Climate Change Resources for Today's Alberta Classroom

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Abstract

Climate change is an important issue and educators have a responsibility to prepare students to face the challenges and future changes that climate change presents. Unfortunately, public uncertainty about the extent and causes of climate change and the interdisciplinary nature of the climate change topic present significant barriers to effectively teaching this topic. In spite of the Alberta *Science 10 Program of Studies* including climate change, Science 10 teachers in Alberta tend to de-emphasize, or even omit, the teaching of the climate unit. Authorized Science 10 teaching resources are outdated, do not address some major misconceptions about climate change, present limited actions to address climate change, and in one case, even perpetuate uncertainty about some aspects of climate change that are considered very certain by the scientific community. This Master's project aims to detail the strengths and limitations of the current authorized climate change resources, and to identify teaching and learning resources that are able to supplement these resources. By finding flexible, accessible, and engaging climate change resources, teachers in Alberta may be better equipped to address misconceptions and will hopefully be more encouraged to give the topic of climate change the emphasis that it deserves.

Keywords: climate change, Alberta, uncertainty, interdisciplinary, misconceptions, teaching resources

Background

In my experience working in several large urban Alberta high schools, I found that teachers either de-emphasize or even entirely omit teaching the climate unit in Science 10. In my role with Alberta Education, I am often asked to work with teachers across the province on science assessment. One thing I have noticed is that many teachers' summative assessments do not include climate content; one can assume that if climate change is not deemed important

enough to be assessed on end-of-unit or end-of-year assessments, then it is likely not being taught. When I have talked to my teaching colleagues or to teachers from around the province about climate change they typically say that it is an important and worthwhile topic for students to know about, but cite a variety of reasons for not teaching it. I have become interested in the contradiction between the lack of emphasis that teachers place on teaching and assessing this topic, and the importance and relevance that teachers say the topic of climate change has for students.

Objectives

My anecdotal experiences with Alberta teachers and climate change teaching have inspired me to find ways to promote the importance of climate change education. Through my Master's project work I hope to encourage my fellow Alberta teachers to become more engaged with this topic and share the importance of understanding and addressing climate change with their students. I have drawn on the literature to identify some of the challenges of teaching about climate change and the major misconceptions that students hold about the topic. The first goal of my project is to provide an analysis of the current authorized textbook resources for teaching about climate change in Alberta, specifically looking at how these resources present the issue of climate change and the extent to which they cover common misconceptions about climate change. This analysis will be particularly useful to Alberta teachers because it will point out the strengths and limitations of the two authorized textbooks. Since the identified misconceptions are widespread, the analysis presented here should be useful to teachers in other jurisdictions teaching about climate change as it can help with a critical look at their own climate change teaching resources. The second goal of my project is to identify some resources that can help supplement authorized classroom resources with more current information and address other

limitations identified in the analysis. Because the curricular emphasis on climate in Alberta appears in Science 10, I will be looking at supplemental resources that specifically support the teaching of the climate unit in Science 10.

The final form of my project will be a paper to submit for publication in an academic journal, but I also intend to share my findings with Alberta teachers through a presentation at the Alberta Teacher's Association Science Council Conference in the fall of 2015. In my position with Alberta Education I hope to use my findings to provide input and expertise regarding the placement and positioning of climate change in future Alberta curricula.

Review of the Literature

Scientific evidence shows that Earth is presently undergoing a warming trend (IPCC, 2014). Although the causes and the very occurrence of global warming continue to be questioned by a few skeptics, the consensus among scientists is that we are beyond the debate (IPCC, 2014). Communicating the causes, current realities, and potential solutions for climate change to students is an important job for educators because the effects of climate change will have significant implications on students' lives and there is little doubt that students will continue to hear about the topic of climate change outside the classroom. In spite of the obvious importance of climate change, many science educators do not feel comfortable teaching about climate change because of the perceived scientific doubt and public confusion surrounding climate change (McBean & Hengeveld, 2000). Also, the discipline-specific training and self-identity of science educators does not translate well into teaching an interdisciplinary topic like climate change. Although climate change features prominently in the Alberta curriculum, Albertan

science educators de-emphasize the topic in favour of discipline-specific content (Chambers, 2011). There is a need for more recent and relevant teaching resources to help teachers in Alberta more effectively address the unique challenges of the climate this topic.

This review will focus on literature that is relevant to an exploration of the attitudes and experiences of teachers when addressing the topic of climate change in Alberta and on teaching and learning resources that can support effective climate change education. First, I will define climate change, next I will outline findings from literature that relate to public perceptions of climate change, then I will examine literature that addresses climate change education at the high school level.

Defining Climate Change

The Intergovernmental Panel on Climate Change (IPCC) is an international scientific body that reviews and assesses the climate change research of thousands of scientists around the world; this organization is considered the foremost authority on the understanding and current state of climate change. In this literature review, and in my research, I will use terms related to climate change as defined by the IPCC's 2014 *Synthesis Report* glossary.

While weather is the state of the atmosphere at a particular time and place, climate represents average weather over a large area and long period of time – at least three decades. Climate change is a lasting change in the weather or weather patterns that occurs over many years. Global warming, although often used synonymously with the term climate change, is only one type of climate change. The term 'climate change' doesn't necessarily indicate negative connotations; however, the concern over the more recent rapid changes in the climate system have made the term climate change synonymous with the environmental issue of global

warming. There are a variety of causes for climate change, including changes in solar radiation received from the Sun, volcanic eruptions, and anthropogenic (human-induced) factors. The IPCC's 2014 *Synthesis Report* states that "warming of the climate system is unequivocal," that "many of the observed changes are unprecedented over decades to millennia," (p. 2) and that anthropogenic activities are "*extremely likely* to have been the dominant cause of the observed warming since the mid-20th century" (p. 4).

Public Perceptions of Climate Change

Before looking at how classroom teachers can, do, and even should communicate the science and societal implications of climate change, it is important to first understand public perceptions of the climate change issue. As members of the public, it can be assumed that both teachers and students come to the classroom setting with similar experiences and misconceptions held by the wider public. Research on public perceptions of climate change indicates that there is significant uncertainty about the causes and effects of climate change. Uncertainty and misconceptions about climate change has been found in groups of children (Ho, 2009), secondary school students (Fortner, 2001), college students (Lombardi & Sinatra, 2012), pre-service teachers (Fortner, 2001), and the wider public (Moser & Dilling, 2004; Sherwood, 2011). The influences of popular film (Lieserowitz, 2004) and mass media controversy (Corbett & Durfee, 2004; Zehr, 2000) can have significant effects on the public perceptions of climate change.

Ho (2009) asked 176 children between ages 11 and 12 from a variety of areas in Ontario to provide illustrations of climate change and to participate in one-on-one, open ended interviews. Her research showed that children are "often confused with a range of other

environmental issues" and that "they are relatively less informed about the causes of climate change than the effects" (p. 132). She notes a startling disconnect between what the students illustrated as climate change and what the scientific community perceives as climate change. Perhaps more surprising is the fact that Ho found that the misconceptions of children about climate change were similar to the climate change misconceptions of adults detailed in the literature. For example, she explains how both adults and children are confused between the processes of climate change and stratospheric ozone depletion. Fortner (2001) found similar results to Ho's in high school students, college students, and pre-service teachers: general confusion between ozone depletion and climate change. Fortner also describes how many of those surveyed mistakenly connected immediate daily weather conditions as evidence for or against climate change (e.g. it is unseasonably cold one day in July, so therefore global warming is not occurring). Her research shows that knowledge of climate change among these students did not differ significantly between urban, rural, or suburban groups, which she states is an indication that students do not learn about climate change from first-hand experiences. Ho also describes how climate change has been popularized by the media, particularly in films such as *The Day After Tomorrow*, and the documentary *An Inconvenient Truth*, but these films do little to clarify the science behind climate change creating further misinformation and confusion.

Leiserowitz (2004) looks specifically at how the Hollywood film *The Day After Tomorrow* influenced the risk perceptions of climate change in the U.S. public. The method for this research was a national survey one week prior to the film's release and another survey four weeks after the film's release. Survey takers were grouped into those who had seen the movie and those who had not. The survey asked participants to rank environmental issues, answer questions about climate change, and to choose a model from a series of conceptual diagrams that

best represented their understanding of the climate system. A media content analysis was also done to determine the quantity and quality of coverage about the film. The results of the study showed, paradoxically, that a high percentage of Americans (83% among those who watched the film and 72% among those who did not watch the film) felt global warming was an important issue, but a low percentage (40% of watchers and 31% of non-watchers) said that they worried about it, and as an environmental issue it was only ranked fifth by watchers of the film and sixth by non-watchers of the film. Although Ho (2009) indicates that this pseudoscience film adds to the confusion surrounding climate change, Leiserowitz (2004) states that in terms of perceived risks, those who watched the film were more likely to have higher levels of concern about climate change and to estimate the impacts on the U.S. (e.g. more intense storms) as more likely, than those who did not watch the film. He does question the permanence of the film's influence. Even though this 2004 study by Leiserowitz was focused on a U.S. audience, Canadians are likely to be influenced by U.S. media and culture in a similar way.

The uncertainty that Ho (2009) found in Ontario children was also found by Lombardi and Sinatra (2012) to exist in college students. Specifically, Lombardi and Sinatra looked at how 153 college students attending a university in the southwestern United States perceived the plausibility of anthropogenic climate change. Their sample included students from all undergraduate levels who were enrolled in introductory physical geography classes at the beginning and end of the course. Different survey measures examined distinctions between weather and climate and the plausibility of climate change. The authors found that college students held two key misconceptions about climate change: students made inferences about climate change based on short-term and local weather events (e.g. a major snowstorm as evidence against global warming); and students confused climate change with the environmental

issue of ozone depletion or with more general environmental issues such as littering or smog. Comparing pre-survey and post-survey results, Lombardi and Sinatra found that instruction resulted in significant increases in understanding of weather and climate systems, but that there were few differences in student perceptions of the plausibility of anthropogenic climate change.

In 2000, the journal of *Public Understanding of Science* devoted an entire issue to investigating global climate change and the public. In this issue, Bord, O'Conner, and Fisher (2000) investigated, through a quantitative regression analysis of surveys, what factors would motivate people to take action on an environmental issue such as climate change. Interestingly, they found that knowledge of global-warming science was not highly related to the belief in the occurrence of global warming, but when it came to deciding what actions to take to address climate change they found that "knowing what causes climate change, and what does not, is the most powerful predictor of both stated intentions to take voluntary actions and to vote on hypothetical referenda to enact new government policies to reduce greenhouse gas emissions" (Bord, O'Connor & Fischer, p. 205).

Both Zehr (2000) and Corbett and Durfee (2004) explore how controversy in the media has impacted the public's perception of climate change. Zehr analyzed a decade of popular press articles about climate change and concluded that:

> (1) Scientific uncertainty was a highly salient theme in climate change articles; (2) Scientific uncertainty was constructed through various, sometimes unintentional, processes, including representations of controversy, new research topics, and an expanding problem domain; (3) Scientific uncertainty was managed in the press such that science remained an authoritative knowledge provider for climate change. An important

> part of this management involved the use of uncertainty in the construction of boundaries between science and the public; (4) these boundaries, in turn, constructed a "misinformed public" identity. This identity may itself be misinformed but, more importantly, it may contribute to inaction among publics who are so represented. (p. 98)

Corbett and Durfee (2004) describe how mass media is the source of knowledge for most citizens, but when the media is covering scientific issues and climate change issues in particular, the reporting is often event-driven, missing content and information about the processes of science, and includes exaggerated controversy. To examine the effect of exaggerating controversy of climate change reporting in the media, Corbett and Durfee (2004) created four different news stories based on a single scientific study and varied the extent of scientific context (background) or controversy in the different stories. Four different treatment groups read the story and then were given a survey about the certainty of global climate change. An analysis of the survey data was done and the authors found that "the inclusion of context increased readers' perceptions of certainty, while the inclusion of controversy reduced perceptions of certainty" (Corbett & Durfee, 2004. p. 142).

Like Corbett and Durfee (2004) and Zehr (2000), Moser and Dilling (2004) also cite the media's influence as a barrier to public understanding of the issue, but they are better able to explain why scientists often focus on communicating uncertainties and the way that the public interprets this focus:

> The complexities of any unknowns…are of greatest interest to scientists. Whether driven purely by curiosity, instrumental reasons, or a desire to protect themselves against attack from peers or advisories, scientists frequently emphasize the complexities and uncertainties in academic and public communications. For lay people, however, these

> complexities are hard to comprehend and mostly uninteresting or esoteric. (Moser & Dilling, 2004, p. 34)

This lack of clarity and unity from scientists on these complex ethical issues exacerbates the public's confusion and leads members of the public to draw their own conclusions, sometimes for political or economic reasons. When an audience of laypersons does not receive a clear message on a complex issue, such as climate change, they are apt to "make up or seek their own framework to help them make sense of the issue" (Moser & Dilling, 2004, p. 35).

Sherwood (2011) describes global warming as a physics problem and he compares the controversy surrounding global warming with other historical scientific controversies in physics. He parallels the acceptance of Copernicus' heliocentric model and Einstein's theory of relativity with the discoveries and acceptance of global warming. He describes the backlash and politicization that accompanied the scientific discoveries of Copernicus and Einstein and he exposes a paradox that occurred in both cases as they gained acceptance:

> Instead of quelling the debate, the confirmation of the theory and acclaim for its author had sparked an organized opposition dedicated to discrediting both theory and author. Part of the backlash came from a minority of scientists who apparently either felt sidelined or could not understand the theory. (Sherwood, 2011, p. 41)

Sherwood (2011) explains that a similar paradox is occurring with climate change – as evidence for climate change grows, skepticism towards climate change is also growing. Sherwood describes how the politicization of climate change and the increasing vilification of scientists as "opportunists, totalitarians, or downright criminals, is also, unfortunately, not new" (p. 41). Sherwood explains that the backlash against paradigm shifts created by new scientific theories

should not surprise us because challenging "the notions that make us feel safe…can turn people away from reason and toward emotion" (p. 41).

Much of the literature I have drawn on is U.S.-based, but there are some significant differences in the perceptions of Canadians about climate change compared to Americans. One 2014 report by a non-partisan think tank, called Canada 2020, provides a comprehensive summary of several national surveys on public attitudes toward climate change in both Canada and the U.S. The report states that "Canadians are more likely [81%] than Americans [61%] to believe there is solid evidence of rising global temperature on Earth" (p. 3), although when broken down by province, only 71% of Albertans agreed that there was solid evidence. Canadians are also more likely to attribute climate change to anthropogenic effects: "nearly 3 in 5 Canadians see human factors as the primary cause of climate change, compared to only 2 in 5 Americans" (p. 6). There has also been a greater shift in Canada about the anthropogenic aspect of climate change opinions over the last few years than American opinions — 58% of Canadians polled in 2013 stated that the primary cause of climate change was human factors compared to only 43% in 2011, but only 40% of Americans polled in 2013 stated that the primary cause of climate change was human factors compared to 37% in 2010 (p. 6). Canadians are also more concerned about climate change than Americans: 32% of Canadians said they were 'very concerned' while 23% of Americans said they were 'very concerned' and only 8% of Canadians were 'not concerned at all' while 22% of Americans were 'not concerned at all' (p. 7).

The literature on public perceptions of climate change shows that children, college students, and the wider public are confused by the science of climate change because of Hollywood science fiction films, the media's need for controversy to turn a profit, the complexity of the science, and the unwillingness or inability of scientists to effectively

communicate with the public. Confusion on the science of climate change makes it difficult to address the environmental issue of climate change. Those members of the public not confused may still be unwilling to accept the evidence of climate change due to the emotional paradigm-shifting nature of the climate-change issue. Although Canadians seem to be more convinced than Americans that climate change is happening, and that humans are causing it, there is still a large portion of the population that is doubtful or discouraged. These findings leave classroom science educators in a precarious and uncertain position and my review will now turn to looking at literature that specifically focuses on an educational context.

Climate Change Education

McKeown and Hopkins' (2010) examination of early and existing U. S. climate change curricula and internet sites reveal that these curricula were developed by scientists and science teachers or geography teachers. Mekeown and Hopkins contend that the complex social, economic and political nature of climate change means that a scientific approach alone cannot effectively prepare students to address the issue or promote positive change. They feel that there are two parts to climate change education: the "climate" part, which is already being inlcuded in science and geography classes, and the "change" part, which requires a broader engagement from teachers of social studies. In Alberta, climate change is not directly included as part of any one specific learning outcome in the social studies programs of studies; however, students are asked in both the *Social Studies 30-1* and *Social Studies 30-2* programs of studies to "analyze the extent to which modern liberalism is challenged by alternative thought" and one type of alternative thought listed is environmentalism (Alberta Education, 2007. p. 22 for *Social Studies 30-1* and p. 34 for *Social Studies 30-2*). Modern liberalism values personal freedoms and may be challenged by environmentalism, which values ecology over economics. For example, asking

someone to make lifestyle changes for environmental reasons, such as giving up a vehicle with low fuel efficiency, could be seen as a threat to personal freedom. Another *Social Studies 30*-1 program of studies outcome asks students to "evaluate the extent to which the principles of liberalism are viable in the context of contemporary issues (environment concerns, resource use and development, debt and poverty, racism, pandemics, terrorism, censorship, illiberalism)" (Alberta Education, 2007. p. 22 *Social Studies 30-1*). The one recommended textbook resource for Social Studies 30-1 in Alberta uses the issue of climate change to highlight the viability of liberalism:

> One of the ironies of liberal democracy is that its liberal principles are directly responsible for the level of economic development, abundance and the consumer lifestyle we enjoy. Yet it is the uncontrolled consumerism of countries such as Canada and the United States that results in, among other things, disproportionate amounts of greenhouse gases in the atmosphere. (Fielding et al., 2009, p. 424)

Based on the approved textbook resource, Grade 12 students in Alberta are likely to discuss climate change in their social studies classroom, but there appears to be little research into how social studies teachers deal with the topic of climate change in the classroom, if at all. An investigation of how science and social studies teachers in Alberta could work together to meet shared goals around climate change could be an area for future study.

Sharma (2012) explains how "scientists for once have been unable to persuade the majority of the American population to identify global climate change as a major threat occurring due to human activity" (p. 35) and he argues that science education must share the responsibility of communicating this message. Although he speaks from a U.S. context, his

description of how schools have been, and can be, used as instruments of social reform can be applied to a Canadian context. Sharma also argues that a global education reform may be necessary to address the global problem of climate change. Sharma posits that "some level of *educationalization* of global climate change" (p. 45) is necessary to affect a change in societal practices. In his paper, Sharma contends that climate change is not merely a technological problem, but instead it is a societal problem that is not being adequately addressed at the school level, and that it absolutely needs to be. He argues that "one cannot even begin to think of solving social problems, and global climate change would indeed be such a problem, without framing the issue in educational terms" (p. 45). Sharma writes that climate change education must be placed "center stage and get deliberated on as *the* key concern facing science education in the 21st century" (p. 46. Italics original). He outlines two major challenges of repositioning climate change more centrally in science education curricula: multiple competing agendas involved whenever curriculum is developed and the pervasive reductionist attitude that schools are merely places to prepare students for post-secondary school or the world of work. Like McKeown and Hopkins (2010), Sharma also argues that the discipline-oriented approach divides science from social studies and other school areas.

McBean and Hengeveld (2000) agree with Sharma (2012) that educators have a key role to play in helping address the issue of climate change, but unlike Sharma, they argue that educators must work *with* scientists to accomplish this goal. Sharma's approach is that scientists have failed and that the education system must take on the task, while McBean and Hengeveld cite scientist-educator collaboration as part of the solution to the climate change problem. They acknowledge that few scientists have time to visit school classrooms, but feel that most scientific experts "are quite willing to respond to questions that the educator or his/her students may have"

(p. 22). McBean and Hengeveld's (2000) paper addresses the tough question of how educators can deal with the challenges of climate change education and they propose several straight-forward strategies for practicing classroom educators.

Most of McBean and Hengeveld's (2000) paper focuses on the challenges of communicating the science of climate change to the public including the ineffective communication skills of scientists and the failure of the media – ideas that were outlined in the first section of this review; however, McBean and Hengeveld go on to describe how these challenges translate into the classroom. They add an additional challenge for both public and educators – misinformation presented by contrarians. Contrarians are those who disagree with the views of the majority of the scientific community on climate change, both in terms of process and risks. Because addressing climate change may threaten a profit-driven economic agenda, there are many groups that stand to benefit by creating doubt about the climate change issue and some of these contrarian groups have produced seemingly credible and professional-looking websites to promote their goal of increased uncertainty. Contrarian information makes it more difficult for educators and members of the public to conduct online research and become informed about climate change science.

I have learned firsthand how confounding contrarians can be. In December 2011, I published a paper in the *Alberta Science Education Journal* that looked more specifically at the impact of contrarian groups on public certainty and climate change education (Bissell, 2011). Following the publication of that paper, a contrarian group I discussed in the paper, called Friends of Science, wrote a letter to the journal editor objecting to my remarks and the editor began to discuss the potential of a lawsuit by the Friends of Science against me. Friends of Science is an Alberta organization that does not believe that climate change is occurring at a

significant rate and that there is no anthropogenic effect on the climate. The organization has a clear economic agenda as evidence by the August 12, 2006 *Globe and Mail* article that reported that Friends of Science received significant funding from oil industry donations funneled through the University of Calgary. The following September, Troy Media published an article by Michelle Stirling-Anosh, the communications manager of Friends of Science, entitled "Teacher's Journal Wants Questions about Climate Change Suppressed," which disagreed with the arguments of my paper, misquoted me, and in the comments section of the online article Stirling-Anosh personally attacked my teaching ability and professionalism. Striling-Anosh's 2012 attack article was more recently (2015, March 8) posted on the Friends of Science Facebook page.

In Moser and Dilling's (2004) paper "Making Climate Hot: Communicating the Urgency and Challenge of Global Climate Change," the authors propose that "trusted messengers" (p. 41) are needed to communicate the issue and urgency of climate change. They state that scientists, who are rarely trained as communicators, may not always be the best messenger. Although Moser and Dilling do not specifically cite educators as examples of their "trusted messengers," their work provides a useful concept and term for how others (Sharma, 2012; McBean & Hengeveld, 2000) have described the potential role of educators positioned as "trusted messengers". Unfortunately, teachers are much less likely to become messengers for climate change if they are fearful that well-funded climate contrarians will attack them for trying to teach the science of climate change.

Dahlberg (2001) sees the complexity of climate change as more of a benefit than a challenge. He feels that climate change is an ideal context for teaching about complex systems, fostering debate, encouraging students to engage in public dialogue, problem solving, and conflict resolution. The climate change topic can allow for "profound growth for students" (p.

10) because it is complex and "nearly every significant problem they will address in their private and work lives will be complex, messy, and involve conflicting data and uncertain consequences" (p. 10). Dahlberg argues that in order to successfully teach about climate change, teachers "must be flexible enough to give up the need for a clear-cut agenda" to "focus more on the process than the outcome" and to "be willing to not know everything" (p. 15). He feels that the role of teachers as climate change educators should be to help students make connections to formulate their own opinions and to avoid indoctrinating students. Dahlberg's (2001) paper has a much less urgent tone that that of others in the literature who write on climate change education; perhaps his tone would be more urgent if he was to write this paper today in the face of much more certain scientific evidence for climate change.

There is very little in the literature that relates specifically to the challenges of teaching about climate change in Alberta. Although Sukhy (2002) mentions how climate change appears as a topic in the Alberta curriculum, her work is more of a general overview of the importance of climate change as a Society, Technology, and Society (STS) topic. Alberta's role as a wealthy oil-producing region is at odds with the implicit questioning of our fossil-fuel dependent culture that can be read in the Alberta curriculum, yet this possible tension in the classroom appears to be largely uninvestigated and could become a dynamic to explore as a further research topic.

The one piece of literature that I could find, which directly addresses the Alberta context, is the 2011 Chambers paper "Right Time, Wrong Place? Teaching about Climate Change in Alberta Schools." In her research on Alberta educators teaching climate change, Chambers (2011) describes the same disconnect I have observed first hand: educators say that they feel that climate change education is important, yet they choose to emphasize the biology, chemistry, and

physics unit content over the climate change content in Science 10. A quotation from an educator Chambers interviewed for this paper illustrates this disconnect:

> [Climate change] is a really good topic and really deserves the time and energy to make it a good topic for students to learn, to make it meaningful, to make it relevant…The importance is certainly there…It's unfortunate that it is also the topic that is ditched when, you know, June rolls along and we are still trying to bumble through the last of biology, chemistry, or physics (Teacher A). (p. 7)

Educators cite time constraints, preparation for future discipline subjects, and future accountability measures (i.e. diploma examinations) as reasons for the de-emphasis. Chambers states that Alberta Educators feel "it is more imperative that students 'get' the necessary biology, chemistry, and physics concepts they will need in order to be successful in Grade 11 science courses, and in turn, Grade 12 diploma-level courses" (p. 7). In her paper, she describes how this "hurried teaching of the climate change unit…constructs both hidden and null curricula" (p. 8). In other words, de-emphasis and placement at the end of the course sends a message to students that climate change is a less important topic than other topics.

Like Sharma's earlier described 2012 work and the work of Fortner (2001), Chambers (2011) also cites educator identity and educator training as a reason science educators are less comfortable teaching about climate change. She describes how training science educators as biology, chemistry, or physics subject specialists leaves them ill-prepared to address interdisciplinary environmental education topics with underlying socio-political aspects, such as climate change. Wise (2010) also notes the same "challenges related to disciplinary 'siloing'" (p.

297) in U.S. teachers after conduction of a large (*n*=628) online survey of Colorado public school science teachers on the topic of climate change instruction.

The research of Lang, Drake, and Olson (2006) supports Chambers' (2011) contention that focusing on three main science disciplines results in a narrow scope that ignores the "social aspects of science and the needs of citizenship" (p. 179). Although they do not specifically address climate change in their paper, Lang, Drake, and Olsen explore educator identity in Canada and Germany and call for a more integrated approach to science education, which Chambers indicated may be the key to successful climate change education. Lang, Drake, and Olson describe how the educators involved in organizing and teaching an interdisciplinary science course felt that their students, and especially their higher-risk students, were more motivated, more aware, and had a deeper understanding of the science concepts than they would have in a traditional format (p. 183). However, Lang, Drake, and Olson caution that attempts to have educators integrate or work between the traditional science disciplines have failed in the past. For example, they describe how the general science reform movement, which began in England in the 1920s, was in constant conflict with established teaching practices and resulted in the abandonment of the reform movement in the 1960s. Lang, Drake, and Olson identify some major challenges of this integrated approach including that the approach asks educators to "develop materials that move them away from the security of their own subjects, from the support of textbooks, and from the rather solitary role of implementing a more or less taken-for-granted curriculum" (p. 184) and that teaching an interdisciplinary topic "may involve accepting that there are zones of grey; this is a message that educators – especially those with a science background – perhaps do not want to hear" (pp. 184–185).

Classroom Resources that Effectively Address Climate Change

If uncertainty about climate change and the intimidating interdisciplinary nature of climate change are major barriers to effectively teaching the topic, then the availability of reliable, reputable, current, and cross-disciplinary teaching resources are much needed. There is ample research on attitudes and perceptions about climate change and there is much literature about how educators should teach or engage with the topic of climate change; however, there appears to be little research that evaluates or promotes particular climate change teaching resources. Even as early as 2001 Fortner stated that, when it comes to climate change, the "media [teachers] use for self-education may be deficient" (p. 28), but Fortner does not make recommendations that address these deficiencies. Choi, Niyogi, Shepardson, and Charusombat (2010) identify that textbooks are still the main source of information for teachers and students even though there are an increasing number of more current and accurate supplemental and supporting materials available for science teachers.

Choi et al. (2010) conducted a review of the literature and identified some of the major misconceptions that students in a variety of countries, including Canada, held about climate change. The misconceptions that they identified are consistent with those identified by other authors discussed in this literature review (e.g. Fortner, 2001; Ho, 2009; Lombardi & Sinatra, 2012; Moser & Dilling, 2004; Sherwood, 2011). Choi et al. note that they did not find any variation in students' misconception by either year of study publication, or by the study location (i.e. country of study), so they consider the misconceptions identified to be widely representative. The misconceptions related to climate change that Choi et al. described were organized into four major areas: basic notions about climate change, causes of climate change, effects of climate change, and ways to resolve or mitigate climate change.

Table 1

Middle and high school students' misconceptions of climate change. Adapted from Choi et al (2010).

	Categories		Students' Misconceptions
Basic notions	a	Confusion about the kind and source of radiation involved in the greenhouse effect	• Sun rays in general • Heat or thermal rays emitted from the Sun • UV radiation reflecting off Earth's surface • Increase in incoming UV or total solar radiation by ozone layer depletion
	b	Confusion between UV and infrared radiation and surface temperature	• UV rays are "hot" • No distinction between UV and infrared radiation and between heat and surface temperature
	c	Confusion about the kinds of greenhouse gases	• Considering all air pollutants as greenhouse gases • Not considering ground-level ozone or natural emissions as greenhouse gases • Not considering CO_2 as a greenhouse gas • Not considering water vapour as a greenhouse gas
	d	Involving concepts of a gas or dust layer that traps heat inside	• Greenhouse gases form a thin layer around Earth and trap heat inside • The greenhouse effect occurs where solar rays are trapped by the ozone layer • Heat is trapped under a layer of dust created by pollution • The atmospheric gases make a barrier bouncing back heat from Earth
	e	Confusion about the definition of greenhouse effect	• Do not know the definition • Confusion between the greenhouse effect and climate change • Considering the greenhouse effect an environmental problem
	f	Confusion between weather and climate	• Able to sense warmer temperatures as an indication of climate change
Causes	g	General environmentally harmful actions are not closely related to climate change	• Littering leads to climate change • Using environmentally unfavourable products/toxins cause climate change
	h	Pollution	Climate change is caused by • Acid rain • Nuclear waste • Heat from car exhaust

			• Air pollution or pollutants in general
	i	Ozone hole	• Ozone holes let more solar energy get into Earth, causing global warming • Ozone holes let cooler air escape out of Earth, increasing the average global temperature • The ozone layer depletion (without further details)
	j	Change in solar irradiation	• Increase in solar energy coming to Earth • Earth is getting closer to the Sun • Solar rays hit more areas of Earth
Effects	k	No change in my lifetime	• Nothing would happen in my lifetime
	l	Climate change claims are exaggerated	• Overestimates of the degree of global temperature change (e.g. about 4°C increase to date and 11°C in 50 years)
	m	Causes skin cancer	• Global warming causes skin cancer
	n	Not understanding different feedbacks of climate change	• The expected climate change is only limited to warming in general
	o	Depletion of ozone layer	• The greenhouse gases cause the ozone layer to deplete • The greenhouse effect causes air pollutants to go up to higher altitudes and attack the ozone layer
	p	Increased air pollution	• Greenhouse gases are air pollutants and increased greenhouse gas concentration leads to air pollution
Resolution/ mitigation	q	Proposing pro-environmental actions in general	• Proposing pro-environmental actions not closely related to climate change as a solution (e.g. protection of rare species, reduction of the global nuclear arsenal, the use of unleaded gasoline, pollute less, put waste in the trash can, clean the streets)
	r	Unaware of the difficulties of controlling CO_2 emissions	• Unaware of people's dependency on fossil fuel and the complexity of CO_2 control
	s	Negative attitude toward taking action regarding climate change	• There is nothing that people can do about climate change • People would not be willing to change their lifestyles

A single resource that effectively addresses all of the misconceptions described by Choi et al. may be difficult to find, so teachers who wish to present students with a comprehensive understanding of climate change science may have to employ several different resources in order to meet that goal.

This review of the literature shows that there is widespread public confusion and uncertainty about climate change and that this uncertainty is a result of many factors, including an incomplete understanding of the science behind the issue, the media's exaggerated controversy of the issue, and misinformation by contrarians. Key misconceptions about climate change are well documented in the literature. Science teachers, who are trained as discipline specialists, often feel uncomfortable teaching about climate change because it is an interdisciplinary topic that is perceived as controversial and uncertain. Teaching resources that are current, interdisciplinary, and that address major misconceptions are needed. It is a goal of this project to identify climate change resources that can meet these needs. The method for evaluating these resources is outlined in the next section.

Method

A review of climate change education literature was conducted to identify the challenges and barriers to teaching the topic of climate change, and to highlight some key criteria of effective climate change teaching resources. The two authorized Alberta Science 10 textbooks were analyzed for how they present the topic of climate change, how they address key misconceptions about climate change, and actions that they suggest to address climate change. New climate change teaching resources were identified that could be used to supplement the authorized resources and their alignment with the Alberta program of studies was described. A rationale for how teachers could use these resources to supplement the Alberta Education

authorized resources was provided. In the following sections, I describe the Alberta context and curriculum relevant to this project, the data sources, and the methods used in the analysis.

The Alberta Context and Curriculum

Alberta's economy heavily relies on oil and natural gas resources and students and teachers in Alberta are very much aware of the economic dependence on this carbon-based economy. Discussion of the contribution of fossil-fuel burning to the climate change problem could be seen as opposing the livelihood of many teacher's and student's families; however, curriculum developers in Alberta have not shied away from the climate change issue. The Alberta high school curriculum addresses and mandates the inclusion of the topic of climate change and outcomes that directly address climate change appear in several high school science programs of studies including *Science 10, Science 14, Science 20, Science 30,* and *Chemistry 30*. Although students choose particular science courses at the Grade 11 and Grade 12 level (20 or 30-level), the majority of Grade 10 students in Alberta take a general science course called Science 10 as a prerequisite to the other science courses in Grade 11 and 12. The 2005 version of the *Science 10 Program of Studies* includes a unit entitled "Unit D: Energy Flow in Global Systems," which entirely focuses on the study of climate and climate change. A 2008 Alberta document, *Percent Weightings in Senior High Science,* indicates that each of the four units in the Science 10 course should have an equal instructional emphasis. The inclusion and equal weighting of this topic in Science 10 means that most Alberta students should come out of high school with an introductory knowledge of climate change issues.

Like all Alberta science curricula, a foundation of Science 10 is its science, technology and society (STS) focus. STS is "concerned with understanding the scope and character of

science, its connections to technology, and the social context in which it is developed" (Alberta Education, 2005. p. 4). There are three different STS focuses in the *Science 10 Program of Studies*: Nature of Science, Science and Technology, and Social and Environmental Contexts of Science and Technology. Unit D, which contains the climate outcomes, is presented in the *Science 10 Program of Studies* with an STS approach that emphasizes the third focus looking at connections between science and society. With this focus, students and teachers are explicitly asked to look at the implications of scientific developments from a variety of perspectives in Unit D. For example, one Science 10 outcome asks students to "identify multiple perspectives that influence a science-related decision or issue *(e.g., consult a wide variety of electronic sources that reflect varied viewpoints and economic, social, scientific and other perspectives on global warming and climate change)*" (Alberta Education, 2005. p. 33).

The *Science 10 Program of Studies* Unit D "Energy Flow in Global Systems" has four general STS and knowledge outcomes, and each of these four general outcomes has 4–6 specific bulleted knowledge outcomes. In Alberta programs of studies, the italicized font indicates that the content is an optional context or example that teachers may use to deliver that outcome and regular non-italicized font is required teaching. There are some generic skill outcomes in Unit D that, through italicized font, suggest climate change as the context for developing these skills. The first two general outcomes in Unit D have students look at several major processes that determine the climate on Earth; in these first two general outcomes students are asked to look at concepts such as solar input or net radiation budget, the greenhouse effect, and how energy is transferred through the atmosphere. The third general outcome relates climate to the world's major biomes. These first three general outcomes provide students with a background that can help them more critically look at the evidence for climate change, which is presented in the

fourth general outcome. The fourth general outcome and its six specific bulleted outcomes on climate change are listed below (*Science 10 Program of Studies*, p. 31).

> 4. Investigate and interpret the role of environmental factors on global energy transfer and climate change
>
> - investigate and identify human actions affecting biomes that have a potential to change climate (*e.g., emission of greenhouse gases, draining of wetlands, forest fires, deforestation*) and critically examine the evidence that these factors play a role in climate change (*e.g., global warming, rising sea level(s)*)
> - identify evidence to investigate past changes in Earth's climate *(e.g., ice core samples, tree ring analysis)*
> - describe and evaluate the role of science in furthering the understanding of climate and climate change through international programs *(e.g., World Meteorological Organization, World Weather Watch, Global Atmosphere Watch, Surface Heat Budget of the Arctic Ocean (SHEBA) project, The Intergovernmental Panel on Climate Change (IPCC); the study of paleoclimates and models of future climate scenarios)*
> - describe the role of technology in measuring, modelling and interpreting climate and climate change *(e.g., computer models, devices to take measurements of greenhouse gases, satellite imaging technology)*
> - describe the limitations of scientific knowledge and technology in making predictions related to climate and weather *(e.g., predicting the direct and indirect impacts on Canada's agriculture, forestry and oceans of climate change, or from changes in energy transfer systems, such as ocean currents and global wind patterns)*
> - assess, from a variety of perspectives, the risks and benefits of human activity, and its impact on the biosphere and the climate *(e.g., compare the Gaia hypothesis with traditional Aboriginal perspectives on the natural world; identify and analyze various perspectives on reducing the impact of human activity on the global climate)*

The skill outcomes that may address climate change are listed below (*Science 10 Program of Studies*, pp. 32–33).

> Ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues
>
> - Identify questions to investigate that arise from practical problems and issues (*e.g., develop questions related to climate change, such as "How will global warming affect Canada's northern biome?"; "How will a species be affected by an increase or decrease in average temperature?"*)
> - use library and electronic research tools to collect information on a given topic *(e.g., research sources of greenhouse gases; research protocols to control human sources of greenhouse gases)*

- select and integrate information from various print and electronic sources or from several parts of the same source *(e.g., collect weather and climate data, both historic and current, from the Internet)*
- identify and apply criteria for evaluating evidence and sources of information, including identifying bias *(e.g., investigate the issue of global climate change)*
- explain how data support or refute a hypothesis or a prediction *(e.g., provide evidence for or against the hypothesis that human activity is responsible for climate change)*
- identify multiple perspectives that influence a science-related decision or issue *(e.g., consult a wide variety of electronic sources that reflect varied viewpoints and economic, social, scientific and other perspectives on global warming and climate change)*

The two textbook resources authorized by Alberta Education for use with Science 10 are *Addison Wesley Science 10,* published by Pearson Canada and *ScienceFocus 10,* published by McGraw-Hill Ryerson. Both textbooks were published in 2004 along with available teacher's resource guides. The Science 10 textbooks have been developed specifically for the *Science 10 Program of Studies*, so they have a very high curricular fit with the outcomes. Both of the teacher's resource guides have a chart that correlates the program of studies outcomes to sections and activities in the textbooks (Pearson Teacher's Resource, Unit D pp. i–ix, and McGraw-Hill Ryerson Teacher's Resource, Unit D pp. 10-2–10-4). Teachers in Alberta are free to choose either of these textbooks for instruction, or any other resources that they feel can help them meet the learning outcomes in the program of studies, and are not required to use the resources recommended by Alberta Education.

Data Sources

For this project I will specifically look at the parts of the Alberta Education authorized textbooks and teacher resources that deal with the *Science 10* Unit D general outcome on climate change. The Unit D section of the *Addison Wesley Science 10* textbook has three chapters. The first chapter (pp. 342–355) brings together some pieces of all four general outcomes in Unit D, including climate change. The second chapter (pp. 356–409) deals with basic climate science.

The third and final chapter of the unit (pp. 410–433), which focuses on climate change, is divided into three sections. In the first climate change section students are asked to evaluate the evidence for climate change; in the second section they are asked to look at social contexts for investigating climate change, such as international collaborations, treaties, and political considerations; and in the final section students are asked to assess the potential impacts of climate change.

The Unit D section of the *ScienceFocus 10* textbook also has three chapters. The first chapter (pp. 362–399) deals with basic climate science. The second chapter (pp. 400 – 431) focuses primarily on biomes, but dedicates several pages (pp. 422–427) to describing natural causes of climate change. The third chapter of the textbook (pp. 432–479) focuses on climate change and is divided into four sections. Section one asks students to evaluate the evidence for climate change, section two looks at how humans have altered their environment, section three examines how climate and biomes may change in the future, and section four discusses human responses to climate change.

Both textbooks introduce the concept of climate change near the beginning of the unit section. The *Addison Wesley Science 10* textbook explains the idea of climate change in the first chapter and an activity is presented that asks students to conduct research to answer the question "Is climate change affecting present day life in Canada?" (p. 353). The project suggests that students display their findings on a class information board and continue to add to the information board throughout the unit. *ScienceFocus 10* references an activity at the beginning of the unit (p. 433) where students are asked to find articles on climate change from different sources and critically examine the source of the article. The *Addison Wesley Science 10* unit concludes with a culminating project where students develop a personal plan to reduce carbon

dioxide emissions. There is no culminating project for the climate change unit in *ScienceFocus 10.*

Data Analysis

The two authorized Science 10 textbooks and their accompanying resource guides were reviewed and compared in the way that they present the science of climate change and the language they use to do so. Close attention was given to the words used to communicate the certainty of climate change. Conditional or hedging words and phrases, such as *if, possibly, might, may be, could be,* used in the context of describing the plausibility or causes of climate change were taken to imply that some aspect of climate change may not be occurring. When these words and phrases were noted in one textbook, this was then compared to the language used in the same topic in the other textbook.

After the initial analysis for the language of uncertainty was conducted, I discovered that Chambers & Rowell (2006) did a similar analysis. Their study included a comparison of the orientation towards action on climate change presented in several climate change resources, including the two authorized Alberta textbooks. They pointed out that the two texts focus on voluntary personal action to address climate change, rather than a need for dialogue and political action that other climate change resources emphasize. Intrigued by their finding, I did an analysis of the two authorized textbooks looking at the types of actions emphasized in each text. Each text has a section dedicated to human responses to climate change, and in this section I looked for the types of actions promoted and which groups (individuals, industry, or government) the text suggested should engage in action on climate change.

This project extends the work of Choi et al. by looking at the coverage of major climate change misconceptions in the two authorized Science 10 textbooks and their accompanying teacher resource guides. The results of the analysis performed by Choi et al. simply states whether the analyzed textbook covered the concept or not; their methods do not qualify the depth of coverage and they do not mention an analysis of accompanying teacher's resource guides. For my analysis, I looked for the content that addressed each misconception in the textbook chapters on climate change, the textbook glossaries, and the accompanying teacher resource guides. I looked for explicit coverage of the concept that could address the misconception without needing further clarification or information. For example, if the misconception was about the kinds of gases that cause and enhance the greenhouse effect, I looked for textbook coverage of the major types of greenhouse gases and a discussion of the roles of these gases in the process. Choi et al. acknowledge that a limitation of their study is that the "scientific concepts corresponding to the student's misconceptions represent the authors' interpretations only" (p. 896). Like Choi et al., my analysis is limited by my own interpretation of whether the content presented sufficiently addressed the misconception or not.

Textbook Analysis

The two authorized Alberta Science 10 textbooks were analyzed to describe and compare how each text presents climate change and the potential responses to the issue of climate change. The language used to communicate the certainty of climate change was also explored in each of the texts. Using major misconceptions about climate change identified in the literature the textbook's coverage of scientific concepts related to these misconceptions was examined.

Emphasis on Climate Change within the Texts

There is a difference between the two textbooks in terms of the placement of introductory activities and sections; this difference in design indicates a difference in the importance that the editor or authors place on climate change. The *ScienceFocus 10* introductory activity on climate change (p. 433) is relegated to a small box at the bottom of the opening unit pages and students are asked to flip to the end of the chapter to find the activity; this is unlike the early activity in *Addison Wesley Science 10*, which takes up a full page (p. 353). By making the opening activity more visible, the *Addison Wesley Science 10* text makes the climate change issue more central to the study of the entire unit. The *Addison Wesley Science 10* introductory activity is also intended to be a unifying activity that continues throughout the entire unit with students adding to a class information board as they find new information on the impacts of climate change,

The *ScienceFocus 10* textbook places more emphasis on the natural factors that cause climate change than the *Addison Wesley Science 10* text does. The *ScienceFocus 10* teacher's resource points out "the significance of the average *rate of increase* in global temperature during the last century" (Unit D, p iv.), but this important point does not come across strongly in the student textbook. *ScienceFocus 10* shows a graph to illustrate the temperature change over time, but then de-emphasizes the importance of this by stating that "it is important to understand that this increase is an average" and that "in some areas there may be cooling" (p. 434). The section goes on to describe effects of climate change, but focuses on the supposedly positive effects, such as reduced heating costs for homes in warmer winters and "land in the northern half of the province [becoming] suitable for growing crops and raising livestock as the taiga is reduced and replaced by grassland and temperate deciduous forest" (p. 435). Two of the sections in *ScienceFocus 10* focus on how climate change may be natural. One section titled "Biomes Change Naturally" (pp. 420–428) describes how climates have changed in the past and explains

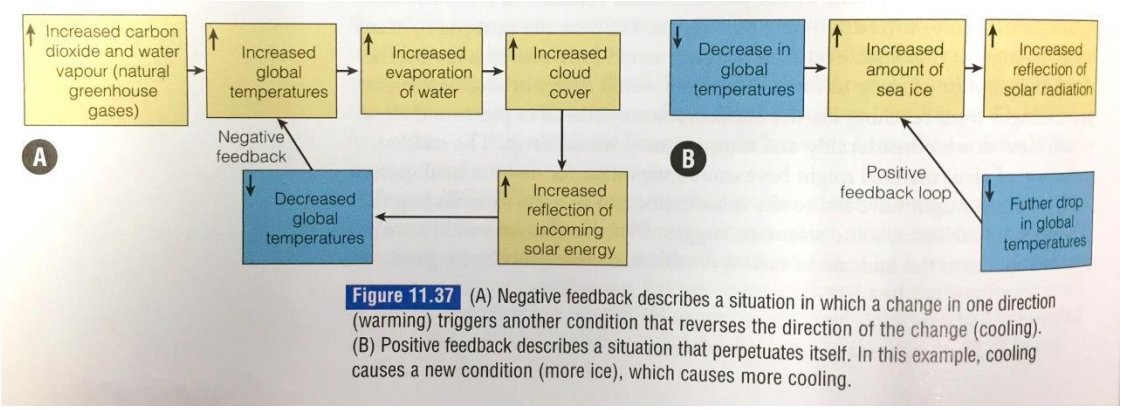
several non-anthropogenic factors for climate change. Another section titled "Climate Affects Life/Life Affects Climate" (pp. 445–448) looks at the effect of deforestation and urbanization and emphasizes how "humans have been changing their surroundings for thousands of years to suit their needs" (p. 445). Neither of these two sections makes the important comparison between the historic rates of environmental change and the current more alarming rates of climate change. Although the difference in the rate of change has been pointed out previously in the text, not re-emphasizing the current rate of change in these two sections leaves students and teachers relying on *ScienceFocus 10* to possibly draw the conclusion that, if climate change is mostly natural, then nothing can or needs to be done to address it.

The *Addison Wesley Science 10* textbook also addresses the topic of natural factors, when it states that "some scientists argue global warming today could be part of a natural climate cycle that occurs over thousands of years" and that this makes the anthropogenic influence of global warming "debatable to some people" (p. 418). However, the use of the phrases "some scientists" and "some people" makes this appear to be a less prevalent idea in the scientific community than the way it is presented in the *ScienceFocus 10* text. The *Addison Wesley Science 10* text also limits the discussion of natural factors and the prevalence of public doubt about aspects of climate change to a single paragraph titled "Other Views on Climate Change" rather than strongly emphasizing the natural causes of climate change by devoting entire sections to the idea, like the *ScienceFocus 10* textbook does.

The *ScienceFocus 10* textbook explains the concept of climate feedback by discussing how "a change in the climate due to any cause can trigger another change" (p. 428). The textbook illustrates this with a diagram showing an example of positive feedback and an example of negative feedback. Surprisingly, this diagram only shows feedback resulting in global cooling,

which leaves the reader with the impression that global cooling is the most probable future outcome. This idea is reinforced in the "Chapter at a Glance" assessment items where students are asked to "describe how cloud cover can act as a feedback to climate change" (p. 429) and the chapter review exercises on page 430 where students are asked to "give an example of feedback in response to a climate change such as a drop in Earth's average temperature." The keyed answer to both questions in the teacher's resource is that "increased cloud cover blocks some of the solar radiation reaching Earth, which then lowers temperatures— a feedback mechanism" (TR 11-67).

Figure 1. Examples of feedback resulting in global cooling from *ScienceFocus10*.



Both authorized textbooks were found to focus on voluntary personal action to address climate change. Although both texts dedicate a few pages to describe potential political actions, such as international agreements, there is no clear indication that industry and governments should be taking decisive action to help combat climate change. The *Addison Wesley Science 10* text has a section that describes the value of international scientific and political collaborations, such as the United Nations Framework Convention on Climate Change and the Kyoto Protocol, but the authors contradictorily end the section by stating that, because of economic concerns, Alberta has developed its own action plan against climate change instead of participating in the

Kyoto Protocol. *Addison Wesley Science 10* highlights voluntary personal action by presenting the culminating project for the unit as a personal plan for reducing carbon dioxide emissions. In this project, students develop a plan to reduce their family's carbon dioxide emissions by 2% over one year through actions like reducing the use of a personal vehicle, while considering the economic and social costs of their plan. The *ScienceFocus 10* textbook presents climate change as an environment-energy-economy issue suggesting improved efficiency, reducing fossil fuel use, and using alternative energy as climate change solutions; however, it does not discuss who should be taking these actions. *ScienceFocus 10* emphasizes personal voluntary action by asking students to carry out a risk assessment of local threats posed by climate change and propose a personal course of action, while considering the cost of each action.

By promoting voluntary personal action and emphasizing the economic risks of taking these actions, both textbooks position climate change an issue that is good to address if individuals can financially afford to make changes, rather than an issue that *must* be addressed at several levels because society cannot afford inaction. Students may see action on climate change as being less urgent than if the textbooks presented action on climate change as a collective responsibility of governments, industries, and individuals.

The two authorized Science 10 textbooks significantly differ in the way that they organize information about climate change and the emphasis that they put on different aspects of climate change. The *ScienceFocus 10* text creates doubt about the plausibility and urgency of global warming by focusing on natural causes of climate change, past changes in climate, and suggests that global cooling is an equally plausible outcome of climate change. The textbooks are similar in that they both emphasize personal voluntary actions over other types of action to

address climate change. These emphases, or lack of emphases, might seem like minor differences, but the way that information is presented in textual resources is hugely significant:

> How students view their role as participants and actors in the world is shaped, in part, by the particular discourses they encounter in science classrooms. The formative power of these discourses should not be underestimated or overlooked. (Chambers & Rowell, 2006, p. 88).

The Language of Certainty

A fundamental idea in science is that scientists must be open to modifying theories about the world when new evidence is presented; however, this does not mean that the public should not trust scientific knowledge as it is based on evidence and provides reliable information to make a decision. The Union of Concerned Scientists (UCS), an American non-profit science advocacy organization, defines scientific uncertainty as it relates to climate change on their website:

> To most of us, uncertainty means not knowing. To scientists, however, uncertainty is how well something is known. And, therein lies an important difference, especially when trying to understand what is known about climate change. In science, there's often not absolute certainty. But, research reduces uncertainty.
>
> Even though it may seem counterintuitive, scientists like to point out the level of uncertainty. Why? Because the want to be as transparent as possible and it shows how well certain phenomena are understood… However, in this culture of transparency where climate scientists describe degrees of certainty and confidence in their findings, climate

> change deniers have linked less than complete certainty with not knowing anything. ("Certainty vs. Uncertainty," n.d., para. 2–7).

Scientists are still working to gain a more complete understanding of climate change and, as new data are provided, future projections about the effects and rate of change are adjusted, potentially resulting in new proposals to address the challenge. The uncertainty about climate change is a potentially exciting topic for teachers as it presents an opportunity to explore some aspects of the nature of science and the work that scientists do. In the context of climate change, teachers could share with students how new knowledge is incorporated into existing theories, how uncertainty can be dealt with by developing models and projections, and how courses of action can be debated. Chambers & Rowell (2006) state that the uncertainty of the climate change topic "may be appreciated as a feature of 'science-in-the-making'" and they see benefits of climate change challenging "the expectations of certainty and presentation of 'facts' in traditional school science" (p. 82). However, it is important to distinguish that the greatest uncertainty lies in predicting the rate of climate change, effects of climate change, and solutions to combat climate change, and *not* whether climate change is occurring or whether humans are responsible.

The major challenge with relying on textbooks for climate change information is that the information in textbooks becomes outdated as new scientific discoveries are made. Both textbook resources recommended by Alberta Education for use with Science 10 were published in 2004. Since the publication of these two textbooks, the IPCC has produced two assessment reports (*Fourth Assessment Report* in 2007 and *Fifth Assessment Report* in 2013) that have each shown more conclusively that there is an anthropogenic influence on climate change.

Although both texts were published at the same time, and with the same IPCC report information available to the authors, the *ScienceFocus 10* textbook presents climate change with more uncertain language about the plausibility of climate change than the *Addison Wesley Science 10* textbook. For example, in the opening pages of the *ScienceFocus 10* "Climate Change and Humans" chapter, the authors state that, "a debate has arisen over whether humans *might* [emphasis added] be influencing climate change at a rate never before recorded" (p. 433). The first section of this chapter is titled "Are Climates Changing?" and this section's introductory paragraph concludes with the rhetorical question, "What, *if anything* [emphasis added], should society do about global warming?" (p. 434). The *ScienceFocus 10* introductory activity also uses uncertain language to describe the activity: "Think about what kinds of decisions are important to make now *if* [emphasis added] climate change will affect future life on our planet" (p. 433). This approach introduces the concept of climate change by questioning whether climate change is even occurring or if students should even bother to worry about it.

A more certain approach is used to introduce students to the plausibility of climate change in *Addison Wesley Science 10*. In the opening pages of the "Energy Flow in Global Systems" chapter of *Addison Wesley Science 10*, the author states that at the end of the chapter "you will be able to assess the evidence that has brought scientists to conclude that human activity can cause climate change" (p. 339). The first section of the climate change chapter is titled "Climate Change – Examining the Evidence" and the introductory paragraph states that "the vast majority of climatologists agree that we are currently experiencing climate change, and that human activity has played a role" (p. 411). The authors of *Addison Wesley Science 10* more accurately target the uncertainty around climate change as an inability to "accurately predict the

rate of climate change or its consequences" (p. 411) and not on whether climate change is actually occurring as *ScienceFocus 10* does.

ScienceFocus 10 continues with an uncertain tone around the plausibility of climate change in its assessment items. For example, in the "Critical Thinking" review exercises at the end of the "Climate Change and Humans" chapter students are asked "what weaknesses in the climate data make some people skeptical that humans are responsible for current and future climate change" (p. 470), in another question they are asked to "make a chart summarizing the evidence for and against the statement that 'the enhanced greenhouse effect is real'" and in another question they are asked to "make a chart summarizing the evidence for and against the statement that, 'If it exists, the enhanced greenhouse effect is a serious problem'" (p. 471). Taken together, the tone of these questions reinforces the idea that there is doubt over whether climate change is occurring or not.

The *ScienceFocus 10 Teacher's Resource* also uses a tenuous language when discussing the anthropogenic contribution to climate change, stating that, "your students are well aware that the debate about reducing human impact on the biosphere and on global warming is quite contentious at this time" (Unit D TR p. iv). The teacher's resource has notes to accompany the textbook's "Ask an Expert" section, and in these notes it states that "even though there are uncertainties about the impact of human activity on climate change, [the expert's] view is that the evidence is compelling enough to act" (Unit D, TR p. vii). The resource cautions that "some students will feel very passionately about one side of the climate change debate or other" (p. TR 12-107) implying that there is a debate to be had over whether climate change is happening or not. The *Addison Wesley Science 10 Teacher's Resource,* on the other hand, has a much more

confident and factual tone, and acknowledges that new evidence must be considered; it states that the key ideas for the Unit D climate change chapter are:

> The evidence on climate change discussed in lesson D3.1 [Unit D, third chapter, section 1] is by no means exhaustive. It is a summary of the key points on climate change as of 2002. This area of research will continue to grow over the life of this book. At the time of publication, international advisory organizations like IPCC had stated that climate change is occurring, and that human activity play a role. The evidence discussed in this section is based on these reports. Debate on the rate at which climate change will occur and on its potential impacts will continue (p. 66).

The authors of *Addison Wesley Science 10* attempt to address the issue of climate change information presented becoming outdated over the life of the textbook. It is noted in the *Addison Wesley Science 10 Teacher's Resource* that "climate change is a rapidly evolving field and new theories will likely be put forth after the publication of the student book" and they suggest that teachers use the introductory activity on page 353 to provide students with "current scientific thinking on this issue" (Teacher's Resource, p. 14). In the margins of the Addison Wesley Science 10 textbook, students are often directed to visit the www.pearsoned.ca/school/science10 website to help with research or learn more about a topic. The website contains current active links to a variety of reputable sources on climate change including the IPCC, NASA, and the National Oceanic and Atmospheric Administration (NOAA).

Science 10 Focus does not go so far as to deny that climate change is occurring. The authors attempt to have students critically assess the evidence that humans are causing the change, but the soft language used by *ScienceFocus 10* about the possibility of human-induced

climate change perpetuates doubt. In their analysis of climate change resources, Chambers & Rowell (2006) also pointed out that *ScienceFocus10* emphasizes uncertainty around the science of climate change, rather than the rate and consequences of climate change. This uncertain language about the plausibility of climate change is no longer appropriate in the face of current overwhelming scientific evidence and the opinion of the majority of climate scientists that climate change is occurring and that humans are causing the change; unfortunately, many Alberta teachers are likely still relying on this outdated text when teaching the climate part of the *Science 10 Program of Studies*.

Addressing Misconceptions

After identifying common misconceptions, Choi et al. (2010) reviewed seven different earth and environmental science textbooks widely used across the United States to see how these texts represented climate change and addressed the major misconceptions. The textbooks Choi et al. looked at were published between 2002 and 2006 and included texts published by the same publishers who were involved in publishing the two textbooks recommended for Science 10 in Alberta. Choi et al. (2010) listed 18 scientific concepts corresponding to the students' key misconceptions and determined if the seven textbooks covered these concepts or not. Each of the textbooks evaluated had strengths and weaknesses. Choi et al. noted that, "about half of the 18 scientific concepts were absent in the majority of the reviewed textbooks" (p. 894). Choi et al. did not conclude that any of the texts were more worthy than the others; instead, they argued for newer textbooks that more directly address climate change misconceptions and for more responsive web-based digital materials and teacher training programs to supplement textbook materials.

The two authorized Alberta Science 10 textbooks and their accompanying teacher's resource guides have been analyzed for this project using the same misconceptions identified by Choi et al. (2010). The results of this evaluation are shown in Table 2 below.

Table 2

Alberta Education authorized Science 10 textbooks' and teacher's resource (TR) coverage of the scientific concepts corresponding to students' misconceptions of climate change. Adapted from Choi et al. (2010).

Scientific concepts corresponding to students' misconceptions of climate change	The targeted students' misconceptions (explained in Table 1)	*Addison Wesley Science 10* (2004) Pearson Canada	*ScienceFocus 10* (2004) McGraw-Hill Ryerson
1) Distinction between weather and climate	f	pp. 342 and 352 TR p. 1 and p. 11	p. 368 TR 11-61
2) Distinction between global warming and climate change	n	p. 415	Not covered
3) Distinction between greenhouse effect and climate change	e	TR p. 2	pp. 368, 435 TR 12-82 and 12-83
4) The probable causes of climate change	g, h, i, and j	pp. 341 and 411 TR p. 66	p. 435 TR 12-82
5) Distinction between pollution and greenhouse effects or climate change	h and p	Not covered	Not covered
6) The global temperature change so far	l	pp. 352 and 354	p. 434
7) Distinction between the ozone layer and greenhouse gases in terms of the interaction with radiation	d, i, m and o	p. 421	Not covered
8) Climate change is already underway	k	p. 411 TR p. 66	pp. 434 and 435
9) The major sources and the kinds of greenhouse gases	c and g	pp. 411–414	pp. 368, 436, and 444 TR 10-8 and TR 12-87
10) Distribution of greenhouse gases in the atmosphere	d	Not covered	Not covered
11) The mechanism of the greenhouse effect	a, d, and e	p. 365	p. 368
12) Solar irradiation change and its	j	Not covered	pp. 367, 422,

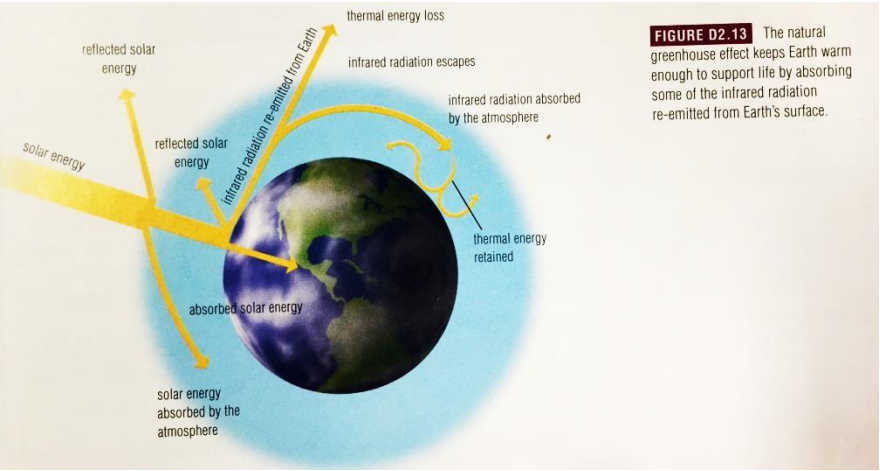
possible impacts on current climate change			and 424
13) Projections of future climate changes according to emission scenarios	s	pp. 410, 419, 426 and 427	pp. 449, 453, and 450 TR 12-82
14) The dependency of human society on fossil fuel and barriers to reducing emission of greenhouse gases	r	pp. 413	pp. 438, 460, and 466
15) How to mitigate climate change	q	pp. 421–425, 429, 432, 433 TR p. 71	pp. 457, 460–465 TR 12-105
16) Distinction between incoming and outgoing solar radiation	a and b	p. 362	pp. 366 and 380
17) Selective absorption of radiation in the atmospheric gases	c	p. 362	p. 366

Each of the two Science 10 authorized textbooks addresses most of the major concepts identified by Choi et al., which is an improvement over the seven textbooks Choi et al. reviewed. Greater coverage of these scientific concepts in *ScienceFocus 10* and *Addison Wesley Science 10* is likely because these two authorized Alberta textbooks were written to specifically meet the climate change outcomes of the Alberta *Science 10 Program of Studies*, while the texts that Choi et al. reviewed were general environmental science or earth science texts. The Alberta authorized textbooks' wide coverage of climate change concepts means that misconceptions about climate change are more likely to be dispelled for students, but the two authorized Alberta textbook are still deficient in a few areas. Neither Alberta textbook directly addresses the distinction between the pollutants that cause climate change and other types of generic pollutants or other air pollution problems (Table 2, Concept 5). Although both textbooks describe the gases that contribute to the natural and the enhanced greenhouse effect, the textbooks do not explicitly state that other types of air pollution *do not* cause climate change or that other types of pollutants can cause different environmental problems, such as acid rain. Without this clarity, students could

make the conclusion that all types of pollutants contribute to climate change, but that the textbook(s) simply chose to focus on a few major pollutants. Choi et al. concluded that all seven of the textbooks they reviewed did not address Concept 5.

Additionally, neither authorized Alberta textbook discusses the distribution of greenhouse gases (Table 2, Concept 10). Choi et al. identify the student misconception that a thin layer of greenhouse gases in the atmosphere surround Earth and trap the heat (Table 1, category d). The authorized Alberta textbooks do not address this by stating that most greenhouse gases, with the exception of stratospheric ozone, are equally distributed in the atmosphere; in fact, the diagram of the greenhouse effect in the *Addison Wesley Science 10* textbook perpetuates this misconception by showing infrared radiation being deflected at a particular level (p. 365) above Earth's surface as if hitting a barrier.

Figure 2. Illustration of the greenhouse effect in *Addison Wesley Science 10.*



The *ScienceFocus 10* diagrams that describe the greenhouse effect (pp. 367 and 380) do not perpetuate this same misconception, but the authors of *ScienceFocus 10* use the analogy of a greenhouse to describe the greenhouse effect – this compares the glass of a greenhouse to

greenhouse gases, which leaves the impression that there is a distinct thin layer like a pane of glass. Choi et al. concluded that only one of the seven textbooks they reviewed addressed Concept 10.

ScienceFocus 10 does not address two misconceptions that the *Addison Wesley Science 10* textbook does. The distinction between the terms 'global warming' and 'climate change' (Table 2, Concept 2) is not made in *ScienceFocus 10*. The two terms are often used interchangeably in *ScienceFocus 10* and the difference is not clarified. The glossary of *ScienceFocus 10* includes a definition for global warming (p. 513), but not a definition for climate change. *Addison Wesley Science 10* does distinguish between these two terms and defines both terms separately in its glossary (pp. 442 and 445). *ScienceFocus 10* also does not address the distinction between the ozone layer and greenhouse gases (Table 2, Concept 7). The text discusses the ozone layer blocking ultraviolet light or forming photochemical smog, and depletion of the ozone layer by CFCs, but does not discuss ozone as a greenhouse gas. *Addison Wesley Science 10* does address the role of the stratospheric ozone layer as a greenhouse gas and explains how a loss of ozone may affect the net radiation budget of Earth.

The one concept that the *Addison Wesley Science 10* textbook does not address, but the *ScienceFocus 10* does, is how changes in solar irradiation may impact current climate change (Table 2, Concept 12). Choi et al. discuss how "many students attribute global warming to an increase in incoming solar radiation, Earth getting closer to the Sun, or the Sun's rays hitting more areas of Earth" (p. 896). *ScienceFocus 10* describes how volcanic eruptions, meteor strikes, and variations in the tilt of Earth's axis and orbit around the Sun (Milankovitch cycles) can alter the solar irradiation budget.

One further drawback to using textbook resources is that they are expensive: a search on the Amazon.ca website quotes a retail price of approximately $155 for either of the two recommended Alberta Science 10 textbooks. The Pearson Canada website quotes a price of $461.95 for the *Addison Wesley Science 10 Teacher's Resource* and the McGraw-Hill Ryerson website quotes a price of $327.45 for the *ScienceFocus 10 Teacher's Resource*. Purchasing enough textbooks and teacher's resources for an entire school represents a major monetary investment and schools aren't likely to spend more money on more print resources to provide more current and accurate climate change content.

Although the two authorized Alberta textbooks cover the *Science 10 Program of Studies* closely and include many important scientific concepts that address climate change misconceptions, they lack current information, one of the texts uses uncertain language that creates ambiguity about climate change, and both are expensive. These two textbook resources are unlikely to be replaced with new authorized resources until the Alberta high school science program of studies changes – a date for this curriculum change is currently uncertain. This means that, in order to teach the Science 10 climate change unit effectively, classroom teachers must supplement the authorized textbook resources.

Online Resources to Support Instruction

The two authorized Alberta textbook resources are highly aligned with the Alberta *Science 10 Program of Studies* and address the majority of the climate change misconceptions identified in the literature. Because these Science 10 textbooks have been authorized by Alberta Education for over ten years, their use as the primary climate change resource in most Alberta classrooms is likely well established. Science teachers are potentially unaware of the deficiencies of the authorized texts previously outlined in this project, and if they are aware, they are unlikely to have the financial resources to replace an authorized textbook with a more current textbook. Even if teachers were to find funds to purchase new climate change textbook resources, Choi et al.'s research showed that other textbooks may be no better at addressing climate change misconceptions than the Alberta authorized resources. Therefore, this project does not aim to identify resources to replace the authorized textbooks, but instead, to find resources that can supplement the authorized resources.

Online resources are the preferred type of resource to supplement the authorized resources because they can better adapt to the evolving knowledge base of climate change science than static print resources and many online resources are free for educators and students. In order to be useful to Science 10 teachers these free online resources also need to be appropriate for a Grade 10 audience and come from a credible and reliable source. As demonstrated by my experience with the contrarian Friends of Science group, web resources require vigorous vetting. North Carolina State University has created a set of criteria specifically for evaluating science web resources that focuses on science content accuracy and these general criteria are useful for evaluating online climate change resources ("Evaluating Science WWW Resources," n.d.). These criteria emphasize the importance of finding web resources that have

credentialed and responsible authors, that are engaging for students, and that take advantage of the multimedia opportunities of online resources. A goal of this project is to highlight supplemental online resources that have climate change information that is current, address misconceptions not dealt with in the authorized texts, are appropriate for a Grade 10 audience, come from a highly credible source, and are available for free.

NASA Global Climate Change Website

One resource that fits these criteria is the NASA *Global Climate Change* website. This site hosts a series of three climate change modules developed by the Public Broadcasting Service (PBS) and the National Aeronautics and Space Administration (NASA) specifically for educators. The NASA website is an extremely reliable, credible, and current source of information and the modules and other resources there are free. The three modules, "Introduction to Earth's Dynamically Changing Climate," "Impacts of a Warming Arctic," and "Coastal Consequences of Sea Level Rise," are targeted specifically for middle to high-school teachers and can also be used directly with students. The modules include video clips, simulations, interactive applets, quizzes, reflective questions and activities. One potential downside of the modules is that they are linked to many other sites with the larger NASA website; students can easily be navigated away from the module content and onto other scientific concepts simply by clicking hyperlinked text within the module.

It takes approximately four hours to work through all three of the modules if all of the videos and multimedia segments are watched and explored, but this could be significantly shortened by choosing segments that specifically address misconceptions not dealt with in the textbook resources or content to meet specific outcomes. Having students work through all three

modules would address several of the Unit D climate outcomes in the *Science 10 Program of Studies*. In particular, *Science 10* skill outcomes that ask students to analyze and interpret climate data would be well covered by having students work through the three modules. See Table 3 for a description of the alignment between the *Global Climate Change Modules from PBS and NASA* and the Science 10 Program of Studies Outcomes.

Table 3

Global Climate Change Modules from PBS and NASA and Science 10 Program of Studies Coverage.

Global Climate Change Modules from PBS and NASA and Stated Objectives	*Science 10 Program of Studies* Outcomes Addressed by the Resource
Introduction to Earth's Dynamically Changing Climate **Objectives:** 1. Analyze diverse kinds of data around the world that document a warming planet. 2. Analyze graphical representations and scientific visualizations of data exhibiting climate change. 3. Consider strategies to engage students in data analysis.	• investigate and identify human actions affecting biomes that have a potential to change climate (*e.g., emission of greenhouse gases, draining of wetlands, forest fires, deforestation*) and critically examine the evidence that these factors play a role in climate change (*e.g., global warming, rising sea level(s)*) • describe the role of technology in measuring, modelling and interpreting climate and climate change *(e.g., computer models, devices to take measurements of greenhouse gases, satellite imaging technology)*
Impacts of a Warming Arctic **Objectives:** 1. Examine graphical data sets and scientific visualizations and evaluate evidence for decreasing sea ice cover and land ice in the Arctic. 2. Trace the feedbacks in the Earth system that are responsible for the sensitivity of the Arctic to global climate change impacts.	• select and integrate information from various print and electronic sources or from several parts of the same source *(e.g., collect weather and climate data, both historic and current, from the Internet)* • identify and apply criteria for evaluating evidence and sources of information, including identifying bias *(e.g., investigate the issue of global climate change)* • explain how data support or refute a hypothesis or a prediction *(e.g., provide evidence for or against the hypothesis that human activity is responsible for climate change)*
Coastal Consequences of Sea Level Rise **Objectives:** 1. Explore how a warming climate contributes to sea level rise.	

2. Examine how satellites collect sea level data. 3. Analyze interactive data to understand the potential consequences of climate change on sea level in different parts of the world.	

Actions to address climate change. The *Global Climate Change* website also has a "Solutions" section that deals with the suggested actions to address climate change. Unlike the two authorized textbooks, which only focus on personal voluntary actions to combat climate change, the *Global Climate Change* website describes how its role is to make "detailed climate data available to the global community – the public, policy- and decision-makers and scientific and planning agencies around the world" ("*Global climate change*," Solutions section, n.d. Para 1). This explicit goal to inform many levels of society positions climate change as a responsibility of governments, industries, and individuals. Rather than promote personal action, like the authorized textbooks do, the "Solutions" section of the website describes how the lack of collective responsibility has forced local action to occur in spite of a concerted global effort: "In the absence of national or international climate policy direction, cities and local communities around the world have been focusing on solving their own climate problems" (*Global Climate Change*, "Solutions", Para 8).

Language of (un)certainty. The two authorized textbooks differ in the way that they present the plausibility of climate change and the extent to which humans are contributing to climate change. *ScienceFocus 10* takes a much less certain tone than the *Addison Wesley Science 10* textbook does. The third of the *Global Climate Change Modules from PBS and NASA*, "Coastal Consequences of Sea Level Rise," includes a section called "Elaborate" that discusses what scientists mean when they use the word uncertainty. This section on scientific uncertainty is written in student-friendly language and could be a useful springboard for a class discussion on

the plausibility of climate change or the uncertain language used in the *ScienceFocus10* textbook.

Addressing misconceptions. Both authorized textbooks are lacking content that can help address some common climate change misconceptions. Neither of the authorized textbooks covers the distinction between general pollution and the specific gases that cause climate change and neither of the textbooks describes how greenhouse gases are distributed in the atmosphere. The *Addison Wesley Science 10* textbook does not discuss how changes in solar irradiation could affect the climate while the *ScienceFocus10* textbook does not describe the difference between global warming and climate change or distinguish between how radiation interacts with the ozone layer and other greenhouse gases. For those teachers using the *Addison Wesley Science 10* textbook, there are parts of the modules that directly address the concept of how changes in solar irradiation can affect climate change. A short video, called *Temperature Puzzle*, describes the impact of changing solar irradiation and one of the *Global Climate Change* webpages on the causes of climate change provides a detailed explanation of solar irradiation and its effect on the climate. The "Frequently Asked Questions" section of the *Global Climate Change* site also provides a straightforward explanation of the distinction between global warming and climate change and an explanation of the interaction of radiation with the ozone layer and other greenhouse gases, which could supplement *ScienceFocus10*'s lack of content on these two concepts. The "Frequently Asked Questions" resource could even be used as an end-of-unit activity with students; since most of the question content would be covered by teaching the *Science 10 Program of Studies* climate outcomes, a teacher could have students check their own understanding by attempting to answer the questions and then clicking on each question to reveal the answer.

EPA's A Student's Guide to Global Climate Change Website

Another resource that fits the criteria to supplement the authorized textbook resources is the United States Environmental Protection Agency's (EPA) *A Student's Guide to Global Climate Change* website. The website contains credible and current information as evidenced by the statement that in developing the website the EPA "tried to use the most accurate, up–to–date information available" and that the "facts and figures that appear throughout this website come from high–quality publications such as peer–reviewed scientific journals, international scientific assessments, and government research reports" ("*A student's guide to global climate change,"* References section, n.d. para 1). The intended audience for the website is middle school students, but the language and content is still appropriate for Grade 10 students. The site is intended to be student self-directed and uses video clips, activities, and a simulated climate change expedition to try and engage students in the content. The website also has a comprehensive climate change glossary that could be used as a classroom resource. It also includes several lesson plans for teachers to implement the content on the website.

The website has four major topics: "Learn the Basics," "See the Impacts," "Think Like a Scientist," and "Be Part of the Solution!" It takes approximately 20–30 minutes to work through each topic if all of the videos and multimedia segments are watched and explored, but teachers may want to only use the segments that specifically address misconceptions not dealt with in the textbook resources. Having students work through all four topics would address several of the Unit D climate knowledge outcomes in the *Science 10 Program of Studies*. Although there are several tables and graphs presented, students are asked to do very little data interpretation with this resource, so the skills components of the *Science 10* climate unit would not be adequately covered by using this resource alone. See Table 4 for a description of the alignment between the

A Student's Guide to Global Climate Change website and the Science 10 Program of Studies Outcomes.

Table 4

A Student's Guide to Global Climate Change and Science 10 Program of Studies Coverage.

A Student's Guide to Global Climate Change Topic and Stated Description	*Science 10 Program of Studies* Outcomes Addressed by the Resource
Learn the Basics **Description**: Earth's climate is changing, and people's activities are the main cause.	• investigate and identify human actions affecting biomes that have a potential to change climate (*e.g., emission of greenhouse gases, draining of wetlands, forest fires, deforestation*) and critically examine the evidence that these factors play a role in climate change (*e.g., global warming, rising sea level(s)*) • identify evidence to investigate past changes in Earth's climate *(e.g., ice core samples, tree ring analysis)*
See the Impacts **Description:** Scorching summers... Melting glaciers... Stronger storms... The signs of global climate change are all around us.	
Think Like a Scientist **Description:** Uncover the cause of today's global climate change.	• describe and evaluate the role of science in furthering the understanding of climate and climate change through international programs *(e.g., World Meteorological Organization, World Weather Watch, Global Atmosphere Watch, Surface Heat Budget of the Arctic Ocean (SHEBA) project, The Intergovernmental Panel on Climate Change (IPCC); the study of paleoclimates and models of future climate scenarios)* • describe the role of technology in measuring, modelling and interpreting climate and climate change *(e.g., computer models, devices to take measurements of greenhouse gases, satellite imaging technology)* • describe the limitations of scientific knowledge and technology in making predictions related to climate and weather *(e.g., predicting the direct and indirect impacts on Canada's agriculture, forestry and oceans of climate change, or from changes in energy transfer systems, such as ocean currents and global wind patterns)* • explain how data support or refute a hypothesis or a prediction *(e.g., provide evidence for or against the hypothesis that human activity is responsible*

	for climate change)
Be Part of the Solution **Description:** Do something today to reduce greenhouse gas emissions!	• assess, from a variety of perspectives, the risks and benefits of human activity, and its impact on the biosphere and the climate *(e.g., compare the Gaia hypothesis with traditional Aboriginal perspectives on the natural world; identify and analyze various perspectives on reducing the impact of human activity on the global climate)*

One drawback of using this resource in Alberta classrooms is that much of the content is presented with a U.S. context, rather than a global context, and the site uses U.S. measurements (e.g. miles, degrees Fahrenheit, gallons of gasoline), and U.S. data (e.g. Sources of U.S. Greenhouse Gas Emissions). Another drawback is that, like the authorized resources, the solutions to address climate change suggested by the resource are all voluntary personal actions, such as planting a tree or purchasing energy-efficient devices.

Addressing misconceptions. For teachers using either of the authorized textbook resources this website specifically deals with two concepts that neither authorized resource addresses: the distinction between pollution and the greenhouse effect and the distribution of greenhouse gases. The "Learn the Basics" topic has a section on greenhouse gases that includes an interactive pie chart of greenhouse gases. By identifying the gases that contribute to the greenhouse effect and displaying these in a pie chart, students are shown that only certain gases are responsible for the enhanced greenhouse effect – as there is no room in the pie chart for other gases, there is no misconception that other gases play a major role in enhancing the greenhouse effect. This helps distinguish between the vague term "pollution" and the gases that are considered major greenhouse gases. When students click on each portion of the pie chart they are shown the average lifespan and global warming potential of each major gas.

The "Learn the Basics" topic also helps to dispel a misconception about the use of the greenhouse analogy by clarifying that the greenhouse effect works differently from how an actual greenhouse works and succinctly explains how greenhouse gases are distributed:

> These greenhouse gases don't just stay in one place after they're added to the atmosphere. As air moves around the world, greenhouse gases become globally mixed, which means the concentration of a greenhouse gas like carbon dioxide is roughly the same no matter where you measure it. Even though some countries produce more greenhouse gases than others, emissions from *every* country contribute to the problem. (*A Student's Guide to Global Climate Change*, "The Greenhouse Effect", para 5).

The website has content that could also be used to address how changes in solar irradiation could impact climate change, which the *Addison Wesley Science 10* textbook does not cover. The "Ruled Out" activity in the "Think Like a Scientist" topic asks students to examine and then eliminate different natural factors, including solar irradiation changes, as the cause of climate change. One of the lesson plans for educators, "Weather and Climate: What's the Difference?" has students look specifically at the difference between the terms climate, weather, climate change, and global warming. This could be used by teachers using *ScienceFocus 10* to address this concept, which is lacking in the textbook.

Summary

The *Global Climate Change Modules from PBS and NASA* primarily address the skills outcomes of the *Science 10 Program of Studies* and the *A Student's Guide to Global Climate Change* website primarily addresses the knowledge outcomes of the *Science 10 Program of Studies*. The two resources complement each other, so if both the *Global Climate Change*

Modules from PBS and NASA and the *A Student's Guide to Global Climate Change* website were used with Science 10 students, the majority of the Unit D climate outcomes would be covered or reinforced (see Table 5). There are only three outcomes that are not covered by these two resources:

- Identify questions to investigate that arise from practical problems and issues (*e.g., develop questions related to climate change, such as "How will global warming affect Canada's northern biome?"; "How will a species be affected by an increase or decrease in average temperature?"*)
- use library and electronic research tools to collect information on a given topic *(e.g., research sources of greenhouse gases; research protocols to control human sources of greenhouse gases)*
- select and integrate information from various print and electronic sources or from several parts of the same source *(e.g., collect weather and climate data, both historic and current, from the Internet)* (*Science 10 Program of Studies*, pp. 32–33).

Table 5

Supplemental Resources to Address Scientific Concepts not Covered in the Science 10 Authorized Textbooks

Scientific concept not covered in authorized textbook (see Table 2)	*Addison Wesley Science 10* (2004) Pearson Canada	*ScienceFocus 10* (2004) McGraw-Hill Ryerson
2) Distinction between global warming and climate change	Covered	*Global Climate Change*: Frequently Asked Questions http://climate.nasa.gov/faq/ *A Student's Guide to Global Climate Change*: Lesson Plans for Educators http://www.epa.gov/climatechange/kids/documents/weather-climate.pdf
5) Distinction between pollution and greenhouse effects or climate change	*A Student's Guide to Global Climate Change*: Greenhouse Gases http://www.epa.gov/climatechange/kids/basics/today/greenhouse-gases.html	
7) Distinction between the ozone layer and	Covered	*Global Climate Change*: Frequently Asked Questions http://climate.nasa.gov/faq/

greenhouse gases in terms of the interaction with radiation		
10) Distribution of greenhouse gases in the atmosphere	*A Student's Guide to Global Climate Change*: Greenhouse Gases http://www.epa.gov/climatechange/kids/basics/today/greenhouse-gases.html	
12) Solar irradiation change and its possible impacts on current climate change	*Global Climate Change*: Explore Video: *Temperature Puzzle* http://climate.nasa.gov/climate_resources/42/ *Global Climate Change*: Causes http://climate.nasa.gov/causes/ *A Student's Guide to Global Climate Change*: Earth's climate in the Past http://www.epa.gov/climatechange/kids/basics/past.html	Covered

Both resources are highly flexible because they present content in a modular way so students can work through specific parts of either resource without having to tackle the entire content. Since the resources are free and accessible to anyone with Internet access and a computer, students could use the resource at home to reinforce material already learned in class, catch up on content missed during a school absence, or learn content ahead of time in a flip classroom context. Teacher planning time to implement the resource content is minimal because the format of the resources is largely self-directed and the *A Student's Guide to Global Climate Change* website even has lesson plans developed to implement the resource. Depending on the authorized textbook resource being used by the teacher, he or she could use parts of each resource to address content deficiencies that target common climate change misconceptions.

A teacher looking for more current climate information and potentially more engaging content would be well served by either of these two resources. These supplemental resources present up-to-date and credible information, are appropriate for a Grade 10 audience, and align

well with the *Science 10 Program of Studies*. Both supplemental resources have no cost for educators and require little modification to implement. Perhaps most importantly, they include important content that is missing from the authorized textbooks and can be used to help address major climate change misconceptions. I would be very confident guiding students through either of these resources in my own Science 10 classroom or assigning my students to employ these resources at home to strengthen their understanding of the science of climate change.

Conclusion

Climate change is a complex and sometimes confusing issue, but one that must be urgently addressed by Alberta educators. A review of the literature shows that public perceptions of climate change are hampered by an incomplete understanding of the science behind the issue, the media's exaggerated controversy of the issue, and misinformation by contrarians. Chambers (2011) work indicates that Alberta educators are daunted by the challenge to address the climate change issue, which academics (e.g. McBean & Hengeveld, 2000; McKeown & Hopkins, 2010; Sharma, 2012) have laid before them in the literature. Teachers struggle with the interdisciplinary nature of the climate change topic and the perception that there is legitimate doubt about the plausibility of climate change. The controversial nature of the topic is perhaps even more sensitive for Alberta educators because the province is so economically dependent on fossil fuels.

Sadly, the call for interdisciplinary reform that Lang, Drake and Olson (2006) call for seems far off in Alberta; widespread curricular reform in Alberta was initially met with excitement in 2009, but now "back to the basics" public pressure in the form of petitions and

protest rallies has cast doubt about the extent of curricular reform (Staples, 2015). The proposed solution of increased scientist-educator collaboration that McBean and Hengeveld (2000) called for in their paper written over a decade ago does not seem to have come to fruition. The study of climate change requires an understanding of a complex Earth system where a changing climate is certain, but the possible outcomes of climate change are uncertain and the proposed solutions are debatable. The literature indicates that teachers have shied away from the complexity of the issue, rather than embraced its complexity as Dahlberg (2001) calls for. If educators are seen by their students as reliable sources of information, as McBean and Hengeveld contend, then educators *must* navigate conflicting information about climate change so that they are in a position to deliver the message about climate change to students in a clear way. Educators in Alberta will only feel prepared to deliver this message if they have the resources to support them.

The current authorized teaching resources for Science 10 are outdated and, depending on which textbook is being used in a particular classroom, there may be a perpetuation of the idea that there is scientific uncertainty about the plausibility of climate change and the extent of human influence on climate change. The current authorized teaching resources are also deficient because they lack some content that can help address major misconceptions about climate change and they only promote personal voluntary actions to help combat climate change. Online resources, in addition to the authorized textbooks, are needed to help teachers teach this topic more effectively. With access to online resources collaboratively developed by scientists and educators, such as the NASA *Global Climate Change Modules*, McBean and Hengeveld's collaborative scientist-educator vision can be realized in a different mode – scientists can be virtually engaging with classrooms through online resources they help develop. The *Global Climate Change Modules from PBS and NASA* and the *A Student's Guide to Global Climate*

Change website, are able to stay current, contain the content that the authorized textbooks lack, position climate change as highly plausibility, and present a wider variety of actions to address climate change. Resources, such as the *Global Climate Change Modules from PBS and NASA* and the *A Student's Guide to Global Climate Change* website, are what Alberta Science 10 teachers should look to in order to address some of the challenges of teaching about climate change.

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