believed in the government role agreed with the scientific consensus, whereas only 8 percent of Texas teachers who did not believe in the government role agreed with the scientific consensus. Chi-square test for goodness of fit showed a significant association between California teachers' views about the government role and the scientific consensus category, ($\chi^2(6) = 346.757, p < 0.001$), suggesting a higher proportion of California teachers who believed in a strong government role, agreed with the scientific consensus than those teachers who did not. Likewise, chi-square test for goodness of fit showed a significant association between Texas teachers' views about the government role and the scientific consensus category, ($\chi^2(6) = 84.733, p < 0.001$), suggesting a higher proportion of Texas teachers who believed in a strong government role, agreed with the scientific consensus than those teachers who did not.

Moreover, agreement with the scientific consensus was higher among California teachers who believed in a strong government role (73%) than Texas teachers (53%). Chi-square test for independence showed a significant association between teachers' views about government role and state category, ($\chi^2(1) = 50.000, p < 0.001$), suggesting a higher proportion of California teachers who believed in a strong government role, agreed with the scientific consensus than Texas teachers. However, agreement with the

scientific consensus was higher among Texas teachers who did not believe in a strong government role (8%) than California teachers (5%). However, this difference was not found to be statistically significant. Chi-square test for independence showed no significant association between teachers' views about government role and state category, ($\chi^2(1) = 0.182, p = 0.670$).

Table 26

Proportions of Teachers With Different Views About Government Role Agreeing With the Scientific Consensus

Government Role	Teachers agreeing with 81% -100% scientific consensus			
	California (N=299)	Texas (N=149)	$\chi^2(1)$	p
It's not government business	15 (5%)	12 (8%)	.182	.670
Government makes laws	219 (73%)	79 (53%)	50.000***	<.001
Neither Agree/Disagree	65 (22%)	58 (39%)		

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Teachers' political affiliations and views about climate change causes. As previously reported, 46 percent of responding California teachers and 26 percent of responding Texas teachers believed that climate change is caused mostly by human activities (Table 20). Table 27 shows the proportions of responding California and Texas science teachers from different political affiliations who agreed with the anthropogenic causes of climate change. The results showed that there was a significant difference among science teachers between Democrats and Republicans. About 69 percent of California teachers who agreed with the anthropogenic cause of climate change were Democrats, whereas only 2 percent of teachers were Republicans. Similarly, 47 percent of Texas teachers who agreed with the anthropogenic cause were Democrats, while 9 percent of teachers were Republicans. Chi-square test for goodness of fit showed a significant association between California teachers' political affiliation and

anthropogenic causes category, ($\chi^2(5) = 401.646, p < 0.001$), suggesting a higher proportion of California Democrat teachers agreed with the anthropogenic causes than California Republican teachers. Likewise, chi-square test for goodness of fit showed a significant association between Texas teachers' political affiliation and anthropogenic causes category, ($\chi^2(5) = 92.711, p < 0.001$), suggesting a higher proportion of Texas Democrat teachers agreed with the anthropogenic causes than Texas Republican teachers.

Table 28 shows that 55 percent of California Democrat teachers agreed with the anthropogenic causes as compared to 7 percent of California Republicans. Similarly, 41 percent of Texas Democrat teachers agreed with the anthropogenic causes as compared to 9 percent of Texas Republicans. Moreover, more California Democrat teachers (55%) than Texas Democrat teachers (41%) agreed with the anthropogenic cause. Chi-square test for independence showed a significant association between state and political affiliation category, ($\chi^2(1) = 42.285, p < 0.001$), suggesting a higher proportion of California Democrat teachers agreed with the anthropogenic causes than Texas Democrat teachers. More Texas Republican teachers (9%) than California Republican teachers (7%) agreed with the anthropogenic cause. However, chi-square test for independence showed no significant association between state and political affiliation category ($\chi^2(1) = 1.923, p = 0.166$).

Table 27
Proportions of Teachers From Different Political Affiliations Agreeing With the Anthropogenic Causes

Political Affiliation	Teachers agreeing with the anthropogenic causes	
	California (N=197)	Texas (N=98)
Democrat	135 (68.5%)	46 (47%)
Republican	4 (2%)	9 (9%)
Independent	40 (20%)	28 (29%)
Libertarian	1 (0.5%)	7 (7%)
Green party	0 (0%)	0 (0%)
I choose not to identify	17 (9%)	8 (8%)

Table 28
Teachers' Proportions of Each Political Affiliation Agreeing With the Anthropogenic Causes

Political Affiliation	Teachers agreeing with the anthropogenic causes			
	California (N=197)	Texas (N=98)	$\chi^2(1)$	p
Democrat	135/246 (55%)	46/113 (41%)	42.285***	<.001
Republican	4/59 (7%)	9/98 (9%)	1.923	.166
Independent	40/87 (46%)	28/98 (29%)	1.515	.218
Libertarian	1/14 (7%)	7/23 (30%)	4.500*	.034
Green party	0/9 (0%)	0/4 (0%)		
I choose not to identify	17/41 (42%)	8/41 (20%)		

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Teachers' views about government role and climate change causes. Table 29 shows the relationship between responding California and Texas science teachers' political views about the government role and their agreement with the anthropogenic causes of climate change. There was a significant difference among science teachers between those who believed and those who did not believe in a strong government role

on one hand, and their agreement with climate change anthropogenic causes on the other hand. Seventy eight percent of California teachers who believed in a strong government role agreed with the anthropogenic causes, whereas only 2 percent of California teachers who did not believe in government role agreed. Similarly, 57 percent of Texas teachers who believed in the government role agreed with the anthropogenic causes, whereas only 9 percent of Texas teachers who did not believe in government role agreed with the scientific consensus. Chi-square test for goodness of fit showed a significant association between California teachers' views about the government role and anthropogenic causes category, ($\chi^2(6)=285.717, p<0.001$), suggesting a higher proportion of California science teachers who believed in a strong government role, agreed with climate change anthropogenic causes than teachers who did not. Chi-square test for goodness of fit also showed a significant association between Texas teachers' views about government role and anthropogenic causes category, ($\chi^2(5)=43.551, p<0.001$), suggesting a higher proportion of Texas science teachers who believed in a strong government role, agreed with climate change anthropogenic causes than teachers who did not.

Moreover, agreement with the anthropogenic causes was higher among California teachers who strongly believed in the government role (78%) than Texas teachers (57%). Chi-square test for independence showed a significant association between teachers' views about the government role and state category, ($\chi^2(1)=34.712, p<0.001$), suggesting a higher proportion of California teachers who believed in a strong government role, agreed with the anthropogenic causes than Texas teachers. Agreement with the anthropogenic causes was also higher among Texas teachers who did not believe in a strong government role (9%) than California teachers (2%). However, chi-

square test for independence showed no significant association between teachers' views about the government role and state category, ($\chi^2(1)=2.778, p=0.096$).

Table 29

Proportions of Teachers With Different Views About Government Role Agreeing With the Anthropogenic Causes

Government Role	Teachers agreeing with the anthropogenic causes			
	California (N=197)	Texas (N=98)	$\chi^2(1)$	p
It's not government business	4 (2%)	9 (9%)	2.778	.096
Government makes laws	154 (78%)	56(57%)	34.712***	<.001
Neither Agree/Disagree	39 (20%)	33 (34%)		

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Teachers' views about climate change and association with their religious affiliations and beliefs. Responding secondary science teachers' views of climate change and association with their religious affiliation and beliefs were also examined. Two questionnaire items were studied, namely teachers' responses regarding the scientific consensus about climate change causes and their views of whether climate change is caused mostly by human activities, natural changes in the environment, or both. Secondary science teachers' religious affiliations and their beliefs about the textual basis of their religion (Bible, Torah, Quran, etc.) were examined.

Teachers' religious affiliations and views of the scientific consensus. Table 30 shows the proportions of responding California and Texas teachers from different religious affiliations who agreed with the scientific consensus, i.e. their agreement that 81%-100% percent of climate scientists think that climate change is caused mostly by human activities. Teachers agreeing with the scientific consensus in California and Texas were distributed among the different religious groups. Chi-square test for goodness of fit showed a significant association between California teachers' religious

affiliations and scientific consensus category, ($\chi^2(11)= 221.977$, $p<0.001$), suggesting a higher proportion of California non religious (agnostic and atheist) teachers agreed with the scientific consensus than California religious (Roman Catholic and Protestant) teachers. Chi-square test for goodness of fit also showed a significant association between Texas teachers' religious affiliations and scientific consensus category, ($\chi^2(6)= 36.481$, $p<0.001$), suggesting a higher proportion of Texas non religious teachers agreed with the scientific consensus than Texas religious teachers.

Table 31 shows significant differences among science teachers who identified themselves as agnostic, atheist, spiritual, Roman Catholic, and Protestant. Eighty percent of California agnostic teachers and 93 percent of California atheist teachers agreed with the scientific consensus, whereas 49 percent of California Roman Catholic teachers and 54 percent of California Protestant teachers agreed with the scientific consensus. Likewise, 62 percent of Texas agnostic teachers and 80 percent of Texas atheist teachers agreed with the scientific consensus, while only 28 percent of Texas Roman Catholic teachers and 29 percent of Protestant teachers agreed with the scientific consensus.

Moreover, agreement with the scientific consensus was higher among California agnostic teachers (80%) than Texas agnostic teachers (62%). Chi-square test for independence showed a significant association between teachers' religious affiliations and state category, ($\chi^2(1)= 9.941$, $p=0.002$), suggesting a higher proportion of California agnostic teachers agreed with the scientific consensus than Texas agnostic teachers. Also, agreement with the scientific consensus was higher among California atheist (93%) than Texas atheist teachers (80%). Chi-square test for independence showed a significant association between teachers' religious affiliations and state category, ($\chi^2(1)=$

17.483, $p < 0.001$), suggesting a higher proportion of California atheist teachers agreed with the scientific consensus than Texas atheist teachers. Similarly, 74 percent of California spiritual teachers agreed with the scientific consensus, while 41 percent of Texas spiritual teachers agreed. Chi-square test for independence showed a significant association between teachers' religious affiliations and state category, ($\chi^2(1) = 8.333$, $p = 0.004$), suggesting a higher proportion of California spiritual teachers agreed with the scientific consensus than Texas spiritual teachers.

Furthermore, agreement with the scientific consensus was higher among California Roman Catholic teachers (49%) than Texas Roman Catholic teachers (28%). However, chi-square test for independence showed no significant association between teachers' religious affiliations and state category, ($\chi^2(1) = 1.391$, $p = 0.238$). Likewise, agreement with the scientific consensus was higher among California Protestant teachers (54%) and Texas Protestant teachers (29%). However, chi-square test for independence showed no significant association between teachers' religious affiliations and state category, ($\chi^2(1) = 1.674$, $p = 0.196$).

Table 30
Proportions of Teachers From Different Religious Affiliations Agreeing With the Scientific Consensus

Religious Affiliation	Teachers agreeing with 81% -100% scientific consensus	
	California (N=299)	Texas (N=149)
Agnostic	47 (16%)	21 (14%)
Atheist	63 (21%)	24 (16%)
Spiritual	34 (11%)	14 (9%)
Roman Catholic	27 (9%)	19 (13%)
Protestant	49 (16%)	37 (25%)
Other ^a	79 (27%)	34 (23%)

Note. ^aIncludes Buddhist, Hindu, Jewish, Mormon, Muslim, Greek or Russian Orthodox and teachers who chose not to identify.

Table 31
Teachers' Proportions of Each Religious Affiliation Agreeing With the Scientific Consensus

Religious Affiliation	Teachers agreeing with 81% -100% scientific consensus			
	California (N=299)	Texas (N=149)	$\chi^2(1)$	<i>p</i>
Agnostic	47/59 (80%)	21/34 (62%)	9.941**	.002
Atheist	63/68 (93%)	24/30 (80%)	17.483***	< .001
Spiritual	34/46 (74%)	14/34 (41%)	8.333**	.004
Roman Catholic	27/55 (49%)	19/68 (28%)	1.391	.238
Protestant	49/91 (54%)	37/128 (29%)	1.674	.196
Other ^a	127/137 (93%)	71/82 (87%)		

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. ^aIncludes Buddhist, Hindu, Jewish, Mormon, Muslim, Greek or Russian Orthodox and teachers who chose not to identify.

Teachers' religious beliefs and views of the scientific consensus. Table 32 shows proportions of responding California and Texas science teachers with different religious beliefs about the textual basis of their religion (Bible, Torah, Quran, etc.), who agreed

with the scientific consensus. Study results showed that there was a significant difference among science teachers between those who believed religious text is the actual word of God, and those who believed it to be an ancient book of fables recorded by man on one hand, and their agreement with the scientific consensus on the other hand. Only 3 percent of California teachers who strongly believed that religious text is the actual word of God to be taken literally word for word, agreed with the scientific consensus, while 33 percent of California teachers who did not believe it should be taken literally word for word, and 64 percent of teachers who believed that it is an ancient book of fables, agreed with the scientific consensus. Chi-square test for goodness of fit showed a significant association between California teachers' religious beliefs and anthropogenic causes category, ($\chi^2(2) = 151.936, p < 0.001$), suggesting a higher proportion of California teachers who believed religious text is a book of fables, agreed with the anthropogenic causes than teachers who did not. Similarly, 6 percent of Texas teachers who strongly believed that religious text is the actual word of God, and 46 percent of those who did not believe it to be taken word for word, agreed with the scientific consensus, whereas 48 percent of Texas teachers who believed it to be an ancient book of fables recorded by man, agreed with the scientific consensus. Chi-square test for goodness of fit showed a significant association between Texas teachers' religious beliefs and anthropogenic causes category, ($\chi^2(2) = 50.042, p < 0.001$), suggesting a higher proportion of Texas teachers who believed religious text is a book of fables, agreed with the anthropogenic causes than teachers who did not.

Agreement with the scientific consensus was also higher among California teachers (64%) than Texas teachers (48%) who believed that religious text is an ancient

book of fables. Chi-square test for independence showed a significant association between teachers' religious views and state category, ($\chi^2(1)= 48.790, p<0.001$), suggesting a higher proportion of California teachers who believed religious text is an ancient book of fables, agreed with the scientific consensus than Texas teachers. Chi-square test for independence also showed a significant association between teachers' religious views and state category, ($\chi^2(1)= 4.225, p=0.040$), suggesting a higher proportion of Texas teachers (46%) who believed religious text is an inspired word of God, agreed with the scientific consensus than California teachers (33%).

Agreement with the scientific consensus was lower among California teachers who believed that religious text is the actual word of God (3%) than Texas teachers (6%). However, chi-square test for independence showed no significant association between teachers' religious views and state category, ($\chi^2(1)=0.222, p=0.637$).

Table 32

Proportions of Teachers With Different Religious Beliefs Agreeing With the Scientific Consensus

Religious Beliefs	Teachers agreeing with 81% -100% scientific consensus			
	California (N=299)	Texas (N=149)	$\chi^2(1)$	<i>p</i>
Actual word of God	10 (3%)	9 (6%)	.222	.637
Inspired word of God	99 (33%)	68 (46%)	4.225*	.040
Ancient book of fables	190 (64%)	72 (48%)	48.790***	< .001

Note. * $p< .05$, ** $p< .01$, *** $p< .001$

Teachers' religious affiliations and views about climate change causes. Table 33 shows the proportions of responding California and Texas science teachers from different religious affiliations who agreed that climate change is caused mostly by human activities. Teachers agreeing with the anthropogenic cause of climate change in California and Texas were distributed among the different religious groups (Table 33).

Chi-square test for goodness of fit showed a significant association between California teachers' religious beliefs and anthropogenic causes category, ($\chi^2(10)= 113.513$, $p<0.001$), suggesting a higher proportion of California non religious (agnostic and atheist) teachers agreed with the anthropogenic causes than California religious (Roman Catholic and Protestant) teachers. Chi-square test for goodness of fit also showed a significant association between Texas teachers' religious beliefs and anthropogenic causes category, ($\chi^2(10)= 71.041$, $p<0.001$), suggesting a higher proportion of Texas non religious teachers agreed with the anthropogenic causes than Texas religious teachers.

Table 34 shows teachers' proportions within each religious group among responding California and Texas teachers, who agreed with the anthropogenic causes. Overall, there was a significant association between secondary science teachers' religious affiliations, i.e., agnostic, atheist, spiritual, Roman Catholic and Protestant, and their views about the human cause of climate change. Sixty two percent of California atheist teachers and 48 percent of California agnostic teachers agreed with the anthropogenic cause of climate change, as opposed to 33 percent of California Protestant and 36 percent Roman Catholic teachers. Similarly, 53 percent of Texas atheist and 32 percent of agnostic teachers agreed with the anthropogenic cause, while 20 percent of Texas Protestant and 22 percent of Roman Catholic teachers agreed. Moreover, agreement with the anthropogenic causes was higher among California atheist (62%) and agnostic (48%) teachers than Texas atheist (53%) and agnostic teachers (32%). Chi-square test for independence showed a significant association between teachers' religious affiliations and state category, ($\chi^2(1)= 11.655$, $p=0.001$), suggesting a higher proportion of California atheist teachers agreed with the anthropogenic causes than

Texas atheist teachers. Chi-square test for independence also showed a significant association between teachers' religious affiliations and state category, ($\chi^2(1)= 7.410$, $p=0.006$), suggesting a higher proportion of California agnostic teachers agreed with the anthropogenic causes than Texas agnostic teachers.

Furthermore, agreement with the anthropogenic causes was higher among California spiritual teachers (65%) than Texas spiritual teachers (32%). Chi-square test for independence showed a significant association between teachers' religious affiliations and state category, ($\chi^2(1)= 8.805$, $p=0.003$), suggesting a higher proportion of California spiritual teachers agreed with the scientific consensus than Texas spiritual teachers. Agreement with the anthropogenic cause was also higher among California Protestant (33%), and Roman Catholic teachers (36%) than Texas teachers (20% Protestant and 22% Roman Catholic). However, chi-square test for independence showed no significant association between teachers' religious affiliations and state category suggesting higher proportions of California Roman Catholic or Protestant teachers agreed with climate change anthropogenic causes than Texas Roman Catholic or Protestant teachers (Table 34).

Table 33
Proportions of Teachers From Different Religious Affiliations Agreeing With the Anthropogenic Causes

Religious Affiliation	Teachers agreeing with the anthropogenic causes	
	California (N=197)	Texas (N=98)
Agnostic	28 (14%)	11 (11%)
Atheist	42 (21%)	16 (16%)
Spiritual	30 (15%)	11 (11%)
Roman Catholic	20 (10%)	15 (15%)
Protestant	30 (15%)	25 (26%)
Other ^a	47 (25%)	20 (21%)

Note. ^aIncludes Buddhist, Hindu, Jewish, Mormon, Muslim, Greek or Russian Orthodox and teachers who chose not to identify.

Table 34
Teachers' Proportions of Each Religious Affiliation Agreeing With the Anthropogenic Causes

Religious Affiliation	Teachers agreeing with the anthropogenic causes			
	California (N=197)	Texas (N=98)	$\chi^2(1)$	<i>p</i>
Agnostic	28/59 (48%)	11/34 (32%)	7.410**	.006
Atheist	42/68 (62%)	16/30 (53%)	11.655**	.001
Spiritual	30/46 (65%)	11/34 (32%)	8.805**	.003
Roman Catholic	20/55 (36%)	15/68 (22%)	.714	.398
Protestant	30/91 (33%)	25/128 (20%)	.455	.500
Other ^a	47/137 (93%)	20/82 (87%)		

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. ^aIncludes Buddhist, Hindu, Jewish, Mormon, Muslim, Greek or Russian Orthodox and teachers who chose not to identify.

Teachers' religious beliefs and views about climate change causes. Table 35 shows the relationship between responding California and Texas science teachers' religious views and their agreement with the anthropogenic causes of climate change. Results showed that there was a significant difference among science teachers between

those who believed that religious text is an ancient book of fables and those who believed that it is the actual word of God on one hand, and their agreement with climate change anthropogenic causes on the other hand. Sixty nine percent of California teachers who believed that it is an ancient book of fables recorded by man, agreed with the anthropogenic causes, whereas only 2 percent of those who believed that it is the actual word of God agreed with the anthropogenic causes. Chi-square test for goodness of fit showed a significant association between California teachers' religious beliefs and anthropogenic causes category, ($\chi^2(2) = 122.613, p < 0.001$), suggesting a higher proportion of California teachers who believed religious text is a book of fables, agreed with the anthropogenic causes than California teachers who did not.

Similarly, 44 percent of Texas teachers who believed their religious text is an ancient book of fables agreed with the anthropogenic causes, as opposed to 8 percent of those who believed it is the actual word of God. Chi-square test for goodness of fit showed a significant association between Texas teachers' religious beliefs and anthropogenic causes category, ($\chi^2(2) = 27.563, p < 0.001$), suggesting a higher proportion of Texas teachers who believed religious text is a book of fables, agreed with the anthropogenic causes than Texas teachers who did not.

Moreover, agreement with the anthropogenic causes was higher among California (69%) than Texas teachers (44%), who strongly believed that religious text is a book of fables. Chi-square test for independence showed a significant association between teachers' religious views and state category, ($\chi^2(1) = 43.263, p < 0.001$), suggesting a higher proportion of California teachers who believed religious text is an ancient book of fables, agreed with the anthropogenic causes than Texas teachers.

Agreement with the anthropogenic causes was higher among Texas (48%) than California teachers (29%), who believed religious text is the inspired word of God. However, chi-square test for independence showed no significant association between teachers' religious views and state category, ($\chi^2(1)= 0.962, p=0.327$). Likewise, agreement with the anthropogenic causes was higher among Texas (8%) than California (2%) teachers, who believed religious text is the actual word of God to be taken literally. However, chi-square test for independence showed no significant association between teachers' religious views and state category, ($\chi^2(1)= 2.273, p=0.132$).

Table 35
Proportions of Teachers With Different Religious Beliefs Agreeing With the Anthropogenic Causes

Religious Beliefs	Teachers agreeing with the anthropogenic causes			
	California (N=197)	Texas (N=98)	$\chi^2(1)$	<i>p</i>
Actual word of God	4 (2%)	8 (8%)	2.273	.132
Inspired word of God	57 (29%)	47 (48%)	.962	.327
Ancient book of fables	136 (69%)	43 (44%)	43.263***	< .001

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Chapter V

Conclusions

This study examined secondary science teachers' perceptions about climate change in California and Texas. The study focused on teachers' knowledge about climate change, their approaches to teaching it in the science classroom, and whether their views about the anthropogenic causes of climate change were linked to their political and religious beliefs and affiliations. One of the objectives of this study was to compare science teachers' perceptions of climate change in a blue state (California) versus a red state (Texas).

Several previous studies have examined science teachers' perceptions of climate change in the US (Herman, Feldman & Vernaza-Hernandez, 2015; Johnson & Holzer, 2011; Monroe, Oxarat & Plate, 2013; Plutzer et al., 2016a; Wise, 2010). Most of these studies were based on small non-representative convenient samples in small geographic areas (Sullivan, Ledley, Lynds & Gold, 2014; Wise, 2010). The current study is based on a relatively large-sized, random sample of secondary science public school teachers in two of the largest states in the nation. There are no published studies found in the literature of secondary science public school teachers' perceptions of climate change in California or Texas. Rare studies comparing science teachers' perceptions of climate change in two different geographic areas have been published (Herman, Feldman & Vernaza-Hernandez, 2015). The current study is the first to compare secondary science teachers' climate change perceptions in California and Texas public schools.

The study was based on responses to an online questionnaire, which was sent to 7,060 secondary science teachers in California and Texas public schools. The questionnaire was previously used to conduct a national study, which examined climate change instruction in US public schools in 2014-2015 (Plutzer et al., 2016a). The questionnaire in the current study was basically similar to that used in the national study, except for eliminating and adding a few questionnaire items. Unlike the national study, the questionnaire was administered exclusively online, and did not include any incentives for responding science teachers.

Responding teachers' demographics

The study included a total of 832 secondary science teachers, with 456 from California and 376 from Texas public schools. The response rate was 13.1 percent among California teachers and 10.5 percent among Texas teachers. California teachers comprised 54.8 percent of the responding teachers, while Texas teachers were 45.2 percent. Interestingly, these rates were roughly similar to the proportions of California (~39 million; 58.3%), and Texas (~28 million; 41.7%) populations (United States Census Bureau, 2017).

There were several demographic similarities and differences among California and Texas secondary science teachers who responded to the questionnaire. Gender distribution was roughly similar among California and Texas teachers, with a majority of females (52% in California and 57% in Texas). Racial distribution was also roughly similar, with 72 percent of California teachers and 70 percent of Texas teachers identifying themselves as white. However, more teachers identified themselves as Hispanic or black in Texas, while more teachers identified themselves as Asians in

California. These proportions are consistent with the populations of the two states (US Census Bureau, 2017).

Texas respondents tended to be more religious than California respondents. Fifty two percent of responding Texas teachers and 32 percent of responding California teachers identified themselves as Christians, being either Protestant or Roman Catholic. In addition, 71 percent of Texas teachers and 48 percent of California teachers viewed the textual basis of their religion as the inspired or actual word of God. These findings are consistent with increased proportions of religious people in red states (Pew Research Center, 2015).

On the other hand, more respondents from California than Texas considered themselves to be nonreligious, and a higher proportion of California teachers regarded the textual basis of their religion as an ancient book of fables recorded by man. About 30 percent of California respondents and 17 percent of Texas respondents identified themselves as atheist or agnostic. These proportions are higher than their corresponding proportions of nonreligious populations in California (21%) and Texas (12%). California respondents' proportion of nonreligious teachers is significantly higher than that of the US population (18%) (Pew Research Center, 2015). Fifty two percent of California teachers and 29 percent of Texas teachers described their religious book (Bible, Torah, Quran, etc.) as an ancient book of fables recorded by man. The increased number of nonreligious respondents to the questionnaire may be due to the higher interest in climate change among this population group.

With regards to their political affiliation, as expected in a blue state, most of responding California teachers were Democrats. However, in the red state of Texas,

responding Republican teachers were slightly less than Democrat teachers.

Approximately 54 percent of California respondents considered themselves as Democrats, while 13 percent were Republicans and 19 percent were independent. These proportions are consistent with the political affiliations of California's general population. As for Texas teachers, approximately 30 percent of respondents considered themselves as Democrats, while 26 percent were Republicans and 26 percent were independent. These findings are contrary to the political affiliations of Texas's general population. However, having more Democrat science teachers in California and Texas is consistent with the fact that the majority of secondary teachers in the US are Democrats (Cook, 2016).

There were a few similarities and differences in the educational background and teaching experience of responding California and Texas science teachers, in terms of their formal education, teaching experience, and type of teaching certificates. For example, the vast majority of responding California and Texas teachers were university graduates. About two thirds of responding California and Texas teachers had more than 10 years teaching experience. On the other hand, while the vast majority of responding California teachers received their standard secondary teaching certificate through traditional program, Texas teachers were equally split between those who got their certification through traditional or alternate program. However, these factors were not the focus of the current study, and may be addressed in a follow up study.

School characteristics of responding science teachers, such as school district location (urban, suburban, rural) and proportions of school graduates going to college, were also examined but not emphasized in the current study. For example, about a quarter

of California and Texas teachers worked in an urban school district, while more Texas teachers worked in rural school districts than California teachers. There may be a relationship between school district type, student achievement level and teachers' perceptions of climate change. These factors may be addressed in a future study.

Teachers' knowledge of climate change

One of the main research questions of this study was to determine how knowledgeable were secondary science teachers about climate change and whether there were any differences in this aspect between California and Texas teachers. Overall, a significantly higher proportion of California teachers than Texas teachers gave medium to high priority to topics that are essential to be included in a unit on climate change. For example, a discussion of "carbon dioxide trapping heat in the atmosphere" was considered a high priority among 87 percent of California teacher and 72 percent of Texas teachers. In addition, "use of coal by utility and electric companies" was considered a high priority topic among 72 percent of California teacher and 60 percent of Texas teachers. Although there was a significant difference between California and Texas teachers in terms of the priority of discussing "incoming shortwave and outgoing longwave energy", only 44 percent of California teachers and 22 percent of Texas teachers considered this topic a high priority. This topic would have been expected to be given a higher priority in a unit on climate change, because it is the mechanism by which carbon dioxide and other greenhouse gases trap heat (Plutzer et al., 2016a).

The majority of California and Texas teachers seemed to have misconceptions with regards to ozone depletion, pesticides and aerosol spray being contributors to climate change. A high proportion of teachers in both states gave high to medium priority

responses to discuss the topics of “depletion of ozone in the upper atmosphere” (70% of California teachers and 83% of Texas teachers), “use of chemicals to destroy insect pests” (57% of California teachers and 71.5% of Texas teachers), and “use of aerosol spray cans” (60% of California teachers and 73% of Texas teachers). Although these foil topics contribute to environmental pollution, they are not relevant to a unit on climate change (Herman, Feldman & Vernaza-Hernandez, 2015; Plutzer et al., 2016a; Wise, 2010). These high numbers of incorrect responses indicate a misunderstanding of scientific knowledge and inadequate preparation of a significant proportion of science teachers. Similar misconceptions about climate change, such as viewing ozone depletion and pesticide use as significant contributors to climate change, have also been reported in previous studies (Herman, Feldman & Vernaza-Hernandez, 2015; Plutzer et al., 2016b; Wise, 2010).

By their own accounts, roughly similar numbers of California and Texas science teachers responded that they had very good to exceptional knowledge of science topics related to climate change, with about half of teachers rating their content knowledge as very good to exceptional on climate change models, and ecology. These rates of content knowledge suggest the need to focus more on climate change models in science teachers’ education programs and professional development for in-service teachers.

As for science teachers’ awareness about their states standards, there appears to be confusion among some teachers, which is more pronounced within Texas teachers. While 65 percent of California teachers were aware that their science standards included human causes of climate change, only 31.5 percent of Texas teachers did. Ten percent of California teachers and 17.5 percent of Texas teachers thought that their standards

included expectations that students should be exposed to both human and natural causes of climate change. In addition, some teachers in both states (16% California and 25% Texas) were not sure whether their state standards included a component on the anthropogenic causes of climate change. Moreover, 15 percent of Texas teachers indicated that nobody expects them to teach about climate change. These responses indicate that a significant proportion of science teachers in both states are not aligning their climate change instruction with their state standards. Their approach to teaching climate change may be based on other factors, such as their personal views about climate change causes, outside pressures, religious and political values (Berkman & Plutzer, 2010; Mansour, 2013; Plutzer et al., 2016a).

Science teachers' approaches to teaching climate change

The study examined science teachers' approaches to teaching climate change in the classroom, and focused on whether students were receiving mixed messages, by emphasizing the scientific consensus about the anthropogenic causes and the natural causes of climate change. The study also focused on classroom debate about causes, potential solutions, and how teachers negotiate the controversy of climate change.

Science teachers were asked to specify their level of agreement with statements that demonstrated a variety of teaching approaches to climate science. These statements represented essential messages of climate science communication (Plutzer et al., 2016a). Overall, responding California and Texas teachers showed different levels of agreement about climate change causes, with uncertainty about climate change causes being more evident among Texas teachers than California teachers. A higher proportion of California (85%) than Texas (68%) teachers emphasized the scientific consensus about the

anthropogenic causes of climate change. Moreover, a higher proportion of Texas (36%) than California (21%) science teachers emphasized the natural causes. Emphasizing the natural causes of climate change will result in providing students with inaccurate information. It may support the efforts of climate change skeptics and deniers who wish to undermine the scientific consensus about climate change anthropogenic causes, to affect climate change instruction (Putzer et al., 2016a).

Moreover, study results indicated that 19 percent of California teachers and 29 percent of Texas teachers were sending mixed messages about climate change causes to their students by teaching both points of conflicting arguments, i.e., climate change is due to natural causes on one hand and scientific consensus about climate change anthropogenic causes on the other hand. A higher proportion of Texas teachers (14%) than California teachers (5%) emphasized deniers' views about climate change causes. On the other hand, a higher proportion of California teachers (75%) than Texas teachers (52%) emphasized the scientific consensus. The national study findings were similar to those of Texas, with 54 percent of teachers emphasizing the scientific consensus, 31 percent of them sending mixed messages by emphasizing both points of view (Plutzer et al., 2016a). These findings may indicate that students, especially in Texas, may be experiencing the political battle over the causes of climate change in the science classroom, where teachers are discussing the scientific consensus and also providing opposing views and misleading information, by emphasizing the idea that climate change is a natural phenomenon (Plutzer et al., 2016a). This may also suggest that politically motivated efforts to create skepticism about the scientific consensus have affected climate change instruction in Texas public schools (Plutzer et al., 2016a).

Results also showed that responding Texas science teachers had a higher tendency than California teachers to encourage students to debate the likely causes of climate change, and to reach their own conclusions about its causes. These findings may suggest that a proportion of Texas teachers wanted students to reach their own conclusions about climate change causes, possibly to emphasize the controversial nature of this topic, rather than the certainty about the scientific consensus with regards to its anthropogenic causes.

Results also showed that significantly higher proportions of California than Texas science teachers' discussed potential solutions students can take to address climate change, such as, policy solutions, current technologies, personal conservation, and career opportunities. This may be related to the fact that California is one of the states that is currently implementing policies to reduce climate change (State of California, 2016). On the other hand, relatively lower proportions of teachers in both states (47% in California and 38% in Texas) discussed policy solutions to address change incentives, like carbon taxes or cap and trade. This is possibly due to teachers' tendency to focus on science concepts and to eliminate more political discussions in the science classrooms. Teachers feel that teaching about the uncontroversial ecological content of climate change is fine, but dealing with the other components such as values, participation and decision-making are more problematic. Hence, many science teachers are intimidated to teach about it and tend to avoid discussing policy solutions to address climate change (Gough, N. & Gough, A., 2010).

Generally, the most common teaching approach to address the climate change controversy, reported by science teachers in both states, was discussing it in the context of the nature of science (64% in California and 65% in Texas). These figures are higher

than that (55%) reported in the national survey by Plutzer et al. (2016a). Results also showed that avoiding all discussion of climate change or allowing students to opt out of portions of their class rarely happened in both states. However, more Texas teachers (51%) than California teachers (37%) do not take a position about the controversy and allow their students to discuss it. Use of this approach was higher among Texas teachers and lower among California teachers than that (47%) reported in the national survey (Plutzer et al., 2016a). These results are consistent with the above-mentioned findings that a high proportion of Texas teachers encouraged students to debate and reach their own conclusions about climate change causes. Moreover, a significantly higher proportion of Texas teachers (40%) than California (25%) teachers indicated that they have given equal time to perspectives that raise doubt that human actions are the main cause of climate change. Use of this teaching approach was higher among Texas teachers than that (27%) reported in the national survey (Plutzer et al. (2016a). Plutzer et al. (2016a) argue that giving equal time may give credibility on positions that are largely rejected by all main scientific organizations.

Teachers' views about climate change

Science teachers were asked about their personal views of the scientific consensus on climate change causes, and whether they think that climate change is caused mostly by human actions, natural changes in the environment, or both. California teachers (75%) showed more awareness of the scientific consensus of climate change causes than Texas teachers (48%). This finding may be explained by the previously noted differences between California and Texas teachers' knowledge about climate change and awareness of their states science standards. However, only about half of California teachers (46%)

and one quarter (26%) of Texas teachers agreed that climate change is due mostly to anthropogenic causes. These rates are lower than that (67.7%) reported in the national study (Plutzer et. al., 2016a). Half (50%) of California teachers and two thirds (65%) of Texas teachers viewed it as caused by both human activities and natural changes in the environment. These rates are higher than that (11.5%) reported in the national study (Plutzer et. al., 2016a). These differences between California and Texas teachers may also be explained by the differences in their climate change knowledge. It may be expected that Texas teachers have a lower rate of personal acceptance of the anthropogenic cause of climate change than that noted in the national study. However, it is hard to explain why California teachers also had a lower rate of personal acceptance of the anthropogenic cause of climate change than that noted in the national study. This may possibly explain the confusion among some California and Texas teachers in emphasizing both human and natural causes in their classes, although the majority (75%) of California teachers agreed with the scientific consensus about climate change causes. These findings may also be consistent with the fact that some teachers were still sending mixed messages to students by emphasizing both human and natural causes.

Responding California science teachers (88%) were more confident than Texas teachers (76.5%) about their beliefs in climate change causes. This may explain the misconceptions and decreased knowledge about climate change noted among a proportion of science teachers in this study. In addition, more California teachers (79%) than Texas teachers (63%) believed that climate change can be mitigated by humans, but were not sure how this could be achieved. This may be due to the fact that California has been implementing policies to reduce climate change (State of California, 2016).

Effect of social factors on teachers' views about climate change

The study examined whether social factors, such as community pressure, political views, and religious beliefs, may have affected teachers' personal views about climate change causes. Secondary science teachers were asked if they have received any pressures from school administrators, school board members, fellow teachers, parents, or local religious or community leaders to teach or not to teach about climate change anthropogenic causes. A higher proportion of responding California teachers than Texas teachers reported being pressured to teach or not to teach about the anthropogenic causes of climate change. Seventeen percent of California teachers and 5 percent of Texas teachers were pressured to teach about human causes of climate change, as compared to 5.9 percent in the national study (Plutzer et al., 2016a). Fourteen percent of California teachers and 8 percent of Texas teachers were pressured to not to teach about human causes of climate change, as compared to 4.5 percent in the national study (Plutzer et al., 2016a). Other studies have reported teachers receiving pressure. For example, 13 percent of responding Colorado teachers indicated receiving pressure from parents, fellow teachers and administrators not to teach about climate change (Wise, 2010). A study of the National Earth Science Teachers Association indicated that around 36 percent of teachers have been pressured to teach both sides of climate change controversy (Johnson & Holzer, 2011). The increased rate of outside pressure received by California teachers, as compared to the national study, may reflect higher community interest in climate change and the public objective of producing an environmentally literate generation in California (California Department of Education, 2017b).

As for political factors, study results found that there is a significant association between teachers' political affiliations and beliefs, and their views of the scientific consensus, and anthropogenic causes of climate change. The largest proportions of responding California (61%) and Texas (43%) science teachers agreeing with the scientific consensus were Democrats. Republican teachers in both states comprised a small minority, while independents constituted a significant proportion in both of California and Texas. In both states, Democrat teachers were more likely to agree with the scientific consensus than Republican teachers. Interestingly, California Democrat teachers were more likely to agree with the consensus than Texas Democrat teachers. Likewise, California Republican teachers were more likely to agree with the consensus than Texas Republican teachers. In addition, the largest proportion of responding California (68.5%) and Texas (47%) teachers agreeing with the anthropogenic causes were Democrats. These results are consistent with previous studies, which indicated that Democrats reported greater concern about climate change and held views about it that were more consistent with the scientific consensus than Republicans (McCright, 2010; Plutzer et al., 2016a). The higher level of awareness about the scientific consensus and anthropogenic causes among California teachers are in agreement with the fact that California is a liberal democratic-leaning blue state, which has been adopting policies to reduce climate change and to support climate change education in its public schools (State of California, 2016).

As for teachers' beliefs in a strong government role to make laws that keep people from harming themselves, which is one of the basic principles of the democratic party, study results found that there is a significant association between teachers' beliefs in a

strong government role, and views of the scientific consensus and anthropogenic causes of climate change. Results showed that the majority of California and Texas teachers who agreed with the scientific consensus, and the anthropogenic causes of climate change, also believed in a strong government role. This association was stronger among California teachers than Texas teachers. These results are consistent with the previous findings about teachers' political affiliation. Study findings suggest that political affiliations and beliefs can play a significant role in determining teachers' views about its causes and the scientific consensus, and may predict their teaching approaches to climate change (McCright, 2011, Plutzer et al., 2016a).

As for religious factors, study results found that there is also a significant association between teachers' religious affiliations and beliefs, and their personal views about the scientific consensus and causes of climate change. There were also significant differences between non-religious groups (agnostic and atheist teachers) on one hand, and religious groups (Roman Catholic and Protestant teachers) on the other hand, with regards to their agreement with the scientific consensus and the anthropogenic causes. In both states, agnostic and atheist teachers were more likely to agree with the scientific consensus and anthropogenic causes, than Protestant and Roman Catholic teachers. In addition, religious and non-religious teacher groups in California tended to be more liberal than their Texas counterparts. California teachers also showed more awareness of environmental issues and were more likely to agree with the scientific consensus than Texas teachers.

As for religious beliefs, study results found that there is a significant association between teachers who believed that the textual basis of religion is an ancient book of

fables and those who believed that it is the actual word of God, and their personal views about the scientific consensus and anthropogenic causes. Results showed that California and Texas teachers, who believed that their religious book is the actual word of God, were not likely to agree with the scientific consensus and anthropogenic causes. On the other hand, teachers who viewed religious texts as books of fables were more likely (particularly in California) to agree with the scientific consensus and the anthropogenic causes. These findings are in agreement with the previously noted differences between religious and non-religious groups, with regards to awareness of environmental issues. A study by the Pew Research Center (2008) showed that Americans' religious affiliations and beliefs are closely related to their political affiliations. Non-religious groups tend to be more Democratic, while religious groups tend to be more Republican. In addition, Americans' religious affiliations and beliefs also have a significant influence on their attitudes and views on social controversial issues (Pew Research Center, 2008).

Study limitations

One of the limitations of the study was the instrument used. Despite their many advantages, online questionnaires have several disadvantages, such as difficulty for participants to grasp the meaning or to analyze some questions and, as a result, the possibility of skipping some questions. The questionnaire used in this study was basically identical to that used in the national study (Plutzer et al., 2016a). The questionnaire may have had some questions, which included wording and terms that were confusing to some teachers. In addition, the questionnaire focused on a few social factors (community pressure, religious and political affiliations), but did not include other factors, such as ethical beliefs and the effect of media.

The study used a random sample that was generated by an educational data and marketing company. The company maintains a huge updated database of educators in the US. The responding teachers from both states had similar, but not identical gender, racial and religious characteristics to their corresponding teachers' population. For example, 57 percent of Texas secondary science teachers who responded to the questionnaire were females, while 63.3 percent of Texas science teachers in 2015-16 were reported by the Texas Education Agency (TEA) to be female. Seventy percent of responding Texas secondary science teachers were white, while 56.4 percent of Texas science teachers were reported to be white (Texas Education Agency, 2017). These differences are small and are not expected to affect the generalizability of the study findings to the entire secondary science teacher population in the two states.

Despite the relatively large size of the study sample, the questionnaire's low response rates raise the possibility of an uneven, self-selected biased sample. In survey research, response rate depends upon a number of factors, such as interest of participants in the survey topic, questionnaire layout, and amount of time needed to complete the questionnaire (Kumar, 2014). Self-selection bias has been reported to be a negative factor in using an online questionnaire. This is due to the fact that those who answer the questionnaire may have attitudes toward climate change that are different from those who do not. The questionnaire's layout may have included questions, which appeared confusing or irrelevant. The lack of opportunity to clarify issues while answering questions is another disadvantage of online questionnaires (Kumar, 2014). In addition, the amount of time needed to complete the questionnaire may have resulted in high

attrition rate of respondents. These factors can favor highly motivated participants who are more interested or passionate about climate change topic.

The comments of some of the teachers who declined to participate in the study showed how the study sample may have not included those who were not interested in the study topic. Some of the declining teachers indicated that climate change was not included in their state standards, or not taught at the secondary school level at their schools. Other teachers had their own reasons to refuse to participate in the study, and left comments such as “it is too politically charged”, “I don’t believe in climate change”, “No comment”, and “I am not in climate change denial, but I do not see it as the monumental problem some see”. Therefore, the views of these teachers were not included in the current study.

Implications for science education

Study findings indicate that a significant proportion of secondary science teachers may not have adequate science content knowledge of climate change and have misconceptions about basic climate change concepts, scientific consensus and anthropogenic causes. Many teachers are sending mixed messages about climate change causes to students by emphasizing both natural causes as well as the scientific consensus. These results are in agreement with previous studies in Colorado, Florida and Puerto Rico, which suggested that secondary science teachers’ deficient knowledge and misconceptions about climate change may negatively affect teaching about climate change in the science classroom (Herman, Feldman & Vernaza-Hernandez, 2015; Plutzer et al., 2016a; Wise, 2010).

The notable differences in knowledge, views, and approaches to teaching climate change between California and Texas teachers suggest that climate change instruction is different in the two states. The higher rates of Texas teachers sending mixed messages, denying climate change or avoiding discussion of climate change in their classes, affect how climate change is being taught. More Texas teachers demonstrated confusion about their state's climate change science standards. This may indicate that a significant proportion of teachers are not aligning climate change instruction with state standards, which is similar to what have been reported by Wise (2010).

The higher climate change awareness among California teachers can be explained by their state's pro-environmental approach and vision. California has been implementing policies to support climate change education in its public schools (California Department of Education, 2017a and 2017b). On the other hand, skepticism about climate change in Texas remains an obstacle to climate change education, which is reflected in the state's science standards and textbooks (Bagley, 2014; McGaughly, 2014). This is also compounded by the fact that NGSS have not been adopted in Texas (Bidwell, 2014).

The study found a higher association between Texas teachers' political and religious affiliations and beliefs on one hand, and their views about climate change causes on the other hand. Findings suggest that more Texas teachers may be using their personal, religious and political beliefs to guide them in teaching about climate change. This may be due to a variety of factors that include teachers' demographic backgrounds, the state's science standards expectations, and Texas' anti-environmental attitudes and worldview stance.

Overall, study findings emphasize the need to enhance secondary science teachers' pedagogical content knowledge of climate change, by improving teachers' scientific knowledge, as well as their teaching approaches to climate change. Adequate preparation of science teachers requires development of pre-service and in-service teacher education programs that focus on teachers' knowledge of basic climate change concepts as well as understanding of climate change models and how the climate system works (Herman, Feldman & Vernaza-Hernandez, 2015; Wise, 2010). Such programs can improve teachers' content knowledge of climate change and the nature of climate change science. These programs are essential in order to eliminate any misconceptions, and raise secondary science teachers' level of awareness of the extent of the scientific consensus about climate change causes. Improving the quality of continuing education programs for science teachers is also necessary in order to keep teachers well informed, and up to date with current knowledge on climate change.

Due to the interdisciplinary nature of climate change science, there is a need to use multi-disciplinary science courses that utilize different approaches to teaching climate change. It is important to integrate climate change units into core courses in science majors at the university level. Such courses may also be included and offered in science teacher education programs (Bissell, 2011; Plutzer et al., 2016a; Todd & O'Brien, 2016).

In order to enhance science teachers' understanding of climate change, it is also necessary to promote socio-scientific decision-making, rather than follow the traditional approach of focusing on teachers' science content knowledge alone. This includes addressing content knowledge of climate change, the nature of climate change science, as well as bringing in historical, economic, political, ethical and social dimensions

associated with climate change into climate change instruction (Herman, Feldman & Vernaza-Hernandez, 2015; Plutzer et al., 2016a; Todd & O'Brien, 2016).

Science teachers should also be able to differentiate between scientific controversy and political controversy in order to be able to teach the science rather than politicizing it (Plutzer et al., 2016a). Hence, training teachers on how to deal with controversial science related issues is important. Teachers need to look for biases, evaluate sources on the Internet or in mass media, and be able to differentiate between reliable and unreliable sources, as well as identify false claims and be prepared to give scientific responses to these claims (Bissell, 2011).

Making climate change more relevant to local environment is necessary to understand climate change. For example, examining climate change impact on local ecosystems and discussing potential policy solutions may provide teachers with more evidence for its anthropogenic causes, so as to view the topic as urgent and realize the need to address it (Bissell, 2011; Herman, Feldman & Vernaza-Hernandez, 2015; Lombardi and Siantra, 2013; Monroe, Oxarat & Plate, 2013).

This study produced a wealth of data about climate change perceptions of secondary science teachers in California and Texas. The current study focused on teachers' knowledge, teaching approaches and personal views about climate change. Further research is needed on items that were not addressed in this study. These include teachers' educational background, teaching experience, types of teaching certificates, as well as teachers' training and continuing education. In addition, school characteristics of responding science teachers, such as school district location (urban, suburban, rural) and proportions of school graduates going to college were examined but not addressed in the

current study. There may be a relationship between school district type, and student achievement level, and teachers' perceptions of climate change. There may also be a relationship between teachers' gender and their views about climate change. Perceptions of secondary science teachers in different science disciplines can also be compared. Future studies can address these issues.

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Appendix A

Climate Change - A Survey of Secondary School Science Teachers

(Copyright 2016 by the National Center for Science Education in collaboration with Eric Plutzer, Penn State University and A. Lee Hannah, Wright State University)

Thank you for participating in this survey to determine how climate change is taught in public schools. The survey will take about 15 minutes to complete. As a reminder, your responses will be anonymous.

We begin with some questions on teaching and curriculum. If you teach different kinds of science classes (such as AP course), please give answers that refer to the class with the largest enrollment at your high school.

Item 1) Consider the topic of climate change, please tell us if this topic is covered in any of the following classes at your school.

	General or College Prep	AP or elective	Not taught, to my knowledge
Chemistry			
Biology			
Physics			
Earth Science			
Environmental Science			
Social Studies			

Item 2) Consider the topic of climate change, please tell us if this topic is covered in any of *your science classes*.

	General or College Prep	AP or elective	Not taught, to my knowledge
Chemistry			
Biology			
Physics			
Earth Science			
Environmental Science			
Social Studies			

Item 3) Below is a list of more specific topics related to climate change. Did any of these come up in class? In answering, think about the *entire last year* that you offered this class

	Covered as part of my lesson plan		Covered in response to student questions	
	YES	NO	YES	NO
Greenhouse effect				
Carbon cycle				
Ice age				
The medieval warming period				
Solar variability				
Ocean acidification				
Sea level change				
Seasonal plant/animal life events (i.e., plant flowering, migration) that respond to climate				
Changes in water quantity and quality				
Changes in ice and snow cover				
Changes in precipitation				
Events described in the Bible such as Judgment Day or Noah's flood				

Item 4) Please indicate your level of agreement with each of the following statements if they apply to your science classes (otherwise select “Not applicable”).

When I do teach about climate change ...	Strongly Agree	Agree	Disagree	Strongly Disagree	Not applicable
I emphasize that average global temperatures have risen in the last 150 years					
I emphasize that natural cycles have produced warming events throughout Earth’s history					
I emphasize that scientific consensus that recent climate change is primarily being cause by human releases of greenhouse gases from fossil fuels					
I emphasize that many scientists believe that recent increases in temperature is likely due to NATURAL causes					
I encourage students to debate the likely causes of climate change					
I encourage students to come to their own conclusions about the causes of climate change					

Item 5) Some curricula also include discussions about potential solutions or steps citizens/decision makers can take to address challenges of climate change. Please indicate whether or not you discussed any of the following.

	Discussed in Class	
	YES	NO
Policy solutions to address change incentives such as cap and trade or carbon taxes		
Efforts to make current technologies more efficient such as hybrid cars or alternative energy sources		
Technologies to mitigate and adapt to the effects of climate change such as geo- engineering		
Things students can do themselves such as walking to school, or turning off lights		
Potential career opportunities related to conservation, new energy technologies or environmental policy		

Item 6) Some teachers tell us that they acknowledge that human-caused climate change is controversial. Tell us about your approach to each of the following.

	I have done this	I have not done this, but might if the situation were to arise	I would not do this
Give equal time to perspective that raises doubt that humans are causing climate change.			
Allow students to discuss the controversy without me taking a position.			
Discuss the controversy in the context of the nature of science.			
Discourage debate because I believe most climate skepticism is not based on sound science.			
Offer to meet with students after class.			
Send an explanatory letter to parents.			
Allow students to opt out of portions of the class.			
Adhere strictly to current state standards and not allow discussion that might become controversial.			
Avoid all discussion of climate change.			

Item 7) Imagine that you were asked to teach a 2-3 day unit on greenhouse gases and recent climate change. What priority would you give to including each of the following possible topics?

	A high priority	A medium priority	It is not necessary to cover this topic	This topic should not be covered	I do not have an opinion
Destruction of forests					
Carbon dioxide trapping heat in the atmosphere					
Use of aerosol spray cans					
People heating and cooling their homes					
Depletion of ozone in the upper atmosphere					
Use of coal and oil by utility and electric companies					
Use of chemicals to destroy insect pests					
Incoming shortwave and outgoing longwave energy					
Emissions from industry					
The impact of launching rockets into space					
Alternative energy sources					
Emissions from transportation sources					
Disruption of species and natural systems					

Item 8) Some topics can be controversial enough that teachers get pressured or lobbied to either emphasize or de-emphasize them. For each of the following, select all that apply.

	No one	School administrators	Local religious or community leaders	Parents	School board members	Fellow teachers	Other
I have received pressure to teach about human causes of climate change from:							
I have received pressure to NOT teach about human causes of climate change from:							

Now we have some questions on your state's science standards and assessments that you use.

Item 9) So far as you know, do your state's science standards include climate change? (Select all that apply.)

- Yes, but it does not include human causes.
- Yes, it includes human causes
- Yes, it includes an expectation that students are exposed to BOTH SIDES
- Yes, but human causes of climate change must be taught as a THEORY
- No, but my local school or school district expects me to teach it.
- No, nobody expects me to teach it
- I am not sure.

Item 10) Have you personally ever had a controversy in your classroom involving topics like evolution, sex education, vaccines, climate change, or genetically modified organisms?

- No -----→ Skip to Question 11.
- Yes -----→ Please tell us what happened. Select all that apply.

	No one	School administrators	Local religious or community leaders	Parents	School board members	Fellow teachers	Other
I have received pressure to teach about it from:							
I have received pressure to NOT teach about it from:							

Regardless of what you do in the classroom, we would like to ask you a few questions about your own personal views.

Item 11) Which of the following comes closest to your view about climate change?

- Climate change is caused mostly by human activities.
- Climate change is caused mostly by natural changes in the environment → Skip to 13.
- Climate change is caused by both natural changes and human activities → Skip to 13.
- Climate change is not happening → Skip to 13.

Item 12) Which of the following statements comes closest to your view about climate change?

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

Item 13) To the best of your knowledge, what percent of climate scientists think that climate change is caused mostly by human activities?

- 0-20%
- 21%-40%
- 41%-60%
- 61%-80%
- 81%-100%
- I don't know

Item 14) Where would you place yourself on each of the following?

“Sometimes the government needs to make laws that keep people from harming themselves”.

- Strongly disagree (It's not the government's business to try to protect people from themselves).
- Disagree.
- Somewhat disagree.
- Neither agree nor disagree.
- Somewhat agree.
- Agree.
- Strongly agree (Sometimes the government needs to make laws that keep people from harming themselves).

Item 15) Please select the phrase below that best describes your confidence about the causes of climate change.

“I am in my beliefs about the causes of climate change”.

- Extremely not confident.
- Moderately not confident.
- Slightly not confident.
- Neither.
- Slightly confident.
- Moderately confident.
- Extremely confident.

Item 16) Please tell us about your formal education background:

- Associate degree
- Bachelor of arts
- Bachelor of science
- Master’s degree in education
- Master’s degree in science
- Ed.D. or Ph.D. in education
- Ph.D. in science

Item 17) Please tell us about your coursework and continuing education in the sciences.
Select “4” for four or more courses.

	Total number of semester/quarter length college classes	Total number of continuing education courses or workshops	I would take advantage of such an opportunity in the future	
	0 1 2 3 4+	0 1 2 3 4+	YES	NO
Biological and life sciences				
Earth and space sciences				
Chemistry and physics				
Courses that devoted one or more class sessions to climate change				
Courses entirely focused on climate change				
Environmental science and environmental education				

Item 18) In what ways do you keep up with scientific debates and advances? Select all that apply.

- I keep up by noting additions and changes to the textbooks I use.
- I keep up through science journalism such as television programs like NOVA, magazines like National Geographic, and the science sections of daily newspapers.
- I keep up by reading scientific journals such as Nature, Cell, etc.
- I keep up by visiting climate science Web sites sponsored by government, academic or non-profit organizations.
- I keep up by visiting Web sites sponsored by groups or individuals who are skeptical about human causes of climate change.
- I keep up by following links that I receive through social media such as Facebook or Twitter.
- I keep up by taking science courses (not science education) as part of my continuing education.
- I keep up by visiting science education Web sites such as the NSTA and the National Academy of Sciences.

Item 19) How would you rate your knowledge on each of the following topics:

	I know less about this topic than many other high school science teachers	Typical of most high school science teachers	Very good compared to most high school science teachers	Exceptional: On par with many college- level instructors
Ecology				
Climate change models				
Weather forecasting models				

Finally, we have some background questions.
--

Item 20) How many years have you taught at this school?

- 1-5
- 6-10
- 11-15
- 16-20
- over 20
- over 30

Item 21) What is the total number of years you have been teaching?

- 1-5
- 6-10
- 11-15
- 16-20
- over 20
- over 30

Item 22) In what type of district is your school located?

- Urban school district.
- Suburban school district.
- Rural school district.

Item 23) What percentage of your school's graduates typically go to college or university?

- 25%
- 50%
- 75%
- 90%

Item 24) What type of teaching certificate do you hold?

- Standard secondary certificate through traditional university/college certification program.
- Standard secondary certificate through alternative certification program.

Item 25) Is your certificate in a single field or multiple fields?

- Single science field.
- More than one science field.

Item 26) What is your gender?

- Male
- Female

Item 27) Which of the following best describes you?

- Hispanic heritage
- American Indian or Alaska Native
- White
- Pacific Islander
- Black/African American
- South Asian
- East Asian
- I choose not to identify

Item 28) What is your present religion?

- Agnostic
- Atheist
- Buddhist
- Hindu
- Jewish
- Mormon
- Muslim
- Orthodox (Greek or Russian)
- Protestant
- Spiritual, but not religious
- Roman Catholic
- I choose not to identify

Item 29) Which of these statements comes closest to describing your feelings about the textual basis of your religion (Bible, Torah, Quran, etc.)?

- It is the actual word of God and is to be taken literally, word-for-word.
- It is the inspired word of God, but not everything should be taken literally, word for word.
- It is an ancient book of fables, legends, history, and moral percepts recorded by man.

Item 30) Politically, I usually identify myself as:

- Democrat
- Independent
- Republican
- Green Party
- Tea Party
- Libertarian
- I choose not to identify

Appendix B

University of Houston Institutional Review Board (IRB) Approval Letter

DIVISION OF RESEARCH
Institutional Review Boards

APPROVAL OF SUBMISSION

October 30, 2017

Rana Khalidi

rakhalidi@uh.edu

Dear Rana Khalidi:

On October 25, 2017, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title of Study:	Secondary Science Teachers' Perceptions about Climate Change
Investigator:	Rana Khalidi
IRB ID:	STUDY00000601
Funding/ Proposed Funding:	Name: Unfunded
Award ID:	
Award Title:	
IND, IDE, or HDE:	None
Documents Reviewed:	<ul style="list-style-type: none">• CoverLetter.pdf, Category: Recruitment Materials;• Study Protocol.pdf, Category: IRB Protocol;• HRP-502e-Template cover letter.pdf, Category: Recruitment Materials;• CITICompletionCertificate.pdf, Category: Other;• Survey Instrument.pdf, Category: Study tools (ex: surveys, interview/focus group questions, data collection forms, etc.);
Review Category:	Exempt
Committee Name:	Not Applicable
IRB Coordinator:	Sandra Arntz

The IRB approved the study from October 30, 2017 to October 29, 2022, inclusive.

To ensure continuous approval for studies with a review category of “Committee Review” in the above table, you must submit a continuing review with required explanations by the deadline for the September 2018 meeting. These deadlines may be found on the compliance website (<http://www.uh.edu/research/compliance/>). You can submit a continuing review by navigating to the active study and clicking “Create Modification/CR.”

U N I V E R S I T Y of
HOUSTON

DIVISION OF RESEARCH
Institutional Review Boards

For expedited and exempt studies, a continuing review should be submitted no later than 30 days prior to study closure.

If continuing review approval is not granted on or before October 29, 2022, approval of this study expires and all research (including but not limited to recruitment, consent, study procedures, and analysis of identifiable data) must stop. If the study expires and you believe the welfare of the subjects to be at risk if research procedures are discontinued, please contact the IRB office immediately.

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,

Office of Research Policies, Compliance and Committees (ORPCC)
University of Houston, Division of Research
713 743 9204
cphs@central.uh.edu
<http://www.uh.edu/research/compliance/irb-cphs/>

Appendix C

Subject: A Survey of Secondary Science Teachers about Climate Change

January, 2018

Dear (First Name):

I am a science teacher currently working on my doctoral dissertation in science education, at the University of Houston, College of Education, Department of Curriculum and Instruction. I am conducting a study on science teachers' perceptions about climate change, in order to examine how climate change is taught in US public schools. I am requesting your participation in a questionnaire for secondary science teachers, which will take about 15 minutes to complete. Your participation in this questionnaire will remain anonymous. Any questions about this study may be directed to Rana Khalidi (principal investigator) at rakhalidi@uh.edu.

Thanks so much for your participation.

Rana Khalidi

Please take my survey.

Follow this link to the Survey:

[Take the Survey](#)

Follow the link to opt out of future emails:

[Click here to unsubscribe](#)