THESIS

CLIMATE CHANGE EDUCATION IN RURAL COLORADO SCHOOLS

Submitted by

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Graduate Degree Program in Ecology

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Summer 2021

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ABSTRACT

CLIMATE CHANGE EDUCATION IN RURAL COLORADO SCHOOLS

Earth system science education is becoming more timely as our understanding of climate change (CC) and the effects across our social ecology systems increase. Climate literacy, however, is threatened by hyper-political discourse regarding the anthropogenic causes of climate change, which is especially heightened in rural spaces, where residents' livelihoods are often the target of scrutiny by media and scientists. In this study, rural Colorado teachers' (n=9) explanations and perceptions of their climate change education (CCE) instructional choices were examined using instrumental case study methodology. This study was written with the intention for submission to *the Journal of Environmental Education* or *Research in Science Education*.

Analysis of multiple data sources (interviews, observations, curricular artifacts, student assessments, school websites) resulted in the identification of three cases defined by the teachers' acceptance of anthropogenic causes of climate change, their use of Claim, Evidence, and Reasoning (CER) instructional model, and their sense of belonging. Participants were grouped into one of three cases: (1) Accepts and teaches CC using CER, (2) Accepts CC but does not use CER, and (3) Does not accept nor teach CC. Teachers' competence and confidence with climate science (*knowing*) as well as their sense of belonging in their rural school and community (*belonging)* affected how they framed (Scientific uncertainty or Conflict/Strategy) climate change to their students. By learning how rural science teachers communicate CC in their classrooms, science education experts and climate scientists can collaborate to (1) design meaningful and effective professional development workshops and (2) collate curricular

resources, including empirical evidence for CC, so rural science teachers feel prepared to teach CC as an socioscientific issue. Moreover, with access to empirical evidence, rural science teachers are better positioned to model scientific argumentation using the CER model in their lessons. Research focused on climate literacy is fundamental to creating an informed generation capable of making conservation, land stewardship, and natural resource management decisions. Rural teachers and students must be included in endeavors to increase climate literacy.

ACKNOWLEDGMENTS

I would like to thank my advisor, Meena Balgopal, for all of the support and guidance she has provided throughout the process of this master's thesis. I would also like to thank my committee members, Kellie Enns and Scott Denning, for the feedback and comments on my research. I would like to thank all the members and associated members of the Balgopal lab (DeeDee Wright, Dani Lin Hunter, Jennifer Brady, Haley Bubb, Emily Stuchiner, Jasmine Bruno, and others) for their collaboration and learning. This thesis was made possible through funds granted by the National Science Foundation and the Office of Vice President for Research at Colorado State University. Finally, I would like to thank my family for all of their love and encouragement, and I would especially like to thank you to my parents, Morry Cater and Peter Scheer, for their endless support.

DEDICATION

I would like to dedicate this thesis to my grandmother, Deborah Scheer, who was a passionate educator, a giving mother, and a loving grandmother. Her support and enthusiasm for my own career in education continues to inspire me to be the best teacher I can possibly be. I love you dearly and you are missed.

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Introduction

As the effects of anthropogenic climate change (CC) become more pervasive and dangerous across social ecological systems, American science teachers have the opportunity to ensure that their students develop stronger climate and environmental literacies (Biello, 2015; IPCC 2018; Melillo et al., 2014; Vitousek et al., 1997). However, climate literacy is threatened by hyper-political discourse regarding the role that humans play in changes to global temperature and carbon dioxide concentrations in the atmosphere despite the overwhelming (97%) scientific consensus (Arlt et al., 2014; Cook et al., 2013; Oreskes, 2005; Plutzer et al., 2016; Trumbo, 1996). Nearly one in three Americans think that climate change is due to mostly natural changes in the environment rather than those that are human caused; this statistic has not changed since 2009 (Leiserowitz et al., 2019). Furthermore, nearly 64% of the nation reported rarely or never discussing climate change (Leiserowitz et al., 2019).

While American public climate literacy is greatly influenced by mass media, teachers are in positions to facilitate secondary students' understanding and reasoning of evidence of anthropogenic CC, as well as behaviors that can either prevent or mitigate the harmful social, economic, and physical impacts of CC (Plutzer et al., 2016; Cordero et al., 2020, Moser, 2010). Anderson (2012) found evidence that climate change education (CCE) interventions led to higher reporting of environmental awareness and pro-environmental behavior in students. Boyes and Stanisstreet (2006) reported that student misunderstandings were traced to conflating Earth System Science (ESS) concepts of the greenhouse gas effect with ozone depletion, underscoring the need for enhanced CC literacy in K-12 science classrooms. Furthermore, Shwom et al. (2017) argued for the incorporation of social science in our CCE framework because this is fundamental in understanding how human-environment interactions and social drivers have a history as well as potential to mitigate climate change. The need for climate change education in our classrooms is well documented, but there is a lack of research on the current practices of rural science teachers and their perceptions of how to best teach CC.

Climate Change Education

Climate change is considered a Socioscientific Issue (SSI), an issue that is diverse, multi-faceted, and draws upon various funds of knowledge including social, cultural, and political, not just scientific (Balgopal et al., 2017; Sadler & Zeidler, 2005). Because SSIs often require teachers to invite students to draw on or integrate other forms of non-scientific knowledge, early career teachers may avoid framing or presenting issues as SSIs (Borgerding & Dagistan, 2018; Ozturk & Yilman-Tuzun, 2017) and, even teachers who have participated in lengthy professional development around CC, struggle to overcome their own beliefs when they teach CC (Liu & Roehrig, 2019; Nation & Feldman, 2021). When climate change is presented as an SSI in the classroom, however, students are able to increase their climate literacy competencies. For example, Dawson & Carson (2018) found that when incorporating argumentation about climate change as an SSI in instructional delivery and curriculum, students improved their argumentation skills. A common argumentation instruction model in science teaching is the Claim Evidence Reasoning (CER) model, which allows teachers to model scientific reasoning for their students (Brown, et al., 2010).

Because CC is a complex SSI, teachers struggle to effectively teach CC in a way that avoids politicization or uncertainty, but rather reinforces the scientific consensus regarding CC (Plutzer et al., 2016; Wise, 2010). Plutzer et al. (2016) surveyed CCE strategies used by American teachers (n=1,500) and found that only 63% of teachers emphasized that global temperatures have risen in the last 150, while only 25% of these teachers strongly agreed with this statement, which was similar to their finding regarding teaching of anthropogenic causes of CC. Furthermore, Plutzer et al. (2016) found that many teachers presented "both sides" of the debate regarding CC and taught that many scientists agree that CC is due to primarily natural causes. This instructional approach threatens climate literacy throughout our education system because it is not necessarily grounded in empirical, scientific evidence.

To increase climate literacy, researchers have focused on K-12 teachers and students by developing curricular and instructional resources. The National Oceanic and Atmospheric Administration (NOAA) developed a climate literacy framework in efforts to expand and strengthen CEE (USGCRP, 2009). Early education of CCE, with emphasis on the anthropogenic causes of climate change due to human behavior, may challenge value systems learned early in life that often influence basic beliefs (or value orientations), which can then shape behavior as an adult, according to social cognitive hierarchy theory (Whittaker et al., 2006). CCE can increase public knowledge about the causes and effects of increasing CO_2 concentrations in the atmosphere, and in turn, help students understand how human behavior contributes to CC. Both individual behavior and collective action is influenced by perception of risk regarding the consequences of climate change; and CCE, with an emphasis on human behavior and the effect on CC, can influence risk perception (Leiserowitz, 2005; Sullivan & White, 2019).

Media are important in spreading knowledge about climate change, but because of its highly politicized nature, there is an underrepresentation of scientifically supported claims throughout the popular news media (Antilla, 2005; Arlt et al., 2014). American public climate literacy is greatly influenced by mass media, so teachers are in positions to facilitate secondary students' understanding and reasoning of evidence of anthropogenic CC in the classroom, as well as behaviors that can either prevent or mitigate the harmful social, economic, and physical impacts of CC (Plutzer et al., 2016; Cordero et al., 2020; Moser, 2010). For students to better understand climate science, researchers argue for the importance of developing students' argumentation skills, so they can make evidence-based decisions about SSIs, like climate change (Dawson & Carson, 2018).

Science Education Standards

Most states follow the Next Generation Science Standards (NGSS), which were formed in collaboration with the National Research Council (NRC), National Science Teachers Association, and the American Association for the Advancement of Science (Achieve, 2013). NGSS are academic science standards that identify key scientific concepts, adjust expectations for different grade levels, and were written by scientists in their field (Achieve, 2013). NRC published the *Framework for K-12 Science Education*, which outlines scientific proficiency expectations for educators and students, which was then turned into specific and deliberate curriculum expectations for state use by Achieve, a nonprofit education reform organization (Achieve, 2013). In total, 20 states across the country have adopted the NGSS standards, and a total of 40 states express interest in adopting these standards.

Colorado recently adapted its academic standards to align with NGSS (Achieve, 2013; CDE, 2020). The recent adaptation of NGSS standards to include explicit language about teaching climate change was one impetus for the current study. The revised standards highlight anthropogenic causes of climate change; more specifically, they state that human activity on Earth has contributed to carbon dioxide concentrations in the atmosphere, which has led to an average global temperature increase (CDE, 2020). .

The Colorado Department of Education (CDE) 2020 Standards outline clear learning objectives in the High School Earth Science curriculum that emphasize human interaction with earth systems:

> *Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere.*

The incorporation of human interaction with Earth systems, specifically anthropogenic causes of climate change, is an amendment from the 2009 Colorado Academic Standards, which simply stated, “Climate is the result of energy transfer among interactions of the atmosphere, hydrosphere, geosphere, and biosphere” (CDE, 2009). With the publication of new academic standards comes implementation expectations for school districts, extended to the 2021-22 school year (Achieve, 2013; CDE, 2020). Colorado teachers are beginning to modify their curriculum to accommodate these changes in standards, and school districts have different resources available for teachers to do so.

Although science teachers across the country are expected to teach this disciplinary core concept within their ESS curriculum, there is evidence that many may not do so because they do not understand climate science or may not have a curriculum (Plutzer et al. 2016; Wise 2010). Moreover, teacher evaluation requires that teachers address state academic standards and prepare their students for state assessments (CMASS; Pitot & Balgopal, 2021). Therefore, all teachers in both rural and urban public schools are expected to teach about anthropogenic climate change in their Earth system science lessons.

Rural Colorado Schools

The Public School Finance Act (1994) delegates funding to Colorado school districts and provides program funding on a per pupil basis (CDE, 2019) which is a funding cap that is defined by cost of living in the area, personnel costs of the school, and size of district, among other factors (CGA, 2018). The size factor tends to favor per pupil funding for rural districts, with most rural districts receiving between $10,000-$16,000 per pupil funding (CDE, 2019; CGA, 2018). Furthermore, the average funding per pupil in Colorado, as of the 2016-17 school year ($7,419), is lower than the national average ($11,392) (CGA, 2018; Hess, 2018). While funding is higher on a per pupil basis in rural districts compared to urban/suburban districts in Colorado, rural schools, on average, have significantly lower enrollment than urban/suburban school districts, with rural schools designated with enrollment of 6,500 students or less (CDE, 2019). As of the 2016-17 school year, 148 of the total 178 school districts in Colorado were identified as rural, and make up 15.3% percent (139,155 students) of the total student population of the state (CDE, 2019; CDE, 2020). Rural districts account for a significant portion of Colorado students but suffer from a lack of available financial resources, which poses potential challenges for rural science teachers to best implement new state science standards. Research on rural education is underrepresented in the science education literature; however, it is needed because it allows researchers to identify how teachers are able to overcome challenges in their classroom or not.

Rural Science Teachers

Colorado is a unique study context to document the implementation of these new science standards because, although the majority (83%) of Colorado school districts are rural, the majority of climate change education (CCE) resources are offered to teachers in urban and suburban districts (CDE, 2019; 2020). Furthermore, the state's rural economy comprises the vast agricultural sector, in communities where public school students also live and work on family ranches. According to voting records, these rural Colorado communities tend towards conservative political affiliation, and studies show a strong correlation between political orientation (ideology and party identification) and the belief in anthropogenic climate change and the adoption of pro-environmental behavior (McCright et al., 2016; Shwom et al. 2017). In a study analyzing public opinion survey data, Marquart-Pyatt et al. (2014) found that political orientation and ideology was the strongest indicator in impacting public understanding of anthropogenic climate change. More specifically, those affiliated with the conservative party are less likely to understand the timing and seriousness of climate change (Marquart-Pyatt et al., 2014; McCright et al., 2016). Rural science teachers are placed in an interesting position as communicators of a highly politicized socioscientific issue (SSI) to a stakeholder community whose profit is tied to industries implicated in anthropogenic climate change (further information about the study context of eastern Colorado in Appendix A).

Rural teachers face additional challenges when presenting CC and other SSIs in the classroom, with less funding due to low enrollment leads to under-resourced teaching staff and fewer professional development resources (Barter, 2008; CDE, 2019). Beyond this, smaller school budgets lead to fewer extra-curricular options for students as well as teachers teaching across disciplines (Barter, 2008; Carlsen & Monk, 1992). There also exists a bias in science education literature toward urban and suburban schools, limiting our understanding of the rural teacher demographic, which leads to fewer professional development tools and other teacher resources (DeYoung, 1987). With a lack of available curricula and educational resources, rural teachers may be less likely to take the role of "cultural border crosser" in their classrooms, as they tackle topics deemed controversial (Borgerding, 2017).

There is a clear need for a deeper examination of how rural science teachers meet the expectations of teaching climate change. There are four major “storylines” that exist about rural teachers, according to Burton et al. (2013): rural teachers are (1) professionally isolated, (2) different from urban/suburban teachers, (3) lacking in professional teaching knowledge and credentials, and (4) resistant to change. Burton et al. (2013) called for more empirical research on rural educators to change the framing of the “rural problem” in education research. The purpose of this study, therefore, is to address the gap in research by documenting the experiences of rural science teachers and examining how they frame climate change to their students. The findings of this research can be used to develop effective and relevant professional development for rural science teachers, as well design follow-up studies, informed by the findings, to examine a larger sample size of rural science teachers across the US.

Conceptual Framework

This study addresses the need for research on rural educators, while examining the timely socioscientific issue of climate change education. This study design used both socioscientific issues and frame theory to inform data collection and analysis.

Socioscientific Issues

Socioscientific Issues (SSIs) are complex topics for which people use scientific reasoning to understand while grappling with social implications of any decisions made (Levinson, 2006). Often SSIs are complicated with varying outcomes, which make it difficult to communicate to the public. Examples of SSIs include biotechnology, genetically modified organisms, reintroduction of wildlife near human-dense areas, and fertilizer run-off and hypoxic water ways. Understanding climate change requires the integration of both biophysical and socio-economic-political knowledge (Nisbet, 2009; Wise, 2010). Moreover, because human behavior has consequences that can either increase or mitigate CC, social systems are tightly linked to the natural systems that explain CC. SSIs are commonly discussed in the media, often through the presentation of scientific evidence in conjunction with formal and informal science perspectives, making it challenging for the public to draw definite inferences (Arlt, 2014). There is value in presenting SSIs in a science education context as they can be used to enhance scientific reasoning and argumentation for students (Liu & Roerig, 2019; Dawson & Carson, 2018). Communicating SSIs is a challenging and unique task for science teachers because, while issues are rooted in scientific evidence, there are often moral, ethical, and societal implications (Dawson & Carson, 2018). Integrating SSIs in the classroom provides an opportunity for teachers and students to draw upon multiple funds of knowledge to make meaning and demonstrate scientific reasoning (Balgopal et al., 2017). SSIs are also relevant outside of the classroom often because of the social and political nature of these topics, which allow students to apply their scientific reasoning to real-world issues. This study examines if and how rural science teachers address CC as an SSI and what frames they use to communicate this topic in the classroom.

Frame Theory

When teachers present new topics, especially socially and economically charged ones, such as climate change, how they frame the topic can shape how their audience interprets it (Nisbet & Scheufele, 2009; Plutzer et al., 2016). Frame theory, first described by Erving Goffman (1974), explains that individuals shape their interpretation of reality through framing. We use frames to interpret reality as well as communicate ideas, and frames are constructed from the various funds of knowledge that we, as individuals, pull from to make meaning (Nisbet, 2009; Balgopal et al., 2017). These funds of knowledge can come from our personal experiences, making frames unique to an individual's lived experience (Balgopal et al., 2017). Nisbet argues that there is "no such thing as unframed information" and that frames are the lens through which we see and interpret the world (Nisbet, 2009). Framing is a common strategy used by news media outlets as they guide the audience in interpreting a phenomenon as contextualization, evidence, agenda setting, anecdotes, stereotypes, etc. are used to communicate about real events (Nisbet, 2009).

Sociologists and communication experts use frame analysis to find patterns in how certain topics are communicated, such as CC, and to identify the types of frames that communicators (like teachers) use to explain their reality (Nisbet & Scheufele, 2009). Climate change is already framed in very polarized ways in popular media (Antilla, 2005; Arlt, 2014). According to Nisbet and Scheufele (2009), there are eight major frames used by policy makers and journalists when communicating science topics. These include Social progress, Economic development/ competitiveness, Morality/ ethics, Scientific/ technical uncertainty, Pandora's box/ Frankenstein's monster/ runaway science, Public accountability/ governance, Middle way/ alternative path, and Conflict/ strategy (Nisbet & Scheufele, 2009; Appendix B). It is possible, however, that science teachers, specifically rural science teachers, may use alternative frames to communicate climate change to their students. In the rural Colorado context, teachers must address the new state ESS standards while recognizing the sociocultural context of their rural schools, and in this vein, it is likely they frame CC accordingly. For example, it is possible that teachers frame CC in terms of the effects on rangeland and agriculture, as this is relevant to the livelihood in their communities.

Research Questions

To identify how rural science teachers communicate climate change to their students, the following questions were asked: (1) what frames do rural Colorado science teachers use and why? (2) What barriers or challenges do they face? (3) What opportunities do they have?

Methods

This qualitative research study is rooted in instrumental case study methodology. Instrumental case study methodology is used to observe the phenomenon (in this case, climate change education) in a specific context to build a better understanding of a broader social experience (in this case, of rural science teachers) (Yin 1981; 2013). Instrumental case study methodology allows us to observe experiences within a smaller context, and then extend our knowledge to a broader phenomenon (Yin, 1981). This study is phenomenological in nature, in that the data used are based on the subjective, lived experiences and perspectives of the participants (Smith & Osborne, 2003). While validity and generalizability are common critiques of case study methodology, Yin (2013) argues for various methods to ensure that case studies meet these standards. Triangulation of data, logic models, and the role of theory to guide analysis are all methods used to ensure validity and trustworthiness (Yin, 2013).

This study was originally designed to focus on classroom observation and teaching style, but with the sudden closure of Colorado school districts due to the spread of COVID-19 in Spring 2020, the focus of most rural schools was altered to accommodate the new online teaching format that most schools adopted. Additional modifications of the research design to accommodate the COVID-19 pandemic include video call interviews via Zoom (2020), classroom observation via Zoom (2020), and digital sharing of classroom curriculum and artifacts.

Positionality Statement

This research was conducted by a graduate student in an ecology program at an American public university. Before conducting this study, she was an Earth Systems Science teacher for several years and was responsible for teaching climate change. This teaching experience was in an urban setting, and the first author has little experience teaching in rural settings. Her personal history with science teaching played a role in teacher interviews, as this commonality allowed for a trusting relationship between interviewer and interviewee. She recognizes that her own experience as a science teacher may have an effect on interpretation on data but various measures, including peer debriefing, inter-rater reliability, and triangulation of data, were sought to mitigate this. The second author is a science pedagogy expert and former secondary science teacher. She has been recently collaborating with and studying rural science teachers. Her previous research has examined evolution, another contentious topic in high school classrooms.

Participants

Nearly twenty rural science teachers were recruited for this study, and only nine teachers agreed to participate. These nine teachers were interviewed representing five different school districts throughout the eastern plains of Colorado. Each school is designated as “small rural” by the CDE with an enrollment of less than 1,000 (some as small as 35 students in a K-12) (CDE, 2019). These school districts include Briggsdale, Fort Morgan, Yuma, Idalia, Akron and Branson. Participant professional teaching experience ranged from 2-16 years. The participants taught grades ranging 6-12, and classes of Earth Science, Biology, Chemistry, among others. Teachers were recruited through two methods, the first was through previous research endeavors within the Balgopal Lab at Colorado State University (CSU), and the second was through the 4-H STEM Education Extension Agent at CSU.

Data Collection

As with most instrumental case studies, multiple sources of data were used to answer the research questions. Data collection included semi-structured interviews with study participants (n=9), classroom observations (via Zoom), ethnographic field notes, materials that teachers shared (lesson plans, student work, and curricular artifacts). Semi-structured interviews inquired about teaching background, school protocols and structure, perspectives on the new NGSS science standards, and climate change curriculum (Interview Protocol 1; Appendix C). Several participants were asked for follow-up interviews (Interview Protocol 2; Appendix C). Teachers were asked about their experience teaching the ESS standards, and if there would be any necessary changes, they would need to make to their curriculum to meet the new academic standards. Teachers were also asked about any challenges they faced in their rural context. Interviews, as well as all other collected data, were recorded, transcribed, and coded using Dedoose software (2018).

Analysis

Data analysis was informed by thematic analysis and frame theory (Braun & Clarke 2006; Goffman, 1974) which helped to identify final themes. Thematic analysis occurred in two stages: 1) a deductive coding process testing the eight science frames described by Nisbet & Scheufele (2009) (see Appendix B) and 2) inductive coding to identify any additional or alternative frames that rural science teachers use. For the inductive coding process, initial codes were methodically and iteratively grouped into broader themes that organize the data around *barriers* and *opportunities*. Codes pertaining to the different levels of community involved in CCE in rural schools were identified (e.g., student experience, curriculum, instructional delivery, assessment, teacher collaboration, parent response, etc.). Throughout this inductive method, emergent themes from the data were identified that reflected the experiences of rural science teachers (Braun & Clarke 2006). Ultimately, several code categories were identified to guide final data analysis (student, teaching/communication, science education policy, profession community, social community, politics of science, etc.).

Once code categories were identified, each data set (transcripts, classroom observation, curriculum, etc.) for all nine individual teachers was collated to help us identify the opportunities and barriers present at each level of teachers' respective communities. The levels of community identified in each rural school are presented in Table 1.

Table 1. Definitions and examples of rural school community levels for qualitative data analysis.

Level	Definition	Example of Opportunity and/or Barrier to CCE
Student	The perspectives, beliefs, and behaviors of individual students that affect CCE in the classroom.	Students tend to disengage with CCE because of the politicized narrative told in the media and in their homes.
Classroom	The curriculum, instructional delivery, and assessment practices in the classroom that affect CCE.	While some teachers have a well-developed curriculum for CCE, others lack any formal curricular materials.
Teacher	The perspectives, beliefs, skills and behaviors of teachers that affect CCE in the classroom.	While some teachers agree with the scientific consensus of anthropogenic CC, others do not.
School	The science education policies, administrative impact, and state standards impact on CCE in the classroom.	There are very few formal evaluative processes in schools to assess NGSS standards.
Professional Community	The teacher community, curricular resources, and formal professional support systems present in schools that affect CCE in the classroom.	Some schools create mentorship programs between early career and established teachers.
Social Community	The cultural and political norms and beliefs of rural communities and their impact on CCE in the classroom.	The conservative ideals of many rural communities reinforces doubt in CC science.

Opportunities were defined as factors that encourage CCE or make CCE more accessible to students. For example, if teachers felt they had access to an informed and well-developed curriculum, this was considered an opportunity for CCE. Barriers were defined as obstacles or factors that inhibit CCE in the classroom. For example, when there lacked a formal evaluative process at the administrative level for NGSS delivery in the classroom, this was defined as a barrier to CCE. This framework was used to identify patterns in CCE throughout rural classrooms; these patterns are presented in the results section.

Instruction of SSIs involves allowing students to explore what types of evidence are used by different stakeholders to make meaning of issues and arrive at decisions (Balgopal & Wallace, 2009). When teachers use the SSI framework, therefore, they give their students the resources to either unpack the arguments that others have constructed or allow them the space to construct their own arguments, drawing on multiple sources of evidence (Balgopal et al., 2017; Balgopal et al., 2018). The Claim, Evidence, and Reasoning (CER) instructional method was used to analyze how teachers helped their students explore CC (McNeill & Krajcik, 2012). The CER model was developed as the skeletal structure of scientific argumentation; teachers present or ask students to identify a Claim, Evidence that supports that claim, and then the scientific Reasoning used to help scientists arrive at the claim using the available evidence (Brown et al., 2010; McNeil & Krajcik, 2008). For example, a scientific claim could be that hot air rises. The associated evidence a teacher could present to students could be hot air balloons, the heat over a campfire, or even the heat in the attic compared to the basement. These are examples of evidence that allow students to observe the claim, but the last piece of the CER model is connecting the evidence to the claim by modeling scientific reasoning. The scientific principle that is used for reasoning in this example is the phenomenon of the excited movement of heated air molecules, its subsequent expansion of volume, and the application of our understanding of density (density = mass/volume). Therefore, teachers could explain that when heated air becomes less dense, it rises. When teachers presented all three components of the CER model, this was considered successful climate change education because it involves scientific reasoning and argumentation (Dawson & Carson, 2018; Monroe et al., 2019).

Several measures were taken throughout data collection and analysis to ensure trustworthiness of this instrumental case study. These include peer and expert debriefing, inter-rater reliability coding, and triangulation of data (Yin, 2013). A former ESS teacher who is now a science education researcher was trained to use the code book. She coded 20% of the data, after which initial coding agreement ranged from 75-90% on different subsets of the data. Subsequently, discrepant codes were discussed to clarify the process, and re-coding resulted in the first 90% agreement. This process was repeated until 100% agreement of the codes was reached.

Findings

In this study, I describe how nine rural science teachers communicate climate change to their secondary students using a Claims-Evidence-Reasoning (CER) framework. Participants were categorized in one of three cases based on their acceptance of CC and their educational practices. The first case (*Accepts and teaches CC using CER*) describes those who accept the scientific consensus of climate change and the anthropogenic forces causing the rise in average global temperatures. These teachers present CC using the CER model. The second case (*Accepts CC but does not use CER*) describes teachers who accept the scientific consensus of anthropogenic CC but do not fully use CER model. The third case (*Does not accept nor teach CC*) describes teachers who do not accept the scientific consensus of anthropogenic CC nor do they present CC in the classroom. These three cases of teachers are differentiated based on how they described *belonging*, i.e., being a part of their rural and professional school communities, and *knowing*, i.e. having the confidence and competency to teach climate science (Table 2).

Table 2. A summary of nine teachers' methods for integrating CCE into their secondary science classroom. Teachers were classified in three groups: Here, "Belonging" refers to teachers' affiliation (number of years) with their rural and professional school communities. "Knowing" refers to teachers' perceived confidence and competency with CC curriculum, especially with using the CER model. The first group, (i)"Accept and teaches CC using CER," is indicated with light grey shading; (ii) "Accepts CC but does not use CER," is indicated by medium grey shading; and (iii)"Does not accept nor teach CC," is indicated by the dark grey shading. All names are pseudonyms.

Case	**Teacher**	**Belonging**	**Knowing**
(i) *Accepts and teaches CC using CER*	Sally	8 years at school	Accepts CC Uses CER
(ii) *Accepts CC but does not use CER*	Mary	13 years at school	Accepts CC Presents Claims and Evidence No reasoning

	Theresa	11 years at school	Accepts CC Presents Claims and Evidence No reasoning
	Wendy	5 years at school	Accepts CC Presents Claims No Evidence, No Reasoning
	Frank	2 years at school	Accepts CC Presents Claims No Evidence, no Reasoning
	Isabel	2 years at school	Accepts CC Presents Claims Presents incorrect E No Reasoning
	Margaret	1 year at school	Accepts CC No Claims, no Evidence, no Reasoning
(iii) *Does not accept nor use CC*	Catherine	20 years at school	Does not accept CC No CER
	Diane	8 years at school	Does not accept CC No CER

Case 1: Accepts and teaches CC using CER

Out of the nine participants, only Sally expressed accepting anthropogenic climate change and also presented climate change in her classroom using all three components of CER: Claim, Evidence, and Reasoning (Table 2). She framed her CC lessons similarly to the Scientific Uncertainty frame, or rather, she presented the high degree of scientific certainty of anthropogenic CC; i.e., she explained that there is overwhelming evidence that humans are changing the climate (Nisbet & Scheufele, 2009). Sally, whose academic background is in life sciences, had taught science for 10 years and has served as the 7th grade life sciences teacher at her school for eight years. While Sally grew up in this rural community, she did not currently live in the rural town where she teaches and instead has commuted over two hours every day from a major city for the last eight years. She recognized that CC divided communities, including rural citizens, who differ on their acceptance of climate science.

> *So, at the beginning of my career, I was perhaps less confident in the ways that I could use my credibility and I also had just sort of less of career stability as a probationary teacher [...] I used to really talk delicately about climate change because it still comes up from time to time. My politics and the politics of the community are not really aligned, and I don't really want to say politics, I want to say my acknowledgement of the truth and the community's acknowledgement of the truth don't align. [...]*

Sally expressed a change in her instructional delivery regarding climate change due to her increased sense of belonging in the school and rural community. As her professional security increased, her confidence in teaching CC increased. Sally acknowledged and accepted the scientific consensus of anthropogenic CC, and presented this in her classroom using the CER model.

> *I used to talk about this out a lot more delicately than I do now. Humans are causing climate change; we have a responsibility to reduce our impacts otherwise there will be consequences. I'm at the point that whatever I say, here is all the research that backs up what I said.*

Sally also acknowledged that as her professional security increased, even though her political views differed from her school community, she chose instructional methods that supported CCE. She, therefore, framed her lessons about climate change as being evidence-based to encourage students to engage in CER discussions while maintaining a sense of mutual respect.

> *I try to meet them with respect. Like, 'Okay, well, tell me, like what evidence?' Always framing it with like, tell me the evidence. So, 'What evidence do you have that this isn't true? Because here is some evidence, I have that this is the best explanation we have.' Like, 'We can definitely disprove theories and we have disproved theories before so, tell me, what evidence are you using?' 'Well, my grandpa said.' Or, 'I saw on the internet.' [...] And they teach research in 7th grade so that's also really helpful to me because we say like, 'Okay, did you run it through the tests? Like what website were you on? Was there an author?'*

Not only did Sally make claims about anthropogenic CC, provide evidence, and model reasoning through the use of "tests," she explained that she teaches students how to find reliable sources during the research process. Sally was aware that her students may go home and share curriculum content with their families.

> *I just always try to be mindful of not making judgement statements. Not saying like, 'People who believe this isn't true are stupid.'... because I don't believe that, also. And knowing and remembering that everything I say is going back to home, so, will I be ready to take that call? And that helps me to be delicate but still like fact based, science based.*

Even with the awareness that the parent community might not agree with her teaching, Sally described her change in perspective around making claims about climate change in a conservative community. *"About 3 years ago I decided to stop using euphemisms for human caused climate change[...] in rural areas they tend to skew more conservative [...]it was after I had attained non-probationary status and I felt a little bit more secure."* Sally was the only teacher out of the nine participants that unequivocally agreed with the scientific consensus of anthropogenic causes of climate change. She also had developed a CCE curriculum that used all three components of the CER model, which she felt comfortable using once her job security increased. Hence, as she felt like she belonged to her professional community, her confidence to teach CC increased.

Case 2: Accepts CC but does not use CER

Six participants fell into the second case because they agreed with the scientific consensus of anthropogenic climate change but did not use a Claim-Evidence-Reasoning model. Instead, these teachers varied in their instructional delivery of CER, some only provided claims and evidence, others provided claims without evidence, and others provided implicit claims or incorrect evidence. These teachers framed their CC lessons around the Conflict/strategy frame, as they presented CC as a dichotomous issue with two equally valid arguments regarding the causes of CC (Nisbet & Scheufele, 2009). This category exposes the patterns present among rural science teachers regarding the barriers and opportunities to CCE.

Lack of modeling scientific reasoning. Mary, for example, presented claims and some evidence about climate change, but did not model scientific reasoning for her students. Mary had a career as a park ranger before becoming an ESS teacher. She has taught at her school for 13 years while simultaneously serving as the assistant principal. Mary claimed to teach about anthropogenic climate change in her classroom by following the newly updated NGSS standards.

> *We get into earth systems and we will talk about how they interact, the impact water has on geology, impact of weather and climate on land. We talk about human impact on land. Farming, mining […] so I go inside the surface and then we do the atmospheric and so that's kind of how I do my earth science [...] Probably the biggest thing we talk about is greenhouse gases, climate change nationally.*

Classroom observation revealed the discussion of greenhouse gases, ozone depletion, photovoltaic smog, and other forms of pollution. During this classroom observation, Mary presented claims without evidence or scientific reasoning. Throughout both the lesson and interview, Mary conflated climate change and smog when asked about the greenhouse gas effect.

> *There's tons of pictures out there about atmospheric gases. I mean, even just the brown cloud in Denver. You know, most of the kids have been to Denver and have seen the brown cloud on a nasty day, so we talk about that.*

The repeated reference of the "brown cloud" over Denver implied a physical and symbolic distance between the rural community and the effects of climate change. While Mary presented claims and evidence of climate change in her classroom, she expressed framing climate change in her classroom so as to present "both sides," implying a lack of scientific consensus regarding anthropogenic climate change.

> *I just want to present both sides and then you know they can make up their own minds. It's touchy. It is a delicate thing, [...] my family is not agricultural [...] but I think that I just present them with information that they didn't have before and it at least just makes them think and that's what I really wanted to do too and make sure that you see every side.*

Mary believed that her lack of a rural identity and agricultural background affects how her students perceive her. Other participants in this category acknowledged how the conservative beliefs and agricultural-based economy of their rural communities shapes their framing as well as student response. Frank, an early career teacher with a national parks service and natural resource management background, who grew up in a rural town, described his experience:

> *You definitely get a sense that there are some of [the students] that are a little defensive, maybe, especially if their families work in the oil or gas industry. I think that as soon as the topic comes up, they'll kind of check out because they know exactly what you're going to say, and you're going to say that it's bad and that it's wrong and that it needs to go away, kind of stuff. So, even if you don't say that; even if you do try to just focus on facts, there are some students who will just feel attacked because the topic is being brought up by itself.*

Dichotomizing climate change. Beyond describing the presence of rural, conservative ideologies in the classroom, many participants in this category described framing CC as "presenting both sides," as Mary articulated. "Presenting both sides" was a common frame used for teaching CC to rural students. For example, Wendy, who has an academic background in chemistry and has taught at her school for five years (more recently becoming the only science teacher responsible for covering multiple grades) explained that *"A lot of the times we'd look up maybe pros and cons of climate change and videos of stuff like that, to where it kind of gives them both sides of the spectrum."* Although she used the word, spectrum, intimating that CC is not a dichotomous issue, she teaches it this way.

Another common frame that participants described using to teach CC was an "evidence based" approach. Frank described focusing on evidence but not reasoning:

> *It's very much just the facts. 'Here's the information. I'm not going to tell you to think one way or the other. That's on your end to critically think. But let's find the facts and the true information out there and then you make your decision based off of that.' Is really the encouragement and the approach that I take.*

Hence, Frank omits modeling scientific reasoning. An "evidence based" approach was how participants explained asking students to draw their own conclusions about CC data without helping them make meaning of it. Wendy described providing evidence and opportunities for her students to draw their own conclusions.

> *Instead of like telling them, 'there's climate change and it's bad, we need to do this,' it's more of, 'let's look at the things that are happening and how the data is changing throughout the years and what's maybe contributing to those changes, either positive or negative.' And so, yeah. I try to do that rather than tell them, 'this is my stance on climate change, and this is why.' I try to just give them the information, so they can kind of make their own decisions on climate change and things that they feel are positives and negatives.*

The teachers that described using an "evidence based" approach and letting students decide for themselves were either early-career teachers or had served at the school for only a few years. Frank, for example, was only in his second year of teaching at his school and had acquired his teaching license through an alternative licensure program. His approach to teaching climate change was designed to avoid defensive reactions from his students.

> *You know we got kids engaged, let's not disengage and start an argument to go off to the side. Let's sort of like...let's bring up the idea, let's talk about some of these aspects of it, but I am not going to harp in. I'm not going to put 'This is good, this is bad' on it. I'm going to kind of sort of like 'Hey, here's some things that we do, here's some things that are effective,' if you want to talk about it and get more in depth and have a discussion on it, great, but if not, here's sort of our presentation of how it works.*

Hence, Frank presented climate change as a scientific topic for which he wanted students to focus on facts, rather than opinions. He anticipated potential classroom management issues, and therefore wanted to be in control of the classroom narrative around CC.

Sense of belonging. Teachers spoke of how their sense of belonging in their school community affected their choices about how to teach CC. For example, Theresa, who had taught biology at her school for 11 years described how her rural identity affects her teaching approach.

> *When we get into some of the climate change stuff there's a very, it's the same thing as if you were teaching evolution in biology, there's a very conservative push-back. But I grew up in a rural town, and I come from the same conservative background, so I think I have developed arguments that the kids accept.*

The sense of belonging extended beyond shared rural identity; participants also described their sense of belonging to their professional community. Thus, their feelings of professional security also affected their CCE decisions. When describing her experience of student and parent responses to her teaching, Theresa described how her growing professional experience has shaped her sense of security in her position.

> *I haven't had any real pushback to any of those arguments in, gosh, several years. When I was brand new, I used to get, you know, 'What church do you attend?' Like I couldn't possibly teach their children if I didn't go to the right church [...] I've been around long enough that, 'What? What are you going to do? Bully me? Into what?' But students don't come in with an attitude like they're going to argue anymore.*

Although most of the participants were classified in this category, as the narrative evidence above demonstrates, there was great variability in their CCE decisions, especially in terms of how they presented claims, evidence, and reasoning to their students. Moreover, these participants' sense of belonging in their community and profession influenced their instructional and curricular decisions around CCE.

Case 3: Does not accept nor teach CC

Two participants were classified in the final category, '*Does not accept nor teach CC*,' which describes teachers who do not accept the scientific consensus of anthropogenic climate change and choose to omit CCE from their curriculum. Therefore, these teachers do not model

CER for their students. These teachers framed their CC discussions around the scientific uncertainty frame, but unlike the teacher who accepted and taught CC, these teachers claimed there was not enough data to draw definitive conclusions regarding anthropogenic climate change (Nisbet & Scheufele, 2009). For them, any level of uncertainty of scientific claims warranted not teaching CC in their classrooms.

Diane had taught grades 5-12 science for eight years and described a high sense of belonging to her school community, as all of her children attended the school. Diane was responsible for covering the science curriculum for a wide variety of disciplines and age groups (i.e., chemistry, physics, biology, earth science, etc.). When asked about Diane's climate change curriculum, she admitted to not teaching it. *"Well actually I'm on the fence about that myself [...] I really don't have [climate change curriculum]. I know it's a topic I need to address but wanting to present it from a balanced approach."*

Upon reflecting on her lack of climate change curriculum, Diane reflected on her own views on the scientific consensus of climate change and her abilities to teach it. She acknowledged the role of anthropomorphic effects on changing climates and Earth systems, *"And that one is kind of a tricky one, you know. [...] I don't doubt that humans are impacting our ecosystems and our climate, I don't…. I'm not against that thinking."* However, she also admitted not being clear about the scientific concepts and evidence used to support scientific consensus about CC. *"But I also know that we have such a short data set of change on our earth so I'm kind of confused actually as to how to approach that one in a way that kind of works for the mindset here in Branson."* She then followed by explaining that rural communities feel targeted as causes of CC.

> *Because I think rural communities also view that differently than city communities. Um, you know, there is such an attack right now on agriculture as being a culprit or a source of climate change and they have proven it's not the cows farting and burping that is causing the methane cloud, but you know, and it's cows grazing that*

actually helps the grasslands, so they're trying to vilify cattle and then when you live in a cattle-centric community [...] Their parent's livelihoods are around the fact that cattle are grazing. [...] so when it comes to climate change, I feel like I have to take a different tact so I haven't figured out the right balance, so I don't teach it frankly.

While Diane's sense of belonging to her rural school community was high, she expressed that her content knowledge and confidence with climate change as a scientific concept was not robust enough to feel that she could effectively teach her students. Furthermore, she acknowledged that she struggled to balance teaching content and validating her students' sense of belonging, a feeling to which she could relate.

Another teacher with a strong rural identity, Catherine, had taught various science disciplines for nearly twenty years. When asked about her approach to teaching climate change, Catherine expressed doubt about anthropogenic climate change and recalled a story of a recent trip to Alaska.

Last year, I went to Alaska and you know what's in the news is global warming and climate change. And I don't know what your impression of it is, or your own opinions are, but, previous to that all we heard is a one-sided thing that like, you know humans are burning fossil fuels and that's the whole cause of this. So I go to Alaska– just a pleasure trip with me and my husband– and we are in Glacier Bay Alaska and the little guy is doing his speech and he says, 'And Earth has been warming for the last thirteen-thousand years,' and I'm pointing out the glaciers, and he's like 'Yes, the Earth has been warming for the last thirteen-thousand years' and I said, 'Umm because what's been in the news is that it has been us for the last twenty years. And that's it.' And he was like, 'Oh no, oh no, no, no.' And I've taken enough Earth Science myself to know we've been in and out of ice ages and um, so… anyways when I see stuff like that, I throw it out to the kids. Something you may want to know because you don't see it in the news. And are we responsible for some of it? Probably, but let's get the full picture here before we try to solve the problem, because who knows what that problem may be.

This anecdote illustrates not only Catherine's doubt in anthropogenic climate change, but how she accessed information about it. She gathers information from the news and from her personal experiences. Her reference of "*the little guy doing his speech*" minimized his expertise. She did not explain who the speaker was and why she questioned his trustworthiness.

Furthermore, what is missing from conversations with Catherine was any mention of CCE curricular materials developed by scientists or other ESS education experts. Catherine was responsible for teaching climate change in previous years to students and described her curriculum as spending two to three classes watching "An Inconvenient Truth" and discussing it with her students (Gore, 2006). *"When we first started teaching [climate change], that was when Al Gore's movie came out and that was always a topic [...] I wanted [my students] to be critical thinkers, so I don't want them to buy [Al Gore's] opinion."* And although Gore presents scientific evidence in his film as evidence to support his claims that humans are partially responsible for changing climates, Catherine interpreted his claims to be opinions that were not fact-based.

Like other teachers, Catherine described her CCE approach as a dichotomous issue for which "both sides" are valid and worth discussing. She encouraged her students to engage in CC debate, and she focused more on "who is to blame," rather than on scientific consensus.

> *I don't want them to buy into the 'we caused it all movement' because the earth has been warming for 12,000 years, and we didn't have much to do with it until the last few hundred years and so … I kind of like, there is this scene in one movie, 'no opinions will be suppressed here today,' so I try to bring that to both sides, you know, whichever side you're on kind of thing.*

Like Catherine, Diane felt that a dichotomous presentation of climate change made sense, although she had not actually implemented climate change lessons. She felt she needed curricular materials first.

> *I probably would present both sides. The way that I thought of teaching climate change is maybe doing more of a debate, but I don't have enough brain space to figure that out. I would have to find something. You know something that has already been created that I can just use.*

Both of these two participants did not agree with and/or expressed doubt about the scientific consensus of anthropogenic climate change. They also lacked or did not use a curriculum that modeled CER. Because both of these teachers are veterans in their profession (having taught in their respective schools for 8 and 20 years), they were the only teachers responsible for teaching climate change in their districts. As a result, students in their school districts receive little or no education on climate change, even though it is mandated by the state academic standards.

Summary

In summary, one teacher (Sally) both accepted anthropogenic climate change and used the CER model in her classroom. Using the frame of scientific uncertainty, she explained to her students that scientific evidence has decreased scientific uncertainty of anthropogenic CC. The majority of participants (n=6) accepted the scientific consensus of anthropogenic climate change but only presented certain parts of the CER model. Their instructional approaches were framed around Conflict/strategy and presented CC as a "two-sided story." Two teachers (Mary and Theresa) presented only claims and evidence, while the remaining four teachers in this category only partially presented the CER model. None of these six teachers modeled scientific reasoning, based on their own descriptions of how they teach climate change. Two teachers neither accepted, nor taught climate change using the CER model. Like Sally, they used the scientific uncertainty frame, but in ways that highlighted that any level of uncertainty was problematic, so they avoided any CC instruction in their classrooms.

Discussion

This study sought to identify the opportunities and barriers to climate change education for rural science teachers, and how this affected how teachers frame their CC lessons. The decision of rural Colorado science teachers to teach climate change in their classrooms is influenced by 1) their understanding of climate science, 2) their acceptance of human-induced changes to Earth systems, and 3) their sense of professional security related to belonging in rural social and professional communities. As a result, some teachers used the recommended model by both the national and state science education communities, while others chose not to do so. Teachers who were confident in both their understanding of climate change and their sense of belonging were more likely to implement climate change lessons using a scientific argumentation model, like CER. To help organize the range of instructional choices that were the result of teachers' perceived opportunities and barriers, three cases were described: *Accepts and teaches CC using CER*, *Accepts CC but does not use CER*, and *Does not accept nor teach CC*. It is noteworthy that only one participant in this research study fell into case 1: *Accepts and teaches CC using CER*. Because two teachers fell into the case 3 (*Does not accept nor teach CC)*, it stands to reason that there are major barriers to CCE in these school districts.

The major opportunities and barriers to CCE for teachers can be explained by their content and pedagogical knowledge (*knowing)* and their affiliation with their professional and personal communities (*belonging*). *Knowing* refers to teachers' confidence and competence with climate change curriculum, which are known to affect teacher proficiency in their subject (Ferguson & Womack, 1993**).** *Belonging* refers to teachers' sense of belonging in both their professional, school community as well as their rural community. The findings of this study present three cases of instructional methods for CCE (Case 1: *Accepts and teaches CC using CER*, Case 2: *Accepts CC but does not use CER*, and Case 3: *Does not accept nor teach CC*) as falling on two axes that represent the spectrum of *belonging* and *knowing,* as seen in Figure 1.

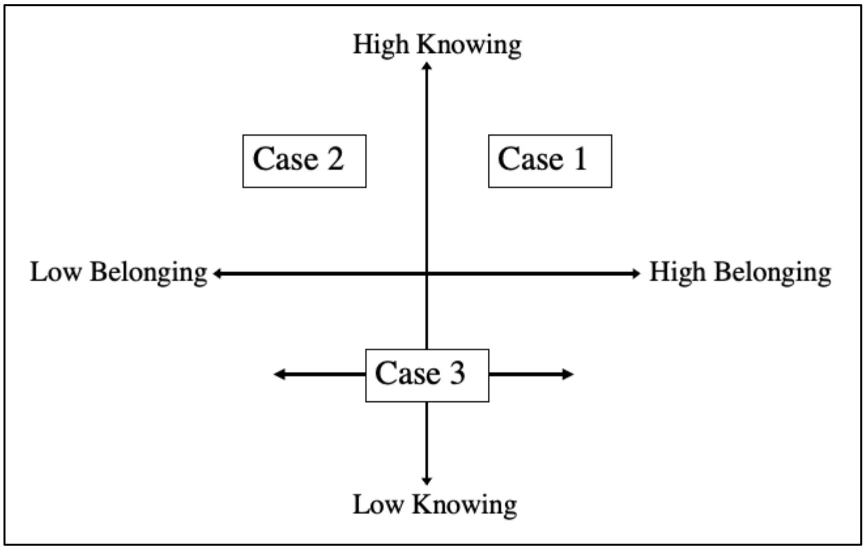

Figure 1. How teachers' sense of belonging and knowing impact instructional choices with CC lessons and define three cases. Case 1 is categorized by high belonging and high knowing, Case 2 is categorized by low belonging and high knowing, Case 3 is categorized by low knowing, and a spectrum of belonging in both rural and professional identity communities, as represented by a horizontal arrow along the x axis.

Studies show how teachers' sense of belonging fosters emotional wellbeing as well as contributes to their professional resilience and identity (Cornu, 2013; Skott, 2019). Furthermore, rural teachers' *knowing* and *belonging* can collectively affect their sense of teacher agency (Wright & Balgopal, unpublished). When teachers have more curricular agency, it affects how they frame SSIs, such as climate change (Wright et al., in revision). Teacher agency, or how past experience relates to one's orientation toward new, future possibilities, has been shown to affect teacher self-efficacy as well depend on one's environmental context (Czerniak & Chiarelott, 1990; Emirbayer & Mische, 1998; Priestley et al., 2012). When teachers believe that they can learn from their past endeavors to teach future lessons in ways that are in alignment with their knowledge and sense of security, they achieve curricular agency (Balgopal, 2020). However, when teachers feel insecure about their own knowledge and sense of belonging, they are likely to shy away from teaching content that might make them feel more vulnerable (Balgopal, 2014).

Knowing

Teachers' *knowledge* presented a major opportunity for CCE, namely when it increased teachers' confidence because they could demonstrate competence around climate science. When teachers demonstrated self-described confidence and competence with CCE, they were more likely to include all three aspects of CER in their teaching, as seen in Case 1 (Figure 1). This connection is key for promoting students' climate literacy because studies show that teacher competency and proficiency in subject matter is linked to student understanding (Ferguson & Womack, 1993).

Teachers who did not feel confident or competent with CC tended to avoid teaching it even if they were the only science teacher in their school. This avoidance likely creates a knowledge gap for large groups of students in these teachers' school districts. Teachers who expressed personal doubt of the scientific consensus of anthropogenic climate change also tended to avoid teaching CC, as was stated in Diane's interview. This inference is supported in other research regarding links between doubt in anthropogenic climate change and lacking pro-environmental behaviors (McCright et al., 2016; Shwom et al. 2017). Even so, Diane expressed that, with sufficient CC curriculum and professional development, she would be open to teaching climate change.

Belonging

Teachers' sense of belonging to 1) their professional community, 2) their school and parent community, and 3) the rural (social) community all affected their instructional choices. As seen in Case 1, teachers expressed more comfort making claims about CC to their students if they felt a greater sense of professional security (Figure 1). Teachers also expressed more freedom to make claims about CC when they felt a greater sense of belonging in their social and parent communities. While sense of belonging is well studied at the student level, especially with regards to identity

(Hurtado & Carter, 1997), further research is needed on how teachers' sense of belonging affects their communication and instructional choices.

As seen in Case 2, however, teachers who did not feel a strong sense of belonging to their professional community did not make strong claims about CC (Figure 1), especially how anthropogenic sources contribute to CC. Earlier-career teachers or those with fewer years of experience at their school admitted that they avoided making major claims about anthropogenic CC and simply presented evidence to their students. In other words, these teachers omit modeling scientific reasoning to their students, which is expanded upon later in the discussion.

Teachers' sense of belonging to the school community and acceptance by the parent community affected their instructional decisions. Because many families of the students worked in the agricultural industry, teachers tended to avoid making claims that may have implicated farming and ranching industries and their roles in anthropogenic CC. However, teachers who taught for more than 5 years at their school expressed a sense of belonging in their school community and an indifference to the parent community's potential response to CCE. This sense of belonging can be forged through relationships with other teachers, teacher work practices, as well as by individual attitudes of teachers (Pesonen et al., 2021).

Additionally, teachers' sense of belonging to their rural community presented as a barrier in some instances, as teachers who expressed a strong rural identity and agreement with the parent community tended to have greater alignment with conservative ideals, and therefore less acceptance of anthropogenic climate change. This is represented in Figure 1 with the use of a horizontal line through Case 3, which represents the variability to how teachers' sense of belonging to their rural identity in Case 3 affected instructional choices (Figure 1). The alignment of teacher perspectives with the parent community lessened when teachers resided in urban communities.

Teachers who were more removed from their rural community (i.e., commuted to work from an urban area, did not grow up in a rural community, or newly relocated to the area) tended to agree with the scientific consensus of anthropogenic climate change. Studies show that political affiliation is a significant indicator of acceptance of anthropogenic climate change as well as pro-environmental behavior (Marquart-Pyatt et al., 2014; McCright et al., 2016). Without further investigation, though, this study is not making the claim that living in rural communities alone is what shapes teachers' understanding of CC.

Framing

Knowing and *belonging* determine rural teachers' access to CCE and their sense of agency, which then informs how they frame CC to their students. Studies have shown that teachers have varying agency in acting as changemakers in curriculum development and this is dependent on context, but also is affected by personal beliefs and attitudes towards change (Balgopal, 2020; Priestly et al., 2012). I argue that, beyond personal beliefs and attitudes, teacher agency is also affected by a sense of belonging. In the context of this study, we perceive teacher agency as teachers' ability to teach about climate change without barriers. The various barriers present in rural schools, however, lead teachers to rely on certain communication frames when presenting climate change. As previously mentioned, Nisbet and Scheufele (2009) identified eight common science frames used by journalists and policymakers to communicate science topics (Social progress, Economic development/ competitiveness, Morality/ ethics, Scientific/ technical uncertainty, Pandora's box/ Frankenstein's monster/ runaway science, Public accountability/ governance, Middle way/ alternative path, and Conflict/ strategy), but these were not developed for analysis of high school science instruction (Appendix B). However, the frame typology is relevant in rural science classrooms especially with regards to CC lessons. More specifically, this study reveals how rural science teachers frame their CC lessons using both the Conflict/ strategy and Scientific/ technical uncertainty frames. Nisbet & Scheufele's Conflict/ strategy frame manifested as a "Both Sides" frame in the rural classroom, while the Scientific/ technical uncertainty frame manifested as "Uncertainty" frame, as referenced in Figure 2. Interestingly, rural science teachers may be influenced by how they see media frame CC and then adopt such strategies in their own curricula. Nation and Feldman (2021) demonstrated that even if teachers accept CC, they are hesitant to teach it. Further studies of why teachers choose to frame CC in certain ways is warranted.

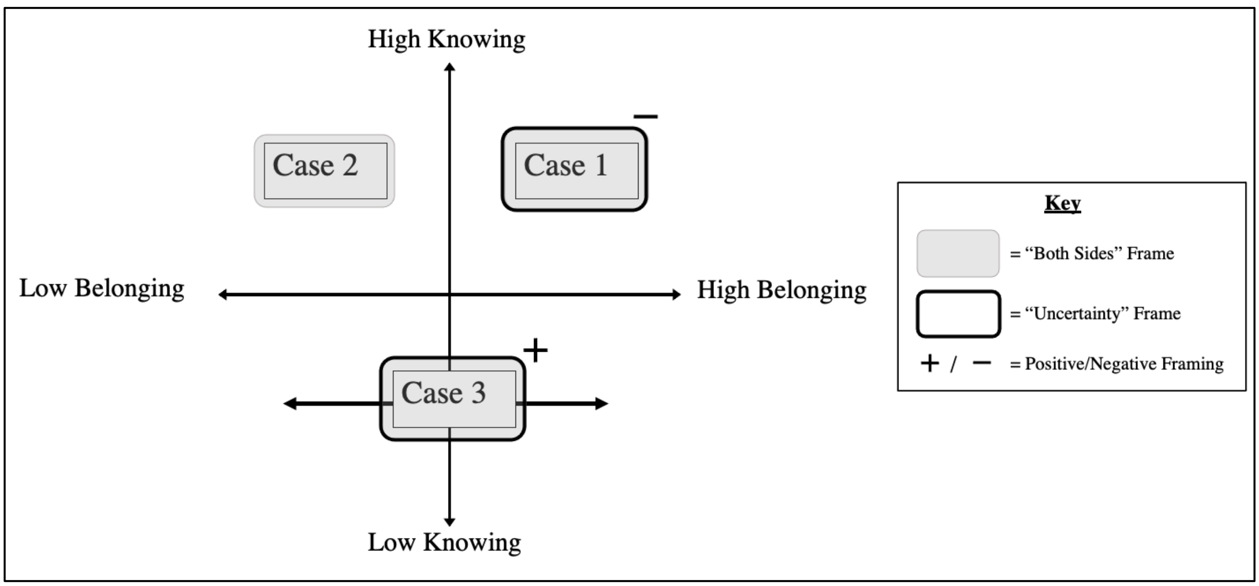

Figure 2. How teachers use of framing ("Uncertainty" and "Both Sides") apply to the three cases of instructional methods as well as along the spectrum of *belonging* and *knowing*. All three cases use the "Both Sides" frame (as indicated by gray shading). Case 1 and Case 3 use the "Uncertainty" frame, as indicated by the outlined box. Case 1 uses the uncertainty frame with a negative lens (-), while Case 3 uses the uncertainty frame with a positive lens(+).

Teachers belonging to all three cases reported teaching climate change by presenting "Both Sides," where teachers discuss the scientific debate over the anthropogenic sources of climate change with their students, as seen in Figure 2 (IPCC, 2018; Oreskes, 2005; Plutzer et al., 2016). This finding is supported by Plutzer et al. (2016) in a study that surveyed climate change education in schools across the country. This study found that many teachers reported presenting "both sides" of the climate change debate when teaching, and nearly 20% of the respondents "did not know" the level of scientific consensus of anthropogenic climate change (Plutzer et al., 2016). When teachers present the causes of climate change as an ongoing, unresolved debate, this delegitimizes the level of consensus and evidence toward our understanding of anthropogenic causes of climate change, and leaves space for student uncertainty (Plutzer et al., 2016). This is most akin to the Conflict/ strategy frame proposed by Nisbet and Scheufele (2009), that posits science topics as having two equally valid schools of thought and therefore "limited expert agreement" (Nisbet & Scheufele, 2009; Nisbet, 2010).

Participants in this study named several reasons for presenting "both sides," including anticipating classroom discussions that were controversial, avoiding making claims that would elicit a response from the parent community, acknowledging that they were not certain of scientific consensus and did not feel confident interpreting the evidence themselves. This raises the question of the role of argumentation and debate in the science classroom. While argumentation can be a useful teaching method, the use of argumentation and debate when presenting climate change may cast doubt upon the amount of evidence and level of scientific consensus (Dawson & Carson, 2018; Plutzer et al., 2016). Others argue that presenting the social controversy surrounding the climate change debate acknowledges the sociocultural diversity in the classroom (Walsh & Tsurusaki, 2014).

Teachers in both Case 1 (*Accepts and teaches CC using CER)* and Case 3 (*Does not accept nor teach CC)* both framed their CC lessons using the "Uncertainty" frame, but in opposite ways (Nisbet & Scheufele, 2009). In other words, Sally, the only participant belonging to Case 1 (*Accepts and teaches CC using CER),* presented CC with no uncertainty (or negatively framing), whereas Diane and Catherine, both belonging to Case 3 (*Does not accept nor teach CC)*, framed

CC with significant scientific uncertainty (positively framing) (Figure 2). These two opposing uses of this frame highlights how *knowing* climate science, both teacher confidence and competence, can impact how science is communicated in the classroom.

Teachers in Case 2 (*Accepts CC but does not use CER)* also reported using an "evidence based" approach when teaching climate change in their classrooms. To avoid making claims about climate change, teachers reported presenting evidence to their students revealing the correlation between fossil fuel emissions and average global temperature over time, but not analyzing this evidence to make claims or model reasoning. Studies show that a constructivist approach to teaching climate change, which emphasizes an evidence-based approach, can be successful in student learning (Rule & Meyer, 2009). Studies also show that science teaching and student learning is most successful when it goes beyond just the presentation of facts, but also incorporates the process of scientific reasoning (Brown et al., 2010; Walsh & Tsurusaki, 2014). In fact, the National Resource Council (2007) and the American Association for the Advancement of Science (1993) assert the fundamental need for science education to incorporate scientific reasoning to encourage rigorous and meaningful science learning. There is overwhelming evidence that shows successful science teaching goes beyond the presentation of facts or evidence, but rather models scientific reasoning. It stands to reason that the "evidence based" approach participants in this case reported is an insufficient method for fostering a successful learning environment for their students and omits a fundamental piece of science teaching. Therefore, I argue for the creation of specialized professional development resources focusing on modeling scientific reasoning in CC lessons, which is expanded upon in the implications section.

The role of reliable sources and accredited evidence becomes increasingly important for teachers that use the "evidence based" approach, as many of these teachers reported involving student-led research projects as a centerpiece of their CC curriculum. Studies show the increasing difficulty for the public, not just students, to find and evaluate reliable sources on the internet, especially for socially controversial topics (Coiro, 2011; Damico & Panos, 2016; Lankshear & Knobel, 2006). When teachers use an "evidence-based" approach, and when they leave the process of finding and assessing evidence to their students, it is all the more important that they teach science literacy and assessing reliability in online sources (Damico & Panos, 2016).

This study reveals the opportunities and barriers present to climate change education in rural classrooms, as well as the communication frames used by rural science teachers. The frames used by rural teachers present opportunities for professional development resources specialized for climate change curriculum in rural schools, which is expanded upon in the implications section.

Implications

Teachers need resources to teach climate change and use both the socioscientific issue and claims-evidence-reasoning models in ways that promote critical thinking. By providing teachers with both resources and professional development, scientists and science educators can ensure that American high school graduates are climate literate. Rural teachers in particular would benefit from specialized professional development resources that work to increase opportunities and decrease barriers to CCE (Howley & Howley, 2005). Unfortunately, many professional development workshops offered by universities are too far from rural schools, and as a result, rural teachers are not the primary target audience (Wilson et al., 2010).

One of the major barriers to CCE in rural classrooms is teachers' personal doubt or uncertainty of the scientific consensus of anthropogenic climate change, which implies a need for increased subject proficiency in climate science for rural teachers. Studies show that teacher proficiency in their subject contributes to student learning (Ferguson & Womack, 1993). Teachers would also benefit from professional development and curricular resources for lessons on resource reliability for student research efforts (Damico & Panos, 2016). Beyond teacher acceptance of anthropogenic climate change, however, the incorporation of modeling scientific reasoning in the classroom presented as another major barrier to CCE in rural classrooms. This implies a need for professional development resources and opportunities for rural teachers to create CC curriculum structured in CER format. Participants even requested CCE lesson plans modeled in CER format available for use.

There is a call for a research-based approach to professional development, especially for climate change education (Hestness et al., 2014). By learning how rural science teachers communicate CC in their classrooms, these data can be used by communication experts to collaborate with teacher educators on how to effectively teach CC and other SSIs. This study highlights the need for specified professional development resources for our rural teachers and provides suggestions and direction. Moreover, this study underscores the need for professional development designed for the specific multifaceted needs of rural science teachers. They not only need opportunities to strengthen their content knowledge of CC and the CER model, but they need teacher educators who recognize the perceived barriers they face (Tytler et al., 2011). Tytler and colleagues (2011) suggested designing rural science teacher professional development explicitly around discourse communities (professional, school, and social), allowing teachers to acknowledge what perceived barriers and opportunities influence their approaches to teaching climate change.

In efforts to increase climate literacy for future generations, and therefore mitigate the impacts of CC on our social ecological systems, scientists and science educators must understand the needs of rural science teachers so they can, in turn, support rural learners.

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APPENDIX A: RURAL COLORADO STUDY CONTEXT

Northeastern Colorado

I have recruited research participants, rural science teachers (n=9), throughout eastern Colorado from school districts including Akron, Briggsdale, Idalia, Yuma, Fort Morgan, Branson etc. The socioeconomic, cultural, and political context of the eastern plains of Colorado tends to differ dramatically from other areas of Colorado, especially those on the front range. For example, Weld County, which includes many of the aforementioned school districts, is a predominantly economically and politically conservative county where the beef processing industry (JBS Swift & Company) acts as the major employer for a total of 4,520 local employees (WCMEL, 2017). Of the ten largest employers of Weld County, four of them are of the oil and gas development industry, specifically Halliburton Energy Services, Noble Energy, Anadarko Petroleum, and Select Energy Services (WCMEL, 2017). According to the Yale program on Climate Change Communication (2019), only 66% of residents in Weld county believe climate change is occurring, and only 50% believe it is caused mostly by human activities (Leiserowitz et al., 2019; Marlon et al. 2016). Morgan County, directly southeast of Weld, is similar in economic breakdown, with the largest employment industries being agriculture (predominately Cargill Meat Solutions Corporation) and the oil and gas extraction industry (Data USA, 2020). Beyond the major employers of northeastern counties in Colorado, many ranchers supplement their income by leasing private land to the oil industry for fracking purposes. This is due to the mineral rights legislation in Colorado, where private landowners hold the rights to surface minerals (sedimentary and fluid) under their land, which includes the oil and gas wells (VCBB*,* 2019).

Most rural counties tend to view the K-12 school in their district as a central location for community engagement. Schools serve as a meeting place for many rural school districts, with its central location and diverse participation from citizens across the county. All of this makes Northeastern Colorado a particularly interesting place to study earth system science teaching and the implementation of the new ESS academic standards.

Agriculture and Ranching in Colorado

The agriculture and ranching industries are fundamental contributors to the economy of eastern Colorado. Livestock is one of the largest contributors to greenhouse gas emissions, totaling 14.5% of global anthropogenic greenhouse gas (GHG) emissions (FAO, 2020). Over 31 million acres are used for agriculture or ranching operations in Colorado (FAO, 2020). The processes of crop cultivation and livestock production contribute to greenhouse gas emissions in a variety of ways. Carbon dioxide (CO_2), nitrous oxide (NO_2) and methane (CH_4) are some of the largest GHG contributors from these industries, with other factors such as land use change and carbon sink removal contributing to emissions. With many community members in these rural schools associated with agriculture and ranching operations, it poses a difficult task for rural teachers who have to holistically discuss GHG emissions in ways that do not alienate or target students or families that ranch.

Hydraulic Fracking in Colorado

While fracking has a contentious history and is widely common throughout Colorado, the oil and gas industry plays an important role in greenhouse gas emission and contributions to carbon dioxide concentrations in the atmosphere (IPCC). This is an important piece to how humans contribute to climate change, which is now a part of Colorado Academic Science Standards. Hydraulic fracturing (fracking) has been implicated in anthropogenic climate change (Evensen & Brown-Steiner, 2018). Like ranching, the energy and oil industry is an important source of income for rural Colorado communities. The presence of the oil and gas industries throughout these rural counties likely helps shape rural citizens' views on earth system science topics. According to the New York Times (2018), drilling applications rose 70 percent in 2018 in Colorado (Turkewitz, 2018). These drilling locations (wells) are spread throughout the state with many producing wells in Larimer County and the Pawnee National Grassland (Turkewitz, 2018). The four major companies responsible for the majority of drilling operations throughout Colorado include Occidental Petroleum Corporation, Noble Corporation, PDC Energy, and Extraction Oil & Gas (Markus, 2019).

Hydraulic fracking produces nearly 43 percent of the oil and 67 percent of the natural gas production in the United States (USDE, 2012). Oil and gas companies establish well sites by drilling into sediment between 5,000-10,000 feet below the earth's surface, below groundwater aquifers (IPAA, n.d.). Once the drilling is deep enough, the drill extends horizontally to inject a fluid (water, sand and a mixture of chemicals dependent on well site) at a high pressure into shale to create fractures in the rock. Shale is a non-porous, impermeable rock that, once injected with this high pressure liquid, becomes more permeable allowing for gas extraction. The shale releases natural gas that would otherwise be impossible to extract from this "unconventional reservoir" (USDE, 2012). Hydraulic fracking uses large amounts of water for extraction that requires costly transportation to the well site. It is also known to cause localized earthquakes due to the high pressure drilling far below the earth's surface, resulting in earthquakes and tremors in areas of the country that are not prepared for earthquakes due to their distance from natural fault lines. There are regular fires that break out at industry sites. Furthermore, the chemicals used in the fracking fluid are, for the most part, unregulated and hold the potential to produce carcinogens that may escape and contaminate the groundwater aquifers (USDE, 2012; Harrabin, 2016).

The majority of fracking operations in Colorado operate on federal land leased to oil and gas companies, specifically from the Bureau of Land Management (BLM) (BLM, 2020). Private landowners throughout Colorado are also able to lease their land to fracking operations as regulated by the Mineral Rights Act, allowing land owners the ownership over the minerals under their property (Zwickl, 2019). As of 2018, BLM land leased out over two million acres of land to oil and gas extraction with over half of this area containing active, producing wells (BLM, 2020). While these sites produce a large portion of the natural gas resources in the US, a portion of this money earned from drilling operations in Colorado are given to the Colorado public school system, interestingly enough (VCBB, 2019). According to the Colorado Petroleum Association, the oil and gas industry raises "more than $600 million per year in revenue for K-12 and higher education" for Colorado public education (VCBB, 2019). This poses an interesting relationship between oil and gas industries and the public school systems in Colorado. Furthermore, many new drilling operations are placed in close proximity to schools, such as the 24-well project near Bella Romero Academy in Weld County (Turkewitz, 2018) located 828 feet from the school campus. The ongoing debate over the regulation of drilling operations in Colorado has compelled communities throughout the front range to push for legislation that minimizes fracking presence in urban and suburban areas (Turkewitz, 2018). In 2016, the Colorado Supreme Court ruled against local government prohibitions on hydraulic fracking, granting power to the state law to regulate extraction (Turkewitz, 2018).

APPENDIX B: NISBET & SCHEUFELE'S (2009) SCIENCE FRAME TYPOLOGY

Table 3. A typology of frames applicable to science-related policy debates (Nisbet & Scheufele, 2009)

Frame	Definition of science-related issue
Social progress	Improving quality of life, or solution to problems. Alternative interpretation as harmony with nature instead of master, "sustainability"
Economic development/competitiveness	Economic investment, market benefits or risks; local, national, or global competitiveness
Morality/ ethics	In terms of right or wrong; respecting or crossing limits, thresholds, or boundaries
Scientific/ technical uncertainty	A matter of expert understanding; what is known vs. unknown; either invokes or undermines expert consensus, calls on the authority or "sound science," falsifiability, or peer-review
Pandora's box/ Frankenstein's monster/ runaway science	Call for precaution in face of possible impacts or catastrophe. Out-of-control, a Frankenstein's monster, or as fatalism, i.e., action is futile, path is chosen, no turning back
Public accountability/ governance	Research in the public good or serving private interests a matter of ownership, control, and/or patenting or research, or responsible use or abuse of science in decision-making, "politicization"
Middle way/ alternative path	Around finding a possible compromise position, or a third way between conflicting/polarized views or options
Conflict/ strategy	As a game among elites; who's ahead or behind in winning debate; battle of personalities; or groups; (usually journalism-driven interpretation.)

APPENDIX C: INTERVIEW PROTOCOLS

Interview Protocol 1

Background Information: Before we get started, I'd love to know a bit more about your experience as a rural science teacher.

1. Name:
2. Current school:
3. Could you please describe your teaching background?
4. How many years have you been at this school?
5. How many years have you been teaching total?
6. What are the current classes & grades that you teach?

Information About Your School: I'd like to know your perspectives about your school and community. I know that each district has different philosophies, management styles, and community relationships.

1. Please describe your school and school district.
    a. Examples: class length, average class size, scheduling for students, anything unique about your school.
2. What academic standards are science teachers expected to follow in lesson planning?
3. Can you explain how teachers are held accountable to standards? In other words, does the administration or the district curriculum visit with science teachers?
4. Are you expected to send your lesson plans or have classroom observations?

Earth System Science Curricula: I'd love to know more about your Earth System Science (ESS) curricula and your thoughts on the new Next Generation Science Standards.

1. In which classes/units do you teach about Earth System Science?
2. Could you please describe what materials you use to teach about Earth System Science in the classroom? What about human-environmental interaction lessons?
3. Could you please describe how you assess your students in ESS units or lessons? Does your school district require common assessments be used in ESS classes? What about human-environmental interaction lessons?
4. Please describe your instructional strategies when teaching ESS lessons.
5. How would you describe your students' interest in learning about ESS lessons? What about human-environmental interaction lessons?

Next Generation Science Standards: As you may or may not be aware, the Colorado Department of Education (CDE) has adopted revised Next Generation Science Standards.

1. Can you tell me what your thoughts are on the revised ESS standards?

2. What areas in your curriculum do you think may need modification to align with new standards?

3. Have you thought about modifying your curriculum to accommodate the new state science standards? What resources would you need to help you do this?

4. How do you think CSU science teacher educators can support rural science teachers?

6. Are there other teachers or colleagues at your school that teach Earth System Science standards?

Interview Protocol 2

Before I begin asking you about ESS teaching, I want to acknowledge that teaching has transformed this year during the pandemic. I would first like to ask a few general questions about your experiences teaching using modified instructional strategies and delivery.

Teaching and COVID-19:

1. Reflecting on your experience teaching during the Covid-19 pandemic, can you tell me what have been the biggest challenges? What have been some new opportunities? As a science teacher? As a rural community member? How do you feel about safety measures in the classroom?

2. How did your school support you while teaching online/ or in a hybrid format? What could they have done differently or better?

3. How do you think CSU could/can better support you while teaching under the pandemic?

Earth System Science Curricula:

1. What ESS topics have you covered this year?

2. How did you decide which topics in ESS to prioritize and why? [Were these decisions you made on your own, or did you have to confer with other teachers, administrators, or parents?] [Are there topics for which you would like to have more content knowledge?]

3. Can you please describe how you model scientific reasoning in your ESS lessons for students? [For example, do you use the claims-evidence-reasoning model, or another kind of teaching model for scientific reasoning? If so, why?] [Are there some ESS topics for

which you are not sure how to model reasoning? Would you like supporting materials or PD in these areas?]

4. Now that CC is part of the state science standards, can you describe how students, administrators, and parents respond (support or challenge) when you teach CC lessons? What is the overall student response when teaching about climate change or ESS topics? How do parents respond when you teach about climate change or other ESS topics? [for example, do they challenge this topic, provide examples from their lives, or praise you for teaching this? Alternatively, do you feel that students are responsive to learning about CC?] Can you describe your community?

6. Do you incorporate guest lecturers in your ESS lessons? If so, what opportunities does that provide for your classroom?

7. Please describe the type of support you receive from your school district, school, colleagues, and parents, as you develop and deliver ESS lessons?