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Climate Change and Political Controversy in the Science Classroom

How Teachers' Beliefs Influence Instruction

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Abstract
Climate change science is complex and perceived to be controversial in nature by some stakeholders. Yet from the perspective of educators and policy makers, climate change science is an important topic to be taught in secondary science education. The presence of controversy can influence teachers' instructional decisions and cause confusion about the science of climate change. This study examines the complex nature between science teacher beliefs and the impact on their instructional practices of climate change–centered curriculum. Findings from the study suggest teachers have strong beliefs about the causes and implications of climate change. However, due to the controversial nature of the topic, the current US political climate, and fear of resistance from stakeholders, teachers did not espouse these beliefs within their instruction of the curriculum and instead remained "neutral" when teaching about climate change.

1 Introduction

Due to the complexity of climate change science, the controversy surrounding the issue, particularly within the USA, and the overwhelming amount of misinformation available to students, it is essential that climate change education be part of the twenty-first century science classroom. Climate change is a complex process in which long-term analysis and projections are difficult to make. Also problematic for science educators is the communication of the process of climate change. Models often used to help educators and students describe, represent, or help to make predictions about the phenomena are oversimplified (Cartier et al., 2001). Educators also struggle to overcome informational outlets about the issue outside of the classrooms; and many students reach understandings about climate change from media outlets, which often misrepresents the issue and reinforce common

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misconceptions that persist within the science classroom (Dawson & Carson, 2013; Gayford, 2002).

Climate change, within the USA, is what Zimmerman and Robertson, (2017) refer to as a type of controversy called an "expert–public disagreement," in which knowledgeable persons agree, and laypersons dispute the issue. Teachers cannot ignore such controversies within their classrooms, and they have a professional obligation to teach expert–public disagreements and support students in discerning when to defer to experts, learning to distinguish fact from propaganda, how to use expert evidence to make well-reasoned arguments, and to distinguish between ideological claims and fact-based positions (Zimmerman & Robertson, 2017). When considering the complex nature of teaching climate change science, along with the controversial nature of the topic, it is important that science teachers' instruction of this concept be examined. Additionally, as teachers begin to incorporate climate change into their instruction, there is an evolving need to investigate teachers' personal beliefs about the instruction of climate change within science education. Gayford (2002) suggests the presence of controversy over an issue can influence teachers' instructional decisions. Additionally, political controversy about the science of climate change may lead teachers to fear objection from administration, community members, and stakeholders (Maibach, et al., 2008).

A closer look at secondary science teacher's espoused belief system and enacted practices within the science classroom is needed to better understand the instruction of climate change. This study encompassed an investigation of secondary science teachers' beliefs and understandings of climate change science through teacher interviews, and classroom observations. Moreover, survey data provided insight into understanding the relationship that exists between teachers and their instruction of climate change science.

2 Background

The complexities of climate change science, and the controversy surrounding the topic within the USA, have influenced how teachers instruct their students about global climate change (GCC) (Maibach et al., 2008). For the past two decades, and particularly during the Trump presidency, climate change has been misrepresented by American politicians, policy institutes, and television or radio commentators as a highly controversial and debatable issue, thus challenging the authenticity of anthropogenically induced GCC (De Pryck & Gemenne, 2017; McCright & Dunlap, 2011; Oreskes & Conway, 2008). In addition, extension programs, non-formal education venues such as afterschool programs, science museums, and camps perpetuate misconceptions about the causes of climate change often citing ozone depletion as a major contributor to global warming. These settings also fail to emphasize the anthropogenic nature of climate change and widely simplify the process of climate change–induced global warming (Chen, 2011; Choi et al., 2010; Sterman, 2011). One-third of the general public in the USA believe scientists disagree on the topic of anthropogenically induced climate change and only half think humans are the primary cause of climate change (Funk et al., 2019; Plutzer et al., 2016). The result of the continued denial of GCC and its causes has been to diminish scientific consensus (Anderegg et al., 2010). The Southeastern US (SEUS), where this study was completed, has one of the most conservative political ideology in the country, which aligns closely with skepticism surrounding climate change. This is especially ironic, as areas within the SEUS have been among the hardest hit by climate change impacts in recent years, and continued

threats pose costly adaptation and mitigation challenges for this region (Carter, et al., 2018; Melillo et al., 2014; Roach, 2005). Hurricanes, storm surge, sea level rise, and increased intensity of storm events will continue to cause coastal flooding, saltwater intrusion, and shoreline erosion in heavily populated low-lying coastal areas within the SEUS (Karl et al., 2009; Melillo et al., 2017).

The continued propagation of false narratives about climate change can be directly confronted within science classrooms, but teachers are not being effectively prepared to address these narratives (Nation & Feldman, 2021). Policymakers and science educators recognize that teaching climate change science is necessary to produce a citizenry that understands the causes of GCC and ways to both mitigate it and prepare for its effects (Gutierrez et al., 2008); however, many science teachers still choose to leave the topic out of their instruction due to barriers such as curricular constraints, lack of understanding, and overall avoidance of engaging in teaching about controversial issues (Bates, 1976; Nation & Feldman, 2021; Rutledge & Mitchell, 2002). Instead, teachers tend to restrict their instruction to the well-understood and uncontroversial areas of science, which include areas of physics and physical science, and photosynthesis within the life sciences (Bunten & Dawson, 2014). By not confronting controversial topics, they misrepresent science as a body of knowledge rather than a process of discovery. It can also lead to a reliance on transmission methods of teaching without engaging students in inquiry (Bentley et al., 2007). To address controversial issues, like GCC, teachers need to provide opportunities for students to construct their own understandings of science issues through discussion, argumentation, and examination in order to better understand the topic (McNeal et al., 2014). For this to happen, we need to understand teachers' beliefs about GCC as a controversial issue (Brownlee et al., 2013; Monroe et al., 2019). Therefore, the following research study was developed to address prior calls to better understand not just teachers' belief about climate change, but the connection between those beliefs and their instruction of climate change within the science classrooms.

2.1 Instruction of Controversial Issues in Science Education

Controversial issues are labeled "taboo" because many people take personal offense and society tends to be divided on the issues and often these separate views are conflicting. These topics are typically avoided in everyday conversation, which makes advocating for one solution particularly difficult within the classroom (Evans et al., 2000; Hoffman, 2011; Stradling, 1985; Wellington, 1986). Controversial issues tend to make students and teachers uncomfortable, as the topic deeply resonates with held values, so much that many respond to information that confronts those values by rejection as a way of protecting their group identity and way of life (Monroe, et al., 2019; Philpott, et al., 2011). As such, there are clear reasons as to why science teachers would avoid controversial topics in classrooms, including the complexity of the science, opposition from stakeholders, and curricular constraints (Bowers et al., 2016; Jones & Carter, 2007; Nation & Feldman, 2021; Sommers, 2014; Wojcik et al., 2014). However, teachers report that the greatest challenge when teaching controversial issues is that students are misinformed, lack knowledge regarding the topic, or already come to class with deeply rooted preconceived notions, and are therefore not open to actively engage in classroom discussions and activities related to the topics (Kuş, 2015). As it is nearly impossible to avoid these topics in the contemporary classroom, it is critical to engage students in discourse that challenges them to develop skills necessary to become informed citizens such as being able to engage in democratic discourse, critically

evaluate issues, and cultivate resolution (Gore, 1999; Lockwood & Harris, 1985; Kivunja et al., 2008).

Ranney, (2012) found people in the USA are less likely than those of peer nations to accept controversial issues such as climate change or evolution as truths. In addition, he found a significant association between the number of university credit hours completed in the content area and teachers' acceptance of the theory of evolution, and the number of instructional days the content was covered in those teachers' classes (Rutledge & Mitchell, 2002). Plutzer et al., (2016) found that "especially for political or cultural conservatives, simply offering teachers more traditional science education may not lead to better classroom practices when teaching climate change" (p. 664), further suggesting a need for new forms of climate change education preparation for educators entering the field of science education, including those that draw on science communication research that focuses on addressing conflicts that teachers (and their students) may feel between their values and the science (Plutzer, et al., 2016). If science teachers are to use effective pedagogical practices for climate change and other controversial topics in science education, they need to learn why it is important and how to teach it effectively (Desimone et al., 2002; Li et al., 2019; Nation & Feldman, 2021). This can be done as part of pre-service teachers in university education programs but, more importantly, because of the large number of alternatively certified secondary science teachers in the USA (Sass, 2005), in-service training of teachers through professional development programs and workshops related to teaching controversial issues is needed (Li et al., 2019). Learning the concepts related to the causes and implications of the issues should remain the goal of instruction of controversial topics; however, because teachers are the most important factor in what is taught and how, it is important to understand teachers' acceptance and beliefs about the issues must be understood and addressed. This can provide insight as to why teachers make certain pedagogical decisions about their teaching of controversial issues.

2.2 NOS and Controversial Issues

Nature of science (NOS) is often defined as an epistemology, a way of knowing, or the values and beliefs essential to the development of science and scientific knowledge (Abd-el-Khalick et al., 1998). There are many models by which to approach NOS among the literature, such as the "Consensus View" (Lederman, 2007), "Whole Science" (Allchin, 2017), and "Family Resemblance Approach" (Irzik & Nola, 2011). The purpose of this section is to examine the relationship between teachers' grasp of NOS and their teaching, and the relationship between their beliefs of NOS and instruction of controversial science issues.

Prior studies have shown teachers' beliefs about NOS can influence their actions in the classroom, students' views on scientific knowledge and practices, and their response to discourse and exposure to controversial science concepts (Brickhouse, 1990; Karisan & Zeidler, 2017). In general, teachers with a more complex understanding of NOS are more likely to be able to help their students learn the complexities of science. For example, Brickhouse, (1990) found teachers who viewed scientific theories as tools to solve problems were more likely to encourage students to use those theories to explain observations. Karisan and Zeidler, (2017) suggest using NOS as a framework for teaching controversial issues requires teachers to be informed about how to guide students in the process of applying their understanding of NOS. Instruction of controversial issues, such as climate change, provides ideal context for enhancing students' and teachers' understandings of NOS (Zeidler, 2014).

Teachers' understanding of NOS can change their pedagogical approach to engage students in the activity of science when it comes to instruction of controversial issues (Sadler et al., 2004; Zeidler, et al., 2002). Other evidence suggests that teachers' beliefs about their own practice and instruction are not always reflected in their teaching practices, especially when educating students about controversial issues (Kinchin et al., 2009; Waters-Adams, 2006; Shi & Lin, 2014). Science teachers faced with the challenging task of educating learners about content that students do not agree with or may be uncomfortable with continues to lead to overall avoidance of the topic (Plutzer, et al., 2020). Teachers may hold certain beliefs about the topics that are worthy of instruction yet may not implement these beliefs in their actual instruction. Studies have found that when confronted with information that challenges beliefs, a common response can include ignoring or rejecting the data (Chinn & Brewer, 1993; Zeidler, et al., 2002). Therefore, determining effective pedagogy for instruction can be attributed to teachers' instructional beliefs and can help better understand why instruction of controversial issues including the ones mentioned above remains so difficult.

It is important to note that beliefs are complex structures that are highly influenced by teachers' own experience in practice (Thompson, 1992). It cannot be assumed that student outcomes are directly related to one single individual belief, but rather it should be seen as resulting from a set of intricate interactions among student, teacher, and the curriculum that develops over an extended period of time (Diekhoff, 1983).

An increased understanding of the process of NOS can lead to an increase in conceptualization of scientific concepts (Karisan & Zeidler, 2017). Therefore, there is a responsibility of science teachers to promote comprehensive understanding of NOS and scientific literacy among students, as it is fundamental to fully understand other science content and how scientific knowledge is constructed. In doing so, students not only become higher achieving in science, but better able to interpret knowledge gained through other experiences (Miller et al., 2006). When teachers and students are more scientifically literate, they can better decipher and critique information from multiple sources as it relates to controversial issues such as GCC (Partin et al., 2013). That said, teachers with a greater understanding of the complexity of how climate change science is progressing, as well as an understanding of how cultural ideology results in GCC being a controversial issue, can lead to an increase in students understanding climate change (Guy et al., 2014).

2.3 Evolution, Biotechnology, and Climate Change

It is important to note that GCC is not the only controversial issue being taught in science classes. Others include evolution and biotechnology. In learning how to teach climate change to a skeptical audience, we can look to how evolution and biotechnology, two different public-expert disagreements, have become less controversial in US schools over time. However, the reasons why some topics are considered to be controversial differ. For example, evolution is considered highly controversial because it contradicts biblical and other religious creation stories. GCC is considered to be controversial in science education, not because it competes with religious ideals, but instead because it directly confronts many conservative political ideologies (Hulme, 2009). In addition, climate change science is a relatively new field, and it is complex and deals with issues of scale, uncertainty, temporal delays, and ethical considerations (IPCC, 2007; Parmesan, 2006; Philander, 2008). Due to the controversial nature and political disagreement of the topic, there is

considerable disagreement about how climate change can be effectively addressed in the classroom (Gayford, 2002).

A decade ago, it was found that only one-third of public-school teachers in the USA presented evolution as it aligned with the recommendations of the scientific community (Berkman & Plutzer, 2011). Further, many teachers were still including creationism in the USA as an acceptable alternative to evolution even after it was found unconstitutional in 2005 in the Kitzmiller v. Dover case, which stated that creationism was religious in nature, and therefore could not be taught in the public schools. In 2019 Plutzer et al., (2020) used the same survey as the one from 2011 and found positive shifts in not only amount of time biology teachers spent teaching the topic of evolution, but also overall acceptance by the teachers. One way researchers account for those shifts is the inclusion of evolution in the Next Generation Science Standards (NGSS) (NGSS Lead States 2013), which has led to a greater number of teachers including evolution in their instruction for a greater amount of class time. Additionally, researchers note a large number of teachers have entered the profession since 2007, many of whom experienced evolution as part of their pre-service teacher preparation, suggesting that professional development and preservice teacher preparation that adequately addresses a controversial issue like evolution can lead to teachers becoming more comfortable with the material, and in turn, more likely to include it in their instruction. The largest impact on teacher acceptance of evolution as an appropriate concept to be taught was professional development, the addition of textbooks that covered the topic, and administrative support for teachers who experience resistance from parents and other stakeholders (Plutzer, et al., 2020). However, findings suggest there is still a large number of teachers who avoid the topic, send mixed messages, or simply admit to endorsing creationism, primarily because their personal beliefs conflict with evolution (Plutzer, et al., 2020).

Biotechnology, another developing field, is recognized in science education as an important emerging topic, as students will be asked to make decisions related to the future of these new technologies (Steele & Aubusson, 2004). The teaching of biotechnology, including stem cell research, genetic testing, and genetically modified organisms is also a controversial issue in the USA because it raises political, social, and economic concerns among the public (Oulton et al., 2004). Studies suggest students who experience a biotechnology content-rich curriculum were more likely to have increased understanding of genetically modified organisms, genetic engineering, and cloning (Dawson & Soames, 2006). However, because of its controversial nature, many teachers have left biotechnology out of their classroom instruction, citing conflicts with available time in curriculum, inadequate understanding of the content, and that there was less practical knowledge within the area of biotechnology for students in comparison with other biological concepts (Steel & Aubusson, 2004).

If society is to benefit from the field of biotechnology, students need to understand what it is (Lock & Miles, 1993). However, as with climate change, Gunter et al. (1998) found that students and teachers were underinformed about the topic and did not understand the scientific processes and implications. Thirty years later, Firat and Köksal, (2019) found that to teachers "the greatest barriers to teaching biotechnology were: no reference books, lacking teaching aids, lacking biotechnology exposure during teacher training and higher education, lacking biotechnology knowledge, lacking skills to conduct experiments, and lacking recent professional development on teaching methods" (p. 45). As a result, they advocate for additional teacher preparation and professional development to better prepare teachers to include biotechnology within their instruction. Also, as with evolution and GCC, teachers struggle to overcome the effects of students

gaining information about biotechnology through media outlets such as television and internet resources, which present gross misunderstandings, oversimplification, and stereotyping of the issues (Gunter et al., 1998, Lock & Miles, 1993; Dawson & Carson, 2013; Gayford, 2002).

Controversial issues involve value judgment, as there is often no one right way to resolve them (Wellington, 1986). Controversial issues in science education go beyond what is usually considered the content of science. They require teachers to access internal moral reasoning about what is important to teach while keeping in good faith to their beliefs, and to engage in ethical reasoning. They require both students and teachers to consider their value judgments when determining the best way to address the issues (Byford et al., 2009). Students will most certainly be faced with these controversial environmental, political, and economical predicaments once they have left school and it is the duty of the educators to prepare them to think scientifically and critically about these issues regardless of personal beliefs or opposition from stakeholders (Dewhurst, 1992; Soley, 1996; Solomon, 2001). However, if climate change science and GCC are to be taught in the schools in ways that build students' abilities to engage in democratic decision-making, as with both evolution and biotechnology, this will largely depend on teachers, their knowledge and understanding of the scientific and societal aspects of the issues (Lock et al., 1995), and their beliefs and intentions for their science classroom (Bybee, 1993).

Given the above, if teachers are to engage in instruction about controversial topics, they will often be faced with the difficult task of addressing their own personal beliefs and values. Mitigating climate change necessitates convincing people to change their behaviors, and research have found that this can lead teachers to feel as if they are exploiting students through their own personal biased instruction (Hines et al., 1987; Nickerson, 2003; Sadler, et al., 2006; Staats, 2003). Thus, teachers are more likely to present the least controversial aspects of divisive topics in science classrooms. Further, teachers report teaching "both sides" or remaining neutral on a conflicting issue in an effort to avoid any bias or personal values that might be expressed through instruction of just one side of the debate (Nation & Feldman, 2021; Cross & Price, 1996). However, there is disagreement in the literature as to whether teachers should remain neutral in their instruction (Oulton et al., 2004). Expression of personal values is a difficult notion for educators to consider as values are often described as a derivative of moral code or ethical principle (Sunderland, 1998). While controversial and value-driven instruction may seem like a novel idea, the research suggests that science teachers should teach content in a broader context, calling for teachers to focus on the nature of controversy in their instruction, recognize individual worldviews, and promote of critical reflection among learners (Oulton, et al., 2004). Rather than remaining neutral, Oulton et al., (2004) suggest teachers share their own personal stance on issues with students and be explicit in the way in which they reached their stance, encouraging and maintaining a sense of open-mindedness, ensuring that students do not reach a decision too hastily, and be willing to change their views. Clearly, for this to happen, science teachers will need to be prepared to do so (Keys, 2005; Olson, 1981; Pajares, 1992).

3 Research Questions

The following research questions guided this study:

1. How do personal beliefs influence teachers' instruction of climate change?

2. How does political controversy affect instruction of climate change within the science classroom?

4 Methods

The National Science Foundation (NSF)–funded project resulted in the development of the climate change education materials found here: (Redacted for anonymity) incorporated into existing secondary marine science curriculum within a school district in the coastal Southeast United States. The curriculum materials, developed by teachers and research scientists, used best practices in environmental education to provide practitioners with resources that were local, place-based, interdisciplinary, and focused on the built and natural environment (Anderson, 2012; Monroe et al., 2013). The goal of the project was to encourage teachers and students to better understand the social, political, and environmental impacts of climate change, including global warming and sea level within the place-based setting of the Southeastern US, which continues to see threats posed by climate change, and the resulting costly adaptation and mitigation challenges (Melillo et al., 2017; Roach, 2005). The curriculum was designed to encourage teachers and students to think about their personal mitigative actions by connecting climate change to their everyday lives and communities (Hallar et al., 2011; Theobald, 2006).

An in-depth look at four secondary science teacher's enacted practices and espoused belief system within the science classrooms was conducted to better understand the instruction of climate change within their classrooms through four observations of the curriculum in each of the four teachers' classroom using the adapted classroom observations protocol (see Appendix 2). The investigation of these four secondary science teachers' beliefs and understandings of climate change science was completed through qualitative data collection of teacher interviews, classroom observations during their instruction of the climate change curriculum, and survey data, which provide insight into the relationship between the teachers' beliefs and their practice.

The interview consisted of six open-ended questions with four of the six having follow-up questions. The questions aimed to uncover science teachers' beliefs about teaching climate change and further understand how their beliefs impact their instruction (see Appendix 3). Thematic coding of the classroom observations, interviews, and qualitative data collected by the survey was completed by two different researchers and reviewed by another (see Appendix 4). Interrater agreement was reached among the research team by consensus.

4.1 Context

The study took place in a large metropolitan coastal area located in the Southeastern US. The school district is the eighth largest district in the country, with over 26 public high schools located in a variety of settings including urban, suburban, and rural (County School District, 2015). All 26 marine science teachers were invited to use the climate change curriculum materials. The project provided teachers with professional development to learn how to implement the material. The district's marine science teachers were motivated to implement the new curriculum materials because content related to the units was embedded into the district-wide summative semester exams.

Table 1 Formal teacher education

Teacher	Educational background	Formal Teacher Education	Number of years teaching	Title I school	School setting
Teacher 1	Human resources	N	11–20	Y	Rural
Teacher 2	Economics/social sciences	Y (not science)	6–10	N	Suburban
Teacher 3	Veterinary technician	N	11–20	Y	Urban
Teacher 4	Chemistry	N	6–10	N	Suburban

Table 2 Teachers' understanding, beliefs, and amount of GCC instruction

Teacher	Level of understanding	Beliefs measured	Level of concern	Amount of GCC instruction
Teacher 1	High	Low	Low	Med
Teacher 2	Med	Med	High	Med
Teacher 3	Med	Med	Med	High
Teacher 4	Low	High	Med	Low

4.2 Participants

The four teacher participants were selected from a larger population to serve as cases for this in-depth study. Teachers were selected based on data from a teacher survey (see Appendix 1). A purposeful selection was used as a representative sample of the district's marine science teachers (Denscombe, 2014). Specific characteristics from the survey were used to select the teachers including the teachers' beliefs and understanding of climate change, amount of time spent teaching climate change, personal beliefs about mitigative actions, and level of personal concern about the implications of climate change. The information from this survey was also used to help determine whether their reported instruction, beliefs, understandings, and level of concern for climate change impacted their instruction of the curriculum. Tables 1 and 2 provide information about the selected teachers.

5 Results

The analysis of the data using the methods described above led to the following themes:

1. Teachers were hesitant to present climate change as anthropogenic, for fear of "push back" from stakeholders and administrators, and instead presented the topic in a "neutral" fashion, indicating they presented "both sides" of the material. Thus, suggesting that there are multiple scientifically accepted causes of climate change, other than anthropogenic-induced climate change, including "natural causes" of climate change.
2. To limit controversy in the classroom, the teachers avoided argumentative discourse within the classroom structure about climate change in which their students would

engage in discussions about the causes or implications of climate change. Instead, they reported presenting the information about climate change as a body of evidence supported by facts, thus, leading students to "make up their own minds" about climate change.

The analysis of the data collected from the classroom observation protocol (see Appendix 2) revealed that teachers' implementation of the curriculum was "very little" to "somewhat" reflective of the intended practices among all the teacher participants. The observed teachers made no real connection to the local place-based approach of the curriculum and did not focus on the negative impacts of climate change on the built or natural environment of the region, which were embedded parts of these lessons in the follow-up questions, and outlined questions for discussion. There was no evidence in the observed lessons of students engaging in dialogue with each other or with the teachers about the causes or implications of climate change.

From their responses to the survey, the four teacher participants in this study self-identified as climate change believers. In addition, as indicated in their survey responses, they had relatively high levels of understanding of climate change and professed beliefs aligned with the scientific community about the best ways to teach, and mitigate the impacts. However, observations of the teachers' lesson found a gap exists between teachers' personal beliefs about climate change and how they teach the topic. Nation & Feldman (2021) found that teachers' personal beliefs about climate change had essentially no impact on their instruction of the curriculum even when exemplary curriculum materials were provided.

The teachers explained in their interviews that they intentionally removed their personal beliefs about the topic in their instruction as not to appear politically biased. It is important to note that the data were collected during the 2016 presidential campaign and election, which added to their fear of pushback from students, stakeholders, and administrators. This was particularly true of the teachers in rural and suburban settings, which typically have more conservative populations than urban areas. As with McNeal et al., (2014), participants in the study intentionally avoided controversial discussions within the classrooms, avoiding opportunities for student-led dialogue or argumentative discourse. As a result they limited opportunities for students to construct their own understandings of scientific issues through discussion, argumentation, and examination in order to better understand climate change. Instead, the teachers reported and were observed presenting climate change as a body of facts supported by evidence and encouraged students to "make up their own minds about the topic." This potentially left the students with news or other media outlets as their primary sources of information about climate change, where it is often misrepresented (Liu et al., 2015). This further perpetuates misconceptions found over a decade earlier in Bentley et al.'s, (2007) study about presenting science as a body of knowledge rather than a process of discovery or allowing for students to participate in inquiry about climate change.

6 Conclusion

We found, as with many other studies related to the teaching of controversial topics, teachers may hold certain beliefs worthy of instruction, but not uphold these beliefs in their actual instruction of the content (Kinchin et al., 2009; Shi et al., 2014; Waters-Adams, 2006). All the teachers observed failed to implement important aspects of the climate change curriculum including discussion and argumentation. They also did not support

claims with the place-based nature of the curriculum. Teachers instead attempted to remain "neutral" in their instruction of the controversial issue.

Hutner and Markman (2016) suggest a new definition for teacher beliefs defined as "operational" instead of "epistemological," and having a belief, such as concern for climate change, does not necessarily result in instructional practices that address those beliefs, but rather the belief must be actively occurring during the process of teaching to be deemed operational. This may be why participants did not actively reveal their own personal beliefs about anthropogenically induced climate change in their instruction of the curriculum, thus, supporting Hutner and Markman (2016), who call for future research to examine why teachers choose not to act on personal beliefs they hold during classroom instruction.

7 Discussion

It is clear climate change education needs to be part of the formal secondary science classroom (Junyent & de Ciurana, 2008; Monroe et al., 2013). However, as seen with past studies, including evolution and biotechnology, teachers need a place for it within the context of their classroom instruction, and students need to become better informed about the causes and implications of climate change.

If controversial topics such as climate change, evolution, and biotechnology are to be taught as part of science classes, the addition of curriculum materials, even if innovative, is not sufficient. Teachers need to understand why it is important for them to use pedagogical practices such as argumentation, discussion, and the connection of content to place if they are to effectively teach climate-centered curriculum in ways that confront other information outlets. In addition, they need to understand that to present climate change science in what they see as an unbiased manner, actually results in a bias that supports unscientific beliefs of climate change deniers and further propels misconceptions. Teacher neutrality when teaching controversial issues underestimates the extent to which dominant ("nonexpert or public") voices are amplified through this strategy while non-dominant ("expert") voices are silenced (Sanders, 1997; Sibbett, 2016). Ho & Seow (2017) and Schreiner et al. (2005) suggest teacher educators should pay more attention to helping teachers address dimensions of the issue of climate change outside of their comfort zones including the need for teachers to be able to challenge traditional subject-matter curricula and assessment methods.

While beliefs about the causes and implications of climate change of the teachers were consistent with scientists, their beliefs about best instructional practices in teaching climate change did not align with the intended curriculum or the literature, consistent with findings from Plutzer et al., (2016) who found "especially for political or cultural conservatives, simply offering teachers more traditional science education may not lead to better classroom practices when teaching climate change" (p. 664). Designing and implementing curricula about climate change requires a balancing act of increasing knowledge of climate change and acknowledging how cultural ideology plays a role in perception and learning (Guy et al., 2014). In order to better prepare science teachers in effective pedagogical practices, further professional development of science teachers is necessary (Desimone et al., 2002; Hestness et al., 2014; Li et al., 2019). This can include preparation of pre-service teachers in university education programs but, due to the large number of alternatively certified science teachers (Sass, 2005), much of this must be done through in-service training and professional development programs and workshops (Li et al., 2019). Teacher preparation and professional development programs can

provide educators with an opportunity to learn about educational theories and pedagogical practices that are recognized as best practices for educators (Rowan 1995, Stoll et al., 2006), especially when dealing with controversial topics. Participation in these types of activities can provide the opportunity to transform teachers' beliefs over extended periods of time (Bryan, 2012; Guskey, 1986; Stoffels, 2005). Tam (2105) identifies the following features of professional development that can lead to teacher change specifically in beliefs and practices:

- Creations of a new structure within the classroom and school,
- Building a collaborative culture in which teachers work interdependently,
- Initiation of interactive learning activities

Participation in professional development training with these characteristics can lead to overall change in teachers' instruction of the content, curriculum, teaching, and learning of controversial science issues. Science teachers need to be actively participating in opportunities similar to those suggested by Bryan (2012) and Tam (2015) to transform their beliefs about teaching climate change science in that the content is not only new and emerging, but complex, and many teachers have prior existing beliefs about the topic born out of media sources and hearsay rather than professional training and science research. In addition, it is beneficial for teachers to understand their own attitudes and beliefs about a subject, especially if they are looking to influence behaviors prior to their instruction of the content (Ham et al. 2007; Powell and Ham 2008). This is particularly important for climate change education, as solutions to climate change typically require changes in human behavior (Hulme, 2009). As seen in past longitudinal studies, future research will need to be done to determine if a shift in including more climate change education into their classroom instruction occurs. As younger teachers enter the workforce who have been adequately prepared to address climate change, the inclusion of climate change into national and state standards, and greater societal acceptance of climate change as a real and imminent threat occurs within the USA, we are hopeful that climate change education will continue to progress within the secondary science classrooms.

8 Limitations and Suggested Further Research

This study took place during the highly contentious US 2016 presidential election. A time when climate change denialism was one of the forefronts of the Republican nominee, Donald Trump's campaign. At the time of this writing, teachers in the USA are finding that the teaching of the science related to the COVID-19 pandemic is controversial, beginning so with the 2020 presidential election. Therefore, future studies should examine the impact of national and local politics, and the distorting effects of social media, on why teachers are reluctant to teach controversial topics.

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Declarations

This study was approved by the university's and the School District's IRBs, and all participants gave their written consent.

Conflict of interest All authors declare that they have no conflicts of interest.

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