

Assessing students' learning about climate change under two different conditions

by

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B.A., University of Victoria, 2003

B.Ed., University of Victoria, 2005

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Supervisory Committee

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Member

Abstract

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This research followed students from three different British Columbia, Grade six classes through two-weeks of instruction on climate change. Pre, post, and follow-up surveys were used to determine the differences in knowledge retention between the students that received, through their science teacher, instruction from a unit and students who received equivalent content instruction from outside presenters. The teacher participant also completed a survey on her experience with the lessons plans. Students' results on the post and follow-up surveys were compared to a control group's results. The teacher-based approach to learning about climate change resulted in higher knowledge gain although no difference was found between the groups' rate of knowledge decline thereafter. The teacher's feedback corresponded to the result of the analyses by theme, showing that the highest gains in knowledge were for the carbon cycle and the human impacts topic, followed by understanding the difference between climate and weather. The students and teacher alike appeared to struggle with the topic of global warming and the greenhouse effect.

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Chapter 1

Climate Change Science in BC's classrooms

Global warming (henceforth, GW) is arguably the single most pressing environmental issue of our time. The consensus of the climate community on the subject of GW is clear: the problem is real, largely caused by human activities and requires immediate action to avert dangerous impacts (IPCC, 2007). As educators of the next generation, British Columbia's K-12 teachers are in a unique position to convey the causes and ramifications of GW to a wide audience. Unfortunately, despite the long-held scientific evidence, it is only recently that educators have started to discuss GW in classrooms. At present, climatology is addressed only briefly in the Science 10 section of BC's K-12 curriculum (Ministry of Education, 2008). For future leaders to understand the science of climate change properly and the implications associated with the science, it is imperative that units for earlier grades be developed that enhance students' knowledge retention and minimizes students' misconceptions of GW and climate change.

Focus of This Research Study

This project developed and evaluated a curriculum-linked BC Grade 6 science unit on climate change. Teacher feedback concerning the effectiveness of the unit was an important aspect in supporting the analysis and providing direction for future research and the further development of climate change curricula. Thus, first the unit was developed, with particular attention paid to key concepts and the associated difficulties previous researchers and teachers have experienced when dealing with the issue of climate change (e.g., see Shepardson, Niyogi, Choi, & Charusombat, 2009).

The topics focused on for this intervention were (a) the differences between weather and climate, (b) the carbon cycle and the human impacts, and (c) global warming and the greenhouse effect. Weather is the current atmospheric state at any given place. It is what is happening right now or likely to happen tomorrow or in the near future. Climate is the average pattern of weather for a particular region, usually taken over a 30-year time period or longer. In other words *weather* is *what you get* and *climate* is *what you expect*. The public sometimes confuses these two concepts, mistakenly stating that a particularly hot day is evidence of climate change. In addition to understanding the differences between weather and climate, the link between the carbon cycle and the greenhouse effect should be understood by students in order for them to understand GW (Shepardson et. al, 2009). Like the water cycle, carbon in the carbon cycle moves between various components of the Earth system by different processes. Understanding where carbon is stored and how it's captured and released—naturally and by human activity—is essential to understanding human-induced climate change. Carbon dioxide, a form of carbon found in the atmosphere, is one of the main greenhouse gases, and as such plays a critical role in regulating the Earth's temperature. Greenhouse gases are named because of their ability to absorb and re-emit infrared radiation (also called long-wave radiation), contributing to the greenhouse effect. The *natural* greenhouse effect, in the absence of any human-produced greenhouse gases, helps Earth to maintain an average global temperature that is hospitable for life. However, as more greenhouse gases, like carbon dioxide, are added to the earth's atmosphere through human activities, such as through the burning of fossil fuels, more infrared radiation is retained in the Earth's system for a longer time (rather than escaping to space) leading to an increased average

global temperature (i.e. the *enhanced* greenhouse effect). Therefore, GW is a type of climate change that is a result of the human-altered greenhouse effect (i.e. *enhanced* greenhouse effect). Subsequent climate changes that occur, such as melting glaciers, or changes in vegetation cycles are delayed responses to GW.

The Purpose and Scope

The purpose of this study is to discover if and how students' experiences with learning about climate change enhance their knowledge and if the subsequent change in knowledge is influenced by the conditions of learning. In other words:

- Do two different delivery approaches influence students' knowledge retention?
- If so, do we see a differential decline in students' retention over time, between two different approaches?

The research followed students from three different grade six classes through two-weeks of instruction on climate change and revisited students one month after the end of the project. A fourth group acted as a control group and did not receive any instruction on climate change. Pre, post, and follow-up surveys were used to determine the differences in knowledge retention between the students that received, through their science teacher, instruction from the unit created as part of this research project and the students who received equivalent content instruction from outside presenters. The teacher participant also completed a survey to provide qualitative feedback on her experience with the lesson plans used to teach GW and climate change. The data collected from the surveys were analyzed to determine any statistically significant differences in knowledge retention

between groups. The qualitative information for the teacher's survey was used to reinforce the statistical findings. The findings will also guide the publication of a future BC curriculum-linked unit.

Chapter 2: Literature Review

Educated citizens are empowered citizens and educators; equipped with knowledge, British Columbia's youth can change the path of future carbon emissions. To build the knowledge of today's youth, educators must understand how to design and deliver effective global warming (GW) lessons with powerful teaching strategies. My literature review therefore focuses on what the literature suggests are key issues to be considered when delivering and developing effective climate change education lessons. In particular, I will discuss and identify (a) students' preconceptions, (b) influences on knowledge retention, and (c) teaching strategies that enhance such knowledge retention. The findings below guided the design of the climate change unit for British Columbia's Grade 6 students used in my thesis research.

The Science and Politics of Global Warming

Public awareness of GW has increased markedly in recent years (especially with the release of media targeted towards non-scientists such as Al Gore's *An Inconvenient Truth*). As a result, the general public sometimes holds the view that climatology is a field still in its infancy. As some question the rationale of teaching "developing science" to students, I first begin by demonstrating that the science of GW is not new.

The theoretical basis of the greenhouse effect was developed as early as 1824 with the publication of *General Remarks on the Temperature of the Terrestrial Globe and Planetary Spaces* by Fourier (1824). Shortly thereafter, Tyndall (1859) measured the ability of various gases to absorb and radiate heat and Arrhenius (1896) made the first

estimate of globally-averaged surface warming for a doubling of atmospheric carbon dioxide. By 1938, Callendar had published a landmark paper: *The Artificial Production of Carbon Dioxide and its Influence on Climate*, that showed even at this early date, a link between the combustion of fossil fuels and an increase in global mean surface temperature had been made. Since then, scientists have continued to measure and record the effects of various greenhouse gases on our earth's atmosphere.

The consensus of the climatology community on the subject of GW is clear and is evidenced by reports such as the Intergovernmental Panel on Climate Change's fourth assessment report (IPCC, 2007). The problem is real, largely caused by human activities and requires immediate action to avert dangerous climate change. The debate that exists now is political, economic, and ideological - not scientific. However, the media has traditionally portrayed GW as a contentious issue; for example, Boykoff and Boykoff (2004) showed that from 1988 to 2002 American newspaper articles gave more or less equal weight to natural variations and human factors as causes of climate change. A follow-up study by Boykoff (2008) on television news coverage from 1995 to 2004 found the same trend. This is continuing albeit to a lesser extent today (Boykoff, 2007). It is not surprising then that many students and adults possess erroneous conceptions of the science of climate change and the impacts of climate change (e.g., Pruneau, et al. 2001). Yet, very few climate scientists disagree with the consensus view. For example, when asked "do you think human activity is a significant contributing factor in changing mean global temperatures?" 97.4% of scientists who actively contribute to research on climate change responded yes; whereas, only 58% of the general public agreed (Doran & Zimmerman, 2009). Similarly, Global Warming's Six America's survey found as

recently as June 2010 that 34% of people surveyed were either disengaged, doubtful, or dismissive of GW, 24% were cautious and only 41% were alarmed or concerned (Leiserowitz, Maibach, Roser-Renouf, & Smith, 2010). Likewise a Canadian study demonstrated that despite students' and adults' erroneous conceptions of the science of GW, they believed climate change would have little impact on their lives and consequently were not that concerned with the issue (Pruneau et al., 2001). Yet, the Intergovernmental Panel on Climate Change (IPCC) has concluded that GW is inevitable and that they are now at least 90% certain that this is mostly due to human activities (IPCC, 2007). According to the IPCC, greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, being added to the Earth's atmosphere by human activities will result in GW. This warming will lead to other changes in the climate system. The increased likelihood of extreme events, such as floods, storms, drought and heat waves, will put humans at risk. Over time human health and agriculture will be impacted along with the marine and terrestrial ecosystems that we depend on.

Thus, educational initiatives will be essential not only to alert the public to the reality and severity of the problem but also to teach sustainable living strategies that will minimize humanity's environmental footprint. There is a clear need for instruction that increases students' long-term retention of the basic science of GW so that they are able to participate fully in the social, political, and economic debates that will ensue as a result of the climate changes. For, without a basic understanding of the science, people are likely to misunderstand the impacts of GW and consequently may make uninformed choices.

A Review of Global Warming Research in the Classroom

Preconceptions: Current Ideas and Misconceptions of Students and Teachers

In developing any new unit, instructors should first consider their students' existing knowledge base. Particularly important are teachers' and students' ideas and scientific misconceptions (or *alternative conceptions* as they are sometimes known). Misconceptions are views or opinions that are incorrect because they are based on faulty thinking or understanding (Driver & Easley, 1978; Erickson, 1979; Posner, Strike, Hewson, & Gertzog, 1982). Since science (and climatology in particular) is based on cumulative development of progressively more complicated principles, misunderstanding of very basic principles can greatly confuse and obstruct further learning. In my opinion, it is for this reason that the largest body of educational research on GW has primarily focused on scientific misconceptions.

The development of students' misconceptions frequently stems from their tendency to over generalize the causes and consequences of environmental problems, leading them to think any "environmentally-friendly" action will reduce GW (Batterham, Stanisstreet, & Boyes, 1996). Boyes, Stanisstreet, and colleagues have done numerous studies to identify students' ideas and misconceptions on GW and air pollution (e.g., see Boyes, Myers, Skamp, Stanisstreet, & Yeung, 2007; Boyes, Stanisstreet, & Yongling, 2008; Boyes & Stanisstreet, 1993; 1997a; 1997b; Daniel, Stanisstreet, & Boyes, 2004; Myers, Boyes, & Stanisstreet, 1999). The typical age range in these studies is 11 to 16 years old with a predominant focus on the knowledge and experience of students in the United Kingdom. In addition, other researchers from the United States, Australia, Greece, and Italy have looked at students' ideas and misconceptions and found similar

results (e.g., see Koulaidis & Christidou, 1999; Mason & Santi, 1998; Rye, Rubba, & Wiesenmayer, 1997; Skamp, Boyes, & Stanisstreet, 2004).

Often these misconceptions stem from misunderstanding the greenhouse effect, which is a general starting point when discussing the role of the atmosphere in the earth system. The greenhouse effect arises from so-called greenhouse gases that allow sunlight to enter the atmosphere but inhibit heat from the Earth's surface from escaping to space. Students often do not understand that the greenhouse effect is a *natural* and important component of our earth system, nor do they realize the variety and importance of various greenhouse gases present in the earth's atmosphere (Boyes & Stanisstreet, 1997a; Koulaidis & Christidou, 1999; Pruneau et al., 2001). Natural levels of greenhouse gases are responsible for keeping the Earth warm enough to sustain life. It is crucial that students be led to recognize that it is the *enhanced greenhouse effect* stemming from anthropogenic emissions of greenhouse gases and land clearing that is the root cause of GW (Boyes & Stanisstreet, 1993; Koulaidis & Christidou, 1999).

A second specific misconception arises from confusion between GW and holes in the ozone layer, both topics that have had heavy media coverage in recent years. The ozone layer is a layer in the stratosphere that strongly absorbs harmful UV rays. Holes in this layer developed as a result of the release of chemicals called chlorofluorocarbons (CFCs), which were used as spray can repellents and refrigerants amongst other things (Henson, 2006). Once the deleterious effect of these chemicals was recognized, their use was phased out and stratospheric ozone is beginning to replenish itself (Henson, 2006). Students often believe the hole in the ozone layer is the cause of GW (Andersson & Wallin, 2000; Boyes & Stanisstreet, 1997; Kilinic, Stanisstreet, & Boyes, 2008; Koulaidis

& Christidou, 1999; Österlind, 2005; Pruneau, Gravel, Bourque, & Langis, 2003; Rye et al. 1997). In recent years, there has been a decrease in coverage of this topic in the media since the issue has been largely resolved and a subsequent decrease in this misconception may follow. In a recent study, Shepardson, Niyogi, Choi, and Charusombat (2009) did detect a noticeable decline in students' linking of the ozone hole with GW and climate change. Instructors should, however, be aware of the issue and, given the current prevalence of this misunderstanding might consider devoting a separate lesson to the topic. This could be used not only to further emphasize the distinction between the enhanced greenhouse effect and the ozone hole but also to demonstrate a situation where an environmental problem was successfully identified and addressed through positive behavioural shifts (Weaver, 2008).

Finally, research indicates that other specific misunderstandings may arise in other areas related to GW instruction. The difference between climate and weather is often poorly understood (e.g., see Shepardson et al., 2009). Adults and students sometimes simplify the issue, believing that the warmer weather associated with GW is a positive thing, yet they appear not to understand that GW is associated with a variety of extreme events that can have devastating impacts on regions not acclimatized to such extremes (Pruneau et al., 2001). Also, students are unaware that different parts of the world experience different seasonal climates, and this initial confusion can compound further understanding at the global level (Environmental Literacy Council & National Science Teachers Association, 2007). As well, students often struggle with concepts of radiation and heat. Sometimes they only associate radiation with the negative impacts of nuclear radiation. Often students are unaware that intangible things, like light, can have

observable properties (e.g., wavelength), or that heat can be transmitted in a variety of ways, some of which involve direct physical contact (i.e., touching a hot pot) and others which involve indirect transmission by light (i.e., light from the sun) (Environmental Literacy Council & National Science Teachers Association, 2007).

Recently, ideas and misconceptions amongst students have been compared across countries (Boyes et al., 2007) with findings pointing to consistencies in knowledge and misconceptions across countries. Also, research is emerging on knowledge differences and retention amongst students living in the same region, but with diverse languages and cultures (e.g., see Lee, Lester, Ma, Lambert, & Jean-Baptiste, 2007). This research across countries and cultures is primarily focused on students' concepts of GW before educational intervention. Likewise, the research on students' ideas and misconceptions is largely pre-instruction.

While most of the aforementioned research has focused specifically on students, unit developers must also be aware of additional research that has been done on pre-service and practicing teachers' ideas and misconceptions. Broadly, these studies have shown that the nature of teachers' misconceptions was similar to that of their students' (e.g., see Demirkaya, 2008; Khalid, 2003; Michail, Stamou, & Stamou, 2006; Summers, Kruger, Childs, & Mant, 2001). The topic of GW is complex and was not one that most practicing teachers learned in school themselves or received subsequent training in (Fortner, 2001), so it comes as no surprise that both teachers and students struggle with this concept.

Awareness of Age, Gender, and Cultural Differences

Although research indicates that the aforementioned misconceptions are relatively consistent across demographics, there are differences in existing knowledge of the climate system with age, gender and culture and these are important considerations to take into account when developing a new unit. First, age has an important influence on student's background knowledge. Findings in GW educational research are consistent with Piaget's cognitive stages as students transition from the concrete to the formal operations stage with age (Piaget, 1950). This represents a shift in students' thinking from limited abilities to reason abstractly to increasing abstract sophistication, with the ability to consider multiple perspectives (Piaget, 1950). For example, the confusions between the effects of local and global pollution decreases with age (Daniel et al., 2004), as students are able to distinguish between their immediate surroundings and the broader environment. Also, older children are more likely to believe the hole in the ozone layer contributes to GW, possibly due to confusing media reports on the two similar but distinct global issues (Batterham et al., 1996), or as a result of the misconceptions adults around them hold. Furthermore, older children feel less of a personal responsibility to reduce the greenhouse effect (Batterham et al., 1996). This may be in part due to the fact that older children are more aware this is a global problem and therefore not entirely a local responsibility. Yet, regardless of age, when polled, the majority of students believe that education on GW could help their understandings of how to fight GW (Daniel et al., 2004).

Second, there are differences in climate knowledge with respect to gender. Boys appear to understand the consequences of an enhanced greenhouse effect better than girls (Boyes & Stanisstreet, 1993; Daniel et al., 2004). Furthermore, they are more likely to

mention the manufacturing steps that could be implemented to reduce atmospheric pollution, such as producing more electric vehicles (Batterham et al., 1996). Boys also are better informed that a reduction in coal and oil use and increase in electric power would help. Older boys are also more comfortable with the idea that nuclear power is a viable option to reducing greenhouse gas emissions (Boyes & Stanisstreet, 1993).

Finally, it appears that culture has little effect on students' knowledge of the basic GW science (Boyes et al., 2007; Lee et al., 2007); however, students' cultural background does appear to affect their attitudes with regards to acceptance of various courses of action to reduce greenhouse gas emissions (Boyes et al., 2007). Students in Hong Kong, when compared with their peers in the United Kingdom and Australia, were more willing to accept government-imposed taxes and laws as means to reduce greenhouse gas emissions and individuals' actions that contribute to emissions (Boyes et al., 2007). Conversely, the students in the United Kingdom and Australia were less comfortable with imposed laws and taxes and preferred companies to take actions rather than individuals. They were also more likely to have pro-environmental attitudes if they had a high concern about the issue; whereas, students from Hong Kong believed that if people's level of knowledge increased about the problem more people would express pro-environmental attitudes (Boyes et al., 2007).

Instructional Strategies for Effective Learning

Not surprisingly, both instructional content and assessment tasks affect learning and knowledge retention (Semb & Ellis, 1994). Bearing this in mind, then what are some key characteristics of good instruction and how have these characteristics been used in educational research on climate change?

Direct instruction techniques and domain specific knowledge acquisition. As a means of overcoming the inherent complexity of GW instruction, various researchers have suggested using direct instruction techniques that are complemented by domain-specific knowledge acquisition. Sadler, Chambers, and Zeidler (2004) suggest that direct instruction on the nature of science must occur in order for students to integrate scientific knowledge into their decision-making processes. Without a strong grasp of the empiricism, tentativeness (that is, the fact that existing theories may be revised as new knowledge becomes available), and social embeddedness inherent to the scientific process students chose GW articles that aligned more with their pre-existing opinions as having greater scientific merit (Sadler, Chambers, & Zeidler, 2004).

Generic terms, such as ‘pollution’ should be avoided, as this leads to confusion between distinct environmental issues. Instead, more specific terms like ‘pollutant’ ought to be used (Boyes & Stanisstreet, 1997b). As well, it should be emphasized that context is important when using terminology. For example, a major constituent of smog is ground level ozone; here, ozone is acting as a pollutant, but in the stratosphere the gas has a beneficial effect. In this kind of setting, concepts can be systematically analyzed as in the following framework for understanding the effects of a given pollutant. First, the student learns about the pollutant’s origins, then they determine its impacts in a particular environmental context and finally they examine the consequences of increased pollutant levels (Boyes & Stanisstreet, 1997b).

Taxonomic frameworks. Taxonomic frameworks could also prove useful for deconstructing generalizations (Daniel et al., 2004). For example, framing action in terms of rethink, reduce, reuse, and recycle. The important thing to consider here is that, in

order for the higher level processing and thinking skills to take place students must have some direct instruction, in attempt to minimize confusion and prevent new misconceptions being formed.

Active learning. Active learning makes it easier for students to assimilate new information into their existing memory structures and results in better long-term retention of knowledge (Semb & Ellis, 1994). Active learning strategies such as situated cognition, constructivism, anchored instruction, and peer tutoring have all been successful learning strategies for increasing long-term knowledge retention (Semb & Ellis, 1994). Environmental education research has shown that long-term memories and knowledge retention occur most frequently if the experience is active (Knapp & Benton, 2006). However, this is a challenge in GW education due to the abstract nature of climate change. Thus, to move from a more concrete to abstract level of thinking about GW topics could be linked to actions (Myers et al., 1999). For example, when discussing the invisible make-up of our atmosphere, the gases could be discussed in relation to their actions: oxygen in terms of its role in actively rusting metal and carbon dioxide as a by-product of respiration by animals (Myers et al., 1999). In addition, students could act out what they can't perceive. For example, the Sierra Club BC's *Climate Change Education Program* (2009) uses a greenhouse gas tag game to demonstrate how increasing the number of greenhouse gases in the atmosphere, increases the likelihood of heat being trapped. Students are divided into those who are *it* (representing greenhouse gases) and those who are not, representing heat attempting to leave the climate system. As more students are *it* in tag, more heat (i.e. students) is trapped, demonstrating the role of increasing greenhouse gas concentrations in enhancing the greenhouse effect. In sum,

much of the educational research on GW supports the notion that active learning effectively engages the learner and provides an excellent opportunity for learning (e.g., see Cordero, Todd, & Abellera, 2008).

Authentic learning. Authentic learning tasks provide an opportunity for the student to use their skills in situations as close to the real world as possible (Bardsley & Bardsley, 2007; Lee & Butler Songer, 2003). For instance, computers might be used to investigate and interpret long-term national and international trends (Batterham et al., 1996; Lee & Butler Songer, 2003) in weather data. Most importantly, educators must empower students through exploration that is personally relevant and meaningful (Batterham et al., 1996; Cordero et al., 2008; Daniel et al., 2004; Lester, Ma, Lee, & Lambert, 2006) thereby, bringing the abstract nature of GW to the concrete reality of the students' world. Students must take ownership of the problems and explore their own connections to them (Daniel et al., 2004). Industrial carbon emissions and lifestyle are linked. Significant portions of today's emissions come from the production of consumer goods and services. These are the same goods and services that are used by today's young people (Daniel et al., 2004). Students must be encouraged to explore their personal connections to energy usage and climate change. For instance, Cordero et al. (2008) suggest that this aim might be accomplished through the use of tools such as a carbon calculator to assess students' own ecological footprint.

Local Curricula. The literature suggests that one of the most effective ways to make lessons meaningful to students is to develop curricula that are local in nature. Students' ideas and preconceptions can be challenged and discussed through debate at a local level (see for example, Bardsley & Bardsley, 2007) to help promote an

understanding of climate change impacts. In other words, the first step to towards understanding of GW is to identify the problems at provincial or national level (Lee et al., 2007), in an active, authentic context. Fortunately, there are many examples of curriculum design that support such local connections upon which new curricula may be modeled. In particular, PING (Practicing Integration in science education) from Germany provides an excellent national and regional framework for the development of a strong integrated science curriculum. Teacher collaboration features prominently in this model (Riquarts & Hansen, 1998). Here in Canada, Ontario teachers have also had success working together to be the change agents in their schools (Lang, Drake, & Olson, 2006). Teachers met regularly to plan and assess an integrated Grade 9 waste-audit course. Students in this course inventoried the school waste and how it was disposed of and then took actions to alleviate the waste-flow problems at their school. At the end of the course, teachers believed their students were more aware of the need to care for the environment as well as more motivated and skillful. Furthermore, the students possessed a deeper understanding of the science concepts than they would have gained in a traditional classroom (Lang et al., 2006).

Constructivist teaching and constructivist learning. A constructivist method whereby students create their own knowledge has been proposed by some researchers (Ausubel, 1968; Driver, 1983; Novak, 1993; Roth, 1989; Yager, 1991). An investigative, inquiry-based approach is useful for overcoming misconceptions and developing knowledge: students should discuss and analyze the options available for action on GW and be assisted in analyzing the cost and benefits of various choices (Fortner, 2001; Mason & Santi, 1998). Through this approach students are not told what must be done,

but are given supporting information (such as accurate scientific data) to inform their decision (Bardsley & Bardsley, 2007).

Research has demonstrated that the constructivist method may not be sufficient on its own, and that it should be supplemented by direct instruction. For example, Österlind (2005) found that students' understanding of the concepts of the enhanced greenhouse effect and depletion of the ozone layer was weakened by a thematically organized, investigative approach. Students had difficulty discovering the meaning of words specific to the research (e.g. fossil fuels) and had difficulty distinguishing between the two separate environmental issues. Interestingly, cognitive conflict, which traditionally helps solidify learning, was absent in the students' group work. Lack of domain-specific knowledge prior to the students' investigation hindered their ability to engage in discussions with peers to clarify preconceptions. As a result, the students' work showed the persistence of common misconceptions after learning (Österlind, 2005).

Interdisciplinary instruction. Finally, another factor that enhances learning is integration of topics across disciplines. Students experience school not only in the context of a single subject but in terms of a day's collective experiences (Stevens, Wineburg, Herrenkohl, & Bell, 2005). Rather than limiting GW education to the science class, its implications should also be addressed in subjects such as social studies and language arts, due to social, political, and economic factors that determine the course of action taken by countries. However, teachers do not always favour interdisciplinary teaching, with regards to GW, as many feel that it would be too time consuming (Gayford, 2002). The existing instructional framework in British Columbia does not need to be modified to teach GW curricula but deliberate attempts should be made to make connections across

subjects. At the very least GW and climate change instruction needs to integrate the science disciplines in order to explore and analyze science from a more systems-based perspective (Shepardson et al., 2009). This is why it is necessary to develop a GW curriculum that can be taught within the prescribed learning outcomes of various subjects independently or collaboratively amongst subject teachers.

Beyond Knowledge Acquisition: Instructional Interventions that facilitate change

One of the ways for society to address anthropogenic climate change meaningfully is to provide future generations with adequate knowledge of the science behind it, in the hope that this will also lead to positive shifts in relevant attitudes and actions. To ensure that educational strategies are effective, post-instructional knowledge, attitudes, behaviours, and values must be examined for change. Knowledge of GW is often a pre-requisite for the development of attitudes and pro-environmental actions (e.g. see Jensen, 2002; Lester et al., 2006; Mason & Santi, 1998) and is often easier to measure than the latter traits. However, GW instruction must not only convey knowledge but also affect a shift in attitudes and behaviours towards the environment and the climate.

The consensus of many in the climate community is that knowledge of GW and its consequences is sufficiently robust that additional research is not needed to justify rapid and significant shifts in industry and lifestyle to avoid dangerous climate change (Weaver, 2008). What emerges clearly from the literature, regardless of the type of learning approach used, is the need to embed the scientific learning on GW within the greater societal context. In addition to understanding the impacts of climate change, students must learn effective ways that individuals, communities and countries can take action on the problem (Jensen, 2002). Not only can this integration enhance learning of

the science but also many of the integration strategies may lead to positive changes in attitudes and actions taken amongst students.

In a review of contemporary issues in curricula (including environmental education) Leming (1992) discovered that, following curricular instruction, knowledge goals were mostly achieved while attitudinal and behavioural goals were achieved in about a third of the studies reviewed. Cooperative learning situations, issues that were viewed by students as personally relevant, opportunity for peer interaction and discussion of attitudes, morals and values, as well as concerns of adults, parents and other community members all played a significant role in students' attitudinal and behavioural shifts (Leming, 1992). Not surprisingly then, a review of the GW educational research reveals similar findings.

Most instruction intervention studies on climate change and GW have found that knowledge does increase after instruction (e.g., Lee et al., 2007; Mason & Santi, 1998) however, the changes in attitudes and values have been less clear. To shift students' attitudes, that are largely based on their prior knowledge (Mason & Santi, 1998), students' misconceptions from erroneous knowledge generalization (Francis & Boyes, 1993) must be overcome.

Mason and Santi (1998) found that in pre-instruction interviews students held many misconceptions on how the Earth warms, consequences of Earth's warming, and actions that could reduce the greenhouse effect. However, after instructional intervention students, in general, became more aware of their prior misconceptions and were more likely to revise their misconceptions. Mason and Santi (1998) attribute this change in

knowledge and understanding to the whole class and small group discussions that the students held on their ideas about GW.

Similarly, an increase in knowledge seems to be linked to an increase in concern and expressions of activism. Jensen (2002) saw knowledge as a pre-requisite for taking positive action on environmental issues and the educational research on climate change issues seem to support this. For example, at the end of a large-scale science, technology, society instructional intervention, the higher students' knowledge on GW was, the more likely they were to express activism (Lester et al., 2006). Likewise, Taber and Taylor (2009) found that in their interviews with students after an instructional intervention on climate change that they attributed their increase in concern with climate change to their increase in knowledge.

Cooperative learning environments also seem to be an effective way to facilitate changes in attitudes. For example, the cooperative learning environment at Woodcraft Folk, an educational charity, resulted in students (ages 9 to 12) who were more likely to be more convinced that climate change was occurring and were more concerned about use of fossil fuels than a comparative sample of children from two primary schools (Devine-Wright, Devine-Wright, & Fleming, 2004). The students also had a greater sense of responsibility and were more likely to view their action towards reducing climate change as significant. The presence of adults with similar values was also seen to contribute positively to the students' value systems (Devine-Wright et al., 2004). Adults that believed climate change was an immediate problem interacted with these students at Woodcraft Folk and these students were more likely to express proactive attitudes than the comparative sample (Devine-Wright et al., 2004).

Overall, it seems that a large majority of students care about the state of the world and have strong feelings on it though their misconceptions often get in the way of their understanding (Littledyke, 2004). Nonetheless, teachers can contribute to the conceptual change in students' mental models. Given that the majority of students' conceptions of science and attitudes about science, in sample population of years 1 to 6 in the United Kingdom, came from classroom experiences, we can reason that teachers play a significant role in conveying 'science' (Littledyke, 2004). Therefore, planned teaching that exposes children to environmental issues and concepts is important (Littledyke, 2004). Very few students mentioned the influences science has on society and on environmental issues (Littledyke, 2004), further reinforcing the need for teachers to make explicit the social embeddedness of science. Regardless of the learning strategy used, given the complexity of the topic, in depth coverage will be far more effective and is necessary to overcome misconceptions (Eylon & Linn, 1988; Fortner, 2001), especially with the strong influences of the situational context. Given this, it seems imperative that different methods of instruction be investigated for their effectiveness at increasing knowledge retention and subsequently impacting attitudes and actions.

Summary of the Literature

The science of climate change is not new. Moreover, there is a wealth of research on GW ideas amongst teachers and students and the results of these studies should be considered and addressed when new curricula are developed. In particular, misconceptions must be addressed with the aim to overcoming them, though this has proven difficult even after instructional intervention (Andersson & Wallin, 2000; Lester et al., 2006; Mason & Santi, 1998). Knowledge is an important precursor to the development of attitudes and behaviours towards climate change thus, explicit instruction on GW concepts should happen before preconceptions, obtained from other less reliable source (such as the media) have solidified. Strategies put forth by researchers in science education, environmental education and by those who've specifically investigated GW curricula are using:

1. Direct-domain specific instruction (e.g. investigating the explicit differences between climate and weather, acquiring the necessary vocabulary, such as 'fossil fuels', using taxonomic frameworks)
2. Active learning (e.g. opportunities for movement, group work or peer tutoring)
3. Authentic learning (e.g. local issues, personally relevant)
4. Some principles of constructivist learning, in conjunction with direct-instruction techniques (i.e. discussion/ analysis of misconceptions)
5. Integration across subjects (i.e. discussing both the scientific and social implications of ongoing climate change)
6. Cooperative and supportive learning environments (e.g. the adults surrounding the students are positive and motivated themselves)

Chapter 3: Methodology

Sample Population

Grade 6 students were chosen to participate in this project because of their developmental age and because the Grade 6 curriculum has a number of prescribed learning outcomes that could be linked to GW. Children aged 10-12 are emerging adults learning to reason abstractly (Piaget, 1950) and look beyond their local boundaries to a global community. This transition is necessary to begin to deal with the scientific, social and political complexity of climate change adaptation and mitigation. Furthermore, climate science is presently only addressed briefly in Grade 4 as weather and in Grade 10 as climate in BC's science curricula. Having the subject addressed at grade 6 spans the gulf in climate-related coverage.

Study Site and Participants

The study was conducted at a Middle School, in Victoria BC and was approved by the University of Victoria's ethical review board and by School District 61. The school was chosen as the study site as the principal and four teachers expressed interest in the study. A meeting was arranged with the lead teacher to discuss the project. With her support, subsequent meetings were arranged with the principal, other participating teachers, and students.

Student recruitment was conducted in person in the classrooms, once all four classroom teachers and the school principal gave permission for their classrooms to participate in the research. The students were given a verbal description of the research process and each student was provided with a *Student Consent Form* to sign, if he or she

chose, that outlined the research process and a *Parent/Guardian Consent Form* to take home for a parent or guardian signature. Students who had returned both a completed *Student Consent Form* and *Parent/Guardian Consent Form* were considered participants in the study. All of the surveys were administered in the students' homeroom classrooms and all the instructional interventions took place within the students' classrooms and on the school grounds. In order to minimize disruption to participants intact classrooms were used and the rate of participation varied between classes ($N_{\text{total}}=66$).

Design and Implementation of the Study

This study consisted of two main design components. The first design component was the *development of two equivalent climate change education approaches*. The first climate change education approach was designed to be presented by the classroom teacher over approximately two weeks during the students' science periods. The second approach was designed to be presented by two visiting educators over two one and a half hour sessions. Both approaches included the same content, similar instructional strategies, and the same total time on task.

I created the unit developed for the teacher-based approach. Some of the lesson plans created were based on previous lesson plans and are referenced accordingly at the end of each lesson plan (see Appendix B). The scope and sequence of the unit was based on my literature review of previous climate change education research (e.g., see Shepardson et al. 2009). An effort was made to include some aspects of direct-instruction in areas that relate to commonly held misconceptions amongst students. For example, the difference between climate and weather was made explicit and reinforced

by a hands-on activity. Furthermore, the unit was linked to BC's Ministry of Education Grade 6 curricula. These links are shown in Appendix B under the headings *Achievement Indicators* and where possible the specific prescribed learning outcome is shown in brackets after the achievement indicator. One practicing middle school teacher, one curriculum and instruction professor, and one Earth and Ocean Science professor reviewed the unit.

The design of the second approach reflects the decision to have it mimic as closely as possible non-governmental organizations' presentation of the climate change material. There is presently no place in the Grade 6 curriculum where climate change science is covered. As such, any exposure that students received on the subject would be ad-hoc or associated with in-class presentations from outside agencies such as Sierra Club BC.

The second design component was the *development and application of survey instruments* that sought to assess students' knowledge on the climate change topics that they were instructed on during the intervention. Standardized instruments are typically too general to provide useful information regarding a particular intervention and consequently can underestimate the effects (Hickey & Pellegrino, 2005, as cited in Klosterman & Sadler, 2010). Therefore, the survey was developed to closely match the intervention. I developed the survey, drawing to some extent on previous surveys produced by Wild BC (K. Mortin, personal communication, 2009), Weather Concepts Inventory (personal communication, T. Pelton & T. Milford 2009), Summers et al. (2001), and Boyes and Stanisstreet (1993). In addition, a *Post-Instruction Teacher Survey* was developed. This survey contained similar items to Wild BC's *Pre-Workshop*

Teacher Survey for their *Climate Change Education Program*, as well as items specific to feedback on the lesson plans used in the intervention. Once designed, completed surveys were reviewed by three public educators: one PhD candidate in climate science, one curriculum and instruction professor, and one Earth and Ocean Science professor (who specializes in climate science), which resulted in several adjustments prior to implementation.

This study can be considered an explanatory mixed methods design whereby the priority is on the quantitative data and the qualitative data helps to support the trends emerging from the quantitative data (Creswell, 2008). The quantitative aspect of the design is a type of pre-test-post-test control group design, most similar to Campbell and Stanley's (1966) *The Nonequivalent Control Group Design*, whereby a control group is compared to the groups receiving treatment. Due to the extensive coverage of climate change in the media I elected to use a control group in order to attempt to account for the effects of learning on the subject matter outside of the classroom environment. Making the assumption that if there was an overall significant increase in the control group's mean from pre to post-test that this could be due to something like unforeseen media coverage on a recent climate event. The qualitative aspect, the *Post-Instruction Teacher Survey* was used to help explain and elaborate on the quantitative results. As well, the feedback gathered from it will be used to refine and adapt the teacher-based climate change education unit that was created and used during this study. Figure 1 demonstrates the design.

Quantitative:

		Time (in days)			
		0	6 - 22	25	64
Type of Instruction	None (Control)	Pre-test	No treatment	Post-test	X
	Presenter-based	Pre-test	2 90 minute sessions	Post-test	Follow-up test
	Teacher-based: Group A	Pre-test	3, 50 minute sessions and 1, 30 minute session	Post-test	Follow-up test
	Teacher-based: Group B	Pre-test	3, 50 minute sessions and 1, 30 minute session	Post-test	Follow-up test

Qualitative:

The teacher-based participant was given a post-instruction teacher survey that gathered information on her experience with the lessons.

Figure 1. Shows the quantitative and qualitative aspects of the research design used for this study. Note: The X denotes no test given.

There were four main phases in the implementation: (a) pre-instructional survey, (b) the climate change education approaches, (c) post-instructional survey, and (d) follow-up survey. The purpose of the *pre-instructional survey* was to provide a baseline quantitative assessment of the students' existing conceptions and knowledge of climate change science. The survey was divided into two parts: 15 multiple choice questions and 15 true or false questions (Appendix A). These questions corresponded to the three themes used to instruct the students in the intervention classes: (a) weather and climate (b) the carbon cycle and the human impacts and (c) global warming and the greenhouse effect.

The two different *climate change education approaches* were implemented in parallel over a two-week period in April, 2010. The classroom teacher was given three lessons plans and materials to instruct with (see Appendix B for resources provided). She

delivered these over three 50 minute classroom periods and one 30 minute session to two different groups, alternating between which group received her instruction first. The two visiting presenters, one a BC certified teacher with experience teaching about climate change and the other an experienced environmental educator for a non-governmental organization, together instructed one group over two 90 minute sessions (see Appendix C for lesson plan used). The first 90 minute session was held 6 days after the pre-test was completed and the second 90 minute session was held 22 days after the pre-test was completed. Students in all three groups received a mixture of in class and outdoor instruction on the school grounds.

The *post-instructional* and *follow-up surveys*, in conjunction with the control group's post-test survey, were used to examine the success of the two instructional-interventions. The post and follow-up surveys had identical questions and layouts to the pre-instructional survey; however, the questions were randomly re-arranged within their sub-headings (i.e. Multiple choice, True/False, Climate/Weather). The post-instructional survey was administered to all participants at the same time three days after the interventions finished. The follow-up survey was administered 39 days later to all participants on the same day.

The *Post-Instruction Teacher Survey* was given to the teacher before the interventions began and was returned after the follow-up surveys were completed.

Procedures for Data Analyses

Participants' scores on the climate change survey were recorded as correct or incorrect. From these scores statistical analyses could be conducted. Statistical analyses

of data were completed using the Statistical Program for Social Sciences 14.0 (SPSS 14.0). This program was used to gather descriptive data as well as conduct multiple one-way analysis of variance (ANOVA's) and paired-samples t-tests. An alpha level of .05 was used for all statistical tests, which were one-tailed as it was assumed that students' scores were unlikely to drop after instruction. An ANOVA was performed to compare the pre- and post-test mean difference scores and the Bonferroni method was used to perform pairwise comparisons following a significant overall test result. The null hypothesis was that the climate change education approach used would make no statistically significant difference in participants' survey scores. Each question on the surveys was coded as addressing either (a) weather and climate, (b) the carbon cycle and the human impacts or (c) global warming and the greenhouse effect (Appendix A). Then, each class's mean pre- and post-test scores by theme were subjected to paired-samples t-tests in order to determine whether or not the differences observed were significant. Finally, a separate ANOVA was conducted on the post- and follow-up tests mean difference scores. The null hypothesis was that there would be no statistically significant difference in the participants' decline in knowledge gained between the different education approaches.

The *Post-Instruction Teacher Survey* was examined qualitatively and used to reinforce the statistical findings.

Limitation of Methodology: Validity and Reliability

The reliability and validity of an assessment instrument (in this case, the climate change surveys) must be considered when assessing the outcomes of an educational

research study. The *reliability* of an instrument is a measure of the stability of results from the instrument; thus, a reliable survey is one that would produce nearly the same results when administered at different times. As well, reliability is a measure of internal consistency; in a reliable survey, similar questions should yield similar results amongst students (Creswell, 2008).

It was difficult to assess the reliability of the survey because student scores were not expected to be consistent from one survey administration to the next (i.e. it was expected that there would be knowledge gains post-intervention). However, the control group, that did not receive any instruction, showed overall consistent performance on the pre and post-tests. Given the brevity of the survey, internal consistency was not assessed. In the future, the survey responses from the control group could be used to assess students' test-retest reliability, yet this pre-assumes that students will have not gained knowledge outside of the study. In this case, it might be preferable to administer two equivalent surveys or add on additional questions to the survey that assess the same piece of knowledge twice to check for internal consistency with regards to answering the questions.

A second important concept is that of the validity of the assessment instrument. Validity refers to how well an instrument captures the subject or research question that it aims to study (Creswell, 2008). For a survey to be valid, scores on a survey should make sense and allow a researcher to make meaningful conclusions from the study sample to the population. Assessing the validity of a single instrument is less straightforward than assessing its reliability. However, threats to the validity of an instrument can often be fairly clearly identified.

What then might impact the validity of the climate change survey? The assumption that the type of instruction was the primary causal factor of change may be incorrect. For example, the individual variations amongst participants' influences outside of the study were not accounted for. These influences include media information from television, internet and books, what students covered with teachers outside of the immediate teacher participants, or what social interactions may have altered participants' knowledge. This is why I used a control group to help control for history and maturation effects. While all English stream Grade 6 students at the Middle School were given the opportunity to participate in the study, not all chose to (or Parent-Guardian consent forms were not obtained) and those that did participate may have had self-selection factors that went uncontrolled for in the experiment. However, data were collected and analyzed from almost all of the Grade 6 English track students at Lansdowne Middle School; yet, the students in the approaches consisted of a non-random sample as intact classrooms were used. Therefore, one needs to be cautious in generalizing the results of this study beyond these groups to other places, times and situations (Creswell, 2008).

It is also possible that participating classrooms may have communicated with one another as they all attended the same school. In order to minimize any rivalry or concerns all participants were made aware they would all be learning similar content but in different manners. The control group received climate change instruction from myself after the teacher-based and presenter-based groups completed their intervention. Here, the instrument might capture changes associated with inter-classroom interactions, thus adversely impacting the validity of the study.

Thus, the basic validity and reliability of my survey instrument has not yet been formally examined, though it was based on pre-existing surveys and peer-reviewed. Additionally the surveys were biased toward the assumption that cognitive and reading abilities would not pose a threat. If the work were to be repeated, a few things could be done to improve the study's validity and reliability. For instance, the survey instruments could have undergone a more rigorous evaluation. Given time limitations and permission protocols, no pilot test could be conducted on a similar Grade 6 population elsewhere. Unfortunately, there has been limited research on this population's (10 -12 year olds) knowledge and understanding of GW and climate change (Taber & Taylor, 2009); consequently, there were few age appropriate surveys on GW and climate change available to draw from. Furthermore, because I was assessing two specific approaches' effectiveness at improving knowledge retention of climate change, my survey questions needed to be specific to the interventions.

Chapter 4: Results

The following chapter examines the results of the pre-, post-, and follow-up instructional survey trends. Statistical analysis of the pre-instructional surveys was done by participant group and by subject theme. Descriptive data for the pre- and post-surveys are presented together by participant group, test (pre-, post-, or follow-up), and gain scores. The gain scores presented here are the difference between a participant's performance on the post-test and their performance on the pre-test. As well as a detailed statistical analysis of the pre- and post-instructional surveys using a one-way analysis of variance (ANOVA) and the succeeding Bonferonni procedure was completed. In addition the pre- and post-instructional surveys were analyzed by theme using paired samples t-tests. These procedures were conducted in order to investigate whether the method of instruction influenced the Grade 6 participants' knowledge of climate change science. Finally, the post- and follow-up survey scores were analyzed using ANOVA in order to investigate whether or not a differential decline in students' retention over time was present between the different climate change education approaches. The qualitative data from the *Post-Instruction Teacher Survey* is presented in last section in order to reinforce the statistical findings.

Pre-Instructional Survey Trends

The pre-instructional *Survey on Climate Change* (Appendix A) was used to examine students' initial level of knowledge on (a) weather and climate, (b) the carbon cycle and the human impacts and (c) global warming and the greenhouse effect. The

overall mean score of 18.29 (out of a possible 30) showed that, on average, students had some knowledge of climate change science before instruction (Figure 2). The pre-survey score distribution appears to be relatively normal and broadly symmetric for the total group and there are no outliers in the data (Figure 2).

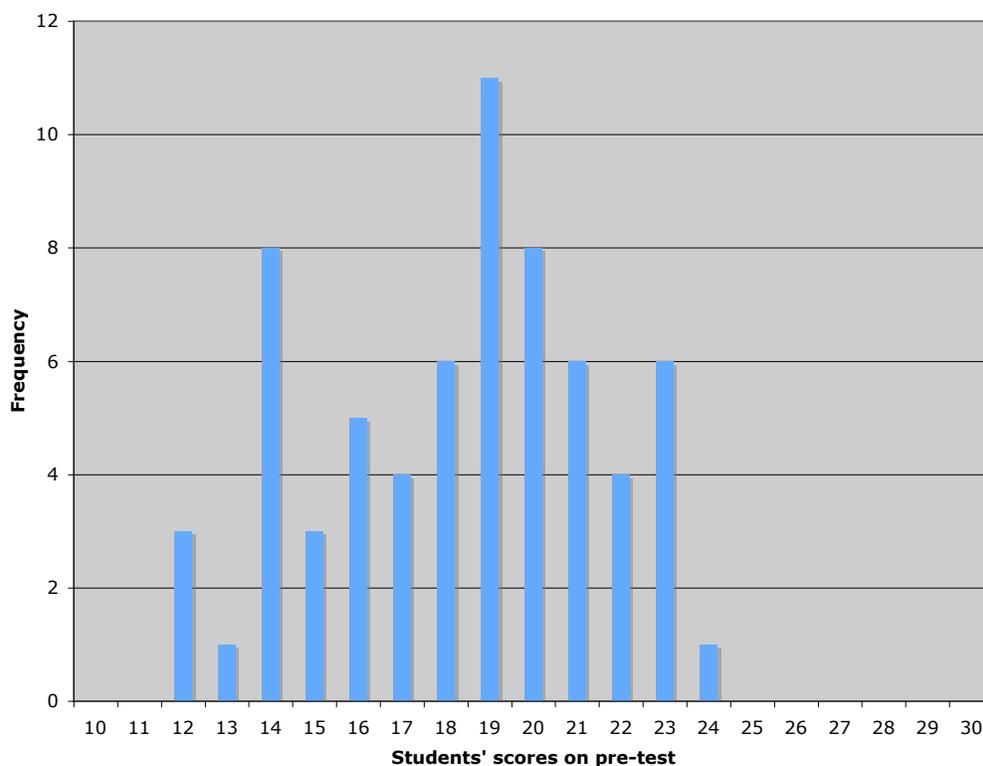


Figure 2. Student scores for the pre-instructional *Survey on Climate Change* (M=18.29, SD=3.17, N=66). Shown is the frequency and the range of all students' scores.

Performance by Theme. Students, on average, showed similar pre-instruction knowledge for all three themes. They showed the lowest understandings of the carbon cycle and the human impacts with an overall average of 59.39% correct. For global warming and the greenhouse effect the overall average was 60.47% correct and for weather and climate 62.12% correct. The range of individual group's pre-test scores can be seen in Figure 3 below.

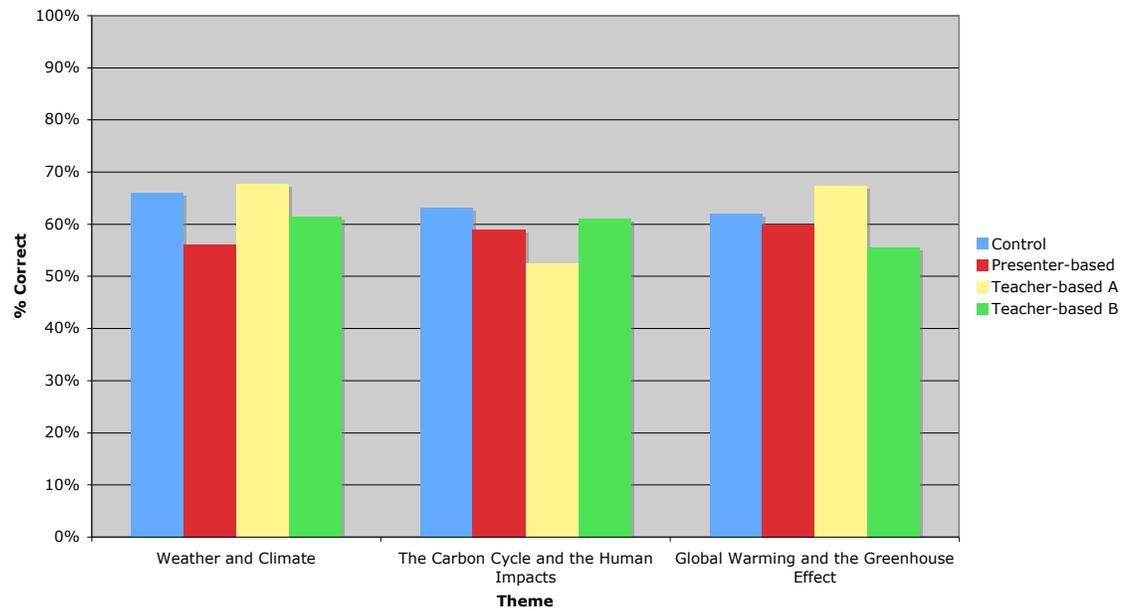


Figure 3. Pre-test mean scores (%) by theme for each participant group.

Post and Follow-up Instructional Survey Trends

Descriptive Data

The presenter-based and teacher-based groups showed larger improvements in their mean difference scores than the control group on their pre and post-tests. (Table 1). This discrepancy in mean difference scores cannot be explained away by the main effects of history, maturation, testing, and instrumentation as these would be affecting all the groups nearly equally (Campbell & Stanley, p. 48, 1963). Nevertheless as discussed earlier in the methodology section there are some possible interactions that can occur. However, the participant group's similarity in pre-test scores both overall and by theme helps to minimize the equivocality of interpretation (Campbell & Stanley, p. 47, 1963).

Table 1.

Descriptive data by participant group.

Participant Group	Survey: Pre/Post	n	M	SD	Mean Difference	Minimum Difference	Maximum Difference
Control	Pre	16	19.13	2.22	+1.13	-5	4
	Post	16	20.25	3.13			
Presenter-based	Pre	19	17.63	3.88	+2.37	-4	11
	Post	19	20.00	4.96			
Teacher-based A	Pre	12	18.75	2.26	+5.00	1	9
	Post	12	23.75	2.49			
Teacher-based B	Pre	19	17.95	3.57	+4.37	-3	10
	Post	19	22.32	5.32			

Note. Scores are out of a possible 30. Shown is the pre and post-survey number of participants per group (n), mean (M), and standard deviation (SD) as well as the mean, minimum, and maximum difference from pre to post-test.

Overall, as seen in Figure 4, those that received teacher-based instruction ($M_A=79.44\%$, $SD=2.49$; $M_B=73.68\%$, $SD=5.32$) out-performed participants who received the presenter-based instruction ($M=65.79\%$, $SD = 4.96$) or no instruction (control group;

M=67.08%, SD =3.13) on their post-tests. It is important to note that although the control group's post-test mean score was higher than the presenter-based the overall gain score was over double for the presenter-based group (+7.37%) as compared to the control-group (+3.54%) whose mean score changed very little (Figure 4).

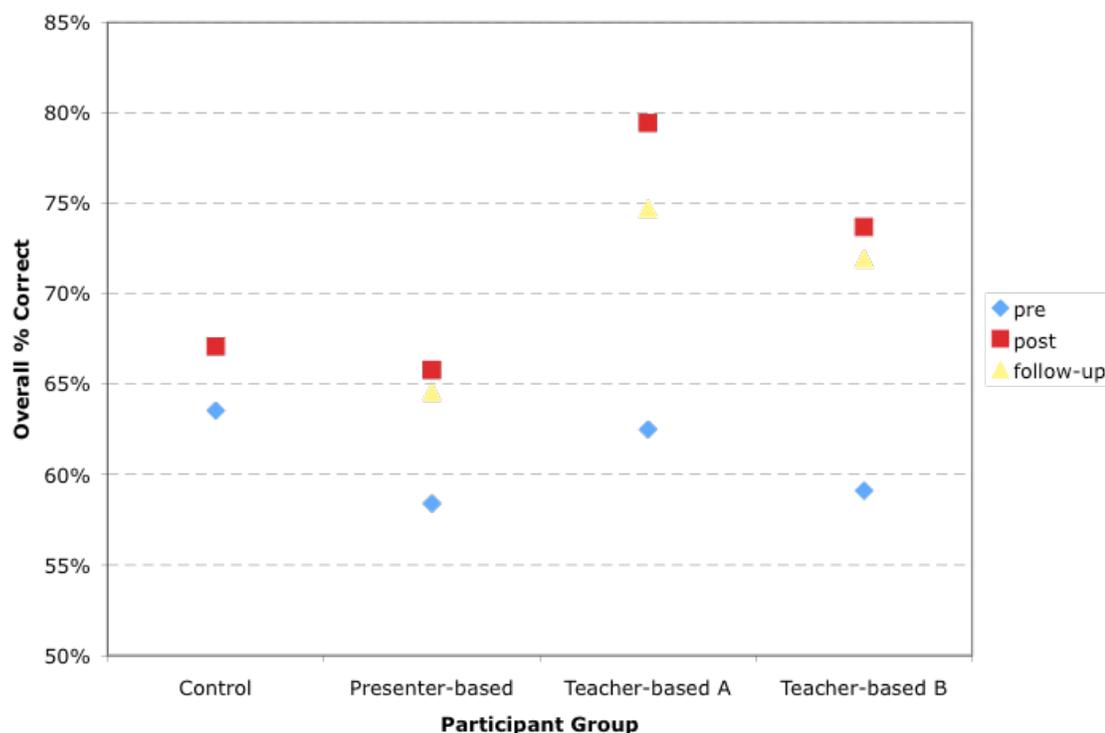


Figure 4. Summary of percentage correct on pre-, post-, and follow-up tests, by participant group.

The participants gain scores show that the teacher-based B group had the highest number of students (47.37%) who gained between 6 to 10 points on the survey, with teacher-based A group next (41.67%); whereas, the presenter-based group had only 11.00% achieve a 6 to 10 point gain and the control had none (Figure 5). Interestingly, teacher-based A group had no students who score decreased after the intervention and teacher-based B group had only 21.05% that performed the same or slightly lower (between -4 to 0) than on their pre-test (Figure 5).

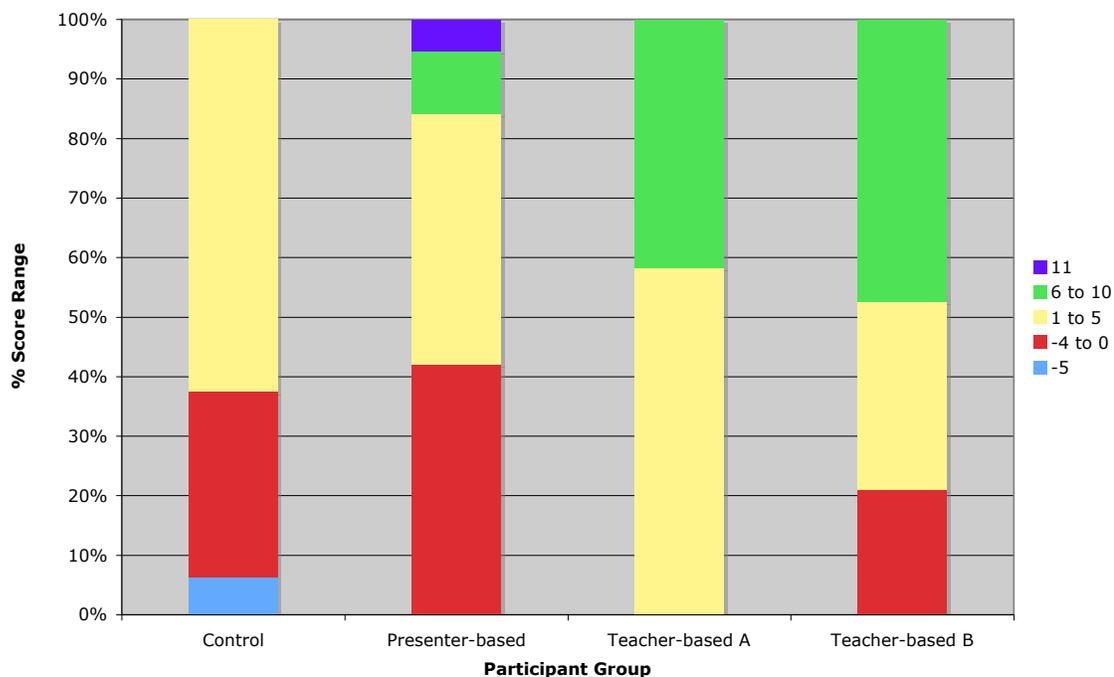


Figure 5. Percentage of students with pre- to post-test gain scores from a minimum of -5 points to a maximum of 11 points by participant group. Positive scores represent increased performance on the survey. Negative scores (shown in light blue and red) represent decreased performance.

One-way ANOVA: Pre and Post-test Mean Difference Scores

In order to further examine the changes in pre- and post-tests scores, a one-way analysis of variance (ANOVA) was conducted to examine the effect of type of instruction on knowledge of climate change. In statistical analyses, a researcher will first estimate the probability of committing a Type I error (i.e., wrongly rejecting the null hypothesis) – this is known as the *alpha level* of the experiment. Prior to starting all statistical analyses in this work, the alpha level was uniformly chosen to be 0.05, consistent with a typical level in educational research studies. An ANOVA generates a result indicating the probability that results could occur by chance, the *p-value*. For example, a p-value of 0.05

indicates that out of 1000 trials, results might occur by chance in 5 of the trials. Results are said to be statistically significant if the p-value is less than the alpha-level.

The ANOVA was conducted on the difference scores between pre- and post-tests. With an alpha level of .05 ($\alpha=.05$), the results (Table 2) showed significant differences between groups due to type of instruction, $F(3, 62) = 146.44$, $p < .005$. In other words, because the probability (p) that this result could have been produced by chance, is less than the alpha level of five percent ($\alpha=.05$), it is statistically significant.

Table 2.

ANOVA table for differences between pre- and post-tests' knowledge scores.

	Sum of Squares	df	Mean Square	F	p-value ($\alpha= .05$)
Difference between groups	146.44	3	48.81	4.70	.005*
Difference within groups	644.59	62	10.40		
Total	791.03	65			

Note. * indicates statistically significant results. For statistical significance, $p < \alpha$ (0.05).

Degrees of freedom (df) for difference between groups is defined as $k-1$, wherein k = number of groups; df for difference within groups is defined as $k(n-1)$; $df_{total} = N - 1$. The F statistic is the ratio of the Mean Square (MS) between groups to MS within groups.

The Bonferroni procedure was subsequently applied because when running several tests it keeps the overall familywise error rate at $\alpha = 0.05$, guaranteeing that the probability of making at least one Type I error will not exceed 0.05 (Howell, p. 380, 2004). At an alpha of 0.05, the post-hoc analysis indicated statistically significant differences among the groups (Table 3). While there was no statistically significant differences between control and presenter-based ($p < 1.00$), there was a difference between

control and teacher-based A ($p < 0.015$) and between control and teacher-based B ($p < 0.026$). This suggests that the teacher-based method of instruction is more effective than the presenter-based method at increasing students' knowledge of climate change science.

Table 3.

Post-hoc Bonferroni procedure on pre- and post-test's difference scores.

Type of Instruction	Mean Difference	Std. Error	p-value ($\alpha = .05$)	95% Confidence Interval	
				Lower Bound	Upper Bound
Control x Presenter-based	1.24	1.09	1.00	4.23	1.74
Control x Teacher-based A	3.88	1.23	0.015*	7.23	0.52
Control x Teacher-based B	3.24	1.09	0.026*	6.23	0.26

Note. * indicates statistically significant result. Participant groups that received an intervention were compared against the control group who did not receive any instruction on climate change. In other words, on average teacher-based A group scored 3.88 points higher on the survey than the control group.

Performance by Theme: Paired-Samples T-tests

In order to investigate further where the differences between participant groups were most prevalent, paired-samples t-tests were conducted on the differences between the pre- and post-test mean scores for each class by theme.

Weather and Climate. All students' scores, on average, increased from pre- to post-test except the control group's whose score remained the same (Figure 6). Teacher-based A's score significantly increased by 15.74% after instruction, $t(8) = 2.39$, $p < .022$, as did Teacher-based B's by 12.28%, $t(8) = 2.56$, $p < .017$ (Table 4). However, the presenter-based group's increased score (3.51%) was statistically insignificant $t(8) = 0.62$, $p > .277$ (Table 4).

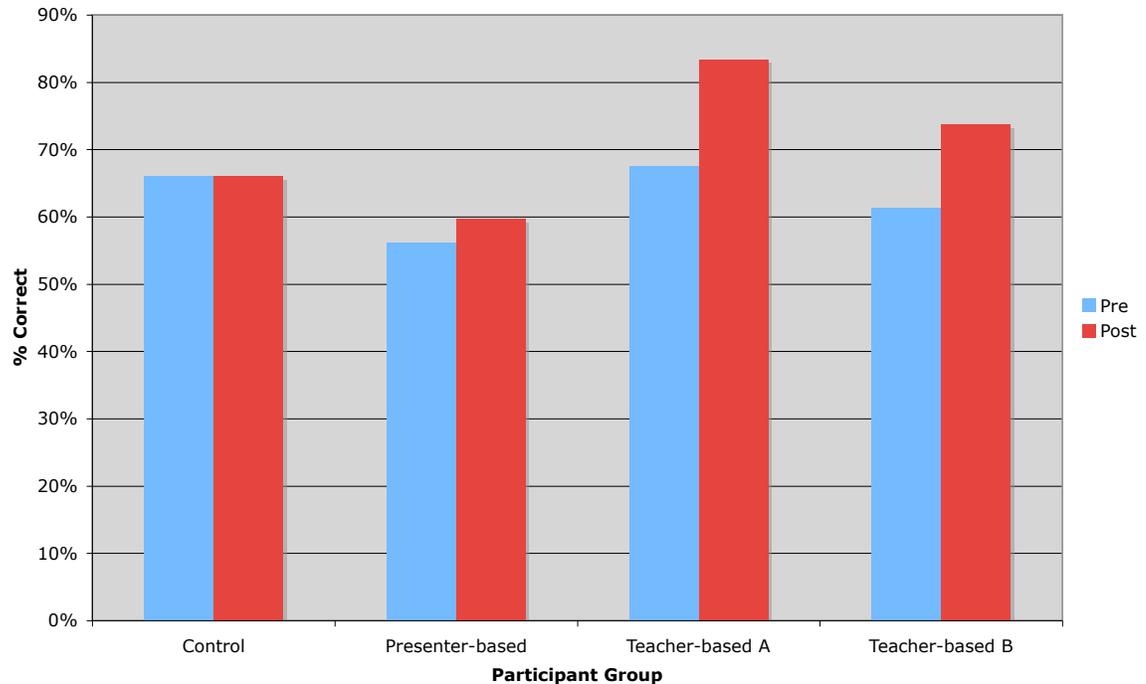


Figure 6. Students' average pre- and post-test scores on weather and climate questions.

Table 4.

Results of the paired-samples t-test on students' weather and climate questions.

Participant Group	Mean % Difference (post-pre)	df	t-value	p-value ($\alpha = .05$)
Control	0.00	8	0.00	0.500
Presenter-based	3.51	8	0.62	0.277
Teacher-based A	15.74	8	2.39	0.022
Teacher-based B	12.28	8	2.56	0.017

Note. Degrees of freedom (df) for participant groups is defined as n-1, wherein n = number of questions on the climate change survey pertaining to the topic.

The Carbon Cycle and The Human Impacts. All students' scores, on average, increased from pre- to post-test (Figure 7). The control group, $t(9) = 1.30$, $p > 0.113$, and presenter-based group, $t(9) = 1.82$, $p > 0.051$, scores were statistically insignificant (Table 5). However, teacher-based A score increased by 30.00% after instruction, $t(9) = 3.59$, $p < 0.003$, and teacher-based B score increased by 19.47% after instruction, $t(9) = 3.26$, $p < 0.005$ (Table 5).

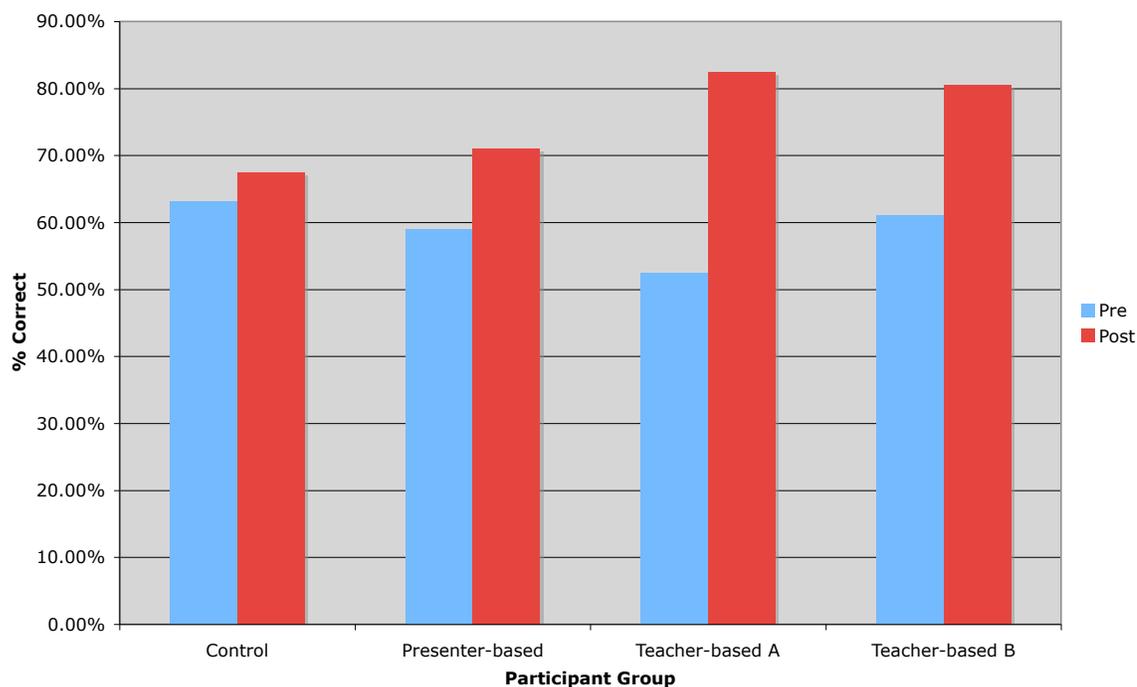


Figure 7. Students' average pre- and post-test scores on the carbon cycle and the human impacts questions.

Table 5.

Results of paired-samples t -test on students' carbon cycle and the human impacts questions.

Participant Group	Mean % Difference (post-pre)	df	t-value	p-value ($\alpha = .05$)
Control	4.38	9	1.30	0.113
Presenter-based	12.11	9	1.82	0.051
Teacher-based A	30.00	9	3.59	0.003
Teacher-based B	19.47	9	3.26	0.005

Note. Variables as defined in Table 4.

Global Warming and the Greenhouse effect. All students' scores, on average, increased from pre- to post-test (Figure 8). However, the paired t -tests showed that none of the increases were statistically significant (Table 6).

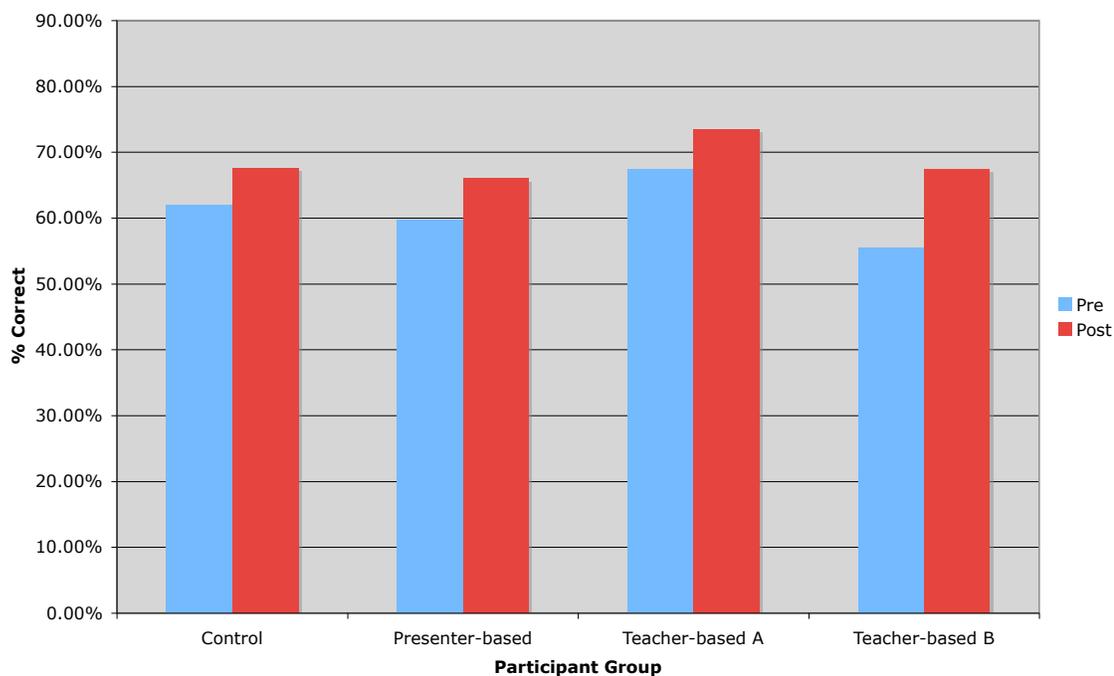


Figure 8. Students' average pre- and post-test scores on global warming and the greenhouse effect questions.

Table 6.

Results of the paired-samples t-test on students' global warming and the greenhouse effect questions.

Participant Group	Mean % Difference (post-pre)	df	t-value	p-value ($\alpha = .05$)
Control	5.68	10	1.24	0.121
Presenter-based	6.22	10	1.51	0.081
Teacher-based A	6.06	10	0.97	0.178
Teacher-based B	11.96	10	1.63	0.067

Note. Variables as defined in Table 4.

One-way ANOVA: Post and Follow-up test Mean Difference Scores

A one-way analysis of variance (ANOVA) was conducted to examine whether or not there was a differential decline in students' retention over time, between the different climate change education approaches from the post- to follow-up tests. The ANOVA was conducted on the difference scores between post- and follow-up tests. With an alpha level of .05, the results (Table 7) showed no statistically significant differences between groups due to type of instruction, $F(2, 47) = 4.91$, $p = .730$. As a result no further post-hoc tests were run. However, it is worth noting as seen earlier in Figure 4 that Teacher-based A who achieved the highest knowledge gained also had the highest decline although the decline was not significantly different from the presenter-based and teacher-based B.

Table 7.*ANOVA table for differences between post- and follow-up tests' knowledge scores.*

	Sum of Squares	df	Mean Square	F	Sig.
Difference between groups	4.91	2	2.46	.316	.730
Difference within groups	365.09	47	7.77		
Total	370.00	49			

Note. Variables as defined in Table 2.

Post-Instruction Teacher Survey Results

Presented here are sections that pertain to the specific research questions and are followed up on in Chapter 5: Discussion; for the complete survey response see Appendix D. When the teacher-based instructor was asked what the three biggest barriers she faced in trying to teach about climate change were, she reported: (a) lack of space in the current curriculum, (b) little knowledge of available resources and current information on climate change, and (c) topic too complex, takes too much time to comprehend, gather resources, and teach. However, she felt that “having an expert in at some point, probably towards the beginning of the unit” (Appendix D, Lesson One, Question 11) would help make it easier for her to integrate climate change into her teaching. At this point in time she had not investigated other regional teaching resources besides the one created by us and used by her for this research study.

The teacher-based instructor thought the “background information was terrific – very informative, interesting and understandable” (Appendix D, Lesson One, Question 1) for the lesson on weather and climate, likewise she felt that there was enough background information to understand and teach about the carbon cycle and humans impacts, and global warming and the greenhouse effect. She also felt that the lesson plan on weather and climate was easy to follow, that the preparation for the lesson was manageable and that her student’s enjoyed the lesson, “particularly the dice activity” (Appendix D, Lesson One, Question 4). Although the teacher felt that the lesson on the carbon balance and the human impacts was enjoyed “very much” by her students and the preparation was manageable, she did offer several suggestions for modification (see Appendix D, Lesson Two). She appeared to feel that there “was a lot of material” (Appendix D, Lesson Two,

Question 7) to learn. In addition this lesson took longer than the others and was done over 1.5 periods (about 75 minutes). The final lesson on global warming and the greenhouse effect appeared to give her the most difficulty. While the preparation was manageable, the game featured in the lesson plan “was a bit hard” (Appendix D, Lesson Three, Question 2). Not surprisingly then she feels that the students were “a bit frustrated initially at the game but that this would be remedied by devoting a whole class to it so that there was a real understanding of the concept as well as the game” (Appendix D, Lesson Three, Question 4). In other words devote one period to the concept and another period to the game itself.

Chapter 5: Discussion

Summary of Findings

Many teachers are uncomfortable instructing on climate change and global warming (GW) because they feel that they do not possess the necessary background information on the subject as they themselves received little if any instruction on it, yet they believe that climate change is a topic their students should learn about (Fortner, 2001; Gayford, 2002). This research supports the idea that, with the necessary background information reviewed by a climate scientist (a critical component in the lesson plans provided), the classroom teacher is more effective than the presenters who have substantially more experience educating on the topic, but less experience teaching in the classroom. All three groups who received instructional intervention showed an overall mean improvement on their post-test scores. However, only the teacher-based interventions showed a statistically significant change. The highest gains in knowledge for the intervention groups were for the carbon cycle and the human impacts topic; followed by understanding the differences between climate and weather. The students and teacher alike appeared to struggle with the topic of GW and the greenhouse effect. Yet, once the students did learn, there was no evidence for differential loss of knowledge. None of the groups showed any difference in their rate of knowledge decline following the intervention, suggesting that the type of intervention method had no impact on the rate of loss of knowledge.

Differential knowledge gains by theme

The students already possessed some knowledge on (a) weather and climate, (b) the carbon cycle and the human impacts, and (c) global warming and the greenhouse effect prior to any intervention. Nonetheless, students' knowledge on weather and climate and on the carbon cycle and the human impacts did increase.

A survey of the literature suggests that a clear distinction between weather and climate is an essential point that must be clearly conveyed to students. For example, Shepardson et al.'s (2009) pre-intervention assessment of seventh grade American students' knowledge of weather and its connection to global climate change revealed that few students recognized that climate change might affect the frequency of occurrence and severity of meteorological events; this suggests that the distinction and linkages between weather and climate remained ambiguous for these students. In contrast, specific attempts were made in my research study not only to explain the difference between climate and weather but also to introduce students to the idea that weather is highly variable and can change from day to day. However, climate is an average that encompasses a range of expected behaviour. In other words, one day that is hotter than average can still be within the range of expected behaviour. For example, survey question 10 (Appendix A) reads:

In Victoria, BC sometimes we have days that are much hotter than average. These are examples of:

- (a) extreme events, and we should be worried because this means the climate is changing*
- (b) extreme events, and we expects some days that are like this*
- (c) climate, we cannot report them as weather*
- (d) climate, which are proof that global warming is happening.*

The answer is (b) and the participant average in all three intervention classes showed an improvement in scores for this question (see Appendix E), suggesting that students in this study became more aware of the variability of weather compared to climate change.

The largest gains in knowledge came from the carbon cycle and the human impacts. Teaching about global warming and the greenhouse effect through an understanding of the carbon cycle is often not done, yet this research demonstrates that both the teacher and the students enjoy learning about this concept and it appears less problematic to understand. This may perhaps be due to the fact that students in Grade 6 are, by this time, already familiar with the concept of cycles. By Grade 6, most students in BC have learnt about the water cycle or other cycles so, by introducing the carbon cycle, students already have prior knowledge to build on. Thus, it may be intuitively easier for students to comprehend that an imbalance in the carbon cycle can create global problems that have impacts at the local level. Shepardson et al. (2009) similarly suggests introducing the concepts of the carbon cycle early on in the sequencing of climate change curricula.

The difficulty understanding the greenhouse effect is well documented for both adults and students (e.g., see Demirkaya, 2008; Khalid, 2003; Michail et al., 2006; Pruneau et al., 2001; Summers et al., 2001). Shepardson et al.'s (2009) review of 16 international studies found that in general students could not identify the types of atmospheric gases involved in the greenhouse effect or distinguish between the kinds of radiation. Deliberate effort was made to address these issues in my research; however, I still found no significant results. Given the brevity of this instructional intervention it is

perhaps not surprising that students did not show a significant improvement in their understanding of global warming and the greenhouse effect. Interestingly, while the presenter-based group improved less than the teacher-based groups in their knowledge of climate, weather, and the carbon cycle their post-intervention scores were about the same as the teacher-based groups on global warming and the greenhouse effect. In future studies, it may be necessary to provide more background hands-on experiments with the concept of radiation before continuing on with a lesson on global warming and the greenhouse effect. For example, a pot of water being heated on the stove can easily lead to a discussion of the types of radiation and heat transfer processes at work.

The results indicate that the teacher-based method of instruction resulted in higher knowledge gain post-intervention and subsequently higher knowledge retention after the 39 day interval where no new climate change science instruction was performed in the classrooms. However, upon closer examination, the presenter-based group while showing no statistically significant differences in knowledge decline after instruction from the teacher-based group, does have a different pattern of knowledge gain than the teacher-based groups. As seen in Figure 5, a larger percentage of participants either seemed to gain a lot of knowledge post-intervention or lost a significant amount of knowledge on climate change science according to their performance on the survey. Whereas teacher-based A group showed a 100% gain in knowledge to some degree (between 1 to 10), and teacher-based B group showed a 78.95% gain in knowledge (between 1 to 10), the presenter-based results were significantly more split with a 57.89% gain (between 1 to 11) and a 42.11% loss (between -4 to 0). It appears that some of the students in the presenter-based group learned equally as well as their teacher-based

counterparts while others did not. Thus, I answered my initial research question—the method of instruction does influence students’ knowledge retention, however, it raises an additional question for future research—why does the method of instruction influence students’ knowledge retention on climate change?

Student engagement and the role of the teacher

There are potentially myriad reasons why the teacher-based groups outperformed the presenter-based groups; I have chosen to focus on a couple I feel are most relevant: student-engagement and teacher-students relationships.

Personal and social-contextual factors influence students’ academic achievement and cannot be understood in isolation from one another (Lee & Shute, 2010). Long-term, large-scale assessments have repeatedly shown that personal factors such as student engagement affect students’ academic achievement (Lee & Shute, 2010). In other words, a student’s commitment or involvement in a project can influence his or her academic performance as Finn and Cox (1992), and Voelkl (1997) have demonstrated. Therefore, it is plausible that the lower performance of the presenter-based group could be a result of students’ perceived lower commitment or involvement in the project as they would be receiving instruction by outsiders and their own teacher was not actively engaged in the climate change education intervention.

Conversely, the reverse process might have occurred in this study wherein academic achievement influenced student engagement (Lee & Shute 2010). Test scores and grades can be significant predictors of students’ academic engagement (Good & Brophy, 2008; Shouse, Schneider and Plank, 1992). Following this logic, the presenter-

based group (which had the lowest mean knowledge score of all groups on the pre-test) could be interpreted as being the least engaged and therefore would have the least gains in knowledge. Indeed, the presenter-based group did have the lowest mean knowledge score on the post-test. They gained more than the control group but still had the lowest post-test mean knowledge score (see Figure 4). However, as previously mentioned it is not only the personal factors, such as student engagement, that play a role in academic success but also the social-contextual factors (Lee & Shute, 2010).

Teachers and peers can influence students' learning (Lee & Shute, 2010). For example, if the presenter-based group's teacher expected little from her students as a result of the intervention the students would likely have given an equivalent amount of effort (Good, 1987). No data was collected on the presenter-based teacher's perceptions of the intervention or on peer norms, but it is possible that these had an interaction effect with student engagement levels. In future, I would not only gather information on the students' enjoyment of the lessons from the teacher-based presenter but also from the presenter-based group's teacher. Wang, Haertel, and Walberg's (1993) meta-analysis on factors influencing student learning found that classroom management was the most important factor influencing learning. Classroom management is more than disciplining students as it includes all the things teachers do to cultivate student involvement and cooperation in classroom activities (Good & Brophy, 2008). Without classroom management skills, the environment is not as productive (Brophy & Evertson, 1976). Establishing a productive environment takes time and effective teachers' classrooms usually result from effective planning and organization that takes place during the first few weeks of school (Emmer, Evertson, & Anderson, 1980). The presenters did not have

the benefit of connecting with the students prior to the intervention that took place in March, well into the established school-year. The presenters' lack of relationship with the students may have resulted in less student-engagement and consequently, poorer performance on the climate change knowledge surveys.

Decline in students' knowledge retention over time

The findings indicate that there was no significant difference in the rate of decline between the intervention groups. Generally the amount of knowledge retained declines quickly at first and then slows down until it eventually levels off (Semb & Ellis, 1994). The follow-up test occurred around five weeks after the intervention, in the middle of the period of rapid knowledge decline (between weeks 1 to 13; Semb & Ellis, 1994). The fact that students had lost very little gained knowledge at this point (see Figure 4) reinforces the notion that much of what is taught in school is remembered (Semb & Ellis, 1994). A differential decline might have been noticed if the students' knowledge levels were measured again after 13 weeks. However, most studies that compare instructional strategies do not find any differential effect on retention (Semb & Ellis, 1994).

Overcoming the barriers to teaching climate change in the classroom

Climate change and GW instruction is relatively new in classrooms. Based on my search of "global warming" or "climate change" in peer reviewed journals in Educational Resources Information Center (ERIC) database, research on the topic seems to have started in the 1990's but has been gaining momentum since the new millennium. It comes as no surprise then that most practicing teachers did not learn about the topic

themselves in school and/or have not received subsequent training in climate science (Fortner, 2001). My research appears to support this observation as, when asked what the three biggest barriers the teacher faced in teaching about climate change, she reported in third place that the topic was too complex, takes too much time to comprehend, gather resources and teach (Appendix D, Lesson One). Related to this, she cited in second place that she has little knowledge of available resources and current information on climate change. In other words, she felt that the topic was complex and she was unaware of resources to teach about it in her Grade 6 classroom. She did not, however, rank that the topic was too controversial for her or that conflicting views make it difficult for her teach. This view aligns with the idea that most people believe climate change is real and that there are negative impacts associated with it (e.g. see Leiserowitz, Smith, & Marlon, 2010, for a recent American study).

Interestingly, the teacher's number one barrier to teaching about climate change was a lack of space in the current curriculum (Appendix D, Lesson One). Given the current way that BC's Grade 6 science curriculum is structured this is perhaps not too surprising. The topic of climate change can easily be integrated into BC's Science 6 curriculum topics (a) processes of science, (b) diversity of life, (c) electricity, and (d) exploration of extreme environment (Ministry of Education, 2005). Interestingly, the initial background information that was targeted by my research study fits more easily into the social studies and language arts curriculum because the specific science learning outcomes (e.g. the difference between climate and weather) are not explicit in the BC Grade 6 science curriculum. Yet, the broader themes of subjects like social studies allows for more specific connections to the BC's prescribed learning outcomes. For

example see Appendix B's *Achievement Indicators* for the connections to BC's Ministry of Education curriculum beyond science. Where possible the specific Ministry of Education's prescribed learning outcome reference is shown in brackets after the achievement indicator. However, the science background information must be taught first so that students' subsequent learning is not riddled with misconceptions, then students can continue on learning about climate change in the context of such BC Grade 6 science curriculum as renewable energy (electricity) and polar regions (exploration of extreme environments). Instruction is particularly powerful when students can explore the topic of climate change through multiple subject areas (Fortner, 2001), although many teachers do not favour teaching GW in an interdisciplinary manner because they perceive it as too time consuming to work with other colleagues in other disciplines (Gayford, 2002). Yet, many teachers of Grade 6 in BC are middle school teachers who teach multiple subject areas, such as both science and social studies. This is why the unit on climate change that is currently in development that builds upon my thesis research is organized around themes that can be discussed in most subject areas. For example, students can learn about the people of the polar regions in social studies, while contemporaneously learning in the science classroom about the scientific processes at work in the polar regions that are disrupted by GW. As many teachers, including the one in this study, identify lack of classroom time as a reason not to teaching climate change, this approach should significantly reduce this barrier as it is better linked to specific subject areas.

It seems then that teachers need support building the background knowledge and accessing quality resources. The teacher in this study felt that "having an expert in at

some point, probably towards the beginning of the unit” would help support and make it easier for her to integrate climate change into her teaching. Overall, it appears that she was most comfortable with the weather and climate and carbon cycle sections of the pilot, while least comfortable teaching about global warming and the greenhouse effect. Again this is consistent with the quantitative findings wherein students gains in knowledge were most evident for carbon cycle and secondly weather and climate; however, these gains were not significant for global warming and the greenhouse effect. Adults and students alike struggle frequently with misconceptions related to the greenhouse effect (Demirkaya, 2008; Khalid, 2003; Michail et al., 2006; Pruneau et al., 2001; Summers et al., 2001) and it appears to be the area where most focus is needed.

Furthering Instruction Beyond the Climate Change Primer Unit

My research has demonstrated that a short primer on climate change science can increase students’ knowledge of the science of climate change. This has positive implications because it means that any subject area teacher can provide about three lessons on the science of climate change before moving onto to the more specific area of climate change that may relate better with their subject area. For example, a BC Grade 6 science teacher after instructing his or her students with three primer lessons may move onto to addressing the Arctic as an extreme environment. In the BC Science 6 Integrated Resource Package students must explain obstacles unique to the exploration of an extreme environment and the technologies being used to address these obstacles (Ministry of Education, 2005). Given that a large amount of the research being done in the Arctic is to do with climate change or potential fossil fuel extraction, this presents an

opportunity for students to learn about this extreme environment and the technologies being used to traverse and study it. Conversely, a BC Grade 6 social studies teacher may after the primer lessons move onto to addressing the impacts of climate change on the people of the Arctic's identity, culture, and relationship to their environment (Ministry of Education, 2006). An even better strategy may be to synchronize teaching of climate change across subject areas.

Climate change is a topic many teachers believe their students should learn about (Fortner, 2001; Gayford, 2002); however, it has been demonstrated that many teachers possess misconceptions on the science of climate change (e.g., see Summers et al., 2001). If teachers learned about the science of climate change at workshops on professional development days they may possess more confidence with the material and this could in turn increase the likelihood of them teaching it in their classrooms. Likewise, providing quality resources that have lessons that are specifically linked to the teachers subject area could also be provided at these workshops. There are already some excellent professional development opportunities put on by organizations such as Wild BC and Sierra Club BC; however, these organizations typically have lessons that relate to building general knowledge of climate change. They often do not cover enough of a particular subject area teacher's prescribed learning outcomes (i.e. the mandatory subject content) to warrant spending the time required for the lessons to be implemented.

Importance of Findings and Suggestions for Future Research

While the findings on students' knowledge of climate change and their associated difficulties with learning on the topic were similar to other findings, this research offers

insight into different approaches on learning about climate change. The students in both the presenter-based and teacher-based groups seemed to struggle equally with the concepts associated with global warming and the greenhouse effect. This may in part be due to an insufficient background on concepts such as radiation and heat as an energy transfer process. Future research should compare different methods of learning on these topics to see if there are better approaches to learning about global warming and the greenhouse effect. This research began to look at different ways to learn about the same topic, structure, and material content, but did not isolate the topics more specifically than by broad themes. However, what these broad themes do tell me is that teachers should not be dissuaded by the complex science of climate change but rather make an effort to acquire suitable and accurate background material that will allow them to first learn themselves about climate change and secondly to use their expertise in classroom management to convey climate change science. In addition, they should remain aware of the common misconceptions that students and adults alike possess and be aware of inadvertently introducing them to their students. Furthermore, this research provides support to the idea that instruction on the carbon cycle should precede instruction on traditionally more complex topics such as radiation and the greenhouse effect, as has been suggested by previous researcher such as Shepardson et al. (2009).

This research study will inform the development of a unit that is specific to British Columbia's Ministry of Education curriculum. The study compared different ways to learn about the same topic and provided an avenue to pilot a developing resource. It incorporated strategies put forth in prior educational research by including elements such as direct-domain specific instruction and active learning. However, because the

study assumed that students possessed limited prior climate change science background knowledge, not all strategies could be addressed. A natural continuation of these initial background lessons would be to connect this global issue to local issues, as well as have students in other subjects other than science begin to address the social and political complexities of climate change.

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APPENDIX A

Survey Questions by Topic and Survey on Climate Change

The questions asked on the student *Survey on Climate Change* were coded as either addressing the theme of (a) weather and climate, (b) the carbon cycle and the human impacts, or (c) global warming and the greenhouse effect. Below is the explanation of how the *Survey on Climate Change* questions were coded before the statistical analyses. Also note that the correct answers for the *Survey on Climate Change* are indicated on the survey in bold.

Weather and Climate

Questions 6, 8, 10, 11 and Climate and Weather questions at the bottom of the second page.

The Carbon Cycle and the Human Impacts

Questions 3, 5, 7, 12, 15 and True/False 4, 5, 6, 9, 10

Global Warming and the Greenhouse Effect

Questions 1, 2, 4, 9, 13, 14 and True/False 1, 2, 3, 7, 8

SURVEY ON CLIMATE CHANGE

Name: _____

Please take a few minutes to answer these questions as best as you can. **Note:** This is not a test.

1. The greenhouse effect is...

- A. **a natural process that helps maintain temperatures that are suitable for life on Earth.**
- B. a process that has been documented only since humans have begun burning fossil fuels.
- C. a condition that is destroying the ozone layer in Earth's atmosphere.
- D. a condition found only in commercial greenhouses.

2. Global warming...

- A. decreases the average surface temperature of the Earth.
- B. **increases the average surface temperature of the Earth.**
- C. is not affecting the weather.
- D. is a natural process.

3. Carbon is found in all living things. Which one of these statements best describes carbon?

- A. Carbon is destroyed through the carbon and water cycles.
- B. **Carbon continuously cycles through Earth's components.**
- C. Humans are the major producers of carbon.
- D. Carbon is destroyed when an organism dies or is eaten.

4. The atmosphere's main greenhouse gases apart from water vapour are:

- A. **Carbon dioxide, methane and nitrous oxide.**
- B. Oxygen and nitrogen.
- C. Hydrogen and oxygen.
- D. Ozone and argon.

5. Fossil fuels are used to make...

- A. vaseline
- B. natural gas
- C. plastics
- D. **all of the above**

6. What is weather?

- A. the average climate
- B. what you expect
- C. the state of the atmosphere averaged over a long period of time
- D. **the state of the atmosphere at a specific time and place**

7. A natural carbon sink:

- A. releases carbon over a short but intense period of time.
- B. is technology developed to capture carbon from the atmosphere and store it underground.
- C. **something that can take in carbon and store it.**
- D. something that can take in carbon and release it quickly.

8. Climatologists (people who study the climate)...

- A. are scientists who do things like measure the windspeed inside a hurricane.
- B. study only the temperature of areas.
- C. try to predict the weather for the next day or week.
- D. **study the changes in average weather conditions over a long time period.**

9. Infrared radiation from the earth's surface...

- A. always escapes to space
- B. **can be absorbed and re-emitted by greenhouse gases**
- C. feels cold
- D. cannot be absorbed by clouds

10. In Victoria, BC sometimes we have days that are much hotter than average. These are examples of...

- A. extreme events, and we should be worried because this means the climate is changing.
- B. **extreme events, and we expect some days that are like this.**
- C. climate, we cannot report them as weather.
- D. climate, which are proof that global warming is happening.

11. Usually in Winnipeg, Manitoba in January the temperature does not go above -13°C. However, more and more days a year, over the past 30 years, have been warmer than -13°C. This is...

- A. because more people live there now, than before, so more people are using their heaters.
- B. an example of weather.
- C. **one piece of evidence for climate change.**
- D. an example of an extreme event.

12. The carbon balance, over the past ten thousand years, has been upset most by...

- A. the sun's natural solar cycles.
- B. volcanic eruptions.
- C. **the burning of fossil fuels.**
- D. deforestation.

13. Which of the following is NOT a greenhouse gas?

- A. **oxygen**
- B. nitrous oxide
- C. carbon dioxide
- D. methane

14. Without greenhouse gases the Earth would...

- A. have a much warmer average surface temperature.
- B. **have a much colder average surface temperature.**
- C. have an atmosphere and an average temperature even more suitable for life.
- D. have no atmosphere.

15. Carbon can be released from...

- A. the soil
- B. living things
- C. the ocean
- D. **all of the above**

True or False? Please circle **T** (true) if you think the statement is correct. Please circle **F** (false) if you think the statement is wrong.

- T** **F** Global warming is one type of climate change.
- T** **F** The sun's infrared radiation is what heats the atmosphere.
- T** **F** Too many greenhouse gases in the atmosphere cause global warming.
- T** **F** Oil and natural gas are made from dinosaur bones.
- T** **F** The ocean plays an important role in the carbon cycle.
- T** **F** Fossil fuels take millions of years to form.
- T** **F** With the greenhouse effect earth's average temperature is -18°C .
- T** **F** The earth's surface can absorb solar radiation.
- T** **F** Carbon is used by living things to grow.
- T** **F** There is no carbon in the soil.

Climate or Weather? Please **circle climate** if you think the statement is an example of climate. Please **circle weather** if you think the statement is an example of weather.

- Climate** **Weather** In the first seven days of January, 2007, in Victoria, BC we received more rain than we normally expect for the entire month of January.
- Climate **Weather** You look out the window, see that it is raining, and pack an umbrella with you to school.
- Climate **Weather** You read on the Environment Canada website that it snowed 4 cm yesterday.
- Climate** **Weather** The climate normal for temperature in Victoria, BC on April 12th is 8°C .
- Climate** **Weather** The average amount of precipitation for the month of July for Alberta is 3 cm.

APPENDIX B

Climate Change Unit

Three lessons made up the climate change unit used to instruct students on climate change science. These three lessons are meant to serve as primers. In other words, they address what I feel are the most pertinent science topics to understanding the topic of climate change. The lessons are found on following this page. Note: All the materials listed in these lesson plans were provided for the teacher to use in her instruction.

Lesson One: Climate vs Weather

Students examined the differences between climate and weather by measuring local weather patterns, simulating climate normals, and examining pictures of various world climates. By comparing daily temperature with averaged climate data, students began to understand that weather is highly variable, but climate is not.

Lesson Two: The Carbon Balance

Students followed the path of carbon through the carbon cycle to learn where carbon is stored and how it circulates. The game highlighted how human actions, through the use of fossil fuels and clearing of the world's forest, result in an increase in the amount of carbon dioxide in the atmosphere.

Lesson Three: The Carbon Kibosh Game

Students were taught the basics of global warming and the greenhouse effect. Students also played a game that models the effects of increasing carbon dioxide in the atmosphere by role-playing either the sun's energy, earth's energy, greenhouse gases, clouds or aerosols.

Climate vs Weather

In This Lesson

Students examine the differences between climate and weather by measuring local weather patterns, simulating climate normals, and examining pictures of various world climates. By comparing daily temperature with averaged climate data, students will understand that weather is highly variable, but climate is not.

Achievement Indicators

Students will be able to...

- **S.S.:** identify, compare, verify, and draw conclusions on the relationship between climate and weather (A1)
- Interpret climate tables and graphs (A2)
- Analyse the significance of extensive weather-data bases for transmitting weather information globally and informing travel preparedness (D2)
- **Math:** recognize the percentage of extreme events present in all climate data (A6)
- Complete tables and create pictorial representation of the table values to reveal a pattern (B1, B2)
- Create, label, and interpret a line graph of temperatures to draw conclusions and solve problems (D1, D3)
- Explain the relationship between climate and probability, including distinguishing between experimental and theoretical probability (D4)
- **L.A.:** work in groups and share information (*Oral*)
- Create information writing that conveys their understanding of the differences between weather and climate and extends this knowledge to packing for a trip (*Writing and Representing*)

Assessment

- Collect student tables, graphs, and calculations of climate averages for evaluation (REPRODUCIBLES 1, 2, 4)
- Evaluate students written responses in their postcards, Part E (REPRODUCIBLE 6)

Lesson Preparation

Time: ⌚ 60 minutes

In Advance: Collect colour images of weather from around the world and record their locations (or use REPRODUCIBLES 3a, 3b). Then, familiarize yourself with how weather and climate data are reported, using www.weather.com or www.ec.gc.ca. If you are on Southern Vancouver Island use www.victoriaweather.ca or www.nanaimoweather.ca to find local patterns.

Materials: Weather images; REPRODUCIBLES 1, 2 (one per group), 4 (one per student); transparency of REPRODUCIBLES 1, 2; world map; dice (two per group); student calculators.

Optional: REPRODUCIBLES 3,5,6

Vocabulary Introduced

Climate: the long term average of weather conditions

Climate Normals: Meteorologists use the term “climate normals” to describe weather measurements that are averaged over a 30 year period. Normals are for a particular location and can be defined for a particular day, month, season, and year. Normals exist at a particular site if there is a long enough observation record.

Climatologist: scientist who studies the climate

Meteorologist: person who studies the weather & climate of regions.

Weather: state of the atmosphere at a specific time and place (e.g. temperature, cloudiness, precipitation, air pressure, wind)

Step by Step

Part A: Climate vs Weather ⌚ 5 min

- Engage: How do you know when to use an umbrella? *It's raining.* How do you decide what to wear in the morning? *I look out the window at the weather OR I read the newspaper.* Say: This is using the weather to make a decision.
- Ask: How about deciding what to pack for a trip? *I ask people what it is like at that time of year in that place.* Say: This is using the climate to make a decision.
- What's different about your decisions regarding what to wear today and your decision about what to pack for a month long trip elsewhere in the world?
- Today we will be looking at the difference between what to wear in the morning and what to pack for a trip. In other words what is the difference between climate and weather?

Part B: Using the data ⌚ 10 min

- Explain: Many people and organizations, including Environment Canada, have been observing, measuring, and recording information on the weather for many years. Inform students that these data (collected from weather stations etc) are used to determine weather patterns, forecast the weather, and create climate models for future predictions. *Optional:* student can go to the computer lab to see how data are recorded online (e.g. www.victoriaweather.ca).
- Ask: How do meteorologists (persons who study the weather & climate of a region) collect information about the weather?



- Summarize on the board:

Information Collected	Instrument Used by Meteorologist
Air temperature	Thermometer
Amount & type of cloudiness	Amount - estimate amount of sky covered by clouds Type - using cloud diagrams to identify
Type & amount of precipitation	Rain gauge (e.g. tipping bucket rain gauge) or using a snow ruler
Air pressure	Barometer
Wind speed & direction	Direction - Weather Vane or windsock Speed - Wind speed scale or Anemometer

Part C: Observing the Weather

⌚ 15 min

- Explain: Students you are now going to 'act' as meteorologists for a particular time and place.
- First we will do an example together as a class. Use the transparency of REPRODUCIBLE 1 to record the weather outside today.
- In small groups have students select an image (REPRODUCIBLE 3a, 3b). Ask them to complete REPRODUCIBLE 1 (weather data) as best as they can using clues from the image.
- Discussion Questions:** How might your weather data change if the season changed in your picture? How many days do you think you would have to observe and collect weather data before you can predict the climate?



5. Reveal to the groups the actual place the image was taken from. Have them record the location on their REPRODUCIBLE 1. Locate on a map.

Part D: Discovering the Climate

⌚ 20 min

1. Explain that their groups will now be predicting the climate of the same area.
2. Distribute REPRODUCIBLE 2.
3. Have the students write the name of their location on REPRODUCIBLE 2 (section A). Record today's temperature at their location in the greyed out areas (see below; use either the actual temperature from www.weather.com or their predicted temperature). Fill in the rest of the second column to make a grid that corresponds to dice roles. *Use example below to explain and model on the overhead:*

Place: Paris, France Temp: Jan 1, 2009 = 13°C	
Sum of 2 Dice	Temperature (C)
2	8
3	9
4	10
5	11
6	12
7	13
8	14
...to 12	...

4. Explain the term “**climate normals**” (Reproducible 2, section B), which is used to describe weather measurements that are averaged over 30 years. Explain that climate normals are compared to one another to determine the changing climate (i.e. shifts in weather patterns). Also, make sure students understand that climate normals are different from the expected annual changes in weather patterns, related to changing seasons. **Provide an example:** In the same location, at the same time of year, a climate normal of temperature was calculated over 30

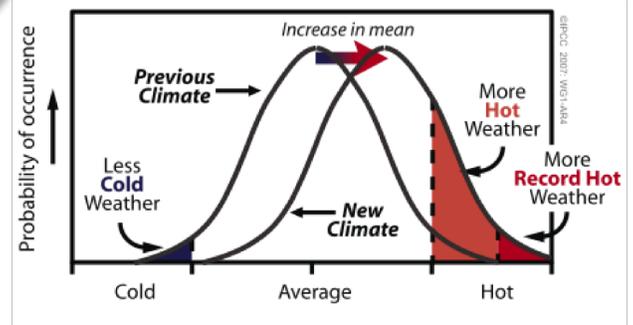
years from 1949 to 1979 and its average was compared with a climate normal of temperature calculated over 30 years from 1979 to 2009. A change in the average was detected, from 13°C to 15°C, and used as evidence for a changing climate.

5. To **simulate 30 years** explain to the students that they will be rolling the dice 30 times to predict the climate. Each time they role the dice, they must record in REPRODUCIBLE 2, section C, the dice's sum (e.g. $3 + 2 = 5$, record 5) and corresponding temperature (using the example table that would be $5 = 11^\circ\text{C}$). This represents the “average” temperature on that day, in that year. Then have students calculate the 30 year average, by adding up the temperatures and dividing by 30 on their calculator.
6. Using a class example, discuss the difference between the “average” climate temperature (i.e. the climate normal detected by rolling the dice) and the observed weather temperature of that day.
 - Could the “average” be the same as the observed temperature? *Yes*
 - Which do you think is more variable: the daily temperature values or the average temperature values (ie. If we rolled the dice again 30 times would the average or the daily temperatures change more)? *Why? Daily*
 - If you were asked to predict the temperature for this day next year, which data would you find the most useful: the current day's temperature, or the average temperature for that day, which was collected over the past 30 years? *Average*
 - You attempted to detect the weather for a particular time and place based on a picture. If you were packing for a trip, which would be more useful, the weather from that picture or information on that climate at the time of year you were going? *Climate information*

6. Briefly summarize the difference between climate and weather using examples. For example, using the table above say: January 1st, 2009 in Paris, France was 13°C. However, when we rolled the dice (simulation) and calculated the average of the last 30 years the expected temperature was 11°C. Thus, the temperature this year was 2°C higher than the expected temperature on this day in Paris, France.
7. Have the groups repeat back their findings to you. Write on the board how they should report their data. Have them say: *The weather temperature on date, in location, is ___°C. However, when we calculated the 30 year average it was ___°C. Which means the temperature was lower than/higher than/exactly what was expected for the climate of this region.*
8. Sum up by telling the students: “**weather is what you get, climate is what you expect**” Have them repeat it back to you several times. Therefore, while weather changes frequently the long-term averages – the climate – remains quite stable. If the class repeated their dice rolls 1000’s more times they would find the average remains fairly constant.

Part E: Applying What You’ve Learned ⌚ 10 min

1. Have each student create a bar graph of the frequency of their dice rolls (REPRODUCIBLE 4).
2. Use these graphs to demonstrate the link between climate change and increases in extreme weather events. Get students to draw a best-fit curve (as in the image above) along the tops of their bars.
3. Explain: Our data is small only 30 points, but when scientists collect thousands of data it usually fits nicely along the curve.
4. Explain that if we did the activity again, say for the next 30 years, and found our curve had shifted, we would have evidence for climate change. Draw and explain the diagram.



6. Show the students another image (or REPRODUCIBLE 5) and explain to the students that for **homework** they are going to **write a postcard** to an adult about the weather (that day) in the picture.
7. Get them to explain in their postcard if this weather is typical of the climate at this time of year or if it’s different from what is expected based on climate normals.
8. Explain to students that they can make up the temperature and climate normals temperatures for this activity or try to find the data online.
9. Also, have them explain in their writing how they used climate normals, to determine what to pack when they visited this climate in winter or summer.
10. **Wrap up** by asking the students what they think the term “climate change” means. How do you think we can detect it? Summarize the discussion by defining climate change as a shift in the average weather that a region experiences. Briefly explain how scientists (climatologists) use the extensive data-base of recorded weather as well as computer models to show that a change is larger than anything that can be explained by natural climate variability.

Sources

The Climate Discovery Teacher Guide, National Center for Atmospheric Research, 2005.

Global climate change: resources for environmental Literacy, Environmental Literacy Council & National Science Teachers Association, 2007.

Weather Where We Live, Wild BC, 2009.

Content Background

Understanding and interpreting local weather data and understanding the relationship between weather and climate are important first steps to understanding larger-scale global climate changes. Through comparing daily temperature with averaged climate data (climate normals), students will understand that weather is highly variable, but climate is not.

When meteorologists describe the “weather” at a particular place and time or the “climate” of a particular region, they describe the same characteristics: **air temperature, type and amount of cloudiness, type and amount of precipitation, air pressure, and wind speed and direction.**

Weather is the current atmospheric state at any given place described in terms of temperature, rainfall, wind, and humidity etc. Weather is happening right now or likely to happen tomorrow or in the very near future. In other words, weather is **what you get**.

Climate is the average pattern of weather for a particular region, usually taken over a 30-year time period or longer. However, climatologists consider “average” weather to be an inadequate definition. To more accurately portray the climatic character of an area, variations, patterns, and extremes must also be included. Thus, climate is the sum of all statistical weather information that helps describe a place or region. In other words, climate is **what you expect**.

In summary, as one middle school student put it, “Climate helps you decide what clothes to buy, weather helps you decide what clothes to wear.”

Information on the weather and climate of British Columbia

Depending on your students’ background you may want to explain how the weather is observed, measured and recorded by many people throughout BC. Officially, Environment Canada oversees a national multilayered network of weather monitoring stations in larger communities and at commercial airports that report weather measurements and observations hourly. They also run an even larger network of climate monitoring stations that report information daily. The data from these stations feed into large numerical models that produce our weather forecasts. Many specialized users such as power companies; universities; avalanche monitoring organizations etc. take their own weather measurements and observations. Often these are posted or made available to the public, as additional sources of weather information (e.g. www.victoriaweather.ca).

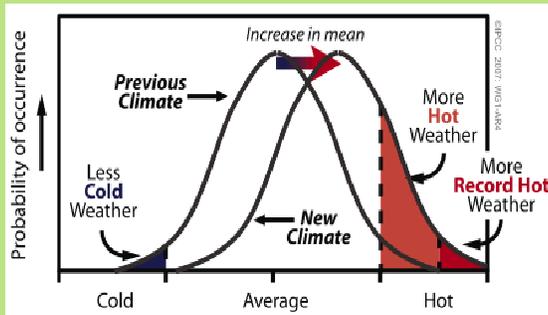
For current weather reports see: http://www.weatheroffice.gc.ca/canada_e.html OR www.weather.com, type in *city name, Canada*

It is important to recognize that BC has a diversity of regional climates due to its coastal location and diverse geography.

For Climate Normals: Environment Canada website - <http://www.climate.weatheroffice.ec.gc.ca/> OR www.weather.com, type in *city name, Canada*, then click “Historical Data.” Then choose “Daily Averages” from the pull down menu at the top and select the appropriate month.

Probability Curves and Climate Change

One common way climatologists represent the vast amounts of weather data that make up climate is by using probability curves. Probability curves can be made for any weather variables, such as temperature or precipitation.



Take the example of a probability distribution for temperature shown in the diagram. The most likely temperature occurs at the centre of the distribution and in this case corresponds to the average temperature (since the distribution is symmetric). As we move to the left or to the right of the average temperature, the probability that a given temperature will occur decreases. Eventually, when we reach low probability values, we identify record hot and record cold events.

Now suppose that we reach a new, warmer climate state with a new probability distribution. The most probable temperature has shifted to the right; that is, the average temperature has become

warmer. But, a second change is apparent. As a result of the shift, extreme warm events have become more likely to occur than they were in the previous climate. At the same time, extreme cold events have become even less likely than in the previous climate. Thus, climate change involves not only a change in the average, or expected temperatures, but changes in the occurrence of extremes as well.

Optional Supplemental Activities

Collecting Weather Data:

Have students in pairs daily collect weather data over two weeks or more, using REPRODUCIBLE 1. Then have students create a graph of their weather data, adding to it each day (Y/vertical axis = temperature, X/horizontal axis = time/days). Help students to choose an appropriate range of values for their temperature axis based on their measurements. If data are collected over several weeks, ask students to identify any patterns they see between the temperature data and the other weather elements measured (cloudiness, wind, precipitation). Also, ask them if they think that their data are “typical” or representative of the weather for the period of time they’ve been monitoring. Variations are normal. Go to www.weather.com and type in your city name to get the local weather. View “Today’s Averages & Records” mid way down the page. Then choose “Historical Data” immediately below “Today’s Averages & Records”. Using the average high, average low, and mean temperature values on the days you plotted, compare to student data.

Partner School:

To better understand that various regions have different microclimates, partner with another class in BC and compare the local weather in each area. Alternatively, have the students compare their class weather data with the data collected by one school in Victoria that is part of the University of Victoria’s School-Based Weather Station Network (www.victoriaweather.ca).

Weather Station:

Check to see if your school has a weather station or if a school nearby does. If you’re on Southern Vancouver Island check out www.victoriaweather.ca or www.nanaimoweather.ca to get weather data, including averages for your area. Use the weather station to explain the types of data collected by the different weather instruments on the station.

Image Sources

www.theclimatecommunity.com/middle-school/
www.vfej.vn/en/category/279/weather/

WEATHER DATA

Date: _____ **Time:** _____ **Location:** _____

Data collected by (names): _____

The temperature is: °C

Other things we noticed about the weather that may affect temperature:

Cloudiness (*Circle one.*)

Clear (clouds in less than 10%)



Few clouds (10-25% of sky covered)



Scattered clouds (25-60% of sky covered)



Broken clouds (60-90% of sky covered)



No blue sky showing (100% of sky covered)

**Precipitation**

- Heavy Rain
 Light Rain
 Light Snow falling
 Heavy Snow falling
 Hail
 Other _____

Wind

- Completely calm
 Light breeze (Wind felt on face. Leaves rustle.)
 Moderate breeze (Flags flap a little, Small branches and leaves move.)
 Strong breeze (Wind whistles, umbrellas turn inside out, bushes sway.)
 Gale (It's difficult to walk in the wind, tree twigs breaking)

A: Discovering the Climate

LEGEND	
Location: _____	
Temperature ____ °C Date _____	
Sum of 2 Dice	Temperature (°C)
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

Names of Group Members: _____

B: Climate Normals

Meteorologists use the term “climate normals” to describe weather measurements that are averaged over 30 years. Normals are for a particular location and can be defined for a particular day, month, season, and year. There are normals for each component of weather that is measured at a particular site with a long enough observational record.

For example, today we will be measuring the *climate normal* of temperature at a particular place.

D: Calculate

Calculate the climate temperature normal for your place. In other words, calculate the temperature it typically is on this day of the year at this location as evidenced by 30 years of data collection.

Calculating the Average: Add up all the temperatures you recorded in the chart below and divide by 30 to get your climate temperature normal.

$$\text{_____ } ^\circ\text{C} \div 30 \text{ years} = \text{_____ } ^\circ\text{C}.$$

On average this is the temperature you can expect today to be.

So next time you travel take a look at climate normals they will help you pack!

C: Record 30 Dice Rolls

Use the chart below to record the SUM of the numbers rolled on the dice and the corresponding temperature in °C, using your legend above.

| Dice Sum = in °C |
|------------------|------------------|------------------|------------------|------------------|------------------|
| = | = | = | = | = | = |
| = | = | = | = | = | = |
| = | = | = | = | = | = |
| = | = | = | = | = | = |
| = | = | = | = | = | = |

Weather Images



Tofino, BC



Victoria, BC, in May



Downtown Miami, FL, USA, June 13, 2007



Varna, Bulgaria (Black Sea Coast), June 25, 2008
(Xinhua/Reuters Photo)



Arctic



Quang Ngai, Vietnam, January, 2010

Reproducible

3a

Lesson

1



←
Houses of Parliament,
London,
England



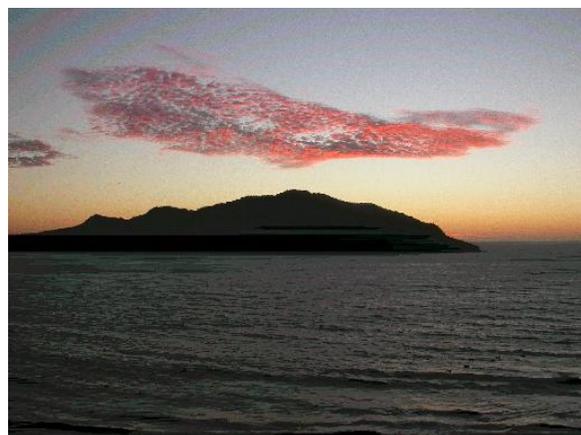
Tasmania (Dove Lake, Cradle Mountain),
Australia (Credit: iStockphoto/Linda & Colin
McKie)



Aspen, Colorado



Location Unknown, however, calm
seas & extensive cloud cover.



Las Flores Beach Resort, Mazatlan, sunset
February? 2009



Near El Chalten, Argentina, November, 2008



Arizona



Northern Michigan

Reproducible

3b

Postcard home:

Pretend you went on vacation in January to the town of Swansea in Tasmania, Australia and you bought this postcard. Use the template below to write a note to an adult at home. Explain to him or her how you used climate normals to help you pack for your trip (e.g. temperature normal, precipitation normal). Let them know if the weather in the postcard was what you expected or different from what you got. You can make up the weather and climate normals OR try to look them up for this area using a website, like www.weather.com.



	Place Stamp Here

RUBRIC FOR THE POSTCARD ACTIVITY

Aspect	Not Yet Within Expectations	Meets Expectations	Fully Meets Expectations	Exceeds Expectations
Weather vs. Climate <ul style="list-style-type: none"> Weather you get. Climate is what you expect Meteorological data mentioned, and/or how it's collected E.g. air temperature, wind speed, type of precipitation etc. 	<ul style="list-style-type: none"> Unclear, unfocused Some information inaccurate or copied Few details; may be irrelevant or repetitive No examples given 	<ul style="list-style-type: none"> States some differences between weather and climate Generally accurate, but may omit key points Includes details and examples; some may be irrelevant or inaccurate 	<ul style="list-style-type: none"> Clearly and accurately demonstrates their understanding of the differences between weather and climate Uses some relevant details and examples to explain the differences 	<ul style="list-style-type: none"> Clearly and accurately explains the differences between weather and climate Multiple examples are well-chosen, thorough, in own words, and specific
Weather Expectations <ul style="list-style-type: none"> E.g. for fully meets: I expected it to be cool (5°C) and windy on the ocean but when I got there it was warm (20°C) and calm. It looks like it does in the picture calm seas showing no wind. 	<ul style="list-style-type: none"> Does not describe how the weather expected was accurate or different from what was received OR may attempt a description that is inaccurate based on the image and accepted ranges of natural variability (eg. -50°C to +40°C) 	<ul style="list-style-type: none"> Describes how the weather expected was accurate or different from what was received; focus may wander Provides only one weather characteristic 	<ul style="list-style-type: none"> Fully describes how the weather expected was accurate or different from what was received Uses at least 2 weather characteristics (e.g. temperature, cloudiness, precipitation and/or wind conditions) 	<ul style="list-style-type: none"> Using clear and expressive language effectively describes expectations of weather and how it differed or was similar to what was received Uses 3 or more weather characteristics
Climate Normals <ul style="list-style-type: none"> Weather measurements averaged over 30 yrs for a particular location. Given for each component of weather (e.g. temp, precipitation) Normals from different time periods are compared to each other to detect shifts in weather patterns Not related to seasons 	<ul style="list-style-type: none"> Does not describe what a climate normal is May provide an example of how to pack for a trip 	<ul style="list-style-type: none"> Describes what a climate normal is; generally accurate, but may omit key points Includes an example; may be irrelevant or inaccurate 	<ul style="list-style-type: none"> Accurately and concisely describes what a climate normal is and how it can help a person pack for a trip Provides an accurate example 	<ul style="list-style-type: none"> Accurately and concisely describes what a climate normal is Provides examples and connections to extreme events and/or climate change as well as packing for a trip
Math: Reasonable estimations, percentages, probabilities <ul style="list-style-type: none"> Temp: 10-25°C For more info see: www.bom.gov.au or information on next page 	<ul style="list-style-type: none"> Does not demonstrate an understanding of likelihood of occurrence of particular weather events describe in their writing 	<ul style="list-style-type: none"> Weather component estimates are off. Appears the student did not consult any sources of weather or climate information in the area 	<ul style="list-style-type: none"> Weather component estimates are generally accurate given this areas climate normals May mention the likelihood of what they got occurring on a visit to the area 	<ul style="list-style-type: none"> Weather component estimates are reasonable given this areas normals Describes how relates to or doesn't relate to extreme events and the likelihood of their occurrence

Conventions <ul style="list-style-type: none"> • Spelling • Punctuation • Complete sentences • grammar 	<ul style="list-style-type: none"> • frequent errors interfere with meaning 	<ul style="list-style-type: none"> • some noticeable errors; these may cause the reader to hesitate or reread parts to confirm meaning 	<ul style="list-style-type: none"> • few errors; these do not interfere with meaning 	<ul style="list-style-type: none"> • sense of control; few errors; these are usually the result of taking risks to use complex language and structures
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Note: The rubric above is a modified version of the BC performance standards for numeracy and writing to communicate ideas and information (reports, articles, letters).

About the Postcard Image:

It was taken from Nick Rains' book *Australia – The Photographer's eye*. Available at:

<http://www.nickrains.com/ATPE.html>. The picture is an image of Freyeinet Peninsula and Great Oyster Bay, which is near the town of Swansea, Tasmania, Australia. Hobart, the capital of the Tasmania, is about 135km southwest of Hobart and its weather conditions are easily found online.

You may want to point out to your students that **January in Australia is midsummer** with average temperatures ranging from a high of 36°C at Alice Springs to 22°C in Hobart and a low of 12°C in Hobart to 25°C in Darwin. Note that these are average maximum and minimum temperatures and actual temperatures may exceed the averages at certain times and in different regions. Except in Darwin, which may record an average 15 inches of rainfall in January, most city capitals would generally be dry with no more than 2 inches of rainfall (source: <http://goaustralia.about.com/od/discoveraustralia/a/ausjanuary.htm>).

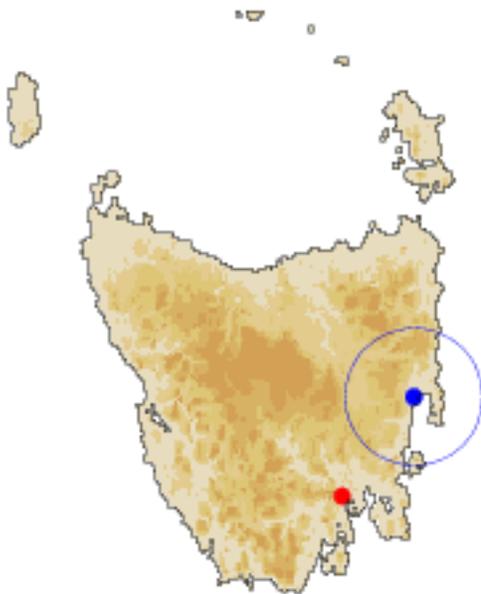


Figure 1. Tasmania. Swansea is the dot with the big circle around it. Hobart is the lower dot.

If students need help discovering reasonable climate averages you can direct them to Australia's Bureau of Meteorology page at: www.bom.gov.au.

Swansea post office's weather station averages for the month of January:

Mean Maximum Temp.	22.2 °C	1957-2009
Mean Minimum Temp.	11.7 °C	1957-2009
Mean Rainfall	49.4 mm	1884-2010
Mean daily sunshine	8 hours	1957-1980
Mean number of clear days	5.7 days	1957-2009

The highest temperature recorded in Tasmania ever is 42.2°C on Jan 30th, 2009 at Scamander. The lowest ever is -13°C at Shannon, June 30, 1983. The highest daily rainfall is 352mm, March 22, 1974 in Cullenswood. Thus, students' predictions should not exceed these extremes and should more closely fit those in the table above.

The Carbon Balance

In This Lesson

Students will follow the path of carbon through the carbon cycle to learn where carbon is stored and how it circulates. The game highlights how human actions, through the use of fossil fuels and clearing of the world's forest, result in an increase in the amount of carbon dioxide in the atmosphere.

Achievement Indicators

Students will be able to ...

- **S.S.:** identify and compare the relationship between the short carbon cycle, the long carbon cycle and infer humans' roles in the cycles (A1).
- Summarize and draw conclusions about carbon sources and sinks (A1).
- Evaluate the effects of fossil fuel technology on the environment and the carbon balance (D3)
- **Math:** Demonstrate an understanding of millennial time scales (A1)
- **L.A.:** Communicate their understanding of the carbon balance (*Oral Language*)
- Use strategies for reading and viewing carbon cycle cards, including summarizing and synthesis on their carbon passports (*Reading & Viewing, Writing and Representing*)
- **P.E.:** Participate in daily physical activity (A6)
- Model fair play (C2)

Assessment

- Collect students' Carbon Passports (REPRODUCIBLE 2) to determine their understanding of how carbon moves through the carbon cycle and observe students' fair play.

Lesson Preparation

Time: 60 minutes

In Advance: Find a suitable indoor or outdoor space to play the game.

Materials: REPRODUCIBLE 1 available online at <http://wildbc.org/index.php/programs/climate-change-education/> under Carbon Cycles! (*optional:*

colour code station signs and activity cards), REPRODUCIBLE 2a/2b (one per student), bag of coloured pencil crayons, REPRODUCIBLE 3 (transparency), REPRODUCIBLE 5 (blown up, poster size)
Optional: REPRODUCIBLE 4, clipboards for passports, chart paper

Vocabulary Introduced

Carbon: An element; compounds of carbon (organic compounds) form the basics of all living organisms.

Carbon Balance: Over long periods of time, there is a carbon balance in natural systems where there is no net gain or loss of carbon in any reservoir. In other words, the carbon sources and sinks are balanced.

Carbon Cycle: The global exchange of carbon between Earth's components (atmosphere, living things, ocean and land).

Carbon Source: Gives off (emits) carbon dioxide or another carbon based greenhouse gas, which can end up in the atmosphere (i.e. soil).

Carbon Sink: Takes up carbon and stores it for some unspecified long period of time (i.e. ocean).

Fossil Fuels: A natural fuel formed in the geological past from the remains of living organisms (e.g. coal, natural gas, kerosene...)

Atmosphere: Layer of invisible gases surrounding the earth (or another planet)

Earth's Crust: The outermost layer of rock, above the Earth's mantle

Step by Step

Part A: Game Setup

Before students arrive: REPRODUCIBLE 1—tape the 5 stations' signs in different areas of a gym (or outdoor space). This game is played in two rounds but only Earth's Crust and Air have different Activity cards for each journey (labeled with either a #1 or #2 at the corner of the card). Place "Journey One" cards at corresponding stations and bag of coloured pencils at the centre of room.

Part B: Where is Carbon? ⌚ 10 min

In your classroom discuss...

1. Last period we talked about the difference between weather and climate. In order to understand climate change we need to understand these differences as well as the carbon cycle. By the end of this lesson we will understand how humans have influenced the carbon cycle. Where carbon is located, is very important to global warming and climate change.
2. Explain: **carbon is an element** and can be found in different forms (molecules and compounds) all around us. If helpful, remind students that an example of a compound is water; it contains two elements: hydrogen and oxygen.
3. Check prior knowledge: Ask "**What things have carbon in them?**" Record responses on the board. If students are having difficulties provide the hint that all life on Earth is carbon based. Identify some of the basic carbon compounds, including carbon dioxide, calcium carbonate (hard shells), and carbohydrates.
4. Ask: "**How could we group these examples into larger groups—the Earth's components?**" For example, students may have said humans and plants have carbon in them. These could be grouped under one of the Earth's components—Living Things. Help students identify the components of the Earth **where carbon is located** (e.g., **atmosphere, living things, soil, ocean, Earth's crust**) and record these on the board. Provide examples for components they did not brainstorm (e.g. Earth's crust has limestone rock, which contains carbon). See *Backgrounder* section *Carbon Everywhere* for examples.
5. Emphasize: Carbon continuously cycles through Earth's systems. **Carbon does not get destroyed**, but rather re-used in different compounds.
6. Provide students with an **example of how carbon cycles** and the different carbon compounds involved. For example, for animals to move and grow they use carbon-based food (e.g. carbohydrates). In turn, animals release carbon dioxide that plants take in to use for growth.
7. Introduce: **Carbon sources** (give off carbon) and **carbon sinks** (take up and store carbon). For example the ocean can take up carbon dioxide (sink) and volcanoes can release it (source).
8. Ask: "**What do humans use a lot of that comes from the deep Earth?**" Ensure students are aware of the varied use and types of **fossil fuels** (gasoline in cars, *Vaseline*, coal in factories, natural gases heating etc), including as a base for making *plastics* (see backgrounder). Explain that we will be looking at how fossil fuels fit into the carbon cycle.

Part C: Carbon Cycle Game ⌚ 25 min

In the gym or suitable outdoor space...

Journey One (Natural Cycle)

1. Inform students they are about to **become carbon** and travel through the carbon cycle before humans discovered uses for fossil fuels.
2. Point out the location of the **five stations**
 - a) Living Things (green)
 - b) Soil (yellow)
 - c) Ocean (blue)
 - d) Air (or Atmosphere) (white)
 - e) Earth's Crust (orange)
3. **Connect the stations to the poster of REPRODUCIBLE 5.** Explain: each of these stations is a component of the Earth and as a carbon atom you will travel through the carbon cycle, **discovering where carbon is found and how it moves** from one place to another. Read aloud examples on the poster.
4. **Explain:** You move from station to station by drawing and following the instructions on a card. After you have read and recorded the information, put the card at the bottom of the pile before moving on.
5. **Distribute:** REPRODUCIBLE 2a and 2b (double-sided sheet). **Explain:** This is your "**Carbon Passport.**" Under *I am at* in "Journey One" write down the abbreviation for the first station you visit

(eg. O for Ocean). Then next to it under *I will*, write down a note of what the card says for how you travel (eg. O – wind and wave mix carbon out of water) then go to where the card says (e.g. in this case, *Air*).

6. **Explain:** If you are not the first at a station you must join the **end of the line and wait your turn** to draw a card. If your card asks you to **STAY** at the station then **record** your information on the passport, place the card at the bottom of the pile, **DO 10 jumping jacks**, and then return to the end of the line. It is important to know how many times you stay at a station! Jumping jacks provide a visual for carbon's length of time at a station. *Optional:* students can read their card aloud to the line-up before moving on.
7. **Explain:** If you fill up all the spaces in Journey One before you hear “Carbon, Stop Cycling” then gather where the pencils are and complete the back page (2b) of your passport. Put a #1 where you started (eg. Ocean) then draw an arrow to #2 your next stop, and continue with the arrows and numbering until you've completed your journey. Compare your journey with another student who finished as well.
8. **TOP SECRET!** As the teacher, you will need to have yourself or an assistant at the Earth's Crust station to help students “escape” using the **Volcano Wild Cards**. If students have been at this station a while (generally about 3 “EC” cards) then simulate a volcanic eruption by waving your hands in the air and making noises. Give them a Volcano Wild Card to read. Have them record “V” on their travel log, return the card to you, and then move to the Air station.
9. **START:** Send equal numbers of students to each station (except the Earth's Crust) and say “Carbon, Cycle!” Check to ensure students are correctly marking their Passports and reading all the information on their cards in order to complete the task assigned. Have students play until their Carbon Passport for Journey One is full (~5-10min). Have early finishers finish the other side of their carbon passport (2b)—see above, step #7. When most have finished yell “Carbon, Stop Cycling” and have them all gather around you.
10. **Discuss:** Ask them what they experienced. It is important that all the students recognize that **some of them got “stuck” at the Earth's Crust and Ocean stations**, while **others may have cycled** amongst the Air, Living Things and Soil stations. Briefly discuss why (see Backgrounder), emphasizing the only way out of the Earth's crust and directly into the atmosphere is through volcanic eruptions (on very

long time scales weathering of carbonate rocks releases carbon into water and soil NOT air). Also, ensure they understand that plants are important for taking carbon out of the atmosphere. Both of these factors are important in understanding the impact of human activities on the carbon cycle in the next round.

11. If time permits, play Journey One again so students have a chance to move to other stations. Start them at different stations. Inform students that they do not need to use their passport this time, rather they should think about how their next journey is different from their first. End by saying “Carbon, stop Cycling!”

Journey Two (Human Actions)

1. **Replace Journey One activity cards with those for Journey Two at Earth's Crust and Air Stations.**
2. Ask students to **predict** what will happen **if the human activities of using fossil fuels and removing forests are introduced**. Explore their explanations.
3. Play game as before, reminding students to use the “Journey Two” section of their passport (2a). Also, remind early finishers to track their new journey on the back page of their passport (2b), but **this time with a different coloured pencil** from the last time. Repeat, without recording (time permitting).
4. Students will **now be held up at the Air Station**. As they are, instruct the students, once more, to do 10 jumping jacks each time they draw a stay card.
5. Allow time for students to share their different journeys with one another.

Part D: Discussion ⌚ 15 min

Return to the classroom

1. Debrief about the game by asking students what they experienced as carbon. **Where does carbon go and why?** Remind students to use their Carbon Passport to remember their journey and to determine patterns.
2. *Draw REPRODUCIBLE 2b's (passport) map on the board.* Select 2 or 3 **students** to come up and **map** their individual **Journey One**, each using different colours.
3. *Now show the students the transparency of REPRODUCIBLE 3* (or draw it on the board) and show them that although it looks different from our map it has all the same components. Point the components out (Ocean, Living Things, Soil, Air, Earth's Crust). Explain that scientists use the *arrows* to show *sources* and *sinks* of carbon. Explain that the

boxes represent sinks where carbon may be stored for long periods of time (Air, Ocean, and Earth's Crust).

4. *Help the students to recognize that there are short and long-term carbon cycles.* The long-term cycles involve the deep ocean and Earth's crust. They take 100,000 (Ocean) to 300 million+ years (Earth's crust). This is why students could not escape the Earth's Crust unless a volcano erupted (*note* volcanic eruptions cannot account for the climate changes observed today).
5. *Explain the Carbon Balance:* carbon is an integral part of the energy flow in ecosystems. Normally, there is, averaged over many years, a carbon balance (or equilibrium) where there is no net gain or loss of carbon in any reservoir because processes like photosynthesis (uptake of carbon) are roughly balanced by respiration (loss of carbon from plants and animals). In other words, the sources and sinks are balanced.
6. *Ask: How do you think humans have disrupted this carbon balance? Compare the natural carbon cycle (Journey One) to the one involving recent human actions (Journey Two).* Did predictions match what happened? As a prompt, ask the students to recall the difference between the activity cards at Earth's Crust and Air between Journey One and Journey Two. If necessary, read aloud the instructions from some of the Activity Cards. Emphasize how in Journey Two, it is human activity, not just volcanic activity, that is releasing carbon from the Earth's crust by using fossil fuels as a source of energy. The result is that more carbon is released into the atmosphere; thus more students ended up at the Air Station.
7. *But aren't fossil fuels part of the carbon cycle? Yes, however, they are part of the long-term cycle.* Explain how over 350 million years ago in the Devonian period, large amounts of carbon were trapped as dead marine organisms (mostly phytoplankton and zooplankton) and were buried by sediments at the bottom of the ocean. Over millions of years the carbon was transformed in the Earth's crust to oil and natural gas. Ensure students understand that oil and natural gas are not made of dinosaurs, but mostly tiny marine organisms that lived well before the dinosaurs. Another fossil fuel—coal is made from partially decomposed land plants becoming buried by sediments. The oldest coal beds began in the Carboniferous period approximately 300 to 350 million years ago. Thus, it took hundreds of millions of years to store the carbon and make fossil fuels but

in several hundred years we've dug up and burned a significant portion of the carbon releasing it quickly into the air and disrupting the carbon balance.

8. *Also emphasize that less carbon was able to leave the Air Station and move to the Living Things Station because of the human activity of clearing forests, resulting in fewer trees to take up the carbon during photosynthesis.*
9. *Summarize* using transparency of REPRODUCIBLE 3: indicate the change in the carbon cycle (balance) by **bolding the arrows from the fossil fuel reserves (Earth's crust), land use change, and deforestation to the atmosphere (air).** Then **reduce the arrows from the atmosphere to living things (like plants).** Explain: Arrow to living things is smaller now than in the past because we have cut down plants to make pastures, build cities etc. Also mention that as the atmosphere warms the ocean also warms and is able to hold less carbon dioxide—further bold the arrow from the ocean to atmosphere at this point.
10. Thus, humans have altered the carbon cycle and disturbed Earth's carbon balance, which in turn has caused changes in our climate. Today the sinks cannot keep up with the sources to the atmosphere so the amount of carbon in the atmospheric reservoir is increasing. The problem with this is that when carbon is in the air it can take the form of molecules such as carbon dioxide or methane, which act to trap heat near the earth's surface. Over the next few classes we will explore why this is a problem that impacts climate and how it is unlike other problems humans have faced. We will also be examining solutions.

Part E: Applying What You've Learned ⌚ 10 min

1. On the back of their carbon passport have students draw and label a fossil fuel reserve as a carbon source. Then collect Carbon Passports for evaluation.
2. On scrap pieces of paper, ask students to write as many plausible ways they can think of to travel between the Earth components. Prompt them: "How can carbon get from the Air to the Ocean?" (eg. From Air (A) – wind mixes carbon into ocean – arrive at Ocean (O)). Remind them to think back to what they read on the activity cards or distribute them to help the students in their task.

Sources

Adapted from “Carbon Cycles!” and used with permission from Wild BC, 2009. www.wildbc.org

Brewer, C.A., & Beiswenger, J.M. (1993). Carbon Dioxide & the Greenhouse Effect: A Problem Evaluation Activity. *The American Biology Teacher*, 55(4), 238-240.

Optional Supplemental Activities

Create a Carbon Card

Ask students if they can think of another source or sink not talked about (e.g. cement production or melting permafrost releasing methane)? Have the student research the source or sink. Then invite students to write new Activity Cards for each station and play the game again. Try adding the different scenarios and observing the impact on the carbon cycle.

NOTE: Reproducible 1 is available online at

<http://wildbc.org/index.php/programs/climate-change-education/> under Carbon Cycles!

Content Background

Like the water cycle, carbon in the carbon cycle moves between various components of Earth by different processes. Carbon dioxide, a form of carbon found in the atmosphere, is one of the main greenhouse gases, and as such plays a critical role in regulating Earth's temperature. Understanding where carbon is stored and how it's captured and released—naturally and by human activity—is essential to understanding human-induced climate change.

Carbon Everywhere

Carbon is one of the basic elements on Earth and is found and stored in a variety of Earth's major components. In each component, carbon can be in different forms (chemical compounds); for example in:

- atmosphere (air) as a gas, like carbon dioxide or methane;
- living things (biotic component of ecosystems) mainly as sugars, starches, and cellulose (various forms of carbohydrates) in plants; and as carbon compounds, including proteins, nucleic acids and carbohydrates in the soft tissues of animals, as well as calcium carbonate in hard structures of animals such as bone, coral and shell;
- soil as the remains of once living things (dead organic matter) and in living bacteria, fungi and other microorganisms (i.e., the decomposers);
- the ocean as dissolved carbon dioxide;
- Earth's crust as calcium carbonate (calcite) in sediments and rock originating from parts of living things (e.g., chalk and limestone) and as modified carbohydrates in fossil fuels (crude oil, coal, and natural gas).

The only place carbon is not found is in things that are composed of pure mineral (e.g., quartz), pure metal (e.g., gold), or simple compounds such as volcanic rocks and salts.

Carbon Sources and Sinks

Terrestrial systems exchange a large amount of carbon dioxide with the atmosphere each year. However, prior to any significant inferences by humans, there was very little gain or loss of carbon because photosynthesis (uptake of carbon) was roughly balanced by respiration (loss of carbon from plants and animals) over the last 10,000 years. The ocean acts as the largest *carbon sink* (takes up carbon and stores it) helping to regulate this balance. In contrast, the decay of dead organisms can act as a *carbon source* (giving off carbon dioxide).

Carbon can be reported by weight as Gigatons of Carbon (GtC, that is 1×10^{15} g of carbon) or by volume as parts per million (ppm). 2GtC is roughly equivalent to 1ppm. The atmosphere exchanges about 120GtC with the terrestrial system, however, it stores about 600GtC in the vegetation and 1500GtC in the soils. The atmosphere exchanges about 90GtC with the ocean, however, the ocean stores about 37000GtC. Overall then, both the terrestrial systems and the ocean are carbon sinks.

Components of the Earth can act both as carbon sources and carbon sinks; however, the time scale of a full cycle varies between components. For example, over a year a plant can grow and take in carbon dioxide and then come autumn, lose its leaves and become a carbon source (e.g. short-term carbon cycle). In contrast the Earth's crust, where most of the Earth's carbon is stored, has carbon that remains buried in the form of ocean sediments and on land for thousands to hundreds of millions of years, and is rarely released, except through erosion of sediments and volcanic activity. The time scale for this process (explained further in carbon cycle section below) is much longer than anything relevant to the existence of humans on Earth, yet we are short-circuiting this very process (a.k.a. the long-term carbon cycle) by the extracting and burning of fossil fuels.

Fossil Fuels

Fossil fuels are a natural fuel formed in the geological past from the remains of living organisms. These plants and algae captured the sun's energy over 300 million years ago. Contrary to popular belief, fossil fuels are not made of dinosaurs; oil is derived mostly from tiny marine organisms that become buried in ocean sediments, slowly changing over time into a fossil fuel. More recent coal deposits are comprised of plant material.

Burning fossil fuels (the remains of once living things, containing carbon, such as wood or marine organisms) as sources of energy releases carbon dioxide into the atmosphere. Other examples of fossil fuels include natural gas, kerosene, propane and even Vaseline (hence the name *petroleum jelly*). We also use fossil fuels as the raw material for many chemical products, including pharmaceuticals, solvents and plastics. Plastics are used to make everything from clothes to skateboards to computers.

Carbon Cycle

The carbon cycle is directly linked to energy use by all life on Earth – including humans. Some of the energy from the sun (visible light) is captured and transformed by plants during the process of photosynthesis and then stored in the chemical bonds of carbon-based compounds called carbohydrates. Carbohydrates are “food” made by plants; they are essential for all life on Earth. The stored energy in these carbon molecules is passed through food chains and food webs and is used by organisms at each level.

Carbon moves through the carbon cycle using various processes. In the **short carbon cycle** (thousands of years), carbon moves between Air, Living Things, and Soil via such processes as respiration and decomposition. Respiration, combustion and decomposition can act as carbon sources to the atmosphere; whereas, photosynthesis in plants acts as a carbon sink. Ocean ecosystems also are part of the short carbon cycle. The carbon dioxide can move from the ocean waters to marine algae (plant-like organisms) to marine animals, to biologically active sediments, then back to the ocean water. Due to its size, a large amount of carbon is stored in the ocean as dissolved carbon dioxide; there is a slow, balanced exchange of carbon dioxide between the atmosphere and the water in the ocean.

In the **long carbon cycle** (millions of years), carbon is taken up by the surface ocean and eventually reaches the deep ocean sediments. Pure rain is slightly acidic because the carbon dioxide in the atmosphere dissolves into the rainwater. When the slightly acidic rainwater comes into contact with certain minerals (in rocks etc.) chemical weathering occurs. In chemical weathering minerals are broken down and the chemical by-products, including bicarbonate ions that contain carbon are eventually transported to the ocean through river runoff or groundwater. Then certain marine organisms use the bicarbonate ions to produce their shells. When they die, they can sink and transport this carbon to the sediments of the ocean floor. As the tectonic plates that contain these sediments subduct under other tectonic plates, the carbon is sequestered into the Earth’s interior, ready to be released into the atmosphere by volcanoes hundreds of thousands to millions of years in the future. Because of this long-term cycle students cannot escape the Earth’s crust in the carbon cycle game, unless a volcano erupts or humans extract and burn fossil fuels. It is important to note that volcanic eruptions are a part of the natural long-term carbon cycle. As such their long-term effects as carbon sources are in balance with the earth’s carbon sinks. Alternatively, living things that die on land may, through a series of processes, end up in long-term storage as coal. Of all the carbon on Earth, most of it is stored in the Earth’s crust as sediments from the ocean and land.

Global Equilibrium – The Carbon Balance

Over long periods of time natural systems try to reach a carbon balance where there is no net gain or loss of carbon in a particular reservoir. In other words, the carbon sources and sinks are in balance. This has changed since the discovery and use of fossil fuels as sources of energy. Land-use changes such as deforestation and industrial agriculture have altered the uptake of carbon dioxide from the atmosphere. For example, deforestation can reduce the amount of plants in an area available to act as carbon sinks. It is thought that to date, land-use changes have accounted for about a third of human emissions of carbon (158 GtC released from land-use change and deforestation), and burning of fossil fuels account for most of the remaining two thirds (330 GtC from fossil fuels and cement production). The resulting 488 GtC released into the atmosphere by human activities has exceeded the overall ability of uptake from natural carbon sinks. This results in more carbon dioxide in the atmosphere, which acts as a greenhouse gas warming the earth (more on this in later lessons).

Travelling Carbon Passport

In this game you are a carbon atom. You are going to travel the carbon cycle stopping in many exciting locations – some of which you probably never have been to before. For each stop remember to record where you went and how you got there. Once you have recorded your card information, place the card at the bottom of the pile before moving on. If your card tells you to stay at a station, record your stay, then DO 10 jumping jacks and return to the end of the line. Your teacher will explain how to fill out your passport using the examples below.

These are the places you may visit:

- | | |
|---------------------------|---------------------------|
| LT (Living Things) | A (Air) |
| S (Soil) | EC (Earth's Crust) |
| O (Ocean) | |

E.g.	LT	be used by plants to grow (respiration); CO ₂ is released to ...
E.g.	A	stay in the Air...
E.g.	A	be mixed into the water ...

Journey One (Natural Carbon Cycle)

Stop #	I am at:	I will...
1		
2		
3		
4		
5		
6		
7		
8		

Journey Two (Human Actions)

Stop #	I am at:	I will...
1		
2		
3		
4		
5		
6		
7		
8		

Travelling Carbon Passport – Back Page

Below is a diagram of all the places you may have travelled to in the Carbon Cycle Game. Put a #1 at your passports start location and then draw an arrow to your next stop. Label this stop #2. Carry on until you've mapped your entire journey! Use a different pencil colour for Journey One (Natural Cycle) than you use for Journey Two (Human Actions).

A Map of My Journey!

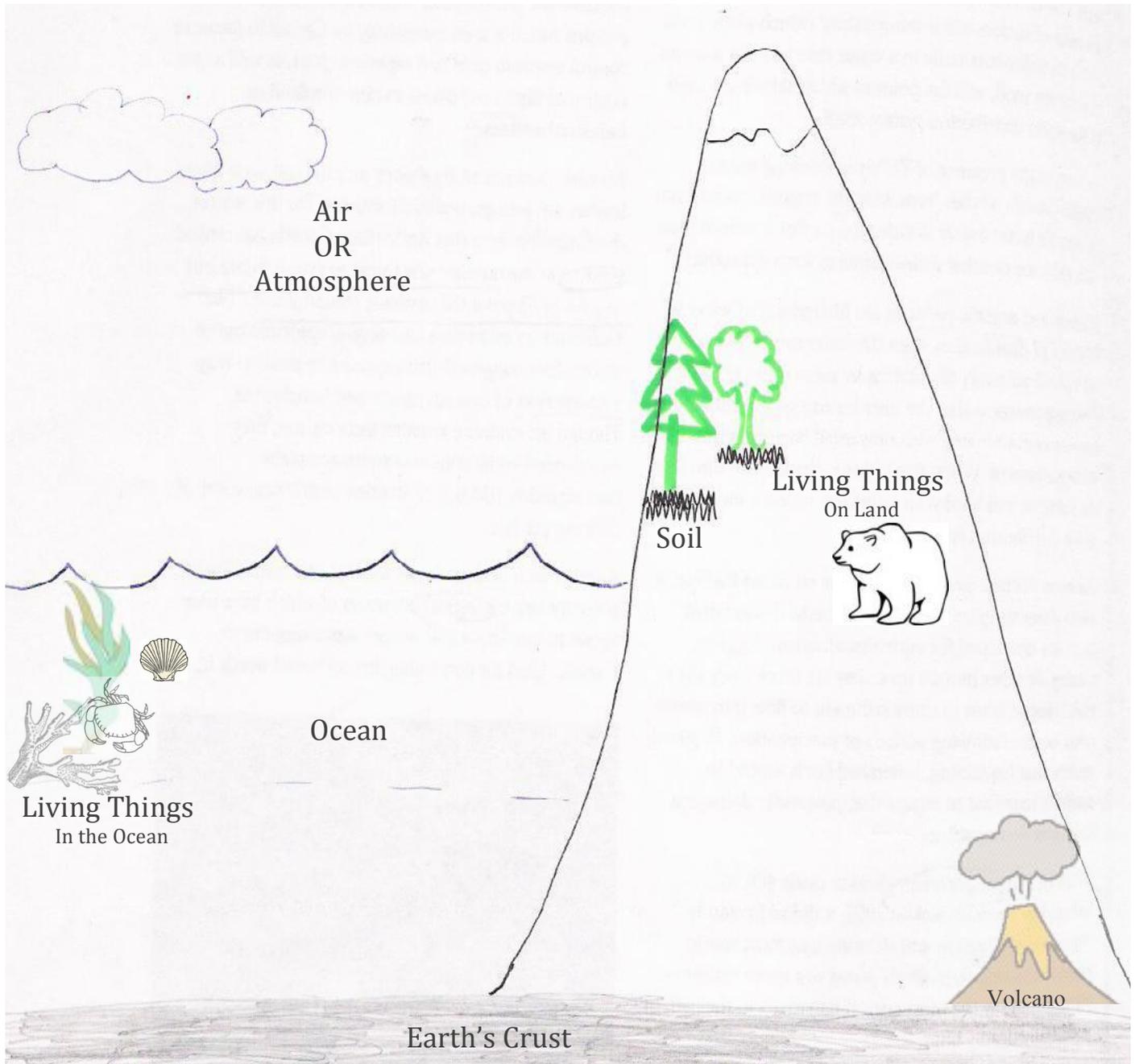
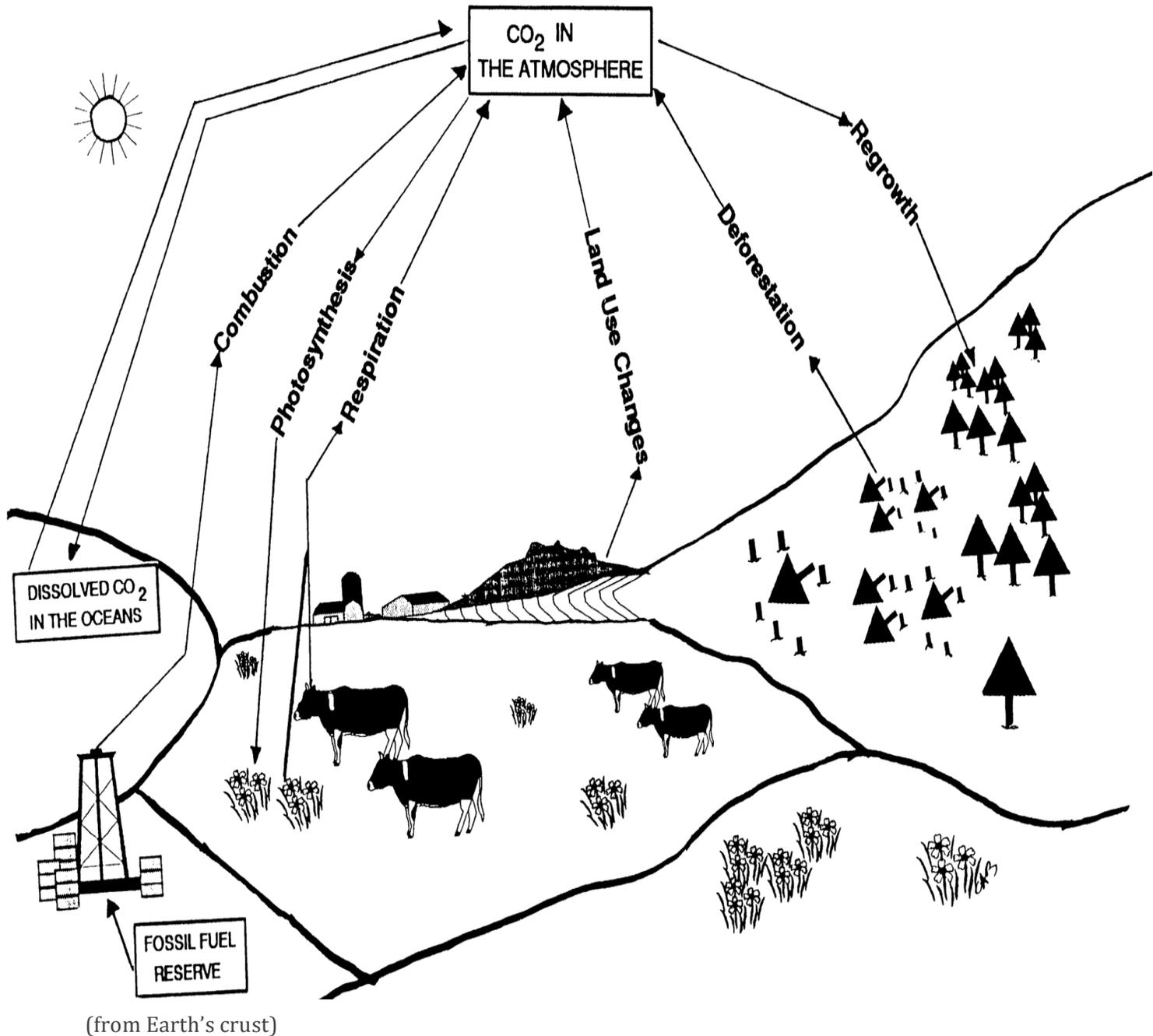


Diagram of the Global Carbon Cycle

Boxes represent sinks where carbon may be stored for long periods of time. Arrows illustrate fluxes to and from carbon sinks.



Source:

Brewer, C.A. & J.M. Beiswenger. (1993). Carbon Dioxide and the Greenhouse Effect: A Problem Evaluation Activity. *The American Biology Teacher*, 55 (4), 238-240.

Reproducible

3

Optional

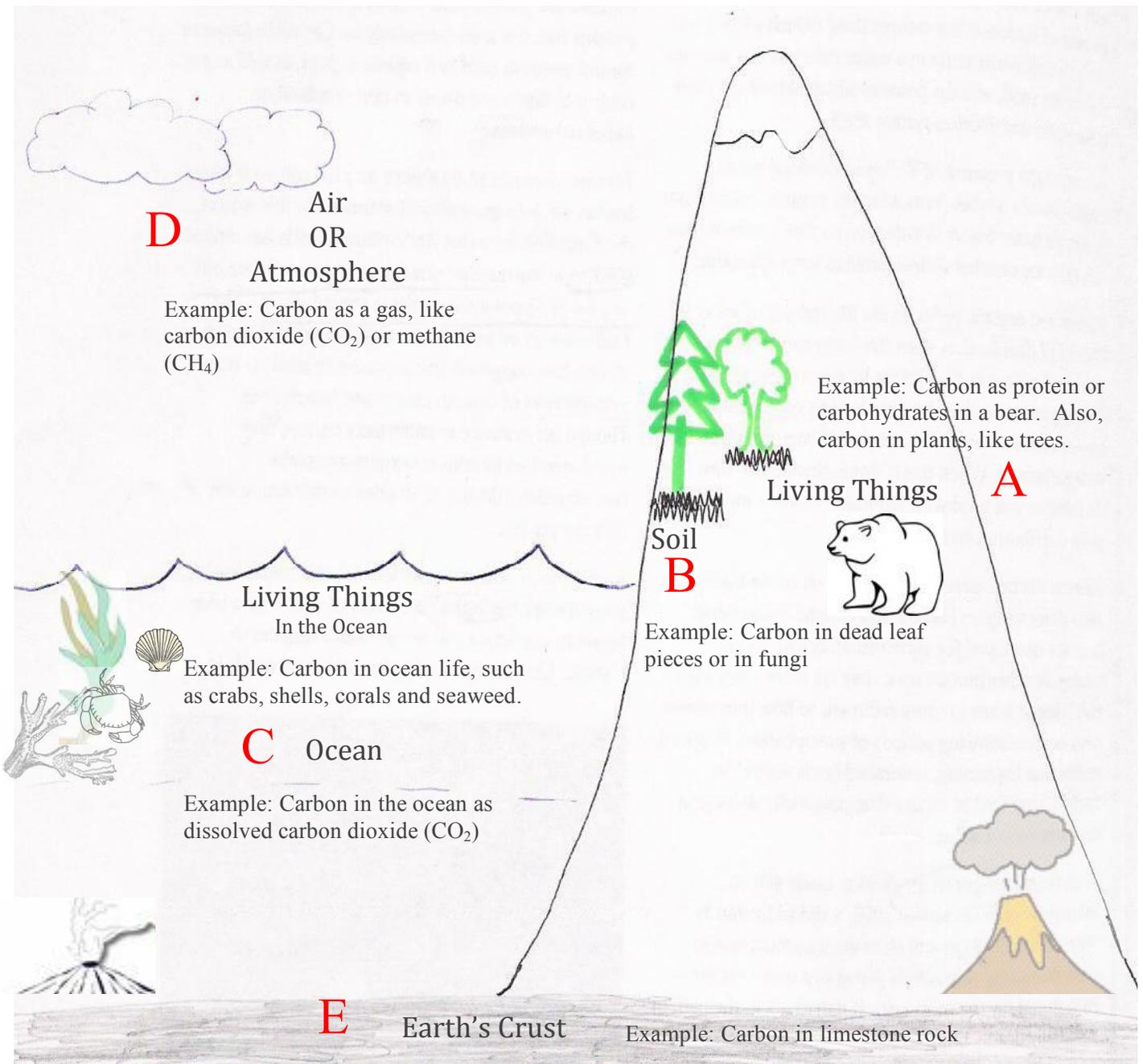
FYI: Factual Tidbits to be used in the discussion after the game has been played.

- The “carbon cycle” isn’t a closed loop. **Carbon moves back and forth** between various reservoirs (a.k.a components –Earth’s crust, Living Things etc). **Carbon does not get destroyed** only transformed.
- The **long carbon cycle** involves rain containing dissolved carbon dioxide “weathering” rocks on land and eventually taking carbon to the deep ocean where it ends up in sediments. The sediments are carried with tectonic plates as they move under other tectonic plates. The carbon is eventually released to the atmosphere when volcanoes erupt.
- **Soils** take carbon dioxide out of the atmosphere but they also release it to the atmosphere.
- While **plant growth** is enhanced with increasing carbon dioxide (CO₂) eventually the ability of the biosphere to absorb CO₂ saturates and decay of organic material balances the extra uptake of CO₂.
- Tiny marine organisms called phytoplankton take in carbon to make the nutrition (energy) they need through a process called photosynthesis. The phytoplankton are eaten by larger marine life. Marine life cannot survive without carbon, but high levels of carbon dioxide dissolved in ocean waters are harmful to marine organisms such as mollusks and corals. **Too much carbon dioxide** makes the **seawater** too **acidic** for clams, snails, & other sea animals and **affects their ability to grow their shells** (see Lesson #4).
- The **ocean** absorbs more carbon dioxide from the atmosphere than the land does. The surface ocean takes in approximately 90 Gigatons of carbon per year. **Cold water** has the ability to store more carbon than warm water.
- The **deep ocean** gets carbon through circulation exchanges with the surface ocean and dead and decaying marine life falling to the ocean floor. When carbon gets to the deep ocean, it usually stays there for a long time before moving on. The deep ocean, including its sediments, holds more than 65% of the Earth's carbon.
- **Making oil and natural gas:** Ocean plants (phytoplankton) and marine creatures die and sink to the bottom to be buried in the sediments below. Over millions of years, the sediments harden into sedimentary rocks, and the resulting high pressures and temperatures cause the dead plants and creatures to transform slowly into oil or natural gas.
- **Making coal:** Millions of years ago (about 350 million years ago) trees, ferns, and other plants grew and died. Some of these dead trees and other vegetation fell into swampy waters depleted in oxygen and turned into peat. Over time, shallow seas covered some of the swampy regions, depositing layers of mud or silt. As the pressure started to increase, the peat was transformed, over millions of years into coal.
- *Today when we burn a fossil fuel, we are harvesting the sun’s energy captured millions of years ago by ocean plants, marine life, and land plants. In other words when we burn fossil fuels we are releasing the CO₂ that these living things drew out of the ancient atmosphere.* In other words, in a relatively short amount of time we are burning large quantities of fossil fuels that took millions of years to form. We are short-circuiting the long carbon cycle by directly taking fossil fuels out of long-term storage and releasing carbon into the atmosphere.
- There has been a **38% increase in the amount of carbon dioxide in the atmosphere** since the start of the Industrial Revolution, 150 years ago.

For a more in depth analysis of the Global Carbon Cycle see:

http://www.globalchange.umich.edu/globalchange1/current/lectures/king/carbon_cycle/carbon_cycle_new.html

Enlarge the image below to show as a poster before playing the Carbon Cycle Game



The Carbon Kibosh Game

In This Lesson

Students will be taught the basics of global warming and the greenhouse effect. Students will also play a game that models the effects of increasing carbon dioxide in the atmosphere by role-playing either the sun's energy, earth's energy, greenhouse gases, clouds or aerosols.

Achievement Indicators

Students will be able to...

- **Sci.:** model the conversion of the sunlight into infrared radiation
- **L.A.:** extend thinking and share information (*Oral*)
- Write an imaginative story from the point of view of a ray of radiant light and/or create a meaningful visual representation of the process (*Writing and Representing*)
- **P.E.:** participate in physical activity (A6)
- Practice movement skills, including offensive and defensive strategies (B1, B2)
- Play fairly and follow directions (C2, C3)

Assessment

- Look for students' ability to distinguish between the terms global warming and climate change
- Monitor students' responses and behaviours as they act out their understanding of how sunlight heats the earth's atmosphere
- Look for students' understanding of the role of increased atmospheric carbon dioxide in rising global temperatures in their story or illustrations

Lesson Preparation

Time: ⌚ 60 minutes

In Advance: Find a suitable open space in gym or outdoors, with boundary markers

Materials: board markers, and several green pinnies. *Optional:* 2 other pinny colours and REPRODUCIBLES 1 and 2 for teacher reference.

Vocabulary Introduced

Climate Change: A change in the average weather patterns regionally or globally.

Global Warming (GW): Type of climate change that refers specifically to *changes in the Earth's average surface temperature* as a consequence of increasing greenhouse gases associated with *human activities*.

Greenhouse effect (GHE): The warming of the Earth's surface and overlying atmosphere by greenhouse gases absorbing and re-emitting infrared radiation back to Earth. *Note:* The *enhanced* GHE refers to an *increase* in GHGs associated with human activities.

Greenhouse gases (GHGs): Gases that absorb and re-emit infrared radiation. Greenhouse gases include carbon dioxide, methane, nitrous oxide, water vapour, as well as certain gases such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF₆) only produced by humans.

Atmosphere: The layer of invisible gases surrounding the earth (or another planet).

Shortwave radiation: Primary radiation received from the sun; also called *sunlight* or *solar radiation*, which includes visible light and ultraviolet light (UVA and UVB).

Longwave radiation: Primary radiation emitted from Earth's surface, with wavelengths too long to be perceived by the human eye; also called *infrared radiation*.

Radiation: Energy that is radiated or transmitted in the form of waves.

Aerosols: Tiny solid or liquid particles suspended in the atmosphere.

Step by Step

Part A: Review ⌚~5 minutes

1. In the first lesson we discussed that climate change is the shift in the average weather that a region experiences. In other words, the climate may be becoming slightly wetter than average in one area or perhaps there are more extreme hot summer days in Arizona than in the past 30 years.
2. But what causes the climate to change? Remember, in our second lesson we recently learned that the carbon cycle has become unbalanced because too much carbon (in the form of carbon dioxide etc.) is being emitted to the atmosphere. Now we will learn how this extra carbon (and other greenhouse gases), released by human activities, heats up the Earth's surface and causes global warming. Which in turn, causes climate change.

Part B: Climate Change and Global Warming ⌚5 minutes

1. Climate Change is often discussed in relation to another term you may have heard of—global warming.
2. Do you think there is any difference between these terms? Discuss with a partner.
3. Ask for feedback. In the media these terms are often used interchangeably, however, they do refer to different, but related, concepts (see backgrounder).
 - *Climate Change*: significant change from one climatic condition to another, e.g. changes could be in the temperature, precipitation, wind or all of the above.
 - *Global Warming*: refers specifically to changes in the Earth's average surface temperature as a consequence of increasing greenhouse gases associated with *human activities*.
 - In other words, global warming is one type of climate change. Through the release of greenhouse gases, humans are changing the Earth's average temperature (global warming). This in turn is causing other changes in climate.

Part C: Global Warming and the Greenhouse Effect ⌚5 minutes

1. **The increased average surface temperature (global warming) is due to the “enhanced” or “anthropogenic” (meaning man made) greenhouse effect.**
2. Ask: What's a greenhouse? How does it work?
3. **Why might it be called the GHE?** Does anyone know how a greenhouse works? *Traps heat to help plants grow.* Can it ever get too hot in a greenhouse? *Yes.* If so what happens to the plants inside? *Die.* How does the farmer control the amount of heat? *Opens the vents or windows.*
4. **The greenhouse effect (GHE) is not bad.** It keeps the Earth warm enough for life to exist. However, when humans add more greenhouse gases (GHGs) to the atmosphere than would naturally be there (by burning fossil fuel and other practices), we make the GHE too strong and as a result the Earth heats up. This is similar to when you start adding more and more blankets on top of you. Your body heat gets trapped near you, it can't escape as easily and you start to feel hotter and hotter. Like the Earth, one blanket (the GHE) is enough, but too many blankets is no good (like the enhanced GHE).
5. The GHE is a result of **greenhouse gases**, such as carbon dioxide, in the Earth's atmosphere absorbing infrared radiation emitted by the Earth and reradiating some of that energy back to the Earth's surface. This traps heat near the Earth's surface and helps keep our planet warm enough for ecosystems to thrive.

MISCONCEPTIONS:
Make sure to emphasize that the GHE is an analogy (see supplemental “pop bottle model” for details)
6. In fact, without the GHE, Earth's average temperature would be **-18°C** — that's 33°C colder than our normal average of **+15°C**. But remember what happens to life in a greenhouse when it gets too hot!

Part D: Chalk Talk on GHE ⌚ 10 min

1. To be drawn on board, using 4 colours, and student input. Student responses are in *italics*.
2. So how does the greenhouse effect (GHE) work?
 - See **REPRODUCIBLE 1** for Images to draw.
 - a) What's the big rock we all live on? *Earth* (draw semi-circle)
 - b) What's that invisible thin layer of gases (thin as skin on an apple) that lies above the Earth's surface? *Atmosphere* (draw green dashed semi-circle above Earth to represent the invisible GHGs). GHGs are fairly evenly mixed in the atmosphere.

Teacher Tip: At this point you may want to explain what invisible gases the atmosphere is made up of.

- c) Now, what's the giant ball in space that provides Earth with energy? *Sun* (draw sun in corner)
- d) Yes, now the sun emits *sunlight* (draw as short squiggles, actually shorter wavelengths) and this energy can pass through the atmosphere and GHGs. *Draw some squiggles passing through the dashes and some going through the spaces.*
- e) When that sun's energy (sunlight) hits the Earth's surface some of it is absorbed. The Earth then emits its own *infrared radiation* (draw as long squiggles, actually longer wavelengths). Over time, the amount of energy entering the Earth system equals the amount of energy being emitted to space.
- f) Heat is trapped by GHGs like carbon dioxide (CO₂) and water vapour. This is good because it makes Earth warm enough to live on. The Earth's average temperature is 15°C. How cold do you think it would be if there were no GHGs in the atmosphere? *-18°C. Draw infrared radiation squiggles that get bounced off GHGs and return to earth.*
- g) However, if Earth was 4°C warmer on average than it is now, we could lose large amounts of the world's known species, like the farmer when his plants get too hot in the greenhouse, so we want some of that heat to escape and it does! It passes the GHGs and goes into space. *Draw another long squiggle getting through.*

- h) But we've upset the balance and were putting too much carbon dioxide and other GHGs (mainly methane and nitrous oxide) too quickly into the atmosphere. That's like filling in the gaps (draw more green dashed lines) with more GHGs which means that there's less chance the Earth's infrared radiation will escape. Thus, global warming is occurring via the "enhanced" GHE.

Teacher Tip: If more questions arrive about the overall effect, see the backgrounder for a written and pictorial summary. The GHE explained in this lesson is a simplified version.

Part E: The Carbon Kibosh Game

⌚ 15 minutes

Teacher Tip: Below is the written explanation for the running game that models the greenhouse effect. See **REPRODUCIBLE 2** for the pictorial explanation.

Round One

1. *Get 2 players to put on green pinnies and become GHGs and stand in the middle of the play area (atmosphere)*
2. We know that GHGs are up in the atmosphere (discussed earlier, like the main carbon ones which are carbon dioxide and methane, as well as nitrous oxide). What else do you think is up there? *Hint, if outside, look up at the sky! *Clouds*
3. There are also aerosols. These tiny particles can be many things (e.g. dust, sea salt, bacteria, sand) and reflect about 1/3 of incoming light. Let's get a couple of clouds and aerosols in the Earth's atmosphere. *Put 2 'cloud' and 2 'aerosol' students in the play area. Make sure that they are spread out, standing and in the middle of the play area.*
4. Where does the incoming light come from? *Sun*. The rest of us will be sunlight. Also called 'shortwave radiation.' *Rest of the students cluster together at one end of the play area.*
5. Now if a cloud or an aerosol tags you, you must stay in space (area around the sun) because you've been reflected.

6. What do you think will happen if a GHG tags you? Nothing! GHGs are not good at trapping sunlight. GHG's please sit down to show this.
7. **YOUR GOAL! MAKE IT TO EARTH!** The other side of the play area. GO!
8. Count how many made it to Earth and how many were reflected. Bring students together and ask the students if this matches what happens in the real world (you can either tell them or have them figure out what $\frac{2}{3}$ and $\frac{1}{3}$ would be in #'s of students). Now, what happens to the $\frac{2}{3}$ that make it in? We know that some gets absorbed by the atmosphere but most of it (about $\frac{1}{2}$) gets absorbed by the Earth's surface, and then is re-emitted as infrared radiation. Also called longwave radiation.

Round Two

9. Direct the clouds, aerosols and GHGs to return to their positions. This time everyone else will try to get back to space, but now GHGs and clouds can 'trap' (tag) people at the Earth's surface. Aerosols can't (overall aerosols act to cool the Earth). Aerosols please sit down to show this. Everyone, GO!
10. Discuss how many made it. You may want to discuss how clouds affect both types of radiation (see Lesson #4 Backgrounder).

Round Three

11. Everyone (except GHGs, clouds, and aerosols) walk on the outside and return to the sun.
12. Two more volunteers are needed as GHGs (they can be CO_2), and can put on green pinnies. Pretend that gasoline (a fossil fuel) was pumped into a car engine, burned up and emitted out the exhaust pipe as CO_2 . *Send the two volunteers to join the other clouds, aerosols, and GHGs.*
13. See how many can get past this time! Add more GHGs and repeat the process. An increase in the amount of infrared radiation being trapped should be seen; sunlight entering remains roughly the same.
14. *Optional:* Repeat Round Three, but add more GHGs, to model another increase in CO_2 .

Part F: Class Discussion ⌚ 10 minutes

1. Discuss what happens as more GHGs, like carbon dioxide released from burning fossil fuels, trap Earth's infrared radiation. *Heats up. More infrared radiation gets absorbed and re-emitted back to the Earth's surface. The energy doesn't escape to space.*

2. Review how Earth has natural systems in place that keep the amount of GHGs in the atmosphere in balance (*carbon sinks-like the ocean*) but we are upsetting the balance by putting GHGs into the atmosphere (primarily by burning of fossil fuels) more quickly than the Earth can remove them. This results in global warming (global average temperature increase).
3. Remember we've removed some carbon sinks by changing the way the land is used. Also because of poor agricultural practices and using man-made fertilizers we've released nitrous oxide that like the carbon compounds, carbon dioxide and methane, acts as a greenhouse gas. Methane can be released from landfills, farm animals and when fossil fuels are refined.
4. This global warming in turn causes other climate changes by adding more energy to weather systems. This extra energy may cause stronger winds, bigger storms and more intense weather. Next lesson we will examine why different regions respond to global warming differently.

Part G: Applying What You've Learned ⌚ 10 minutes

1. Have students: Write a story from the point of view of a ray of light hurtling towards Earth from the sun. What happens to it? Can you describe its cousins', infrared radiation, journey from the Earth's surface? Explain what happens when extra CO_2 is added to the atmosphere. AND/OR
2. Create an illustration showing light from the sun entering the Earth's atmosphere. Include several possibilities such as: light being converted to infrared radiation and then being trapped in the atmosphere by CO_2 molecules, light reflecting from clouds etc...
3. Tip: draw the sunlight as 'shortwaves' (tiny squiggles) and Earth's infrared radiation as 'long waves' to distinguish between the two.
4. **Now that students have an understanding of the carbon cycle and the effect of greenhouse gases on climate** (not daily weather) have students for homework or in class explain, in writing, how they could either enhance a sink to uptake more carbon (e.g. plant a tree) or reduce a source by making a personal commitment to some action (e.g. walk to school). Ask the students to explain how their action helps reduce greenhouse gases in the atmosphere.

Sources

Climate Change Education Program, Grade 6-8, Sierra Club BC, 2008.

at www.wildbc.org.

Global climate change: resources for environmental literacy, Environmental Literacy Council and National Science Teachers Association, 2007.

The Greenhouse Effect, Wild BC, 2009. Available online

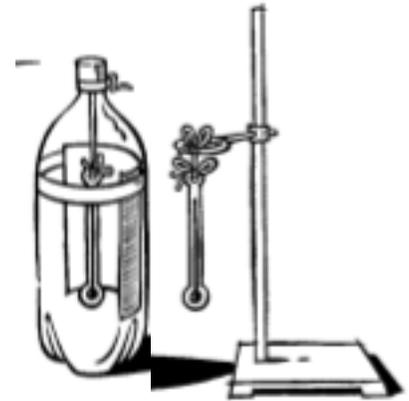
Optional Supplemental Activities

And Earth is just right...

Have students research the “Three Little Bears” story of Venus, Earth, and Mars’, their atmospheres and temperatures and present it on a poster. *Hint one is too hot, one is too cold and one is just right! Then, ask the students to explain the natural greenhouse effect and how it is important to ecosystems. Look for evidence of a basic understanding of how the natural greenhouse effect results in a life-sustaining average global temperature.

Pop Bottle Model

Suspend a thermometer on a string inside a 2 litre pop bottle. Then from the same height suspend another thermometer in the outside air. Place a lamp above (100 Watts is best) and equal distance from the thermometers. Turn it on and record the temperature changes on both thermometers for 10 minutes. Graph the results. The bottle emulating greenhouse gases traps the heat and thus the air inside heats up faster. Ask students to describe the physical changes in the air of their plastic bottle when visible light was added. How is this experimental set-up similar to a greenhouse? Why doesn’t the temperature in a greenhouse, or the air in the bottle, continue to rise? Why did the temperature level off? Help the students to understand that over time, if all the variables are constant, a balance or equilibrium between the energy in and energy out of the system will be established. Remind students that the temperature in a greenhouse or in the bottle can be regulated by releasing the warmed air through openings such as windows. Explore how well the experiment simulates or models what is



happening on Earth. What variables of Earth’s systems are not included? The experiment is similar to Earth in that the air in the bottle retains heat just as the atmosphere does. However, the reason why the air in the bottle is warmer than the surrounding air is not because of greenhouse gases. It is because the bottle does not allow the warm air to mix with surrounding air. The experimental model does not simulate the complexity of Earth’s systems as many variables are not included. Some variables include the effect of greenhouse gases themselves; water vapour; ocean and air currents; differential heating of landmasses; and layers of the atmosphere with slightly different composition of gases.

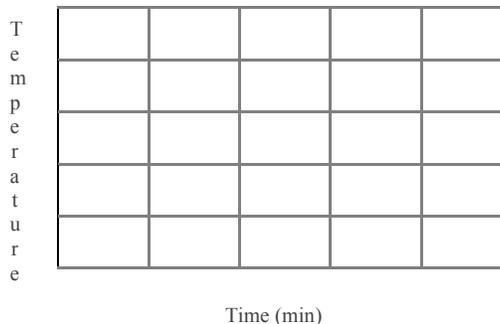
Pop Bottle Model: Collect the data!

Use the table to help you collect the temperature data.

Time (mins)	Temperature of room air (°C)	Temperature of air in the bottle (°C)
0		
2		
4		
6		
8		
10		

Graph your data!

Plot the data points and connect them into two lines: One line for room temperature and one line for bottle temperature



Key:

Room
Bottle

Content Background

Global Warming and Climate Change

People often use the words global warming and climate change interchangeably, and depending on how they do this it may not be a problem. Global warming is a type of climate change that refers specifically to changes in the Earth's average surface temperature as a consequence of increasing greenhouse gases associated with human activities. Therefore, subsequent climate changes that occur, such as melting glaciers, or changes in vegetation cycles are delayed responses to the global warming. Global warming is a result of the anthropogenic (i.e. human-caused) greenhouse effect (also called the *enhanced* greenhouse effect).

Understanding the Greenhouse Effect

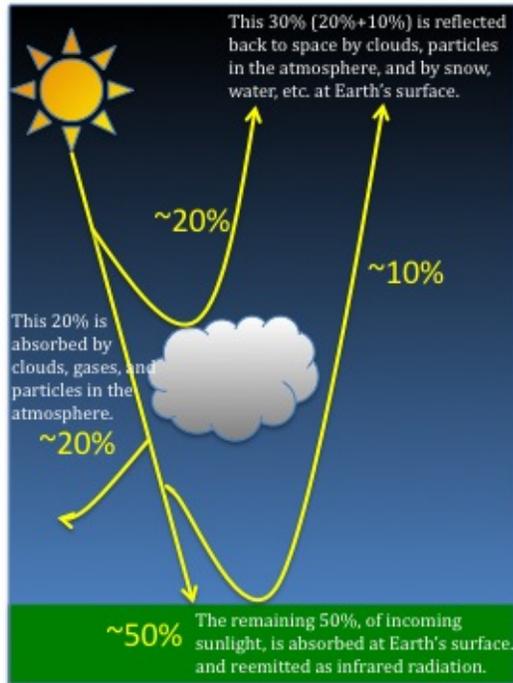
The greenhouse effect is a natural phenomenon that helps Earth to maintain an average global temperature that is hospitable for life. The Earth's atmosphere is a gaseous mixture made up primarily of nitrogen (N₂; 78%), oxygen (O₂; 21%) and argon (Ar; 0.9%). The remaining fraction of one percent is a mix of greenhouse gases (e.g. CO₂, CH₄, H₂O, SF₆) and trace gases. Greenhouse gases are able to absorb and reemit infrared radiation (also called long-wave radiation) from the Earth's surface and atmosphere before it is lost to space.

Greenhouse Gas	Chemical Abbreviation
water vapour	H ₂ O
carbon dioxide	CO ₂
methane	CH ₄
nitrous oxide	N ₂ O
ozone	O ₃
chlorofluorocarbons	CFCs
perfluorocarbons	PFCs
hydrofluorocarbons	HFCs
hydrochlorofluorocarbons	HCFCs
sulphur hexafluoride	SF ₆

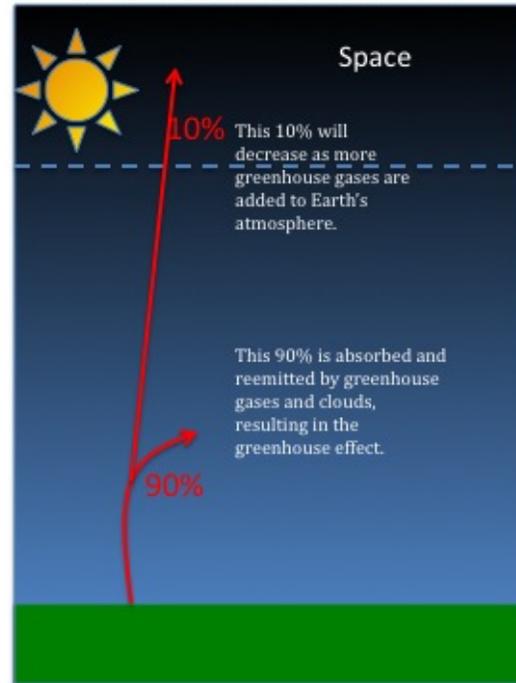
In order to understand the greenhouse effect, it is necessary to understand what happens to the energy Earth receives from the Sun (solar radiation). Short-wave energy in the form of visible light passes through the lower atmosphere. Approximately 30% of the visible light is reflected back out to space by clouds, and particles in the atmosphere and by snow, water, etc. at the Earth's surface. In the atmosphere, clouds, gases and particles absorb 20% of the incoming visible light and the remaining 50% is absorbed at Earth's surface. Once absorbed, the visible light energy is transformed into infrared radiation, which can be emitted in all directions. While some of this infrared radiation immediately escapes into space, much is absorbed and reemitted back to Earth and into the atmosphere by gases that naturally occur in the atmosphere – the greenhouse gases. This process is known as **the natural greenhouse effect** and it is responsible for keeping the Earth's temperature warm enough to support life. Without it, the average temperature on Earth would be -18°C and could not sustain life systems.

The Greenhouse Effect in Detail

Incoming Solar Radiation

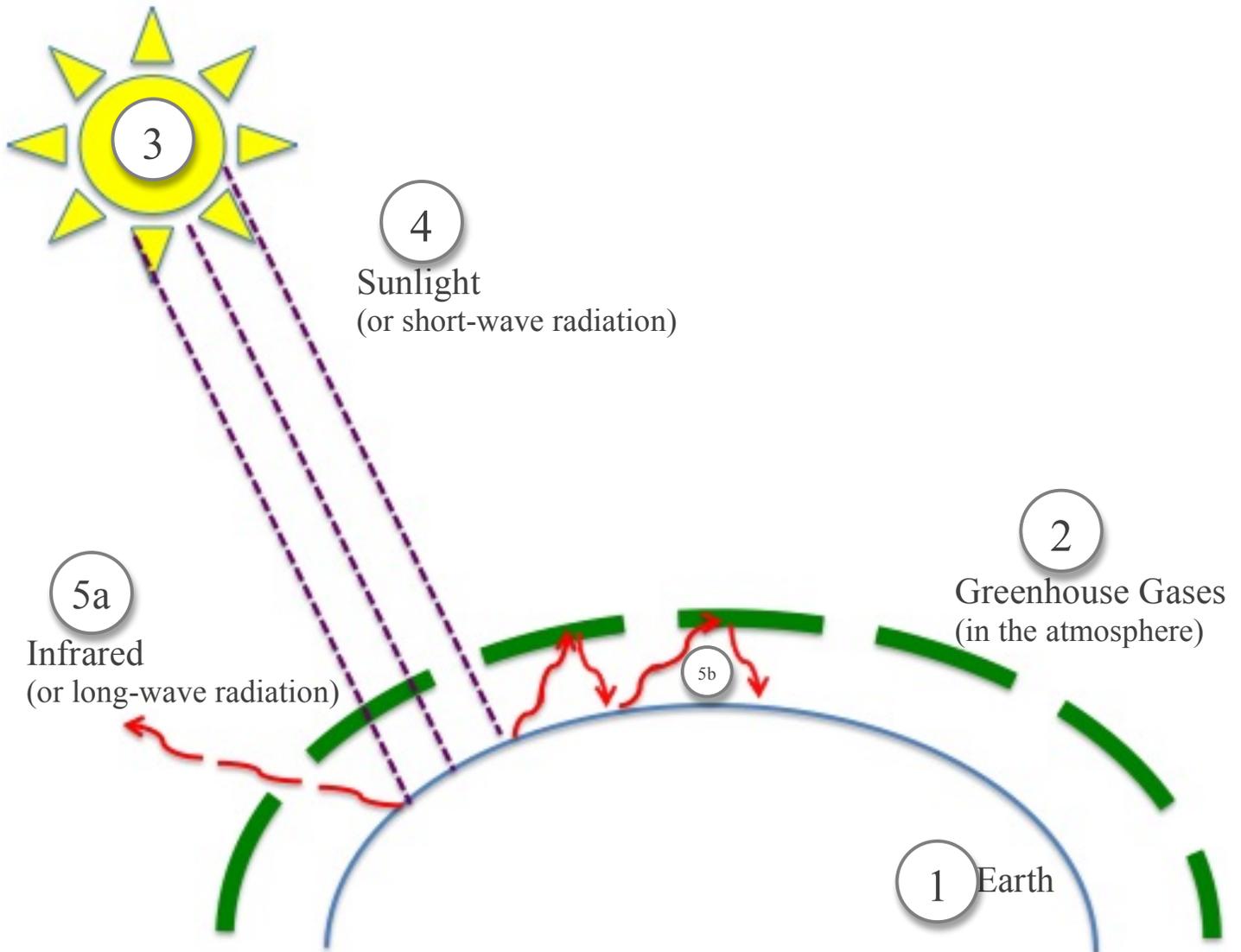


Outgoing Infrared Radiation



Overall, the energy entering the Earth's system is balanced by the energy leaving it. The pre-industrial level of atmospheric greenhouse gases kept the average global temperature relatively stable over the past 10,000 years. Unfortunately, human activity is altering the composition of the atmosphere by increasing the amount of greenhouse gases. For example carbon dioxide (CO₂) has increased by approximately 38% since the Industrial Revolution began in the 1750's. The result is that more longwave radiation is retained in the Earth's system for a longer time, leading to an increased average global temperature – this is called the **enhanced greenhouse effect**. Humans putting more greenhouse gases into the atmosphere cause the enhanced greenhouse effect that is responsible for global warming. Global warming causes climate change by adding more energy to weather systems. Global warming of just a few degrees perhaps seems insignificant, however, this can cause changing weather patterns, including stronger winds, increased drought in some regions and more extreme weather. That is, global warming changes what we expect to occur.

Part D: Drawing of the Greenhouse Effect



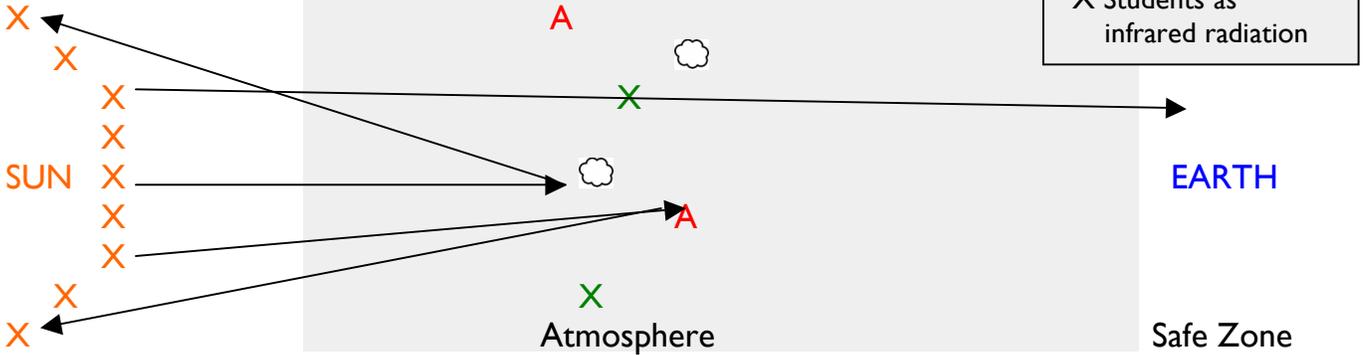
Note: The numbers are to demonstrate the order to draw in. They do not need to be drawn on the chalkboard. The only labels needed on the chalkboard are sunlight, infrared radiation and greenhouse gases.

First start with only 3-4 greenhouse gases, then draw more greenhouse gases going over top of the places where infrared radiation was previously escaping from. You'll then have to erase the "escaped" squiggles and draw instead the squiggle being re-radiated back down towards the surface of the earth.

Part E: The Carbon Kibosh Game

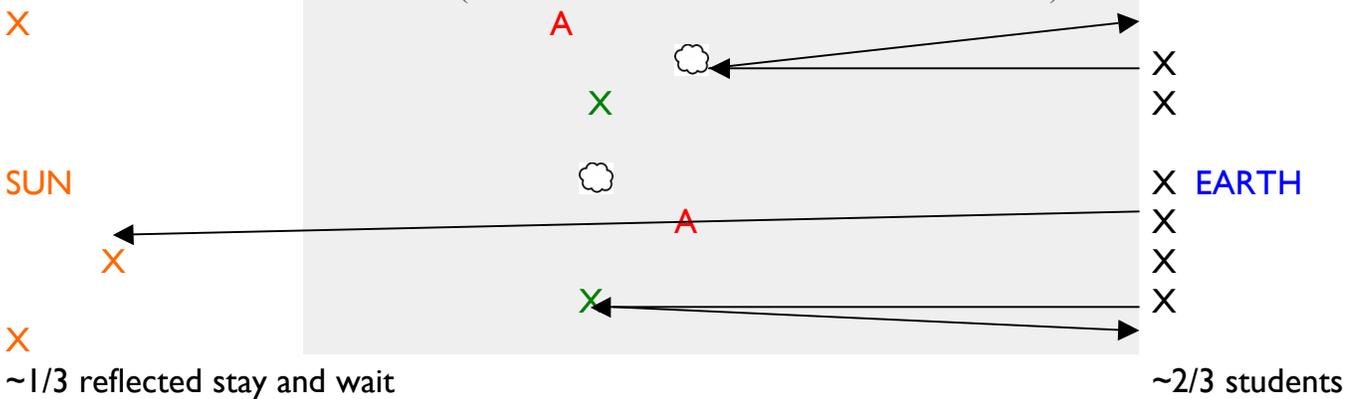
Round One:

- Sunlight (shortwave radiation) travelling towards earth
- Reflected by clouds and aerosols (when tagged)
- GHGs have no effect (GHG students sit down to demonstrate this)



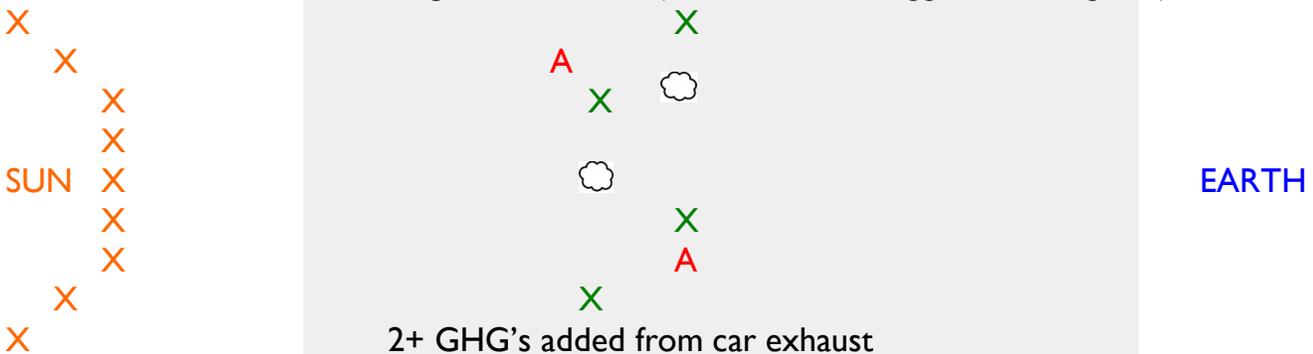
Round Two:

- Earth's infrared (longwave) radiation travelling towards space
- Absorbed and re-radiated by clouds and GHGs (when tagged)
- Aerosols have no net effect (Aerosol students sit down to demonstrate this)



Round Three:

- Run Round One and Two again – now with more GHGs
- Sunlight reaching earth remains roughly the same
- Infrared radiation leaving earth decreases (i.e. more heat is trapped in atmosphere)



APPENDIX C

Script for presenter-based intervention

Climate Change Education Program 6-8: Visit One

Theme: Climate Change is a global issue in need of local solutions. This program shows the interconnection existent between ecology, economy and technology – teaching students what causes climate change, what its impacts are and may be, and how we can approach the subject positively to create real and beneficial change.

Objectives: After the program students should be able to:

1. Understand the concept of climate change, including history and causes.
2. Understand the concept of the carbon cycle and how it relates to climate change.
3. Identify some local and global impacts that climate change is/will be having.
4. Develop an understanding how individual and group actions can reduce climate changes impact.
5. Promote stewardship actions for themselves, their school and their community.

Props:

Laptop, projector, extension cord

Carbon Cycle game passports

Carbon Cycle game station signs with coloured markers

Dice

Action Challenge Chart

Carbon Dioxide costume

Set-up:

Laptop and projector

Speak to the teacher about the Action Challenge Chart

Total Time: 85 mins

1. INTRODUCTION (10 min)

Today I am here to talk about something you've all probably been hearing a lot about lately: climate change! Does anyone want to explain what climate change is all about? Today we're going to look at a slideshow and play some games to figure out what it is that's going on and what we can do about it.

Before we do though it is important that you understand the differences between climate and weather. Any ideas?

Weather is what you get! Climate is what you expect!! Can you repeat that? Give some examples: over past 30 years the temperature in winter in Regina has been warmer on average. It rained 6cm yesterday. The average amount of rain for September is 15cm. It's sunny out. *On June 12th it was much hotter than it normally is in June* (extreme event still normal weather).

So **weather is the state of the atmosphere at one place and time**. Anyone know what the atmosphere is? Invisible layer of gases above planet where weather happens!!

Whereas **climate is the long-term average (30 yrs +) of weather conditions**

You might have heard another name that is sometimes used instead of climate change... any guesses? Global warming. Usually people saying climate change and global warming are talking about the same thing. If we want to get technical, the term climate change could be used to talk about the earth's natural cycles over thousands and millions of years. Sometimes the earth warms, sometimes it cools – like when there's an ice age. These sorts of changes have always been a part of the earth's history. The term global warming means a time when the average temperature of the earth is getting warmer. And that's what is happening right now. And what's different about what's happening right now is that this time, it's humans causing the temperature of the earth to go up. And it's happening much much faster than ever before. We're going to talk about why that is, and how the everyday things that we do are connected so that we can figure out what we can do!

2. POWER POINT PRESENTATION (Part One 10 minutes)

The Carbon Balance: Fossil Fuels Origins

- | | | | |
|---|----------------|---|--|
| 1 | Intro Slide | • | Our web address |
| 2 | Earth in space | • | What's this everyone? <i>Earth!</i> & what heats it up? <i>The Sun!</i>
And our life on earth is possible because it is not too hot & not |

too cold.

- Our earth is all about balance...not too much of this, not too much of that...when we look at it from space like this we realize that earth is a *living system* made up of millions of parts all working together
- There are a few CYCLES that keep it JUST RIGHT. Can anyone give me an example of a cycle in nature that you might have studied? Water cycle.

Today we're going to be looking at something called a CARBON CYCLE. A carbon cycle works pretty much the same way as the water cycle, carbon exists in many places on the earth and over time gets transferred from one form to another.

- 3 Picture of Healthy Forest
- Life is also possible because there is air (Oxygen) to breathe. How are carbon and air part of the carbon cycle do you think? Carbon dioxide is sucked in by plants and the plants give us oxygen.
- 4 Cartoon person & leaf in balance on scale
- For a long time, the carbon going into the air was pretty much in balance with the carbon sucked up by the plants. This is called the CARBON BALANCE.

What are some ways that carbon dioxide is transferred from the earth to the air? Volcanoes, trees dying, fires.
How do people affect the carbon cycle? How do we move carbon from the earth into the air? In the past through *fires* (release CO₂) & *land clearing* (decaying matter releases CO₂) (note: breathing isn't a significant source)

- 5 Volcano
- In order to understand how humans have disrupted this balance we have to go back 360 million years, ago during the carboniferous period.

The earth looked very different, even where continents were looked different, it had volcanoes (before dinosaurs time!) and there were some creatures and sea life.

- 6 Lush foilage (horsetail)
- The earth was covered in big ferns, trees and other green stuff – as well as big swamps. Overtime all these plants and creatures ended up storing a lot of carbon (plants breath it in,

animals eat plants or animals containing carbon & use it to grow)! When all this lush foilage died and the sea creatures died their carbon was stored eventually deep in the earth and we didn't see it again until...

7 Black Goo

- we discovered something deep down in the earth that was made from these dead plants and creatures and took millionsof years to form into?????. Do you know what it was? *Fossil fuels*

- Yes, that's why they are called "fossil fuels" they're from the time of fossils, and they are full of all that carbon stored up by the trees, other leafy things & small creatures before our time! And that's why it's called the carboniferous period because there was so much "carbon" that died and over millions & millions of years got pushed down into the earth through earthquakes and shifting of the continents and eventually became fossil fuels.

- **This discovery of fossil fuels by humans has changed the carbon balance.**

ENTER Mrs. Carbon Dioxide. She is an old grannie so picture the confused old grannie voice.

Mrs. CO₂: *"Ah did I hear my name? I'm so confused I have no idea what happened?!?! The last thing I remember was wandering around in this pretty warm place full of volcanoes and really large ferns & trees & then I went to sleep oh for such a long time, you know us old people! And then I was rudely awakened, dug up out of my bed, and stuck in this incredible dark place. I could hear an engine running....vrmm...and then next thing I knew I traveled down a pipe and was spit out into the "atmosphere"? is that the right name? And poof these two silly little "oxygen" children grabbed onto me and they won't let go!! She shakes her arms & continues to look perplexed. Oh sigh and I've been confused ever since floating and floating around and...what wait a minute everything looks so different!! What year is it? 2010! Oh dear me I really slept a long time I went to sleep 360 million years ago!!!*

Other Educator: Who is this that has wandered into the class, what do you think she is? It sounds like she is a carbon dioxide molecule! Well actually Mrs. Carbon Dioxide, we were just talking about the carbon cycle... so maybe we can help figure out what happened to you.

Mrs. CO₂: *"Oh wow that sounds lovely...I'd love to stick around.*

3. SLIDE SHOW (Part Two – 10 minutes)

The Carbon Balance: Fossil Fuels Issues

- 8 Burning Goo 9 We know that humans discovered fossil fuels deep in the earth. But what do we do with them, why was this discovery so important? We burn them to make energy that powers our homes, cars, factories, etc. What are some examples of fossil fuels? Diesel, oil, **natural gas**, etc.
- 10 Pumping Gas • Since the industrial revolution (about 200yrs ago) the time when we started burning up fossil fuels in factories & engines we've enabled more people to live on this planet using this carbon energy, which in turn increases the demand for carbon which keeps this cycle going (draw circle, circle).
- 11 Factory Image
- 12 Plastic bottles
- Many factories burn fossil fuels to make things BUT ALSO they make things with fossil fuels. Can you think of anything that is made with fossil fuels??? **Plastic and Vaseline!!!**
- 13 Exhaust Pipe • Yes us humans are very clever! We figured out how to get carbon energy from old dead plants & animals. When we burned up those old plants & animals all that carbon from millions of years of the sun's energy got released fast! **Where does it get released to? The atmosphere.** *In fact isn't that where you ended up Ms. CO2?*
- 15 Cartoon person & leaf NOT in balance on scale • The problem is that we are putting out so much carbon, so fast, that all our friends, the green leafy things, & the oceans and all the places carbon goes to keep things in balance can't keep up. **CARBON IS OUT OF BALANCE!**
- Remember how long it took to make fossil fuels? *360 million years.* Yes, and now you can see why the CARBON BALANCE has tipped because we've played around with the scale! All of the sudden in the last 200 years, we've released that stored carbon from deep earth that has been there for millions of years & put it into the atmosphere.
- 16 Hot Earth • And because of this our planet is getting warmer & causing us problems!

Mrs. CO2: Hey wait a minute, maybe I can help out. If the students understand all the places I've travelled to, maybe that'll give them an idea of how to restore the balance. Let's play a game.

During the game Mrs. CO₂ can circulate in character asking people about where they are and how they got there...relating to her own tales of traveling.

4. Passports to the Carbon Cycle Game (20 minutes)

adapted from NCAR's Nitrogen Cycle Game & their online Carbon Cycle Game

- We know that carbon is an extremely important part of life on earth, it's in all of us & in most things on earth, and it moves around, just like other important things on earth (ex.nitrogen & water)
 - Where do you think we find carbon in and around the earth? Plants, atmosphere, soils, deep ocean, marine life... **draw on the board**
 - In this game, everyone is going to be a carbon atom. Each person will have this Traveling Carbon Passport. Your job is going to be to fill it up by travelling through the carbon cycle. All around the room we have set up signs for the different stages of the carbon cycle.
 - We will put a few of you at each station to start.
 - You will write your start location in the first box. At the station is a dice. You will roll it and then read the sign at your station. It will tell you what station to go to next depending on what you rolled.
 - For example, if I start at the Land Plants station and roll a 3 or 4, it says on my poster: "Carbon is released back to the **atmosphere** when plants respire (breathe)". So what station would I go to next? The atmosphere station!
 - Your job is to write down all the stations that you visit.
 - Keep going until you have filled up all 10 boxes. You might go to the same stations more than once, but that's ok. That's how things work in nature!
 - Assign groups of students to the 7 stations posted around their classroom & about one third should be in the "deep earth station". These students start in Deep Earth and then go to the atmosphere when they are burned as fossil fuels. They are supposed to notice if they or anyone else ever gets to the Deep Earth station again.

PLAY GAME

- When students are finished, have them trace where they have been on the drawing on the reverse of their passport
- Have one or two students share their journeys and discuss some of the ways that they traveled.

MENTION: When they leave a station (or "earth component") they become a CARBON SOURCE to the atmosphere but when they return to a station they become a CARBON SINK because the carbon is now stored there and not in the atmosphere.

- Did anyone visit one station more than once? Yes! In reality carbon can do that! Goes here there everywhere but there's somewhere it doesn't go very often, & it takes it a long time to get there, which place do you think that is?
- Who started somewhere that hasn't been mentioned? **Deep earth. Have one of these students talk about how they left Deep earth.**
- How long do you think it takes to get back to "DEEP EARTH" storage? Millions of years!

Mrs. CO₂: Well I still don't seem to understand why too many of me and other CO₂ friends in the atmosphere is a bad thing?

Other Ed Team member: Well let me explain why tipping this balance to too much carbon in the atmosphere is a problem.

5. Chalk Talk: The Greenhouse Effect (to be drawn on board) (10 minutes)

- Where is that carbon mainly going when we burn fossil fuels? Which part of that carbon cycle? *Atmosphere*
- Exactly and it's going there in the form of CO₂
- So what's the atmosphere made of? Mostly Nitrogen, Oxygen, but also very important Green House Gases! CO₂ is the GHG's we humans are putting up fast when we burn fossil fuels (FYI: In order of abundance: water vapor, **carbon dioxide**, **methane**, **nitrous oxide**, ozone, CFCs)
- too much too quickly, tips the balance, & causes global climate change, let's look at how this happens
- **DRAWING** (This drawing is the same one as in Lesson 3 for the Teacher-based Intervention)
 - 1) What's the big rock we all live on? *Earth* (draw semi-circle)
 - 2) What's that thin layer of gases (thin as skin on an apple) that's above the earth's surface? *Atmosphere* (draw green dashed semi-circle above earth to represent the invisible GHG's)
 - 3) What's the giant ball in space that helps heat earth? *Sun* (draw sun in corner)
 - 4) Yes, now the sun emits "*light energy*" (draw as short squiggles, actually shorter wavelengths) and this energy can pass through the atmosphere & GHG's. *Draw some squiggles passing through the dashes & some going through the spaces*
 - 5) When that "*light energy*" hits the earth the earth absorbs some of it, and then emits its own "*heat energy*" (draw as long squiggles, actually longer waves).
 - 6) This heat is trapped in our atmosphere by GHG's, like CO₂, which is good because this is what makes earth warm enough to live on. Our entire earth's average temperature is 15°C. Without GHG's it'd be -18°C. Much colder on average (we'd still have colder & warmer parts)
 - 7) Draw "*heat energy*" squiggles that get bounced off GHG's & return to earth
 - 8) But we want some of that heat to escape so that the earth doesn't get too hot & it does! It passes past the GHG's & goes into space (draw another long squiggle getting through)
 - 9) But we've upset the carbon balance and were putting too much carbon dioxide to quickly into the atmosphere, & that's like filling in the gaps and making our atmosphere thicker (draw more green dashed lines). This means there's less chance CO₂ will escape, that heat gets trapped and makes the temperatures on Earth warmer.

6. Climate Change Problems (15 minutes)

Mrs. CO2: Wow, well now I understand why too many of me and my other greenhouse gas friends in the atmosphere cause a problem! We actually heat up the planet, but what happens to earth when we change this carbon balance and heat it up?

- I'd like you all to get into groups of 3-4 (use table groups or ask teacher beforehand) and brainstorm the "climate change problems" you've heard/seen about in the media.

Let them do this for about 5 mins. Then discuss those they don't know. The slide show below, contains many but there's no need to discuss them all, especially if they had our G4/5 presentation before. As you go through this process correct any "science misconceptions" students may have about what global warming causes. Eg. Every hurricane isn't caused by global warming...we'll always have them.

Some examples of climate change effect on animals and Earth

- 17 Polar bears
- who knows what this is? **Polar bear**
 - where do they live? The **arctic**, on ice fields near the ocean. Polar bears need the ice fields to get out and catch their prey. What do polar bears eat? – mostly seals and fish..
 - So what might be happening to them? With warmer temperatures, their ice fields are melting earlier in the spring and forming later in the fall. Polar Bears also use big ice flows (big rivers of floating ice between two large sheets of ice) to get out to the good places to hunt. With less big pieces of ice to ride on in the ice flow and thinner ice sheets, the polar bears are having a hard time getting out to the good places to hunt in the ocean. So what, then, is going to happen to the polar bear? (Starve or try to swim & drown) Exactly, and it's happening a lot these days. In fact, scientists say that in about 50 years (or even less), we might not have any more polar bears in the wild because there might not be enough ice for them to get out to the seals and fish.
- 18 Hurricane & Floods
- All this is happening because it's getting hotter in here, another thing that happens is when things get warmer we have more tropical storms
 - because things like this (hurricane) form when there are large pools of warm ocean water
 - Hurricanes usually only form if the surface ocean temperature is above 27°C
 - and as the air warms up the oceans get warmer too (like a cold drink in the sun)

-So Climate Change is affecting people

-Hurricanes are becoming more frequent -how do hurricanes effect people? discuss

-And it's not just hurricanes. Scientist predict we will see many more severe weather events related to climate change, like heavier windstorms on the coast, more rain in some places (increase in precipitation intensity, harder for longer, deforestation increases chance of floods) and more drought in others.

19 Mountain Pine beetle

- but let's move somewhere closer to home.

- who knows what this is? – it's called a ? **Mountain Pine Beetle**. It's about the size of half a grain of rice (*show SCBC sample*), lives on pine trees, and eats under their bark. If you get enough mtn. pine beetles, they can even kill the tree.

- anyone ever been driving up into the interior and seen all the red trees now? (*change if in interior*). Those are all trees that were killed by mountain pine beetles.

- &, believe it or not, climate change is part of the reason that there are so many mountain pine beetles now. They lay their eggs under the bark of the pine trees, and their larvae hatch under there. If the winters are cold enough, (have "cold snaps" multiply days in a row that dip below -40°C) they can kill the larvae and there will be less beetles the next year.

- but, with the earth getting warmer, our winters haven't been quite cold enough, so the beetles are going crazy and there's so many of them that scientists think that 85% of our pine trees will be gone in ten years!

-*Optional*: discussion on impacts to forest industry

20 Biodiversity Loss (golden toad)

-Polar bears aren't the only species having a harder time surviving because of climate change.

- Warming temperatures mean that some species can't survive where they used to live. Animals can migrate (move to new places) if there's space for them to move into but other species like trees don't move so easily. Red Cedars on the West Coast are one species that like to live in cool moist areas. Scientists think that they might die off as our temperatures go up.

-Salmon also only like to live in and spawn in cool waters and as ocean temperatures increase they will move farther north than Vancouver Island. And when a stream gets too warm it can dry up or be too hot for the salmon to go back to spawn in.

-Amphibians such as frogs are most threatened world wide, drought makes smaller ponds & thus the UV rays get to the

embryos & kill them

Depending on how much GHG's we reduce between 15-50% of plant & animals species could be extinct by 2050!

7. Climate Change Solutions Brainstorm (5 mins)

Now that we've heard about those big problems, it's important to realise that we do have the power to reduce climate change and that there are things we can all do to help. In your groups, come up with as many ideas as you can of things we can do to fight climate change. Make a list of their ideas on the board.

CCEP 6-7: Visit Two

Objectives:

- review information presented in the first visit
- reinforce knowledge through active games
- continue to make connections between everyday actions and climate change while promoting stewardship

Props:

- ropes or other markers for game boundaries
- green armbands
- relay props:
- 'step by step' activity props

1) REINTRODUCTION & REVIEW (10 mins)

What did we talk about last time? Climate Change/ Global Warming

Review:

- The Carbon Cycle
- The Carbon Balance
- How our global climate is changing!
- Greenhouse Effect:

(Do as prompt/ student response scenario...with hand actions I find helps, find your own routine & stick to it, your quick version of the effect with actions & call back prompts, it really helps solidify their understanding)

- o We all live on EARTH (*capitalization indicates students response*)
- o What's the thin layer of gases above the earth called? ATMOSPHERE
- o What's in the atmosphere that traps heat? GREEN HOUSE GASES
- o And how are humans upsetting the carbon balance?
- o By burning too much? FOSSIL FUELS too quickly
- o Which releases which green house gas? CARBON DIOXIDE

- o Which goes up up into the atmosphere and traps? HEAT
- o It took millions of years to store that CO₂ but it's now been released in 200 years.

2) GATEKEEPERS GAME: CO₂ 's Story (15 mins)

- Go outside. Explain the Game.
- Get 2 student volunteers to be “cloud” and an “aerosol” & have them stand on the center line
- Everyone else stands on “space’s” border line (5-10m back, they are all light energy)
- Now everyone has to try and get past the cloud & aerosol to Earth’s Surface (the other side border line (5-10m back). If they tag you stand off to the side.
- After that first try, discuss how many got “tagged” so you see that’s how it works in real life some of the sun’s energy doesn’t make it to the surface of the earth, it usually bounces off clouds or aerosols, not by being “tagged,” ok you that got tagged may go & join the rest of the group down on earth’s surface!
- Give the 2 students green pinnies (now they are GHG’s) & have them stand on the center line
- So now what are you all going to do? “bounce-off” earth & transform into “heat energy,” which is a different wavelength (longer) & can’t pass through GHG’s, as you will all do in a minute & try to escape back to “space” (the side border they started from). Students run across. Students that are tagged stand off to the side
- Discuss. Hurray, the GHG’s trapped “X #” of heat so our planet doesn’t freeze!
- But what happens if there’s more GHG’s in the atmosphere?? Any volunteers to be more GHG’s. Pick 2-3 more.
- Everyone starts at earth again. Repeat process.
- Count how many got tagged returning to space. “X #” ahhh I see so more heat was trapped. It’s getting hot in here!! And we know the effects that has on the earth.
- Ok now that you know how the game works you are going to play it on your own a modified version. We’ll start with 2 GHG’s on the center line. Anyone who gets tagged running back into “space” is going to become a GHG (that’s the change! Rather than standing off to the side you’re now going to be one of those CO₂ molecules humans released from deep earth and join the GHG’s on the line). Watch out for each other because you’ll all be running back & forth at different times. GHG’s remember you can only catch those trying to go to space not those entering.
- After they’ve played a few runs like this, they should have a good visual of how much faster heat starts getting trapped as we release more GHG’s into the atmosphere.

3) Climate Action Relay (20 mins)

- 1) We're going to see if you can remember what some of the problems caused by climate change are. Pick up a sentence describing a problem and match it with the correct photo on the poster.
- 2) Now we're ready to take action to fight global warming by reusing clothing instead of buying new clothes. Put on your second-hand clothes!
- 3) Now we're going to make some renewable energy with this skipping rope symbolizing a wind turbine. You must skip 10 times to generate some environmentally friendly renewable energy we can use
- 4) Run to the store, buy a local apple from the bin (pick up fake apple from bucket, must find a BC one!), as you run eat it! (pretend) and then put it in the compost (bucket with lid) so it doesn't go to the landfill & release methane
- 5) Now run to the landfill & pick up a piece of recycling you see there and run it to the recycling factory & put it in the right place!

4) "Step by Step" Eliminate the Excess (30mins)

THIS WAS ELIMINATED DUE TO TIME CONSTRAINTS

- Return Inside
- So as you can see there's tons we can do, but the most important thing is to....
- Everyone's probably heard of the 3R's but what's the fourth?
- Review why it's necessary to "rethink" our way of life. Because currently we do things that are damaging not only to ourselves but to our planet, it's creatures, and other humans that share this planet with us.
- Any of you played our "Apple Game" before?
- Some of you may remember it's a step by step game that traces every step along the way for an apple to get to our hand here in BC from New Zealand
 - If class is unfamiliar with this quickly do the game
- Now what you're going to do as a class is work in teams to make your own "step by step" game like the "Apple Game"
- You'll need to get into groups of 2-3 people
- I'm going to come around to each team and you can draw from this paper bag what process you will have to trace from the beginning of it's life to end when it has been used up!
 - Hint! Don't forget about what it may be carried in or put in when you get it!
 - If you don't know all of the steps that's fine, you can always make up a step that's realistic eg. Your paper bag was shipped by truck to the "Superstore in Duncan, BC," just try to think of as many as possible.
 - Once you've listed all the steps you can think of...start to think of solutions, ways to eliminate some of the steps or change the steps to be friendlier to our climate.
 - Items in the "paper bag": Plastic Bag, Banana, Slurpee, T-shirt, Chocolate Bar Pencil, Bottled Water, Big Mac
- Circulate around the classroom helping groups get more ideas and think of solutions
 - Have groups share with the class

- That's great, so as you can see that's why "rethink" is the most important R. When we go to use something or purchase something or get rid of something, we must always remember it came from our earth, and often times it came from a great distance so do we really need to waste it? Or do we really need to buy it in the first place? Perhaps we can use our own mug rather than take another paper one.

APPENDIX D

Post Instruction Teacher Survey

Please Note: Questions #1-8 will be asked for each of the four lessons the teacher will instruct on.

Regarding Lesson One (on weather vs climate):

1) Did you feel that there was enough background information to understand and teach the topic? If not, please elaborate on what you feel was missing (e.g. diagrams, more reference material etc...).

I thought the background information was terrific – very informative, interesting and understandable. However I'd like to see the background information at the front of each unit – it gives the teacher confidence that they will have the necessary understanding to teach the concept.

2) Was the lesson plan easy to follow? Do you have any recommendations for changes in the sequencing and presentation of information?

I ended up teaching this lesson over 2 periods 55 minutes each. The first period the students were "meteorologists" and in the second period they were "climatologists."

Perhaps discuss "how to pack for a trip vs. dress for the day" before introducing Part D on discovering the climate, rather than at the beginning of the lesson.

I discovered the students don't really check the weather to determine what to wear on a daily basis – next year I'll switch it to preparing for an outdoor field trip and brainstorm some other specific situations that might determine what a student wears. The lesson was long – it could be broken into 2 lessons quite easily. Part E – the bar graph – is essentially a lesson on its own and the students would need to have prior knowledge of graphing before this could be attempted (this in effect would be a third lesson). I would only include it as an extension or as a separate math lesson. I would also be clear that the postcard assignment would be an extension – ideally it would be tied in with Social Studies, with the students incorporating the climate of a country that they're studying (grade 6 does the study of a third world or developing country or Japan).

Now being familiar with the lessons, rather than passing the students out colored photographs of various weather, I would have photos on the LCD projector and have all students (either in partners or working groups) do all photos (maybe 4 photos).

Lesson plan was easy to follow.

3) Did you find the preparation for this lesson manageable?

Yes

4) Do you think that your students enjoyed this lesson?

Yes, particularly the dice activity

5) What was your favourite part of the lesson?

Discovering climate normals

6) What, if anything, would you modify if you taught this lesson again?

I'd intentionally teach it over 2 periods.

At the start do a pair share: A/B what's the difference between weather and climate?

Additional Question to Discuss: "What season do you think your picture was taken in? How would

the climate be different 2 seasons from when this picture was taken?"

Additional Question to Discuss: "If you were going to travel to your picture place, is this one image enough to decide what to pack?" Answer: No, need to know more long-term data.

I'd model Reproducible #2 (Discovering the Climate) using Victoria as an example. Then have the whole class do it (which is what I did when I taught it this time).

I would put the extreme events graph on the overhead to explain to the class.

7) Do you have any suggestions of alternative activities that you feel would better teach the concepts that are in this lesson?

Each teacher will deliver the lesson in their own way, however any way it could be incorporated/suggested, to use techniques such as predicting, KWL charts, accessing prior knowledge, A/B partner talk, and word sorts, among others, would be beneficial. As much as it's about the content, it's about the students engaging – the less teacher talk the better.

8) Do you have any further comments on this lesson?

I didn't feel they needed to graph the climate data in my class, however, I do think it's important to discuss the extreme events graph. I found the explanation of the graph a bit confusing though.

I didn't do the postcard activity, as for my particular class I didn't feel it was necessary.

We will be researching the climate of areas of the world we are currently studying in social studies and examining the relationship between climate and GDP. Will also be examining how this may be affected by climate change. It fits nicely with our social studies unit on poverty.

9) What are the 3 biggest barriers that you face in trying to teach about climate change? (Rank them from 1 to 3, with 1 being the biggest barrier).

2 I have little knowledge of available resources and current information on climate change.

1 Lack of space in the current curriculum

No framework exists for climate change to be taught as an integrated subject

Lack of relevant learning resources that tie into learning outcomes

3 Topic too complex, takes too much time to comprehend, gather resources, teach.

Topic too controversial, conflicting views make it difficult to teach.

Not a priority for me/ subjects I teach

No support from peers, administration

Other:

10) Have you found other regional teaching resources (e.g. posters, maps, pamphlets from community groups, etc.) that are valuable for teaching climate change? Please list names and/ or sources of resources below.

I haven't really investigated at this point.

11) Please comment on what resources and/or support would make it easier for you to integrate climate change into your teaching.

Having an expert in at some point, probably towards the beginning of the unit

Regarding Lesson Two (on the carbon balance):

1) Did you feel that there was enough background information to understand and teach the topic? If not, please elaborate on what you feel was missing (e.g. diagrams, more reference material etc...).

Yes

2) Was the lesson plan easy to follow? Do you have any recommendations for changes in the sequencing and presentation of information?

I had the students come up to the board and record a place where they thought they could find "carbon." Then we discussed how it is everywhere (with a few exceptions) and then students came up again and added to the board. We then grouped the places where carbon can be found into groups (e.g. non-living, living things). This connects nicely with the Grade 6 IRPS for classification (5 kingdoms). This led to the discussion of the categories used in this lesson: living things, air, soil etc.

I also asked the question "if carbon does not get destroyed what happens to it?" Answer: transforms. We also looked at the periodic table of elements in our agendas.

I would also go over the game in the classroom prior to actually playing it, and I think I would distribute the cards and have the students familiar with the possible transformations before playing. I would play it once then do a debrief before playing it the second time.

3) Did you find the preparation for this lesson manageable?

Yes – although the information that students need to record while playing the game needs to be modified – too much writing, and too difficult to write all that in a tight time frame for many students.

4) Do you think that your students enjoyed this lesson?

Very much

5) What was your favourite part of the lesson?

Watching the students gradual understanding of the carbon cycle as they filled out their passports after the game.

6) What, if anything, would you modify if you taught this lesson again?

I wouldn't use the poster. I would use the back of their passport to discuss the examples of where carbon is.

I would spread out the activity cards face down and not worry about students standing in line, but rather pick up a face down card and follow its instruction and the return it face down after recording its information.

I wouldn't worry about a "bag of pencils" I'd just get each student to bring 2 of their own colours. Also as above in questions 3

7) Do you have any suggestions of alternative activities that you feel would better teach the concepts that are in this lesson?

I would like to see the FYI tidbits and background information adapted to be readable at the grade 6 level. I found that it was a lot of material for myself to learn and if the students could read it themselves and we work through it together it could be beneficial to everyone!

I also took the key terms in this lesson and had the students, in another class period, sort them into groups they thought belonged together. I then provided them with the definitions to the words and have the exam their groups and see if they would change their grouping. This helped familiarize them with the key scientific terms in the lesson. This could actually be done at the beginning of the whole unit.

8) Do you have any further comments on this lesson?

This lesson took about 1.5 periods (75mins) so I had a bit of extra time in the second period after I had discussed the carbon cycle.

I felt that it was difficult to get the students to understand what "carbon" is, as they haven't done chemistry yet. However, looking at the periodic table of elements in their agendas and comparing carbon (the basic unit of life) to cells (the basic building blocks of life) helped, as did comparing the carbon cycle to the water cycle. I think making those connections is very important! We also played this game subsequently once the students had better understanding and the enjoyment level was very high.

Regarding Lesson Three (on the enhanced greenhouse effect):

1) Did you feel that there was enough background information to understand and teach the topic? If not, please elaborate on what you feel was missing (e.g. diagrams, more reference material etc...).

Yes

2) Was the lesson plan easy to follow? Do you have any recommendations for changes in the sequencing and presentation of information?

The game was a bit hard to get my head around – again, going over it in the classroom first would be useful, and doing a “trial” game/walk through first. I would break this lesson into two as well as I think the game could take a whole block – parts A,B,C and D in one lesson and Part E in a second lesson.

3) Did you find the preparation for this lesson manageable?

Yes

4) Do you think that your students enjoyed this lesson?

I think they were a bit frustrated initially at the game but that this would be remedied by devoting a whole class to it so that there was real understanding of the concept as well as the game.

5) What was your favourite part of the lesson?

The brainstorming around the Greenhouse Effect – “blanket” explanation excellent.

6) What, if anything, would you modify if you taught this lesson again?

As above

7) Do you have any suggestions of alternative activities that you feel would better teach the concepts that are in this lesson?

No!

8) Do you have any further comments on this lesson?

As with the carbon cycle game, we played this subsequently and students really enjoyed and got it – important to play the game from time to time to keep the concepts in their heads.

APPENDIX E

Percentage Scores by Survey Questions

THEME: Weather and Climate

	Q6	Q8	Q10	Q11
Teacher-based A				
Pre-	66.67%	66.67%	33.33%	91.67%
Post-	58.33%	91.67%	75.00%	83.33%
Follow-up	33.33%	91.67%	58.33%	75.00%
Teacher-based B				
Pre-	36.84%	78.95%	31.58%	78.95%
Post-	52.63%	78.95%	57.89%	78.95%
Follow-up	31.58%	89.47%	42.11%	78.95%
Control				
Pre-	31.25%	75.00%	43.75%	93.75%
Post-	56.25%	87.50%	37.50%	75.00%
Presenter-based				
Pre-	47.37%	52.63%	21.05%	57.89%
Post-	31.58%	52.63%	31.58%	73.68%
Follow-up	26.32%	78.95%	26.32%	57.89%

	CW1	CW2	CW3	CW4	CW5	Total Mean
Teacher-based A						
Pre-	58.33%	100.00%	91.67%	66.67%	33.33%	67.59%
Post-	91.67%	100.00%	91.67%	91.67%	66.67%	83.33%
Follow-up	58.33%	100.00%	91.67%	75.00%	50.00%	70.37%
Teacher-based B						
Pre-	47.37%	94.74%	52.63%	89.47%	42.11%	61.40%
Post-	47.37%	100.00%	68.42%	94.74%	84.21%	73.68%
Follow-up	52.63%	89.47%	84.21%	84.21%	68.42%	69.01%
Control						
Pre-	43.75%	100.00%	75.00%	93.75%	37.50%	65.97%
Post-	56.25%	81.25%	75.00%	68.75%	56.25%	65.97%
Presenter-based						
Pre-	47.37%	84.21%	57.89%	68.42%	68.42%	56.14%
Post-	68.42%	78.95%	89.47%	57.89%	52.63%	59.65%
Follow-up	63.16%	89.47%	68.42%	68.42%	42.11%	57.89%

Note. CW1-CW5 refer to the True/False type Climate or Weather Questions that are located at the end of the survey.

THEME: The Carbon Cycle and Human Impacts

	Q3	Q5	Q7	Q12	Q15	
Teacher-based A						
Pre-	16.67%	16.67%	50.00%	50.00%	41.67%	
Post-	75.00%	75.00%	50.00%	100.00%	100.00%	
Follow-up	66.67%	91.67%	83.33%	100.00%	91.67%	
Teacher-based B						
Pre-	31.58%	57.89%	31.58%	68.42%	52.63%	
Post-	89.47%	73.68%	63.16%	84.21%	78.95%	
Follow-up	84.21%	68.42%	57.89%	89.47%	89.47%	
Control						
Pre-	50.00%	68.75%	25.00%	50.00%	75.00%	
Post-	68.75%	68.75%	25.00%	56.25%	81.25%	
Presenter-based						
Pre-	26.32%	47.37%	31.58%	73.68%	52.63%	
Post-	63.16%	68.42%	15.79%	78.95%	73.68%	
Follow-up	47.37%	84.21%	36.84%	84.21%	68.42%	
	TF4	TF5	TF6	TF9	TF10	Total Mean
Teacher-based A						
Pre-	83.33%	58.33%	58.33%	58.33%	91.67%	67.70%
Post-	75.00%	100.00%	83.33%	66.67%	100.00%	84.26%
Follow-up	58.33%	100.00%	91.67%	66.67%	91.67%	77.26%
Teacher-based B						
Pre-	52.63%	57.89%	84.21%	78.95%	94.74%	68.23%
Post-	73.68%	89.47%	84.21%	78.95%	89.47%	81.87%
Follow-up	68.42%	94.74%	89.47%	73.68%	100.00%	81.35%
Control						
Pre-	81.25%	87.50%	43.75%	62.50%	87.50%	70.52%
Post-	81.25%	87.50%	68.75%	50.00%	87.50%	71.22%
Presenter-based						
Pre-	63.16%	78.95%	63.16%	52.63%	100.00%	67.64%
Post-	42.11%	89.47%	94.74%	89.47%	94.74%	74.46%
Follow-up	21.05%	78.95%	84.21%	78.95%	89.47%	65.50%

THEME: Global Warming and the Greenhouse Effect

	Q1	Q2	Q4	Q9	Q13	Q14
Teacher-based A						
Pre-	8.33%	91.67%	83.33%	83.33%	58.33%	50.00%
Post-	41.67%	91.67%	100.00%	91.67%	66.67%	91.67%
Follow-up	58.33%	83.33%	58.33%	66.67%	50.00%	100.00%
Teacher-based B						
Pre-	10.53%	73.68%	57.89%	52.63%	78.95%	31.58%
Post-	63.16%	84.21%	78.95%	84.21%	63.16%	68.42%
Follow-up	57.89%	78.95%	68.42%	78.95%	73.68%	57.89%
Control						
Pre-	50.00%	100.00%	62.50%	87.50%	50.00%	0.00%
Post-	25.00%	100.00%	75.00%	93.75%	75.00%	25.00%
Presenter-based						
Pre-	21.05%	73.68%	78.95%	57.89%	68.42%	31.58%
Post-	26.32%	68.42%	89.47%	73.68%	68.42%	68.42%
Follow-up	21.05%	68.42%	84.21%	68.42%	84.21%	52.63%
	TF1	TF2	TF3	TF7	TF8	Total Mean
Teacher-based A						
Pre-	100.00%	33.33%	83.33%	91.67%	58.33%	70.10%
Post-	75.00%	16.67%	100.00%	91.67%	41.67%	75.93%
Follow-up	100.00%	25.00%	91.67%	58.33%	75.00%	77.73%
Teacher-based B						
Pre-	84.21%	21.05%	84.21%	78.95%	36.84%	68.93%
Post-	63.16%	10.53%	78.95%	78.95%	68.42%	72.40%
Follow-up	84.21%	15.79%	78.95%	63.16%	63.16%	74.45%
Control						
Pre-	81.25%	18.75%	75.00%	93.75%	62.50%	68.30%
Post-	81.25%	12.50%	93.75%	87.50%	75.00%	71.50%
Presenter-based						
Pre-	84.21%	36.84%	73.68%	73.68%	57.89%	68.87%
Post-	68.42%	31.58%	84.21%	78.95%	68.42%	77.45%
Follow-up	78.95%	36.84%	94.74%	78.95%	73.68%	76.02%