

UNIVERSITY OF THE WITWATERSRAND

School of Geography, Archaeology and Environmental Science

**FET Geography Teachers' Knowledge and Perceptions
of Climate Change and an Evaluation of the Textbooks
used for Climate Change Education**

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Declaration

I, Jessica Olivia Saja Vujovic, declare that this thesis is my own, unaided work. It is being submitted for the degree of Master of Arts in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

A handwritten signature in black ink, appearing to read 'Jessica Vujovic', written in a cursive style.

Jessica Olivia Saja Vujovic

22nd July, 2013

Abstract

Climate change education, at both primary and secondary school levels, has been recognised as a key approach through which to enhance the knowledge and understanding of climate change among learners. The success of climate change education is largely dependent on the resources through which learners acquire knowledge of climate change, namely teachers and textbooks. This two dimensional study investigates FET geography teachers' knowledge and perceptions of climate change, and provides a critique of the geography textbooks used most frequently by these teachers in climate change education. To investigate teachers' understandings of climate change, the study employed a qualitative non-experimental research design, which encompassed semi-structured interviews conducted with 32 geography teachers in Gauteng province, South Africa. A number of key inconsistencies, misconceptions and gaps were found to exist in teachers' knowledge and perceptions of climate change. The value of the nine FET level geography textbooks for climate change education was assessed, and critiqued using a classification process based on criteria developed by the researcher. This assessment revealed a number of shortfalls in the textbooks' provision of relevant, accessible and accurate information on climate change. It is important that these flaws and shortfalls in both teachers' knowledge and textbooks representations of climate change are rectified as they are likely to have implications for the ultimate success of climate change education in schools.

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List of Acronyms

CAPS	Curriculum and Assessment Policy Statement
CFCs	Chloroflourocarbons
DBE	Department of Basic Education
DoE	Department of Education
DEAT	Department of Environmental Affairs and Tourism
EIA	United States Energy Information Administration
EPA	United States Environmental Protection Agency
ESD	Education for Sustainable Development
FAO	Food and Agricultural Organisation
FET	Further Education Training
IPCC	International Panel on Climate Change
PCK	Pedagogic Content Knowledge
RNCS	Revised National Curriculum Policy Statement
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund

CHAPTER ONE: INTRODUCTION

1. 1 Introduction

Scientists have increasingly highlighted that humans have, and continue to, cause damage to the Earth. A key environmental issue which has been particularly linked to human activity is that of climate change (IPCC, 2007a; Davis, 2010; United Nations, 2010). Prominent figures and organisations have emphasized the need for all individuals in society to change their approach to the environment to prevent the exacerbation of climate change (UNEP, 2010). With this in mind, education has been targeted as “...the most effective means that society possesses for confronting the challenges of the future...” (UNESCO, 1997, paragraph 38).

At both primary and secondary school level, climate change education has the potential to play a crucial role to develop awareness and improve understanding of this important issue. This in turn could drive important environmental value, attitude and behaviour changes, which may contribute toward climate change mitigation (UNEP, 2006a; UNESCO, 2009a, b). In addition, climate change education may equip learners to better adapt to the predicted social and projected environmental impacts of climate change (UNESCO and UNEP, 2011a). Lastly, climate change education may generate learner support for, and awareness of, key mitigation policies and legislation put in place by local governments (UNEP, 2006a).

The South African government, along with many other countries, has recognised the importance of climate change education in schools (UNFCCC, 2000; DEAT, 2004). It has been acknowledged that through climate change education “...future development pathways and the wellbeing of South African society” may be ensured through developing understandings of climate change and providing learners with the knowledge from which to adapt to and mitigate climate change (DEAT, 2011, 44). Due to the important implications of climate change education for South African society and its environment, the South African government has ensured that the topic of climate change “...is included in all relevant aspects of formal education curricula” (DEAT, 2011, 44).

The ultimate success of climate change education in schools is predominantly dependent on the primary resources through which learner understanding and knowledge of climate change is established (Khalid, 2003; DEAT, 2005; Choi et al., 2010). These resources are primarily the teachers of environmentally related subjects such as geography, and written resources such as textbooks used in climate change education.

Oakes and Saunders (2002) highlight that often teachers will impart their knowledge in conjunction with the information provided in textbooks or other resources when teaching learners about a topic. Some teachers encourage students to openly enquire about topics being covered in class. Thus, in this instance, teachers become a guide or “resource’ for students’, in sharing their understandings and helping learners gain insight into subject matter (Graves, 1982, 57). As a result teachers have a major influence over learners’ conceptualisations of a topic. This point is emphasized by Khalid (2003) who highlights that if educators hold inaccurate understandings and perceptions regarding a topic, it is quite likely that they will pass on these misconceptions to their learners in the classroom.

The tools and resources provided and/ or available to educators to guide their teaching of the issue are central to the success of climate change education in schools. Although a variety of resources exist which may guide teaching and learning of climate change, textbooks remain one of the key resources most frequently used by learners and teachers alike to enhance knowledge and understanding of a myriad of scientific concepts, including climate change (Choi et al., 2010). This is particularly true in the South African context where textbooks are the primary tool and resource used by teachers for climate change education. Well written textbooks are essential to the education process as they allow learners from diverse backgrounds to engage meaningfully with subject matter (Oakes and Saunders, 2002; Mohammad and Kumari, 2007). Thus, with regard to climate change education, these resources have the potential to foster teaching and learning in a way that can deepen awareness and understanding. Textbooks need to be carefully structured in terms of the adequacy; relevance and clarity of presented information (Mohammad and Kumari, 2007). This will ensure that learners gain a clear and enhanced awareness and understanding of climate change.

1.2 Rationale of Research

Although the significance of both teachers and written resources in ensuring the success of climate change education in schools is clear, little research has been conducted in South Africa as to teachers' knowledge and perceptions of climate change, nor the value of the textbooks available to geography teachers for the purpose of climate change education.

This research aims to identify the aspects of teachers' knowledge and understanding of climate change which may need to be broadened, corrected or clarified. In addition, this research will uncover the features of textbooks used for climate change education which may need to be improved upon or extended. Investigation of these two closely linked dimensions may assist in ensuring that learners are educated about climate change in an accurate and consistent manner. It may better enable climate change to be taught in a meaningful way, to enhance knowledge, understanding and awareness of climate change and its related aspects.

1.3 Aim of Research

The aims for this research include:

1. To investigate teachers' knowledge and perceptions of climate change:
 - a) To determine the extent to which teachers' knowledge and perceptions of climate change are accurate;
 - b) To determine whether any gaps or inaccuracies in teachers' knowledge and perceptions of climate change exist which may inhibit the success of climate change education in Gauteng schools;
 - c) Should inaccuracies and gaps in knowledge and perceptions exist, the research seeks to clearly identify and outline these. This will allow for such inaccuracies and gaps to be addressed by relevant educational bodies;
 - d) To improve understandings of teachers' knowledge and perceptions of climate change, where no such research has previously been conducted in South Africa.

2. To critique a selection of textbooks available to geography teachers for climate change education:
 - a) To determine the extent to which textbooks provide accurate, assessable and relevant coverage of climate change

1.4 Context of Research

This research focuses on secondary school educators who teach learners from grades 10 to 12 [Further Education and Training (FET) level] in schools within the Gauteng Province of South Africa. According to the national curricula, climate change and issues relating to climate change, are required be covered in the subjects of Geography, Life Sciences, Physical Science and Geography (DoE, 2008a,b,c,d). However, only teachers who teach Geography have been interviewed, as this is the subject which covers the issue most intensively and comprehensively. The themes of climate, weather and natural disasters all form part of the curriculum for FET Geography (DoE, 2008a,b). Lastly, it is important to highlight that educators in private, government and township schools have been interviewed to ensure diverse representation.

1.5 Research Questions

1. What are geography teachers' perceptions of climate change?
2. What are the misconceptions which teachers hold with regard to climate change?
3. How useful are the textbooks available to geography teachers for climate change education?

1.6 Teachers' Knowledge and Perceptions of Climate Change: Overview and Terminology

Teachers' knowledge and perceptions of variety of scientific phenomena have been explored in many domains. A variety of societal educational constructs have been used to frame these knowledge and perceptions, including: 'concept', 'conception', 'misconception', 'erroneous' and 'conceptualisation'. In previous international studies in which teachers' knowledge and perceptions of climate change are explored, similar terminology is used (Dove, 1996; Groves

and Pugh, 1999; Khalid, 2003; Papadimitriou, 2004; Bozdogan, 2009; Boon, 2010; Coskun and Aydin, 2011). In accordance with this, these terms are used frequently during this research to describe teachers' knowledge and perceptions of climate change. The distinction between these terms is detailed below:

Concept refers to a mental device for interpreting a unit in the stream of sensations that we experience (Robertson, 1994). Concepts are developed by humans as a means through which to organise the world into units of meaning. It is important to highlight that concepts may have differing meanings and associations in different contexts (Robertson, 1994).

Conception refers to an individual's own particular understanding of single or multiple concepts (Robertson, 1994) e.g. conceptions of climate change and its impacts on humans. A conception represents a form of interpretation which helps individuals to understand and comprehend the world around them (Robertson, 1994). In this way a conception represents "...a qualitative relationship between an individual and some phenomenon, which allows the individual to interpret the phenomenon" (Chamberlain, 2003, 7).

Misconception describes incorrect mental constructs surrounding particular ideas, topics, objects or events (Thompson and Logue, 2006) e.g. climate change has resulted in increased instances of skin cancer. Misconceptions may occur as a result of a lay individual, such as a teacher, receiving incorrect or conflicting information from a particular source (Thompson and Logue, 2006). There are a variety of sources, such as the mass media, which account for the development of misconceptions. Learners may develop misconceptions as a result of receiving inaccurate or flawed information from a teacher in the classroom environment or from peers and parents (Thompson and Logue, 2006).

Error (or erroneous) is used for an idea which is scientifically incorrect (Chamberlain, 2003), e.g. climate change will result in tsunamis and earthquakes.

Conceptualisation refers to the way in which a particular individual may understand, envisage, comprehend or create meaning of particular experiences and phenomena (Robertson, 1994), e.g. relating the process and functioning of a greenhouse to the mechanism of the natural greenhouse effect. It is important to highlight that individuals conceptualisation of experiences and phenomena are context dependent (Robertson, 1994).

1.7 Structuring of Further Chapters

In **Chapter 2** a review of the literature pertaining to this research is presented, which includes: the issue of climate change; the importance of teachers' knowledge and perceptions in ensuring the success of climate change education in schools; previous studies which have investigated teachers' knowledge and perceptions of climate change; climate change education, its importance and relevance and the frameworks and approaches which add meaning, value and direction to climate change education; and the importance of evaluating resources used for climate change education in South African schools, and previous studies which have evaluated textbooks used for climate change education in schools.

In **Chapter 3** the research methodology is presented and justified. The research employed a qualitative non-experimental research design encompassing a standardised semi-structured interview approach to uncover teachers' knowledge and perceptions of climate change. A set of criteria were developed as a means through which to critique a selection of textbooks available to geography teachers for climate change education.

In **Chapter 4** the limitations, inaccuracies and misconceptions prevalent in teachers' knowledge and perceptions of climate change that were uncovered in this research are illustrated. This chapter outlines the primary sources of information used by teachers for information on climate change and explores the influence and effects of these sources on teachers' knowledge and perceptions of climate change. Finally, teachers' apparent attitudes of disinterest and apathy toward climate change are discussed.

In **Chapter 5** the shortfalls in information on climate change among textbooks used most frequently by geography teachers for climate change education are illustrated. The implications of the shortfalls on the success of climate change education in schools are also addressed.

Finally, in the concluding **Chapter 6**, the main findings of the research are synthesized. Recommendations are made for addressing limitations in teachers' knowledge and perceptions of climate change and for enhancing the value of textbooks available to geography teachers for climate change education. Finally, suggestions for future research in this discipline are made.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Climate change has increasingly been recognised as having far-reaching global impacts and economic consequences (Adger et al., 2001; O'Neill and Oppenheimer, 2002; Parmesan and Yohe, 2003; Emanuel, 2005; United Nations, 2010). The phenomena has been cited by many key figures, including the United Nations Secretary General, as one of the most pertinent and pressing environmental issues of our time (Parmesan and Yohe, 2003; Root et al., 2003; UNEP, 2010; United Nations, 2010).

A growing awareness and concern for climate change prompted the formation of the International Panel on Climate Change (IPCC) (Swart et al., 2009). The IPCC aims to present the world with scientific knowledge in and around climate change; communicate the possible environmental, social and economic impacts of climate change; and assess and devise mitigation strategies (IPCC, n.d.; Swart et al., 2009). The organisation is widely acknowledged to be an authority on all aspects related to climate change (Rekacewicz, 2005; Swart et al., 2009).

Following the establishment of the IPCC, many key world leaders agreed to sign the United Nations Convention on Climate Change (UNFCCC) (Barret, 1998). This convention recognises that anthropogenic climate change represents a major environmental and social issue, and thus urgent steps need to be taken to mitigate the phenomena (Whitmarsh, 2005; UNEP, 2006a). The ultimate goal of the convention is to develop frameworks which guide successful action to minimise greenhouse gas emissions and thereby reduce the threat of climate change (UNEP, 2002; Appleton et al., 2007).

A major outcome of the UNFCCC has been the creation of the Kyoto Protocol (Barret, 1998; Whitmarsh, 2005). The Protocol was developed in 1997, and sets greenhouse gas emission reduction targets for developed countries depending on their respective levels of industrialisation (Barret, 1998; Whitmarsh, 2005). The Protocol also extends to developing countries, but does not require them to meet any reduction targets, as this may

place strain on their growing economies (Burroughs, 2003; Rumsey and King, 2009). Governments which have ratified the Protocol have put various policies and legislation into place, at both national and more local levels. These are aimed at reducing the risk and impacts of climate change through decreasing the levels of greenhouse gas emissions (Halvorssen, 2008).

Public support is vital to ensuring the success of such policy and legislation (UNEP, 2006a). Through raising public awareness of the issue, support may be generated, and changes in individual behaviours and values may occur. Thus, many governments and non-governmental organisations are employing a variety of approaches to increase public awareness of climate change (UNEP, 2006a). One such approach is to use education in schools as a means through which to teach climate change and potential solutions to the problem (UNEP, 2006a; Chawla and Cushing, 2007). Education is believed to be one of the strongest tools which society can use to address environmental issues (UNESCO, 1997). This is because it may ultimately ensure that young people become environmentally aware citizens who are willing to contribute to protecting the environment.

However, for learners to change their outlook and behaviours, and for them to contribute toward climate change mitigation, it is vital that these individuals gain a clear understanding of climate change and the issues surrounding it (Khalid, 2003). Central to this aim are carefully composed and informative resources provided for climate change education. In addition, it is important that learners are educated by their teachers, who themselves are a resource, about climate change in a way which is free from misconceptions and inaccurate perceptions (Khalid, 2003).

This literature review comprises six main themes: climate change; scientific and political responses to climate change; climate change and the mass media; teachers' perceptions of climate change; climate change education; and climate change education in the South African context.

2.2 Climate Change

The focus of this section is on climate change and its predicted impacts. To understand the causes and effects of climate change an outline of climate and the factors which influence the Earth's climate is provided. This is followed by a summary of climate change at various scales: the expected impacts of climate change at a global scale, and the impacts that are predicted to occur in South Africa. Attention then shifts to the scientific complexity and uncertainty which surrounds climate change. Finally, climate change and its ties to climate variability will be discussed.

2.2.1 The Earth's Climate and Climate Change

Climate is commonly referred to as the mean weather of a specific area, for which the average and variability of temperature, precipitation and wind over a set timeframe, in a specific area, are taken into account (IPCC, 2007a; UNESCO and UNEP, 2011a). This timeframe could be weeks or months, but technically spans over thirty years (IPCC, 2007a). The climatic system may change over time due its own internal dynamics or due to external factors such as volcanic eruptions or anthropogenic changes in the atmosphere (IPCC, 2007a). Climate has effects on both the physical spheres such as landscapes and agriculture, and social spheres such as the economy (Ahrens, 1982; Reay, 2002, Root et al., 2003). In addition, different regions or places often experience differing climates due to a variety of factors or climatic controls, such as the amount of sunlight an area receives (Ahrens, 1982; Root et al., 2003; IPCC, 2007a).

Solar radiation drives the climatic system (Burroughs, 2001). During the day solar radiation from the sun reaches the outer layer of the Earth's atmosphere (Burroughs, 2001). Approximately 30% of this incoming radiation which makes contact with the outer layer of the Earth's atmosphere is reflected back into space (IPCC, 2007a). This is largely due to the presence of clouds and aerosols in the atmosphere (IPCC, 2007a). A small fraction of incoming solar radiation is reflected by snow, ice and deserts on the Earth's surface (Houghton, 2009). The remaining solar radiation which is not reflected back into space is absorbed by the Earth's surface (IPCC, 2007a). To maintain a balance of energy, the Earth must radiate the same amount of energy received from incoming solar radiation back into space, which is achieved through emitting longwave radiation (Houghton,

2009). This thermal radiation is constantly emitted from Earth (IPCC, 2007a; Houghton, 2009).

Some of this emitted infrared radiation escapes permanently through the atmosphere. However, the majority is trapped and then re-radiated back toward Earth by clouds and naturally occurring greenhouse gases (such as carbon dioxide, water vapour and nitrous oxide) present in the atmosphere (IPCC, 2007a; Houghton, 2009). This process is known as the natural greenhouse effect and it keeps the Earth's surface and its biosphere "...at an equitable temperature for planetary processes to operate" (Salinger, 2005, 26). The amount of solar radiation entering and exiting the atmosphere can easily be altered and affected by changes in greenhouse gas concentration (IPCC, 2007a).

Since the industrial revolution, there has been a marked intensification of certain anthropogenic activities, such as burning of fossil fuels for the creation of energy, and deforestation for development (IPCC, 2007a; Houghton, 2009). The IPCC (2007a) asserts that such activities have caused an increase in the concentration of greenhouse gases, particularly carbon dioxide, in the atmosphere. This has led to what is termed the 'enhanced greenhouse effect', where the blanketing effect has intensified, thus preventing radiation from escaping back into space from the Earth (Houghton, 2009). The result of this has been a warming of the climate system. However, such warming is regionally variable, as anthropogenic influences have caused some areas to experience a **decrease** in average temperatures (Walther et al., 2002; IPCC, 2007b). There are a variety of other changes to climate in various regions which have been reported, and other changes which have been predicted to occur, as a result of increases in greenhouse gas emissions (IPCC, 2007a; Houghton, 2009). These changes, at various scales, will now be discussed.

2.2.2 Climate Change and its Observed and Predicted Impacts and Effects on a Global Scale

The IPCC asserts that a general warming of the Earth's climate system is undeniable (IPCC 2007b). This assertion has been proven to a large extent by a variety of observations which have been made over the past decades. Examples of these observations include increases in global air temperature, with the previous twelve years ranking among the "...warmest years in the instrumental record of global surface

temperature...” (IPCC, 2007c, 30). As a result of this warming there has been thermal oceanic expansion and a melting of glaciers, ice caps and polar ice sheets which has triggered a steady rise in sea level. Furthermore, melting of mountain glaciers and icecaps, as a result of rising temperatures, have been observed both in the northern and southern hemispheres (Baker et al., 2006; IPCC, 2007b). In addition, over the last half century there has been an increase in the number of hot days and nights over most land surfaces, while the number of cold days, cold nights and frost events has declined (IPCC, 2007b). There have been varying changes in precipitation levels across the globe (IPCC, 2007b). It has been reported that precipitation has increased greatly across northern and central Asia, northern Europe and in the eastern regions of North and South America (IPCC, 2007b). Conversely, precipitation levels have decreased in the Mediterranean, the Sahel, southern Africa and areas of southern Asia (IPCC, 2007b).

The IPCC (2012) reports observed changes in the nature of some extreme events due to the changes in the global climatic system. A recent special report released by the organisation highlights that changes in the frequency and intensity of extreme weather events over the last sixty years have been recorded (IPCC, 2012). It is important to emphasize that the level of confidence ascribed to the specific changes in the intensity and/or frequency of respective extreme events differs (Swart et al., 2009). This is largely due to the fact that extreme events are generally rare in occurrence, which means that there is little data available to make definitive “...assessments regarding changes in their frequency or intensity” (IPCC, 2012, 6; Swart et al., 2009). *Table 1* (p. 12) provides a brief outline of the observed changes in extreme events, the level of confidence ascribed to these changes, and the regions of the globe where the changes are most pronounced.

Table 1: Outline of the Observed Changes in Extreme Events (Adapted from: IPCC, 2012, p. 6)

Extreme Event and Associated Changes	Regions Where Prevalent	Level of Confidence/Likelihood
Decrease in the number of cold days and nights and general increase in amount of warm days and nights	Globally	Likely
Warming trend in daily temperature extremes	Asia Africa and South America	Medium confidence Low to medium confidence
Increase in number or length of heat waves and warm spells	Most Regions (not all)	Medium Confidence
Occurrence of longer and more intense droughts	Europe and West Africa	Medium confidence
Increases in heavy rainfall events	Some Regions	Likely
Increase in frequency, intensity and duration of tropical cyclone events	Globally	Low Confidence
Increase in tornadoes and hail events	Not Applicable due to small spatial scale of phenomena	Low Confidence
Increases in coastal high water levels due to sea level rise	Globally	Likely
Occurrence of longer droughts	Europe and West Africa	Medium Confidence

It is important to highlight that in some regions the IPCC (2012) has reported a decrease in the occurrence of certain extreme events. For instance, while some areas have experienced longer lasting and more intense droughts, in other regions drought occurrences have become less frequent, less powerful and/or shorter in duration (IPCC, 2012). In addition, due to limited evidence, the IPCC (2012) is unable to make any definitive assessments regarding the changes in some extreme events. In particular, changes in the number and frequency of flood events at both regional and global scales have been difficult to estimate (IPCC, 2012). This is mainly due to the complex effects of constant changes in land use and architecture and the fact that there are inadequate instrumental records of flood events at both regional and global scales across time (IPCC, 2012).

Natural variability is generally a driving force behind the occurrence of, and changes in, the majority of extreme events (IPCC, 2012). However, it has been suggested that in the case of some extreme events, changes may be linked to the influences of anthropogenic climate change (IPCC, 2012). These include increases in warm temperature extremes, heavy rainfall events, extreme coastal high water levels and tropical cyclones (Baker et al., 2006; Mann and Emanuel, 2006; Knutson et al., 2010; IPCC, 2012).

Changes in other extreme events (such as droughts, heat waves and tornadoes) in various and differing regions have also been recorded (IPCC, 2012). However, due to insufficient and inconsistent data there is less confidence in the extent to which such changes may be linked to anthropogenic climate change as opposed to natural variability (IPCC, 2012). Nevertheless, it has been highlighted that as anthropogenic climate change has already had an impact on some extreme events it may contribute to significant changes in other extremes in future decades (Textor, 2012). However, the IPCC (2012) emphasize that the degree to which anthropogenic climate change will affect future extremes is uncertain. This is primarily due to the fact that the extent and rate of anthropogenic climatic changes is still in question.

Observations, such as those discussed above (and demonstrated in *Figure 1*, below), are important as they indicate the possibility for future changes in the Earth’s climatic system (IPCC, 2007b). It is predicted that future changes in climate will have a variety of environmental and social impacts. It is expected that the greater the level of changes in the Earths’ climatic system, the more extensive and detrimental these impacts will become (IPCC, 2007c). Examples of these future changes and some of their impacts will now be discussed.

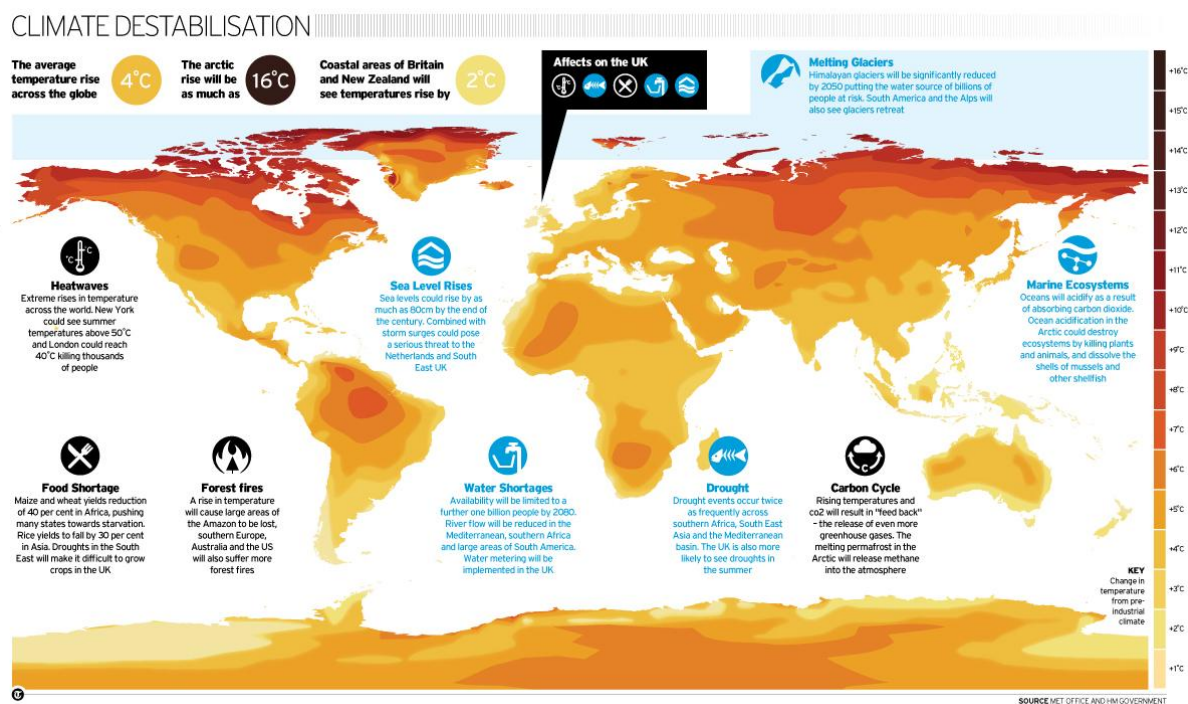


Figure 1: Map demonstrating global impacts of climate change (MET Office, 2009)

It is expected that, as a result of decreased rainfall, there will be increased levels of fresh water and food insecurity over areas in the mid-latitudes and dry tropics (IPCC, 2007c). In addition, there will likely be considerable instances of extreme rainfall events in certain areas, including those where the rainfall average has been predicted to decrease (IPCC, 2007c). This will heighten the risk of flooding which will ultimately pose “...challenges to society, physical infrastructure and water quality” (IPCC, 2007c, 49; Fatti and Vogel, 2011).

It is also predicted that the sea level will continue to rise for centuries to come, as a result of climate change (Baker et al., 2006; IPCC, 2007b; IPCC, 2007c). This will have a variety of social and environmental impacts. For instance, it will contribute to the loss of wetlands and mangroves, which are home to important and rare flora and fauna (Titus et al., 1991; Baker et al., 2006; IPCC, 2007d). In addition, a rising sea level poses a great threat to coastal infrastructure such as piers and beach front houses (IPCC, 2007d). The IPCC (2007c) also warns there could be increased instances of flood related loss of human life through drowning.

Lastly, the IPCC asserts that an increase in the frequency and/or the intensity of extreme events can be expected. For instance, it is suggested that as tropical ocean surfaces warm, tropical cyclones will become more intense, resulting in greater wind speeds and precipitation levels (Mann and Emanuel, 2006; IPCC, 2007b, Knutson et al., 2010). There is also a likelihood of an increase in more intense heat waves lasting over an extended duration of time. In addition, the IPCC (2007b, 783) projects “...increased summer dryness and winter wetness in most parts of the northern middle and high latitudes”. It is anticipated that summer dryness will bring a greater risk of drought (IPCC, 2007b). However, along with the greater risk of drying, there is also a likely possibility of higher precipitation levels and flooding, due to a “...greater water-holding capacity of a warmer atmosphere” (IPCC, 2007b, 783). With this in mind, the IPCC (2007b) proposes that a pattern of short, intense rainfall events spread between longer dry episodes can be expected for some regions. Linked to these changes, the IPCC (2007b) comments that wet or dry extremes can be expected for areas where mean rainfall levels are expected to respectively either increase or decrease.

Thus, it can be seen that changes in climate, such as increases in temperature and instances of extreme weather events, may have a variety of physical and environmental impacts on the globe (IPCC, 2007c). Communities who will be particularly affected by the impacts associated with climate change are those whose economies or day-to-day survival is dependent on resources which may be adversely affected by long term climatic changes (Brooks et al., 2005; IPCC, 2007c). Less wealthy/low income communities are also labelled as being particularly vulnerable due to their low adaptive capacities (Erikson et al., 2007).

2.2.3 Climate Change and its Predicted Effects on South Africa

Climate change has had a variety of effects on South Africa and is expected to have further implications for the country in the future (Archer et al., 2010; Davis, 2010; Madzwamuse, 2010). Some of these effects and implications are discussed, below.

Scientists have projected that South Africa's temperatures will increase by 1-3°C by 2050 (Gbetibouo and Ringler, 2009; Davis, 2010; Engelbrecht et al., 2011). It is expected that these increases in temperature will be "...greater toward the interior, and less in coastal areas" (Davis, 2010, 7). Due to the predicted warmer temperatures, it is expected that evaporation levels will increase markedly (Archer et al., 2010). Thus, it is argued that regions in the country which are prone to wet summers will experience more extreme and prolonged rainfall events over this period (Archer et al., 2010). In addition, it is projected that most regions in South Africa will experience more intense rainfall events (Davis, 2010). However, increases in intense rainfall events will not necessarily result in an increased percentage of the country's **total** rainfall (Lumsden et al., 2009; Davis, 2010). This is reflected in the projection that the country's mean rainfall is expected to decrease by 5-10% (Madzwamuse, 2010).

Despite increases in intense rainfall events it is projected that, overall, South Africa will be drier, with the northern and western regions of South Africa experiencing more frequent and longer lasting dry spells during the spring and autumn seasons (Lumsden et al., 2009; Archer et al., 2010). In addition, it is thought that much of South Africa will experience an overall increase in drought frequency and intensity (Lumsden et al., 2009;

Davis, 2010). Increases in drought frequency and occurrence may also occur in regions where total rainfall is projected to increase (Davis, 2010).

Due to the above mentioned drying, drought and decreases in mean rainfall, it is predicted that South Africa will experience acute fresh water shortages (Lumsden et al., 2009; Archer et al., 2010; Madzwamuse, 2010). Water is already a scarce resource in the country, and it is thought likely that the added stress of climate change will result in the country having limited access to fresh water within the next few decades (Archer et al., 2010; Madzwamuse, 2010). Increased levels of water insecurity will impact negatively on a variety of spheres such as agriculture, biodiversity and human health (Archer et al., 2010; Davis, 2010; Madzwamuse, 2010).

Another important effect of climate change in South Africa is a marked decline in crop production linked to increases in temperature, dry spells and resulting water shortages (Hassan, 2006; Davis, 2010; Tubiello et al., 2007). This decline is expected to have ramifications for South African society, including job losses in the agricultural sector, which in turn result in increased levels of poverty and unemployment (Hassan, 2006). Furthermore, Madzwamuse (2010) suggests that decreased crop yields will greatly impact on small scale farmers and the rural poor, who are reliant on their crops for day-to-day survival, and who have low adaptive capacity. This vulnerability is a concern, as it can potentially increase levels of food insecurity in South Africa (Madzwamuse, 2010).

Lastly, there are a variety of health risks which are expected to emerge in South Africa as a result of climate change. South Africa will be particularly vulnerable to an increase in water and vector borne diseases, such as bilharzia and malaria (Kovats et al., 2001; Madzwamuse, 2010). These diseases will be caused by an increase in extreme rainfall events and changes in ecosystems, brought about by climate change (Archer et al., 2010; Davis, 2010; Madzwamuse, 2010).

2.2.4 Scientific Uncertainty Surrounding Climate Change

As highlighted previously, the majority of scientists are in agreement that the Earth's climate is changing, and that this can be largely linked to the marked increase of certain anthropogenic activities (Oreskes, 2004; Whitmarsh, 2005; IPCC, 2007b). However, there is still some uncertainty surrounding the issue of climate change. As a result of

these uncertainties, scientists and key scientific bodies have been unable to make absolute and definitive projections regarding the rate at which climate change may occur, and the possible future impacts and effects (Whitmarsh, 2005; Quiggen, 2008).

Scientific uncertainty surrounding the impacts and effects of climate change is seen to be as a result of a variety of factors. First, uncertainty stems from climatic systems, which by nature are highly complex, intricate and unpredictable (Quiggen, 2008; Swart et al., 2009). For instance, while it is known that increasing levels of greenhouse gas emissions are leading to a rise in temperatures, there are a variety of other forcings (such as changes in solar intensity and volcanic eruptions), which have the potential to affect climate. These forcings generally show no long term trends, and are thus inherently unpredictable. The unpredictability of forcings has therefore made it difficult for scientists to determine the extent to which they may contribute to climate change in the future (Quiggen, 2008).

Another factor contributing to uncertainties regarding climate change relates to poor understanding of some of the feedbacks operating within climatic systems. This has particular implications for scientific knowledge around the extent to which such poorly understood feedbacks may contribute to carbon dioxide emission levels (Quiggen, 2008; Swart et al., 2009).

Last, one of the primary causes for uncertainty in predicting the speed at which climate change may progress stems from difficulties which scientists face in calculating future greenhouse gas emission levels (Quiggen, 2008). There is uncertainty regarding the extent to which the world's population will grow in forthcoming years (Grove and Lopez-Gunn, 2010). There is also uncertainty concerning the nature and degree of the technological advances and shifts in social, political and economic structures which may occur (Whitmarsh, 2005). In addition, it is unclear to what extent policies and programmes aimed at reducing greenhouse gas emissions, such as the Kyoto Protocol, will be successful (Whitmarsh, 2005; Grove and Lopez-Gunn, 2010).

In light of the above the IPCC has, since its establishment, ensured that uncertainties have been addressed in its Assessment Reports (Swart et al., 2009). It is important to note that in each of its Assessment Reports, the IPCC's Working Groups have differed in terms of

their approaches to the treatment of uncertainties (Swart et al., 2009). In the most recent Fourth Assessment Report, three different approaches were used to communicate uncertainties, each employing different language (IPCC, 2007c). The first approach in the Fourth Assessment Report was used when uncertainties were assessed qualitatively. This approach is categorised by providing the extent “...of agreement in the literature on a particular finding” and the amount of evidence available which substantiates a finding or prediction (IPCC, 2007c, 27). Where uncertainty was considered in a more quantitative manner in the Fourth Assessment Report, expert judgement was used to assess the “...correctness of underlying data, models or analysis” (IPCC, 2007c, 27). According to the judgement made, a scale was used to describe the level of confidence of the chances of a prediction or finding being accurate (IPCC, 2007c). *Table 2*, (p. 18) illustrates the scale used to prescribe levels of confidence.

Table 2: IPCC Scale of Scientific Confidence (IPCC, 2005, p. 3)

Terminology	Degree of confidence in being correct
Very high confidence	At least 9 out of 10 chance of being correct
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

When uncertainty was judged according to both expert judgement and statistical investigation of evidence, a scale of likelihood was used to illustrate the probability of some “...well defined outcome having occurred or occurring in the future” (IPCC, 2005, 4).

2.2.5 Climate Change and Climate Variability

When discussing climate change, it is important to examine another closely linked phenomenon: climate variability. The two terms (climate change and climate variability) often appear together and are often used interchangeably in a variety of scientific documents and reports on climate. As a result, climate change and climate variability are often confused, or thought to refer to the same phenomena (Jonsson, 2010). Whilst it is important not to conflate these two terms, the links between the two concepts are important.

Climate change has been exacerbated primarily due to an enhanced greenhouse effect brought about through an increase in certain anthropogenic activities, which have generated a rise in greenhouse gas emissions (IPCC, 2007a). The phenomenon is associated with permanent shifts in average global climate patterns.

In contrast to climate change, climate variability refers to periodic changes to the “...mean state of the climate on all temporal and spatial scales” (USAID, 2007, 2). Variations in climate can last from several weeks to decades, however, it is important to note that the impacts of changes are not permanent as with climate change (Gruza and Rankova, 2004). Climate variability can either be caused by “...internal processes within the climate system...or variations in the natural or anthropogenic external forcing” (IPCC, 2001, 789). However, commonly, climate variability occurs either due to internal natural processes such as El Niño, or external natural process such volcanic eruptions or changes in solar output (IPCC, 2007b; Jonsson, 2010). The most well-known examples of climate variability are extreme events such as long periods of droughts or floods brought on by the El Niño and La Niña cycle (USAID, 2007).

Thus, it can be seen that there are a number of differences between climate change and climate variability. First, climate variability is periodic, whilst climate change is long term. Second, climate change is mainly human induced, while climate variability is generally a result of natural processes (Jonsson, 2010). Another key difference between the two is that while climate variability worsens already existing physical and social problems (such as land degradation or water shortages), climate change tends to directly cause such problems (Jonsson, 2010).

Despite these differences, these two phenomena are often conflated by lay individuals who mistakenly tend to attribute events occurring as a result of climate variability to climate change (Stehr and von Storch, 1995). It has been suggested that the reason for this, is that events linked to climate variability occur over a shorter time frame than events related to climate change (Stehr and von Storch, 1995). As a result, people tend not to notice slowly evolving changes in climate and rather turn their attention to short term, climate variability-related changes, as they are more tangible and immediate in effect. Stehr and von Storch (1995) argue that some lay individuals tend to incorrectly associate such tangible and

immediate events with climate change, as they are consistent with (although mostly unrelated to) the greatly publicised predicted effects of climate change. It could be argued that this may cause people to constantly attribute all changes in weather to climate change resulting in skewed perceptions of climate change.

The differences which exist between climate change and climate variability do not mean that the two phenomena should be viewed and treated in total isolation of each other (UNEP, 2006b). This point is illustrated by UNEP (2006b, 1), who state that climate change will ultimately “...lead to an increase in the frequency and intensity of climatic extremes such as droughts and floods, some of the very elements which define climate variability”. Thus, it is important to consider that climate change is likely to cause an increase in the frequency and intensity of such events when creating strategies to minimise the scope of potential impacts caused by extreme events associated with climate variability (UNEP, 2006b).

2.3 Climate Change and the Mass Media

The mass media is strong and influential in influencing society’s perceptions of climate change. The ways in which the media frames the issue of climate change, and the implications which this framing may have on the public’s perceptions of climate change, is examined. This is then linked to a discussion and evaluation of the impacts of mass media on climate change education.

2.3.1 The Role of the Mass Media in Perceptions of Climate Change

The general public has been found to be extremely reliant on the mass media as a source from which to gather knowledge and information on scientific topics (Lowe et al., 2006). Thus, forms of mass media, such as newspapers, television and radio, play a large role in moulding the public’s perceptions and understandings of climate change (Lowe et al., 2006).

The media’s importance is thought to lie in its ability to make lay individuals more aware of the issue of climate change (Weingart et al., 2000; Crist, 2007). However, in order to draw the public in, the media has greatly sensationalised the phenomenon and emphasized it as being the most pressing environmental issue of our time. Weingart et al.

(2000) highlight how in order to ensure climate change is 'news worthy', scientific uncertainties regarding the problem have been transformed into imminent catastrophes. An excellent example of how the media may sensationalise climate change can be drawn from Al Gore's well-known documentary, *An Inconvenient Truth*. It has been argued that many of the claims relating to climate change and its science that were made in the documentary are sensationalist and aim purely to attract a large number of viewers (Lewis, 2006). As a result, much of what is stated by Al Gore in the documentary has been labelled as being "...either one sided, misleading, exaggerated or just plain wrong" (Lewis, 2006, 2). A good example of such sensationalist claims made by Al Gore in *An Inconvenient Truth* is that the first ever South Atlantic tropical cyclone on record occurred as a result of climate change (Lewis, 2006). Although scientists do suggest that anthropogenic climate change may cause an increase in the intensity of tropical cyclones, it has been emphasized that it is extremely difficult to link climate change to tropical cyclone events with certainty (Mann and Emanuel, 2006; IPCC, 2007a; Knutson et al., 2010).

Through sensationalism, the media has drawn the public's attention to climate change (Lowe et al., 2006). However, there are a number of negative impacts as a result of the sensationalism of climate change. For example, it has resulted in many lay individuals forming extreme and alarmist perceptions of climate change, seeing climate change as a dangerous phenomenon (Carter, 2006). In addition, the media's alarmist framing of climate change has resulted in many lay individuals feeling overwhelmed by the magnitude of the issue as portrayed by the mass media (Swim et al., 2009). As a consequence, some individuals have developed feelings of apathy toward climate change, believing that they cannot meaningfully contribute towards mitigating the issue due to its perceived severity and enormity (Swim et al., 2009). It has been suggested that the mass media's sensationalist and alarmist framing of climate change has resulted in the public's attention and concern being diverted away from other pressing environmental issues (Crist, 2007).

Apart from forming alarmist perceptions of climate change through sensationalism, the mass media has been noted as impacting on lay individuals' perceptions of the issue in a number of other ways. One of the most notable is through referring to climate change as

‘global warming’, or using the two terms “...indiscriminately or interchangeably” (Whitmarsh, 2009, 403).

During the 1980s and the 1990s the term ‘global warming’ was argued to illustrate and enforce the global nature and severity of the phenomena (Whitmarsh, 2009). However, over the past decade there has been a movement away from the use of ‘global warming’ toward the use of ‘climate change’ or the ‘enhanced greenhouse effect’, particularly in scientific and political circles (Whitmarsh, 2009). Scientists have argued that ‘global warming’ fosters a range of misperceptions regarding the phenomena among the general public (Shome and Marx, 2009; Whitmarsh, 2009). For instance, ‘global warming’ misleadingly suggests that climate change is associated only with warming on a global scale (Shome and Marx, 2009). However, scientists have asserted that some areas have experienced cooling while others have warmed (IPCC, 2007b). Thus, it could be argued that some lay individuals may wrongly assume that warming is a pervasive effect of anthropogenic climate change. In addition, Shome and Marx (2009) highlight that the term has led some people to believe that the world will consistently grow warmer and warmer. However, it has been suggested that “...each year might not be warmer than the previous one” (Shome and Marx, 2009, 2). Furthermore, many tend to assume that the impacts associated with climate change are only heat related (Whitmarsh, 2009).

In terms of education, the mass media, with its sensationalist framing of climate change, could have a strong influence on the approach which educators may use to teach learners about climate change. In addition, the use of the term ‘global warming’ in the media, may result in teachers forming a variety of misperceptions regarding the climate change phenomena, which may be passed on to learners in the classroom. Fortner et al. (2000) warn that educators should become more aware of the influence which mass media may have on their teaching. It is also emphasized that educators should become sensitive to the negative implications which the media may have on the ways in which learners perceive the issue of climate change (Fortner et al., 2000).

2.4 Teachers’ Perceptions of Climate Change

This section has two themes. The first theme outlines the important role which teachers’ knowledge and perceptions of classroom topics play in promoting learner understanding

of subject matter and the importance of teachers' perceptions of climate change. The second theme focuses on seven international studies looking at teachers' perceptions of climate change.

2.4.1 The Importance of Teacher Perceptions

The resources provided or available to South African teachers for climate change education are central to ensuring that learners gain an adequate understanding of climate change. Another equally important resource is the teachers themselves, as teachers often impart their own knowledge in conjunction with the information provided in textbooks (Oakes and Saunders, 2002). Furthermore, some teachers encourage students to enquire openly about topics being covered in class. In this way teachers become a valuable resource for learners through communicating their knowledge and understandings and providing learners with valuable insights into topics covered in the classroom (Graves, 1982).

Thus, teachers have the potential to influence the level of knowledge and understanding which learners have regarding a particular topic. This argument is acknowledged by Khalid (2003) and Boon (2010), who both highlight that it is extremely important that teachers have a sound knowledge of any topic they teach, as it is likely that any misconceptions or inaccurate understandings which they hold will be passed on to learners.

With the above discussion in mind, it could be argued that to ensure the ultimate success of climate change education in schools, it is vital that teachers' conceptions and understandings of climate change are assessed. In the South African context, little research regarding teachers' perceptions of climate change has been conducted. However, such research would be valuable as it would reveal which aspects of teachers' knowledge need to be improved upon. In the long term this may ensure that learners are taught about climate change adequately and accurately, which may ultimately foster environmental attitude, behaviour, and value changes and provide learners with the knowledge to successfully adapt to and mitigate climate change (UNFCCC, 2000; UNESCO and UNEP, 2011a).

2.4.2 International Studies on Teachers' Perceptions of Climate Change

This theme will outline seven international studies which have focused on teachers' perceptions of climate change. As there is very little literature on the perceptions of climate change held by secondary school teachers specifically, this theme will focus on teachers involved in education at primary school level and student teachers. The majority of these studies concentrate on student teachers, who are studying to become teachers. However, these studies are still useful as these students will one day become teachers, and may pass on their perceptions of climate change to learners (Groves and Pugh, 1999).

The majority of studies concerning teachers' perceptions of climate change, have been conducted in Europe, and consequently represent a northern, first world perspective. Thus, similar studies relating to teachers' perceptions of climate change should be conducted in a third world context as entirely different results and findings may emerge. This may allow for context specific findings which highlight particular aspects of third world teachers' perspectives and knowledge on climate change that may need to be improved or extended. In the long run this may benefit student learning around the topic, and thus fortify the ultimate goals of climate change education in these regions.

The methodologies of each of the selected studies are fairly similar in nature. Each study used questionnaires as the primary method of data collection (Dove, 1996; Groves and Pugh, 1999; Khalid, 2003; Papadimitriou, 2004; Bozdogan, 2009; Boon, 2010; Coskun and Aydin, 2011). Three studies, (Dove, 1996; Groves and Pugh, 1999; Coskun and Aydin, 2011), employed only closed-ended questions in their questionnaires, while two studies, (Papadimitriou, 2004; Bozdogan, 2009), used only open-ended questions. The remaining two studies, (Khalid, 2003; Boon, 2010), used a mix of open and close-ended questions. The majority of the studies were large in scale, with questionnaires being distributed to (on average) 170 participants (Dove, 1996; Groves and Pugh, 1999; Papadimitriou, 2004; Bozdogan, 2009; Boon, 2010; Coskun and Aydin, 2011). The study conducted by Khalid (2003) had a much smaller sample group, with 27 student teachers participating.

2.4.2.1 Outline of Results Found in Selected Studies

As there are commonalities in the findings of each of the selected studies, their results are summarised in tabular form. An analysis of the findings presented in the tables is provided. First, teachers' understandings of the greenhouse effect are discussed, following which, teachers' perceptions of the causes of climate change are examined. Third, teachers' understandings of the impacts and effects of climate change are outlined and finally, teacher impressions of the actions which should be taken to mitigate climate change are assessed.

2.4.2.1.1 Teachers' Understanding of the Greenhouse Effect

A major finding from the studies selected was that while many of the teachers and student teachers have a basic knowledge of the greenhouse effect, they display deeper conceptual misunderstandings and lack scientific knowledge on the topic (see *Table 3*, p. 26). A reason for this could be that teachers do not engage sufficiently with scientific and academic material on climate change, but primarily gather their information from the easily accessible mass media (Khalid, 2003, Daskolia et al., 2006, Boon, 2010). Information on climate change presented by the mass media tends to be inaccurate and sensationalist, thus leading lay individuals to hold a variety of misconceptions (Groves and Pugh, 1999; Daskolia et al., 2006). For instance, many have highlighted that the media portrays carbon dioxide as "...the only greenhouse gas" (Khalid, 2003, 44), and this has led to some lay individuals being unaware of other prominent greenhouse gases such as water vapour or methane (Dove, 1996; Khalid, 2003). This finding is reflected in the majority of the selected studies, as many of the interviewed teachers identify only carbon dioxide as being a greenhouse gas and had little/no knowledge of the other important gases (see *Table 3*, below). Thus, it is clear that the mass media has played a substantial role in misinforming educators and creating conceptual gaps in their knowledge (Khalid, 2003; Daskolia et al., 2006; Boon, 2010).

Table 3: A Summary of Teachers' Understandings of the Greenhouse Effect

Findings from studies:	Dove, 1996	Groves and Pugh, 1999	Khalid, 2003	Papadimitriou, 2004	Bozdogan, 2009	Boon, 2010	Coskun and Aydin, 2011
Basic understanding of the greenhouse effect		✓	✓	✓	✓	✓	✓
Conceptual misunderstandings of the greenhouse effect/ Lack of scientific knowledge surrounding greenhouse effect	✓	✓	✓	✓	✓	✓	✓
Carbon dioxide identified as a greenhouse gas	✓		✓	✓	✓	✓	✓
Little knowledge of other greenhouse gasses	✓		✓	✓	✓	✓	
Properties of the ozone layer and greenhouse effect mistaken	✓	✓	✓	✓	✓	✓	✓
Human activity identified as only driver of increasing greenhouse effect			✓				✓
Natural phenomena attributed to the increasing greenhouse effect			✓				
Greenhouse effect causes skin cancer	✓	✓	✓	✓			✓

As shown on *Table 3* (above), a large percentage of teachers from all studies erroneously linked ozone layer depletion to the enhanced greenhouse effect (Khalid, 2003, 40). These teachers believe that ozone layer depletion allows “...more radiation to the Earth, which increases the greenhouse effect...” (Dove, 1996, 43). This perception is incorrect as the function of ozone layer and the workings of the greenhouse effect are not directly related (Coskun and Aydin, 2011). The ozone layer protects the Earth and its occupants from the sun’s damaging ultra-violet rays. In contrast, the greenhouse effect ensures that the Earth’s surface remains warm by “...keeping the long-wave radiation reflected from the earth via greenhouse gasses” (Coskun and Aydin, 2011, 292).

Some teachers incorrectly named increased skin cancer as being an impact of the greenhouse effect (*Table 3*, p. 26). It is likely that this misconception is as a result of these teachers conflation of ozone layer depletion and the greenhouse effect. This is illustrated by the fact that instances of skin cancer are not scientifically associated with the greenhouse effect, but rather attributed to ozone layer depletion, when increased levels of ultra-violet rays are able to reach the Earth and effecting human skin (Coskun and Aydin, 2011).

2.4.2.1.2 Teachers' Perceptions of the Causes of Climate Change

Table 4: A Summary of Teachers' Perceptions of the Causes of Climate Change

Findings from studies:	Dove, 1996	Groves and Pugh, 1999	Khalid, 2003	Papadimitriou, 2004	Bozdogan, 2009	Boon, 2010	Coskun and Aydin, 2011
All types of pollution cause global warming and climate change		✓		✓		✓	
CFC use leads to climate change		✓					
Industrial emissions lead to climate change.				✓			
Climate change caused by ozone layer depletion		✓	✓	✓	✓		
Acid rain causes global warming and climate change		✓		✓			

In some of the studies it was found that many teachers hold key misconceptions and inaccuracies in understanding the causes of climate change. In studies conducted by Groves and Pugh (1999), Papadimitriou (2004) and Boon (2010) a number of teachers incorrectly causally link pollution to climate change. Examples include general air and environmental pollution, chemicals and radioactive waste. In studies conducted by Groves and Pugh (1999) and Papadimitriou (2004) many teachers incorrectly named acid rain as one of the causes of climate change (*Table 4*, above).

As shown in *Table 4* (p. 26), in the majority of studies, teachers were found to believe incorrectly that ozone layer depletion contributes to climate change (Groves and Pugh, 1999; Khalid, 2003, Papadimitriou, 2004; Bozdogan, 2009). In these studies many teachers stated that the thinning of the ozone layer has allowed more of the sun's rays to reach the Earth's surface, thus leading to temperature increases and climate change. These teachers were found to conflate or even link ozone layer depletion and the greenhouse effect (*Table 4*, p. 27).

2.4.2.1.3 Teachers' Perceptions of the Impacts and Effects of Climate Change

Generally teachers across the selected studies hold relatively accurate conceptions of the impacts and effects of climate change. This is illustrated in *Table 5* (below), which shows that teachers in these studies correctly identified that climate change will result in impacts and effects such as changes in climatic and weather patterns, sea level rise, melting of the polar ice caps, desertification and drought.

Table 5: A Summary of Teachers' Perceptions of the Impacts and Effects of Climate Change

Findings from studies:	Dove, 1996	Groves and Pugh, 1999	Khalid, 2003	Papadimitriou, 2004	Bozdogan, 2009	Boon, 2010	Coskun and Aydin, 2011
Will result in climatic and weather changes	✓	✓	✓		✓	✓	✓
Temperatures will rise	✓	✓	✓	✓	✓	✓	✓
Polar ice caps will melt	✓	✓	✓		✓	✓	✓
Rainfall will increase	✓		✓				✓
Rise in sea level	✓				✓	✓	
Decrease in crops						✓	
Increase in plant growth due to more moisture and warmth	✓						
Climate change causing more sunshine and thus photosynthesis	✓						
Extinction of flora and fauna					✓		
Desertification					✓		
Natural disasters					✓		
Drought.					✓		
Increase in disease					✓		
Famine					✓		
Wars					✓		
Migration as a result of a reduction of living space					✓		

In some studies, there were a variety of inaccuracies and flaws uncovered in teacher and student teachers' knowledge of the impacts and effects of climate change. For example, in three studies, teachers believe that climate change will cause an overall global increase in rainfall (Dove, 1996; Khalid, 2003; Coskun and Aydin, 2011). This conception is inaccurate, as climate change is expected to cause some areas to receive more rainfall and others to receive less (Coskun and Aydin, 2011). In a study conducted by Dove (1996), a few student teachers erroneously linked climate change with "...higher sunshine levels, then perceived this as stimulating photosynthesis" (Dove, 1996, 97). Lastly, it was found in a study conducted by Papadimitriou (2004), that some student teachers tend to use recent short-term weather events as evidence of the impacts of climate change. This suggests that some teachers may be incorrectly confusing weather with climate (Papadimitriou, 2004).

2.4.2.1.4 Teachers' Perceptions of Mitigation Strategies for Climate Change

Generally, the majority of teachers in the studies hold relatively accurate conceptions of the steps that need to be taken to minimise climate change. This is illustrated in *Table 6*, (p. 29), where it can be seen that participants pointed to important mitigating activities such as planting trees, using alternative energies and reducing car use. However, although many of the teachers demonstrate a basic knowledge of appropriate mitigating strategies,

there is no evidence that they have a deeper understanding of why certain preventative steps or actions are helpful (Groves and Pugh, 1999; Papadimitriou, 2004). This limited or superficial knowledge may, as has been previously mentioned, be due to the fact that teachers tend not to engage with scientific material on climate change (Dove, 1996; Groves and Pugh, 1999; Khalid, 2003; Papadimitriou, 2004; Bozdogan, 2009; Boon, 2010; Coskun and Aydin, 2011). Papadimitriou (2004) argues that without science as a foundation, teachers may lack knowledge of the causes of climate change and this will make it difficult for them to comprehend why certain strategies would be helpful.

Table 6: Teachers' Perceptions of Mitigation Strategies for Climate Change

Findings from studies:	Dove, 1996	Groves and Pugh, 1999	Khalid, 2003	Papadimitriou, 2004	Bozdogan, 2009	Boon, 2010	Coskun and Aydin, 2011
Planting trees will help reduce climate change	✓	✓		✓	✓	✓	✓
Reduce water use					✓		
Recycling paper will help reduce climate change							✓
Recycling (in general) will help reduce climate change				✓	✓	✓	
Burying rather than burning waste will help reduce climate change							✓
Use nuclear power plants instead of burning coal	✓						
Reduction of car use will help reduce climate change		✓		✓	✓	✓	
Use of unleaded petrol will help reduce climate change		✓					
Using alternative energy sources will help reduce climate change				✓		✓	✓
Reduce electricity consumption				✓	✓		✓
Reduce food consumption				✓	✓		
Decreasing polluting activities will help decrease climate change				✓	✓		
Informing society/ raising awareness about the issue will reduce climate change				✓	✓		
Public participation in environmental groups will help reduce climate change				✓			
Using environmentally friendly cleaning products will help reduce climate change				✓	✓		
Reduce the use of compounds which harm the environment				✓			
Use of harmful materials for the ozone layer should be decreased					✓		
Keeping beaches clean will help reduce climate change		✓					
Conservation of endangered animal species		✓					
Protection of rare flora		✓					
Reduction of nuclear stock piles will help reduce climate change		✓					

Interestingly, in some studies it was found that some of the mitigating actions suggested by teachers are not specifically related to the prevention of climate change. Rather, some

suggestions made are commonly associated with reducing or mitigating environmental problems in general. Examples of these include the belief that actions such as keeping beaches clean and using environmentally friendly cleaning products will help to reduce climate change (Groves and Pugh, 1999; Papadimitriou, 2004). The lack of specific knowledge regarding preventative strategies may either be as a result of participants merging environmental issues into a single construct, or as a result of a lack of engagement with scientific information on climate change (Papadimitriou, 2004; Daskolia et al., 2006).

2.4.2.2 Summary of Key Findings from International Studies

From these studies it is clear that teachers hold a variety of misconceptions regarding climate change and related issues. These misconceptions arise due to either, a lack of scientific knowledge or confusion of the issue with other environmental problems.

2.5 Climate Change Education

This section on climate change education comprises four themes. Firstly, the significance of climate change education in schools is examined. A broad outline of some of the challenges associated with climate change education follows. Focus will then shift to the value of Education for Sustainable Development as a framework for climate change education. Finally, the section examines the implications of the environmental education approach for climate change education.

2.5.1 The Significance and Importance of Climate Change Education

As concerns regarding climate change have grown, education has been targeted as one method through which to address the issue (UNEP, 2006a). The importance of education lies in its ability to raise awareness of climate change, and thus inspire behavioural, value and attitude changes amongst various members of society (UNEP, 2006a). It has been proposed that through inspiring these changes, education around climate change is “...laying the foundation for a more sustainable world” (UNESCO, 2009b, 7). Climate change education may help individuals to make informed decisions which will benefit the environment and thus minimise the impacts of climate change (UNESCO, 2009b). Furthermore, education around climate change will help generate public support for

important mitigating strategies and policies put in place by various governments (UNEP, 2006a). Finally, many highlight that education is crucial in helping individuals to successfully adapt to the variety of social and environmental impacts of climate change (UNESCO and UNEP, 2011a).

Educational approaches to climate change have focused primarily on two groups in society (Devine-Wright et al., 2004). The first of these is the general public, who are targeted through means such as general awareness campaigns. The second group are school children, at all ages and levels, who are “...reached through specific environmental education programmes” and their school curricula (Devine-Wright et al., 2004, 494). UNESCO and UNEP (2011b) emphasize that through education, the youth are able to gain a broad scientific knowledge of climate change and build an understanding of the ways in which climate change may impact directly and indirectly on their lives and environments. School children are one of the most important groups in society to pursue as they are the future generation, and thus need to be prepared to one day make the best decisions for the planet (UNESCO, 2009a,b). In addition, educating the youth about climate change is imperative as they need to be equipped to adequately adapt and respond to its impacts (Papadimitriou, 2004).

It is particularly important to target school children in developing countries and rural areas. This is because these are the regions which are going to be most affected by climate change both environmentally and socially (UNESCO, 2009b; UNESCO and UNEP, 2011a). Thus, it is important that youth in these regions have knowledge on how to successfully adjust to and cope with the associated impacts (UNICEF, 2008; UNESCO, 2009b; UNESCO and UNEP, 2011a).

However, the importance of teaching learners about climate change stretches far beyond the above mentioned aspects. Dahlberg (2001) highlights that climate change is an ideal teaching tool with a variety of benefits for learners, for example, climate change creates a practical and relevant learning experience for learners. This is because students are exposed to the issue of climate change on a daily basis through a variety of channels such as the media and internet, thus making learning about climate change tangible and

applicable for learners and thus ensuring that they become motivated to learn (Dahlberg, 2001).

2.5.2 Major Challenges Associated with Climate Change Education

As mentioned previously, a central aim of climate change education is to provide the youth with tools to adapt successfully to the impacts associated with climate change. In addition, climate change education seeks to increase awareness regarding the issue and inspire behaviour, value and attitude changes in these individuals so that they can contribute towards reducing the threat (UNESCO, 2009a, b). However, there are a number of challenges associated with ensuring the success of climate change education. First, for climate change education to achieve its key objectives, it has been suggested that it needs to be integrated into all educational agendas and policies (UNESCO and UNEP, 2011a). However, this integration will require an almost entire restructuring of such agendas and policies. This represents a major challenge, as it calls for an immense amount of support from policy makers, and cannot solely be initiated and coordinated by educational practitioners (UNESCO and UNEP, 2011a).

A further challenge facing climate change education is that the time to effect change is running out. It has been emphasized that the next ten years are crucial as they “...represent our last opportunity to drastically curb greenhouse gas emissions and moderate significant climate change impacts” (Haslett et al., 2011, 4). Therefore, learners who are currently in school represent a crucial generation, as they will have the ability to bring about vital change through their behaviour and values (Haslett et al., 2011). In light of this, it is important that educators involved in climate change education develop pedagogies which equip students with the ability and skills to work towards curbing the threat of climate change.

Third, another challenge facing climate change education is the various ‘barriers’ which prevent meaningful engagement in contributing toward mitigating climate change among lay individuals (United Nations, 2010). For instance, the United Nations (2010) highlights that, in certain countries and contexts, infrastructure, social dynamics and political systems do not support meaningful change in environmental behaviours, attitudes and lifestyles. This is particularly demonstrated by a finding which shows that

many countries have yet to impose policies which encourage and support environmentally friendly lifestyles. Political barriers are recognised as playing a key role in hindering lay individuals, and particularly the youth, from meaningful civic engagement. Although the value of youth participation in political processes is widely accepted, the equally important role which youth may 'actively' play in decision making processes and informing better policy outcomes is still largely unrecognised (United Nations, 2010). As a result of this, while the youth are generally able to participate in decision making processes, these individuals are often not awarded the right to overtly influence such processes. This may ultimately minimise the potential for youth to act as catalysts for positive environmental and social change (United Nations, 2010).

Another major challenge regarding climate change education is a growing phenomenon known as 'green fatigue' (Haslett et al., 2011). Green fatigue refers to attitudes of disinterest and apathy developing among members of the general public toward the issue of climate change. It has been found that levels of green fatigue among lay individuals have been increasing over the past years (Shields, 2010). It could be suggested that the reason for this is twofold. First, over the past decades society has been made increasingly and consistently aware of the growing threat of climate change, through a variety of channels, such as the media and political leaders (Thorne, 2009). It has been found that this continual exposure to, and hype regarding, climate change has made lay individuals disinterested in and disenchanted with the issue (Thorne, 2009; Shields, 2010; Haslett et al., 2011). The mass media has, arguably, contributed to heightened levels of green fatigue among lay individuals. It has been reported that generally the mass media sensationalises climate change (Weingart et al., 2000). Examples of this sensationalism include mass media portraying climate change as a severe environmental issue, which is likely to have catastrophic global consequences (Weingart et al., 2000; Carter, 2006). This sensationalism has led to many members of the general public feeling overwhelmed by the mass media's portrayed scale and extent of climate change. Swim et al. (2009) report that as a result of this lay individuals have developed attitudes, indicative of green fatigue, of indifference toward climate change believing that its progression is beyond their control. Thus, green fatigue has led to a large portion of society becoming apathetic about climate change and unwilling to act to prevent it from worsening (Shields, 2010). Haslett et al. (2011) suggest that there is evidence of green fatigue among learners, who

“...are increasingly ‘over-saturated’ and disinterested in learning about climate change” (Haslett et al., 2011, 6). Thus, green fatigue represents a considerable challenge to climate change education as it means that learners will become less willing to engage meaningfully with the topic (Haslett et al., 2011).

In addition, a major component of climate change education is teaching learners the key negative impacts of climate change, such as loss of human and animal life, sea level rise and drought (Haslett et al., 2011). However, some have argued that alarmist teaching has prompted some learners to develop green fatigue and become despondent, feeling that they cannot contribute to mitigating the threat due to its severity and scale (Wilson, 2007; Haslett et al., 2011). This presents a further challenge to climate change education, as it has prompted a drop in learner interest in the topic (Haslett et al., 2011).

For climate change education to be successful it needs to draw on and integrate a variety of disciplines and use a problem-solving based approach to teaching and learning. Thus, another fundamental challenge facing climate change education is to avoid becoming rooted in traditional educational approaches, which are single disciplinary and promote narrow and limited thinking (Haslett et al., 2011).

Finally, the call for teachers to integrate climate change into classroom topics has become increasingly pressing (UNESCO and UNEP, 2011a). This integration is proving to be challenging for many teachers, as climate change is a hugely complex and scientific topic, often difficult to comprehend, and even harder to teach to learners (UNESCO and UNEP, 2011a). However, in order to address this challenge, a number of guides have been developed which aid teachers in their understanding and teaching of climate change. Two of the most recent of these have been published by UNESCO and UNEP (2011a) and UNESCO and UNEP (2011b). These guides provide teachers with an easy to understand outline of climate change, and the aspects closely linked to, and affected by the phenomena (UNESCO and UNEP, 2011a, b). In addition, the guides draw attention to various mitigating and adaptation strategies and provide references for additional resources which teachers can refer to. It is important to highlight that the guides emphasize the relevance and value of climate change education in schools. Guides such as these are vital if climate change is to be effectively incorporated into classroom topics.

2.5.3 The Importance of Pedagogic Content Knowledge in Climate Change Education

The notion of Pedagogical Content Knowledge (PCK) was developed in 1987 by an educational researcher, Lee Shulman, and has ultimately contributed towards expanding understandings of teaching and teaching methods (Solis, 2009). Shulman (1987) introduced the notion of PCK, believing that teachers' subject knowledge and their pedagogical knowledge should no longer be considered as separate entities, but should rather be blended and merged. Thus, PCK is a theoretical framework concerned with encouraging the joining of these two forms of knowledge. Shulman (1987) defines PCK as teachers' knowledge of how to represent and explain subject matter covered in the classroom so that it is clear and understandable to learners (Archambault and Crippen, 2009). Shulman (1987) emphasizes that PCK includes teachers' knowledge of the aspects of subject content learners may battle with, and the preconceptions or misconceptions based on their personal backgrounds and contexts which learners may have towards topics. PCK consists of the ability to apply the correct teaching strategies to counteract any shortfalls in student knowledge (Archambault and Crippen, 2009). With this outline in mind, it can be seen that PCK can be described as a crucial foundation for teaching, whereby educators hold a deep understanding of the subject which they teach, and of a variety of teaching strategies to aid students in their learning of subject content (Rojas, 2008).

To develop a rich and well founded PCK, it is crucial that teachers take a number of steps (Juang et al., 2008). First, it is vital that teachers become involved in a variety of aspects of education, such as curriculum development. In addition, to develop their PCK, it is important that teachers take part in "...research based activities, the application of learning in everyday classroom practice, information technology, and collaborative learning..." (Juang et al., 2008, 147). Finally, Griffen et al. (1996) suggest that in order for educators to build their PCK, it is vital that they constantly enhance their knowledge of teaching methods and approaches.

PCK has been recognised as one of the most important conceptual frameworks a teacher must perfect, and has gained immense popularity in approaches to education (Juang et al., 2008). In terms of climate change education, it is vital for teachers to develop a sound pedagogical content knowledge for a number of reasons (McCaffrey and Buhr, 2008). First, climate change has been noted as being an extremely scientific and complex issue, and as such, it is

vital that teachers are able to present it in a way which provides learners with a clear and comprehensive understanding of the topic. As highlighted earlier, PCK provides teachers with the knowledge base from which to do this (McCaffrey and Buhr, 2008; Archambault and Crippen, 2009). However, it is also important that teachers are able to extend education regarding climate change beyond the scientific facts, to give learners the relevant tools and practical knowledge to successfully adapt to, and mitigate against, climate change (UNESCO and UNEP, 2011a). It could be argued that a sound PCK gives teachers an excellent foundation from which to do this.

Secondly, it has been illustrated by a number of studies that many learners hold a number of misconceptions regarding climate change (Bostrom et al., 1994; Bjorn and Wallin, 2000; Kilinc et al., 2008; Shepardson et al., 2009;). Thus, in this regard PCK is essential, as it will give teachers the ability to recognise prevalent misconceptions and put in place strategies to correct them, ensuring that students are put on the correct path to making important environmental value, behavioural and attitude changes (UNFCCC, 2000; McCaffrey and Buhr, 2008). It is important to highlight that many teachers themselves have also been found to hold numerous misconceptions regarding climate change (Dove, 1996; Groves and Pugh, 1999; Khalid, 2003; Papadimitriou, 2004; Bozodogan, 2009; Boon, 2010; Coskun and Aydin, 2011). However, it could be argued that if teachers develop a robust PCK, their own misconceptions will be corrected. It is important that teachers hold minimal misconceptions regarding climate change, as there is a danger of teachers passing on such incorrect conceptions to learners (Khalid, 2003).

2.5.4 The Importance of Education for Sustainable Development as a Framework for Climate Change Education

Traditionally, climate change education was placed in the realm of hard science, where it was taught only in relation to “...atmospheric composition and process from a natural science perspective” (UNESCO and UNEP, 2011a, 55). However, increasingly it has been emphasized that climate change education needs to be extended beyond this, and integrated into a variety of disciplines, if it is to achieve its ultimate aims and objectives (UNESCO and UNEP, 2011a).

With this in mind, it has been suggested that Education for Sustainable Development (ESD) represents an ideal framework to guide climate change education towards successfully achieving its primary aims and objectives (United Nations, 2010; UNESCO, 2010; UNESCO and UNEP, 2011a,b). There are a variety of reasons for this. First, ESD provides a basis for education regarding a spectrum of "...environmental, social, economic, ethical and political issues" (UNESCO and UNEP, 2011a, 56; UNESCO and UNEP, 2011b). Therefore, it provides the perfect platform from which to help lay individuals understand the assortment of impacts linked to climate change, and ensures that the issue is integrated into a range of disciplines. Second, ESD is extremely flexible, which allows it to be applied in a variety of ways so that it is appropriate and pertinent for the setting in which it is being implemented (UNESCO and UNEP, 2011a). Thus, when used as a framework for climate change education, ESD guarantees that climate change is given deeper meaning, importance and relevance to learners. ESD promotes active learning and creative ways of contextualising climate change so the issue becomes real and relevant (UNESCO, 2009a,b). This provides an ideal framework for developing skills, knowledge and behaviour change which may allow lay individuals to successfully adapt to and mitigate climate change (UNESCO, 2009a,b).

In addition, ESD and climate change education are essentially working towards similar goals of environmental preservation and protection, thus making the ESD framework perfectly matched to guide climate change education (UNESCO and UNEP, 2011a). Finally, ESD equips individuals with the ability to make decisions within the community and protect the environment (UNESCO, 2009a; UNESCO and UNEP, 2011a; UNESCO and UNEP, 2011b). This aspect of ESD highlights its value as a framework for climate change education, as these are important skills which need to be fostered to ensure the ultimate success of climate change education.

2.5.5 Environmental Education Approach in Climate Change Education

In the school environment, climate change education may not always be linked to a broader environmental education approach (UNESCO, 2009a,b). However, it could be argued that there is a strong relationship between the environmental education approach and climate change education. Thus it is vital that the two are linked as this will contribute to the success of climate change education in schools.

The formation of the environmental education approach and its gradual introduction into a variety of educational spheres and environments can be traced back to the 1960s (Sauve, 2005). It was during this time that environmental consciousness and concern among the world's leaders and citizens first emerged due to warnings of an environmental crisis as a result of anthropogenic activities (UNEP, 2002). These warnings and the resulting environmental concern have triggered a variety of landmark texts, conferences and events (Lotz, 1996). Examples of these are the United Nations Conference on Human Environment in 1972 and the United Nations Conference on Environment and Development in 1992, which resulted in the publication of Agenda 21 (UNEP, 2002). Environmental education was born through such responses, as they resulted in the formation of directive legislation, frameworks and principles such as the Tbilisi Declaration and the Belgrade Charter (Lotz, 1996).

In essence, environmental education seeks both to increase the world's understanding of the environment and its problems, and to teach individuals how to live sustainably (Pooley and O'Connor, 2000; Tihagale, 2004; Chawla and Cushing, 2007). In so doing the approach aims to bring about social transformation through developing the correct values, attitudes, knowledge, skills and motivation to allow citizens to participate meaningfully in matters concerning the environment (Hungerford and Vlok, 1990).

To achieve its aims and objectives, environmental education contains three major guiding approaches (Fien and Gough, 1996). These approaches are education *in*, *about* and *for* the environment. Education *in* the environment aims to increase environmental awareness through taking learners into the field and allowing them direct environmental experiences (Thomas, 2005). Fien and Gough (1996) highlight that through creating environmental awareness, education *in* the environment may help promote important attitude changes in learners.

Education *about* the environment acknowledges that to encourage behavioural change and action, it is imperative that learners understand and are knowledgeable about the environment and its issues (Fien and Gough, 1996; Thomas, 2005). Thus, this approach focuses on theoretical classroom-based learning about the "...natural systems and

processes and the ecological, economic and political factors that influence decisions about how people use the environment” (Fien and Gough, 1996, 232).

Education *for* the environment lies at the crux of environmental education. This final approach builds on education *in* and *about* the environment to help learners “... develop an environmental ethic and the motivations and skills necessary to participate in environmental improvement” (Fien and Gough, 1996, 205). There are four concepts and principles which guide education *for* the environment: interdependence, resource management, values and lifestyle choices, and social action (Fien and Gough, 1996). Briefly put, the principle of ‘interdependence’ suggests that humans and the environment are intricately linked and cannot be viewed in isolation of each other (Fien and Gough, 1996). Thus this principle suggests that environmental education should highlight this link to learners, so that all individuals across the globe have the obligation to ensure that both natural and social systems are preserved and protected to guarantee their own future wellbeing. The concept of ‘resource management’ refers to the sustainable use of the Earth's finite and renewable resources by humans (Fien and Gough, 1996). As humans rely almost entirely on natural resources for their day-to-day survival, resource management is of crucial importance. Thus, the principle of resource management seeks to assist students in growing an understanding and appreciation of the Earth's natural resources, which will ultimately allow and encourage them to make correct and enlightened choices regarding resource use (Fien and Gough, 1996).

The third principle emphasizes that the values and lifestyle choices of individuals affects the degree to which they impact the environment and its resources (Fien and Gough, 1996). This principle highlights the importance of creating environmentally responsible citizens whose values are shaped around environmental issues, who are able to recognise pressing environmental issues, and who can create viable solutions to environmental issues (Fien and Gough, 1996). Lastly, social participation examines individual’s perceptions and attitudes toward the environment and tries to encourage learners to become active environmental citizens (Fien and Gough, 1996).

As previously mentioned, climate change education ultimately seeks to increase learners’ knowledge and understanding of climate change, and through this inspire environmental attitude, behaviour and value changes which may lessen the effects of climate change

(UNESCO, 2009a,b). Thus, direct parallels between the aims of climate change education and the aims of the environmental education approaches can be drawn. With this in mind, it could be argued that utilisation of the environmental education approach in climate change education may ensure that climate change education is strengthened, and that students adopt important attitude, behaviour and value changes.

The four principles of interdependence, resource management, values and lifestyle choices and social action which guide education *for* the environment reinforce this point (Fien and Gough, 1996). Arguably these principles are relevant and useful to climate change education as they are pertinent to the mitigation of climate change.

2.6 Climate Change Education in the South African Context

This section examines the importance of climate change education in the South African context, with particular reference to its role in mitigation and achieving sustainable development. Secondly, this section focuses on the importance of the resources provided or available to educators for climate change education in South Africa. This is then linked to a discussion on the need for the evaluation of these resources. Finally, a brief outline of previous studies which evaluate textbooks used for climate change education is provided.

2.6.1 The Importance of Climate Change Education in South Africa

Climate change may have significant ramifications for the South African economy, environment and society (Archer et al., 2010; Davis, 2010; Madzwamuse, 2010). Arguably, in South African society, poorer individuals and marginalized communities with low adaptive capacities may be worst effected by climate change. The effects of climate change in South Africa are likely to have the greatest impacts on the resources on which citizens are most dependent, such as water and agriculture (Archer et al., 2010; Davis, 2010; Madzwamuse, 2010).

The South African government has recognised the urgency of lessening the potential impacts of climate change, by implementing a variety of mitigating measures and enhancing the adaptive capacities of South African citizens (DEAT, 2010; UNFCCC, 2000). In particular, the importance of climate change education as a strategy has been

recognised, and hence the South African government has made a commitment to educating lay individuals such as youth in primary and secondary schools and the general public about climate change (DEAT, 2010; UNFCCC, 2000). Evidence of this commitment is clearly demonstrated in a recent White Paper which outlines the South African government's 'National Climate Change Response' strategy (DEAT, 2010).

The value of climate change education in South Africa lies not only in its role in mitigation. Increasingly the South African government has shown a commitment to achieving sustainable development, and climate change education has been labelled as an excellent tool to facilitate this (UNESCO, 2010). Through highlighting aspects such as the intricate link between humans and the environment, climate change education is recognised as having the potential to help learners understand the significance of sustainable development (UNESCO, 2010). Linking to this, it is emphasized that through an increased awareness and understanding of climate change, learners may be able to take part meaningfully in mitigation activities which by extension promote sustainable development (UNESCO, 1997; UNESCO and UNEP, 2011a). In addition, through encouraging environmental attitude and behaviour changes in learners, climate change education has the potential to put South Africa on a path toward achieving sustainable development (UNESCO, 2010).

2.6.2 The Need to Evaluate Climate Change Education Resources in South African Schools

To contribute towards the success of climate change education in schools, the government has ensured that a variety of tools and resources are provided or made available to educators to facilitate their teaching of the subject (DEAT, 2005). The most important resources provided or available to teachers for climate change education are textbooks. Textbooks play a crucial role in fostering a meaningful teaching and learning process (Oakes and Saunders, 2002).

However, despite the clear importance of textbooks in climate change education, little evaluative research of these resources in the South African context has been conducted. The evaluative process is extremely important as it uncovers the features of textbooks which may need to be extended or improved upon to ensure that learners gain a sound

knowledge of topics (Kent et al., 1996). Thus, with regards to ensuring the success of climate change education in South Africa, it could be argued as emphasized being essential that an assessment of relevant textbooks occurs.

2.6.3 Previous Studies Evaluating and Assessing Textbooks used for Climate Change Education

There is currently very little research both internationally and locally which provides a critique of the textbooks used for climate change education, such as those utilized in Physical Science, Geography or similar disciplines. However, one study, conducted by Choi et al. (2010), presents analysis of eighteen climate change related concepts in seven Earth Science and Environmental Science textbooks used in American schools. The seven textbooks used in their study were selected for evaluation based “...upon their common use, their reach to varying audiences... for varying purposes” (Choi et al., 2010, 896).

The primary aim of their study was to examine the extent to which particular representations of climate change related concepts in those seven Earth Science and Environmental Science textbooks foster misconceptions of climate change among middle and high school students (Choi et al., 2010). The study sought to critique the value of selected textbooks for climate change education, through establishing the extent to which these textbooks built solid and accurate understandings of climate change and its related concepts. The climate change related concepts selected for analysis in their study were based on common misconceptions identified among high school and middle school students. These concepts included:

1. Distinction between weather and climate
2. Distinction between global warming and climate change
3. Distinction between the greenhouse effect and climate change
4. The probable causes of climate change
5. Distinction between pollution and greenhouse effects or climate change
6. The global temperature change so far
7. Distinction between the ozone layer and greenhouse gases in terms of the interaction with radiation
8. Climate change is already underway
9. The major sources and the kinds of greenhouse gases

10. Distribution of greenhouse gases in the atmosphere
11. The mechanism of the greenhouse effect
12. Solar irradiation and its possible impacts on current climate change
13. Projections of future climate changes according to emission scenarios
14. The dependency of human society on fossil fuel and barriers to reducing emission of greenhouse gases
15. How to mitigate climate change
16. Distinction between incoming and outgoing solar radiation
17. Selective absorption of radiation in the atmospheric gases
18. Distinction between the kinds of radiation and surface temperature

(Choi et al., 2010, 893)

The results from the study conducted by Choi et al., (2010, 894) indicated considerable differences between respective textbooks' "...presentation of climate change concepts". However, overall it was found that the majority of textbooks selected for analysis provide adequate basic scientific explanation of some of the key concepts pertaining to the greenhouse effect and climate change (Choi et al., 2010). These include: the distinction between weather and climate; the distinction between global warming and climate change; the distinction between the greenhouse effect and global warming; the degree of the current global mean temperature increase; the major sources and types of greenhouse gases; the mechanisms of the greenhouse effect; possible climate change mitigation strategies and the distinction between incoming and outgoing solar radiation (Choi et al., 2010, 894).

However, eight of the eighteen scientific climate change related concepts were not included in the majority of evaluated textbooks (Choi et al., 2010). Three of the seven textbooks used in their study were found **not** to differentiate between outgoing and incoming radiation and did **not** explain the links and differences between surface temperature and infrared radiation (Choi et al., 2010). Four textbooks did not detail the process of selective absorption of particular wavelengths in the atmosphere. Explanations of these two closely linked concepts are vital if students are able to adequately understand the greenhouse effect and its functioning (Choi et al., 2010). Six of the seven textbooks analysed in this study did **not** emphasise that greenhouse gases are scattered throughout the atmosphere. It is argued that this may perpetuate the common misconception found among many students that greenhouse

gases occur in a type of layer or lid in the atmosphere, beneath which heat is trapped (Choi et al., 2010). None of the textbooks selected for evaluation in their study provided a distinction between pollution, climate change and the greenhouse effect. Furthermore, in many cases textbooks were found to explicitly and erroneously link these concepts. This may foster the misconception apparent among some students that **all** types of air pollution contribute to and drive the greenhouse effect and climate change (Choi et al., 2010). Four textbooks did **not** make clear the difference between climate change and ozone layer depletion. The authors suggest that this may perpetuate the already prevalent misconception among students that the two processes are linked or related (Choi et al., 2010). None of the textbooks emphasized that climate change is currently in effect and has already had an impact on social and environmental systems on Earth (Choi et al., 2010). This may reinforce the misconception among some students that climate change will not have an effect on their surrounding environment or life whilst they are alive.

Thus, it is clearly demonstrated that many of the textbooks selected for analysis in the study conducted by Choi et al. (2010) contain a variety of flawed representations of key climate change concepts. These inadequate or inaccurate representations may ultimately enhance student misconceptions of climate change and its related aspects. Thus, the findings from these studies indicate that these textbooks may not be entirely useful for climate change education, and support the endeavour to study the value and accuracy of South African geography textbooks in this study.

2.7 Conclusion

Climate change is a far reaching, pressing issue that is likely to have a variety of environmental, social and economic impacts on South Africa (Adger et al., 2001; Madzwamuse, 2010). In light of this, the South African government has recognised the importance of ensuring that every effort is made to reduce climate change and minimise the scope of its potential impacts (UNFCCC, 2000). Thus, the government has adopted a variety of mitigating strategies, one of which is the incorporation of climate change education in schools (UNFCCC, 2000).

Climate change education has been highlighted as a vital strategy due to its potential to encourage the youth to change their habits and develop healthy environmental

behaviours, values and attitudes which may contribute toward effective climate change mitigation (UNEP, 2006a). In addition, climate change education is labelled as being an important means through which to provide learners with an enhanced knowledge and understanding of climate change and in so doing strengthening the adaptive capacities of these individuals (UNESCO and UNEP, 2011a). However, for this to occur, learners need to acquire an in-depth and robust understanding of climate change and related issues (Khalid, 2003). Essential to the acquisition of knowledge are the textbooks provided or available to educators who are teaching climate change education. These need to be structured to ensure that learners are able to fully engage with and understand the subject (Oakes and Saunders, 2002; Mohammad and Kumari, 2007). In addition, for learners to gain a clear understanding of climate change it is important that they are able to benefit from the knowledge of their teachers who, as a vital resource need to be free from misconceptions, limitations and inaccuracies in knowledge (Khalid, 2003).

This research seeks to evaluate the teachers' knowledge and perceptions of climate change and critique some of the textbooks for climate change education available to geography educators in Gauteng. As both of these aspects are under-researched in South Africa, this research provides a useful indication of areas that may need improvement or development. This may assist in ensuring that learners are educated about the topic in a way that will encourage them to become environmentally aware and active citizens.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

This chapter describes the qualitative methods selected to answer the research questions (reiterated below), and the rationale behind these choices. Firstly, the methodological approach used to uncover teachers' knowledge and perceptions of climate change is detailed and examined. In addition, the sample of teachers interviewed is outlined, and ethical considerations are explored. Attention then shifts to the methodological approach employed to critique textbooks available to geography teachers for climate change education. Lastly, the key limitations to this research are detailed.

RESEARCH QUESTIONS:

1. What are teachers' perceptions of climate change?
2. What are the misconceptions which teachers hold with regards to climate change?
3. How useful are the textbooks available to geography teachers for climate change education?

3.2 The Research Process

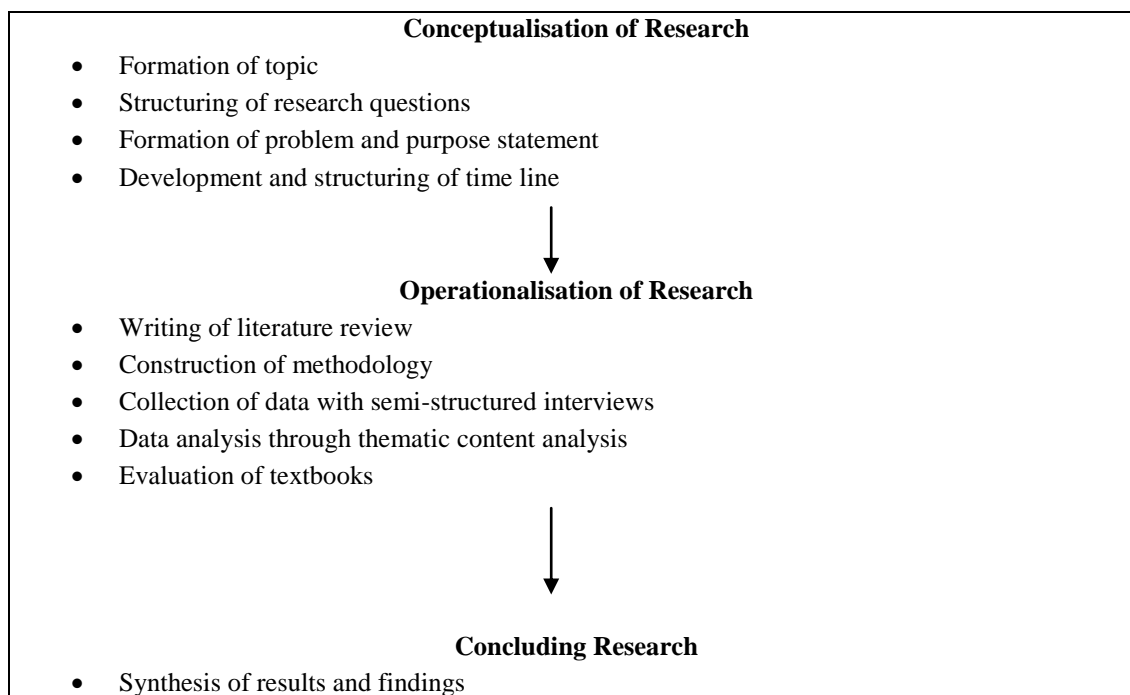


Figure 2: The Research Process (Adapted from: Badenhorst, 2010, p. 48)

3.3 Research Methods and Data Analysis:

3.3.1 Qualitative Research and Design:

This research employs qualitative research methods which are concerned with documenting and understanding social phenomenon and multiple realities from a variety of individuals (Schmacher and McMillian, 1993). Thus, qualitative research methods “...involve documenting real events, recording what people say (with words, gestures and tone), observing specific behaviours, studying written documents...” (Neuman, 1997, 328).

There are two major qualitative research designs: experimental design and non-experimental design. In non-experimental design the researcher records and studies certain realities and experiences of participants (Schmacher and McMillian, 1993). As this research is concerned with the realities and experiences of teachers, with regard to their perceptions of climate change, non-experimental design was employed.

One of the major types of non-experimental design is that of surveys (Schmacher and McMillian, 1993). Surveys are ideal for this type of research as they are the most accurate way to ascertain a participant’s perceptions, attitudes and beliefs about a certain topic or issue. The primary method of collecting data in survey research is through either administering questionnaires or conducting interviews (Schmacher and McMillian, 1993). The primary method of obtaining data in this research was through semi-structured interviews, conducted with geography teachers from both private and government schools. In keeping with the parameters of qualitative research, results from the interviews are represented in the form of words and observations made during the interviews (Neuman, 1997).

3.3.2 Semi-Structured Interviews

The survey used in this research is in the form of standardised semi-structured interviews conducted with each teacher (refer to *Appendix A*). Each of these interviews were recorded and transcribed.

There are a number of advantages associated with the use of standardised semi-structured interviews in research. A set of standardised questions allows for the researcher to maintain control over the interview process, and over the process of gaining information from participants (Bassey, 2006). In addition, the nature of semi-structured interviews permits the researcher to ask “...additional questions to follow up on any interesting or unexpected answers to the standard question” (Mitchell and Jolley, 2013, 302). Follow up questions are useful as they can yield unexpected findings which may add value to the overall research (Knox and Burkard, 2009). In addition, follow up questions give room for complexity and individuality in participant responses which enrich data and findings (Hill et al., 2005).

However, it is important to note the limitations which are associated with the use of follow-up questions in the interview process. First, follow-up questions are not standardised, thus each interviewee may be asked different and varying follow-up questions at any point during the interview. The result of this may be elements of a data set which are not uniform and thus difficult to analyse and fit into the overall findings of the study (Mitchell and Jolley, 2013). Another limitation of follow-up questions relates to the freedom they give researchers to decide “...which answers to probe and how to probe them” (Mitchell and Jolley, 2013, 302). This may create the potential for a researcher to ask leading questions, and thus bias overall results and findings. During this research these concerns were taken into account, and with every interview effort was made not to select follow up questions which would bias results or findings.

In this research the interview questions were structured in the form of open-ended questions. Open-ended questions allow for the researcher to grasp a participant’s view point on a particular topic, and give participants the freedom to respond in their own words (Neuman, 1997; McBurney, 1998). This questioning style is best suited to this project, as the ultimate aim of this research is to gain a unique understanding into the perceptions of and knowledge about climate change held by teachers.

3.3.2.1 Analysis of Semi Structured Interviews

In keeping with the qualitative data collected, thematic content analysis was employed to analyse open ended questions. Thematic content analysis is used widely as a qualitative

analytic method as it allows for “rich and detailed, yet complex account of data” (Braun and Clarke, 2006, 86).

Thematic content analysis is concerned with the identification of themes or patterns that emerge from data (Braun and Clarke, 2006). A realist approach to thematic analysis was adopted where teachers’ own unique understandings and perceptions of climate change have been captured (Braun and Clarke, 2006). The following phases suggested by Braun and Clarke (2006) to guide thematic content analysis were followed in this research to ensure a rigorous and methodologically sound approach.

Phase one states that the researcher should become familiar with the data set (Braun and Clarke, 2006). Familiarisation occurs through transcribing data, reading through the data set a number of times, writing down initial ideas, and taking note of any emerging patterns or themes. Phase two involves the researcher creating codes from the collected data. Codes refer to any part of the data which the researcher finds particularly interesting or important, and in addition pertain to “...the most basic segment, or element, of the raw data or information that can be assessed in a meaningful way regarding the phenomenon...” (Braun and Clarke, 2006, 88). Thus, the process of coding allows for a researcher to arrange data into meaningful sets.

The third phase of thematic content analysis may be initiated once a researcher has coded their data. By this stage a researcher should ideally have a lengthy list of codes which have been documented from across the data set. In the third phase of thematic analysis the different codes are examined in relation to how they may form a dominant theme or sub-theme (Braun and Clarke, 2006). Therefore, once this phase is completed, the researcher should have a number of potential themes and sub themes and all the extracted elements of data which correspond to these themes (Braun and Clarke, 2006). In the fourth phase the chosen themes are closely examined and critiqued. In so doing, the researcher may identify certain themes which do not have sufficient data to validate them and need to be removed, or two or more themes which can be merged into one. The ultimate outcome of the fourth phase should be a refined set of themes. In addition, by the end of the fourth phase, the researcher should be well acquainted with the various themes (Braun and Clarke, 2006).

The fifth phase of thematic content analysis requires the researcher to engage with themes at a deeper level (Braun and Clarke, 2006). Thus, it is during this phase that a researcher actively engages with themes through developing a comprehensive understanding of each theme and its data. Once this is established, a researcher should commence with a detailed analysis of each theme and its respective data. In addition, Braun and Clarke (2006) suggest that in this phase it is important that a researcher determines what each theme contributes to the overall research, through establishing how each theme relates to the research questions. The final phase involves the final report write up on the findings related to the data collected under each of the themes. In short the report should provide a detailed account of the data which communicates and illustrates the benefit and value of the research (Braun and Clarke, 2006).

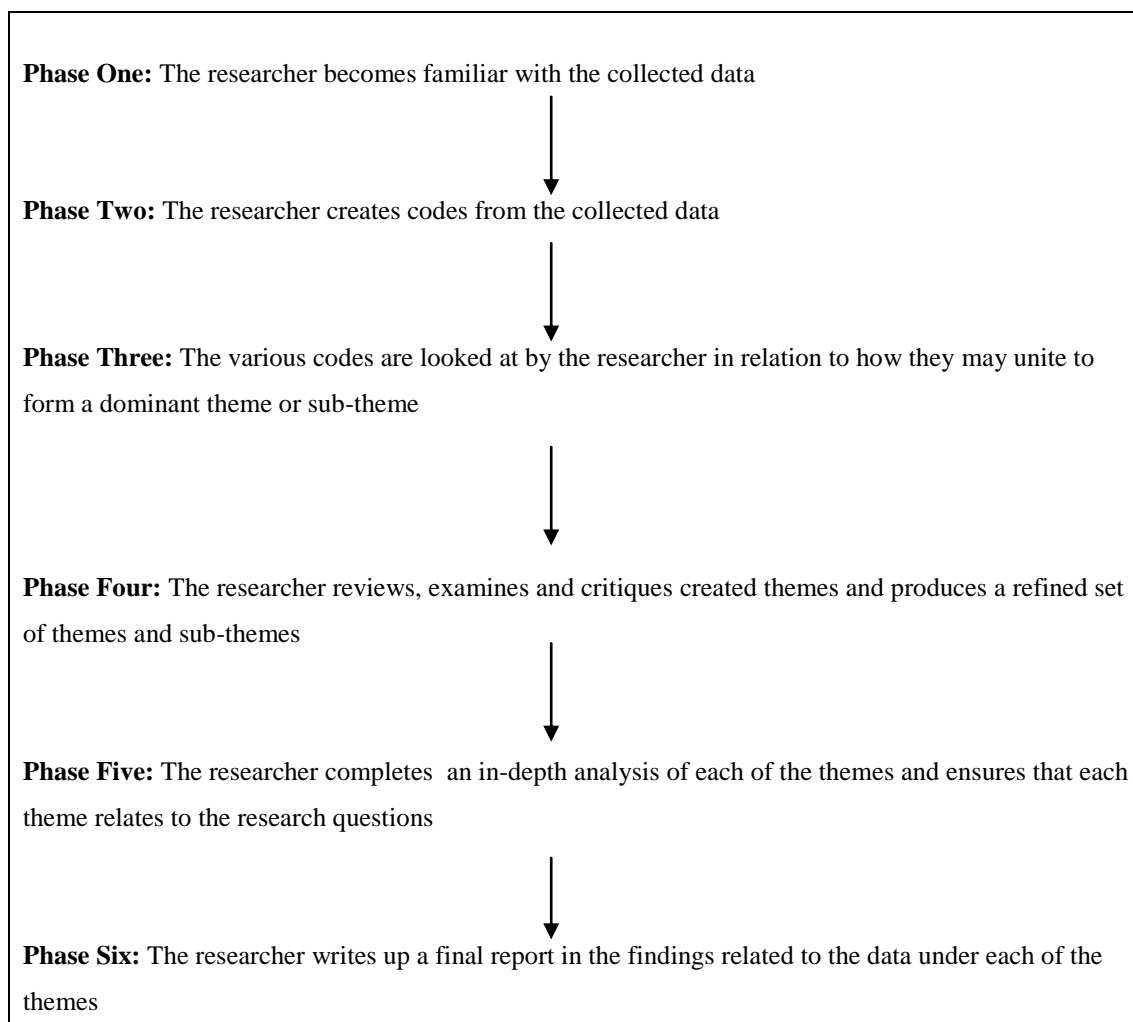


Figure 3: The Process of Thematic Analysis (Adapted from: Braun and Clarke, 2006, p. 93)

There are a number of advantages associated with the use of thematic content analysis for analysing qualitative data (Braun and Clarke, 2006). First, thematic content analysis is classified as being easy to understand and conduct. This characteristic makes the method widely accessible to researchers, regardless of the degree of research experience (Braun and Clarke, 2006). Another strength of thematic content analysis lies in its ability to add meaningfully to research through generating unexpected results or findings. Furthermore, an additional recognised benefit of the method is that it allows for key aspects of extensive or lengthy data to be summarised. In addition, thematic content analysis allows for a rich description of data by the researcher (Braun and Clarke, 2006). A further advantage is that the method allows for both similarities and dissimilarities to be identified across a data set. The results yielded through thematic content analysis are usually assessable and understandable to lay individuals (Braun and Clarke, 2006).

There are a number of disadvantages tied to thematic content analysis. A key disadvantage lies in the characteristic flexibility of the approach, which allows for a variety of analytic choices (Braun and Clarke, 2006). Although this aspect is in some ways advantageous, ultimately it may make it difficult for a researcher to select specific parts of data to focus on. Other disadvantages of thematic content analysis become clear when the method is compared to other approaches used in qualitative analysis. For instance, unlike a narrative centred approach, thematic content analysis does not allow for an individual account which may compliment or oppose data to be specifically recognised (Braun and Clarke, 2006). Ultimately, the presence of such individualised consistencies or contradictions may add unique value and insight into research. However, despite these disadvantages, Braun and Clarke (2006, 96) emphasize that overall the majority of disadvantages associated with thematic content analysis “...depend more on poorly conducted analysis or inappropriate research questions than on the method itself”.

3.3.3 The Use of Diagrams and Explanatory Paragraphs to Assess Knowledge of the Greenhouse Effect

Qualitative interviewing can be used as one of many approaches to address a study’s research questions (Mason, 1996). Documents are often used in addition to, or in conjunction with, interviews to add a different dimension or greater depth and insight to a study. Documents are usually defined and understood as being text-based, for instance

diaries and newspapers (Mason, 1996). However, drawings, pictures and cognitive maps, for example, can also be defined as documents. Mason (1996) explains that these visual documents can either be pre-existing or a researcher can ask a participant to produce a picture or cognitive map which relates to some aspect of the study.

Teachers were asked during the interviews to draw a diagram of the greenhouse effect and explain their diagram in a short paragraph. The greenhouse effect is a vital base from which climate change and its related concepts may be understood (Shepardson et al., 2011). Inaccurate understandings of the greenhouse effect may indicate crucial misconceptions regarding climate change. Thus, assessing teachers' understanding of the greenhouse effect through diagrams and written paragraphs serves as a further means of identifying teachers' knowledge of climate change.

3.3.3.1 Analysis of Diagrams and Explanatory Paragraphs

Each diagram was examined, and the accuracy and conceptual perceptions demonstrated were assessed. The diagrams were used in conjunction with the data from the interviews. In addition, the accompanying written paragraphs were analysed through the use of thematic content analysis. Themes identified through the analysis of the paragraphs were then linked to themes which emerged during the analysis of the interviews. This process ultimately serves to triangulate and strengthen results.

3.4 Sample

3.4.1 Criteria and methods for the selection of participants

To investigate teachers' perceptions of climate change, both male and female geography educators from private and government schools who teach learners from grade 10 to grade 12 (FET level) in Gauteng Province, South Africa were interviewed. When selecting teachers to interview, an even spread between the Heads of Departments and post-level 1 teachers was achieved to ensure optimum research findings.

As a base from which to select teachers to be interviewed, a pre-determined number of private and government high schools were chosen using purposeful sampling. Once high schools had been identified, purposeful sampling was employed to select teachers for

interviewing. Purposeful sampling is used by researchers who “...base a survey on a sample that is chosen to meet some particular definition” (McBurney, 1998, 160). This method compliments this research as there is a clear definition of the required sample for the research. Purposeful sampling also encourages the selection of suitable and knowledgeable participants, and thus allowed for and encouraged in-depth and informative data to be collected and analysed (Schmacher and McMillian, 1993).

3.4.2 Sample Size

Six private and ten government high schools located in Gauteng were chosen via purposive sampling. Five of the ten selected government schools are located in township areas in Gauteng to allow for a diversity of government schools and teachers. To maintain the anonymity of teachers and schools, the selected schools are not named. From each of the chosen high schools, two FET level geography teachers who teach geography were interviewed. Twelve private school teachers and twenty government school teachers were interviewed. A total of 32 teachers participated in this research.

3.5 Textbook Evaluation

3.5.1 Methodological Approach to Textbook Evaluation

An additional component of this research includes a critique of some of the textbooks available to geography teachers for climate change education. The following textbooks were chosen for evaluation and analysis in this research:

- Focus on Geography (Grade 10, Grade 11, and Grade 12),
- Geography for all (Grade 10, Grade 11, and Grade 12)
- Oxford In Search of Geography (Grade 10, Grade 11, and Grade 12).

These textbooks were selected for evaluation based on the interviews conducted with geography teachers. During interviews (refer to *Appendix A*) teachers were asked which textbooks they use to facilitate their teaching of climate change. Thus, the above textbooks were selected for evaluation as they were found to be the most frequently used by interviewed teachers for teaching climate change. Each of the above textbooks selected for analysis were written in accordance with the stipulations and guidelines of

the Republic of South Africa's, Department of Education's Revised National Curriculum Statement (RNCS) for Geography at FET level (DoE, 2008a,b).

The extent to which textbooks provide relevant, accessible and accurate information was critiqued. Textbooks were categorised according to set criteria developed by the researcher (see *Table 7*, below). This set of criteria (*Table 7*) will be described and defined in greater detail in *Chapter 5*. In developing this set of criteria, the criteria employed in a similar study conducted by Choi et al. (2010) were considered and integrated. In addition, the criteria used were generated with the ultimate aims and objectives of climate change education in mind. Thus, the criteria used in this research allows for a sound and meaningful assessment of the value of textbooks for climate change education.

Table 7: Criteria for the Textbook Assessment

1.	Textbooks which enhance understanding of the greenhouse effect	Textbooks which do not enhance understanding of the greenhouse effect
2.	Textbooks with sufficient coverage of climate change	Textbooks with insufficient/scanty coverage of climate change
3.	Textbooks which contain entirely accurate information about climate change	Textbooks which contain inaccuracies in information about climate change
4.	Textbooks which make climate change relevant and applicable to the South African context	Textbooks which do not make climate change relevant and applicable to the South African context

3.6 Limitations to Research

Although this research was carefully prepared and conducted, there were some unavoidable limitations. These will now be briefly discussed and outlined.

3.6.1 Sample Size

A key limitation to this research is a relatively narrow sample size. Thirty-two FET geography teachers from government and private schools located in Gauteng were interviewed for this research. In Gauteng, there is a diversity of private and government schools which, generally, require one or more teachers qualified to teach the subject of geography at FET level. Therefore, the number of individuals who participated in this research is a small representation of the total number of FET geography teachers in Gauteng. As a result of this limitation, the findings of this research cannot be generalised to the broader

community of FET geography teachers in Gauteng. However, it is statistically improbable that the findings from this research are limited to the sample group. Thus, this research may reflect trends in knowledge and perceptions of climate change which may be prevalent among a portion, beyond the sample group, of FET geography teachers in Gauteng.

3.6.2 Teacher Anxiety Surrounding Interviews

None of the teachers approached for participation in this research declined. However, a number of teachers were initially reluctant to be interviewed. It emerged that a reason for their reluctance was anxiety around the belief that, if responses to the interview questions were not consistently accurate or correct, it would reflect badly on them as geography teachers, particularly as their answers would appear in this thesis. These teachers eventually agreed to be interviewed once it had been explained that, for ethical reasons, teachers' names and places of work would not be used in this thesis. However, it could be suggested that, despite their eventual willingness to participate, concern and anxiety may have caused them to be more guarded during interviews.

In other cases teachers stated during the interview that they had concerns over the accuracy of their answers and how this may reflect on them as geography teachers in days leading up to the interview. The majority of these teachers confided that as a result of this concern, they had refreshed their knowledge of climate change through additional reading. This may result in some findings not being an entirely accurate representation of teachers' **personal** perceptions and understandings of climate change, or their previous teaching of climate change to learners.

3.6.3 Teachers' Qualifications

During interviews teachers were not required to disclose their place of training or highest academic qualification. With hindsight, this may have been an important consideration, as such factors could potentially have played a crucial role in developing teachers' attitudes toward and perceptions and understandings of climate change. However, none of the teachers interviewed were in their first year out of university. Consequently, the majority of the information which teachers may have gained during university study is most probably outdated, and their knowledge is more likely to be influenced by current discussions in the media and in textbooks.

3.6.4 Textbook Evaluation

South African education policy and guidelines are presently undergoing a period of change and reformation (DBE, 2011a). In 2009, the Department of Basic Education (DBE) made a call for the present Revised National Curriculum Statement (RNCS) to be reviewed. The outcome of this review pointed towards a distinct lack of clarity in the RNCS, and suggested that a number of improvements be made to the curriculum (DBE, 2011a). In light of this, the DBE took the decision to modify the RNCS, and thus, "...a single comprehensive Curriculum and Assessment Policy (CAPS) was developed for each subject..." (DBE, 2011b, 3). This amendment will be gradually phased into each schooling level from 2012 to 2014, and will effectively "...replace Subject Statements, Learning Programme Guidelines and Subject Assessment Guidelines in Grades R- 12" (DBE, 2011b, 3).

The implementation of CAPS is significant with regards to this research, as it has meant that the textbooks which are being used in the present curriculum will be rewritten and changed in line with the requirements and modifications apparent in CAPS (DBE, 2011a). This research critiques the value of Grade 10-12 (FET) NCS geography textbooks for climate change education. This therefore represents a key limitation of this research, as the textbooks selected for assessment are those which will be gradually replaced by updated textbooks which follow the guidelines of CAPS. However, despite this, it could be suggested that such an assessment is still valuable as it will open doors for a follow-up study to be done in the future which evaluates CAPS textbooks. This will be interesting and important as it will allow a comparison between the evaluation of the RNCS textbooks in this research and the future CAPS textbooks. In addition, as CAPS is being phased in over a two year period, many of the textbooks for FET level geography may not be in the process of being rewritten yet. Thus, this research may assist authors in identifying the best possible ways in which to write about climate change so that learners can meaningfully engage with the topic. Furthermore, it is likely that NCS geography textbooks may still be used a resource for teaching climate change in conjunction with textbooks updated in line with CAPS. Thus, the assessment may still act as a useful guide for teachers with regard to ensuring meaningful climate change education.

Nine FET geography textbooks were selected for evaluation as they were found to be used most frequently by interviewed teachers for climate change education. However, these texts represent only a small percentage of textbooks which are available and could be used by geography teachers for climate change education at FET level (under the NCS). Thus, overall findings relating to the evaluated textbooks value for climate change education cannot be generalised to **all** geography textbooks which may have been used for climate change education under the NCS.

3.7 Ethical Considerations

The teachers who were interviewed in this research do not fall into a vulnerable group category, thus it was not necessary to submit an ethics clearance application to the University of the Witwatersrand's Ethics Committee. However, an application for permission to conduct this research was submitted to the Gauteng Department of Education (GDE). Only once permission had been granted by the GDE did the research commence (*Appendix B*).

Once the research was approved by the GDE, a formal letter was written to the heads of respective schools requesting permission to interview FET level geography teachers from their schools (*Appendix C*). The letter included a brief outline of the research, and an estimation of the amount of time that would be spent interviewing each teacher. Only once this permission was obtained, were teachers approached for interviews.

Before conducting the interviews, all aspects of the research, such as the aims and how the findings will be used, were explained to each teacher. All teachers were then required to sign a consent form (*Appendix D*). Teachers were requested to sign a further consent form for the taping of interviews (*Appendix E*). To ensure the anonymity of teachers interviewed, teachers' names and their places of work are not listed at any point in this thesis.

With regard to the textbooks selected for assessment in this research, minimal ethical considerations were required. It was recognised that there was no need to ensure the anonymity of the textbooks selected for assessment in this research, as these textbooks have

been published in the public domain and thus inferences as to their use for climate change education are free to be made by any individual for any purpose. In addition, the selected textbooks are written following the guidelines of the RNCS and are currently in the process of being replaced by new textbooks written in accordance with the new CAPS syllabus, thus the findings of this research are unlikely to have any impact on subsequent sales of the textbooks.

CHAPTER FOUR: TEACHERS’ KNOWLEDGE AND PERCEPTIONS OF CLIMATE CHANGE

4.1 Introduction

In this chapter teachers’ perceptions of climate change and its related aspects are explored. Firstly, teachers’ knowledge and understanding of the greenhouse effect is outlined. Focus then shifts to a detailed exploration of teachers’ understandings and perceptions of climate change. Thirdly, an examination of the sources of information which teachers rely on for information on climate change is provided. Lastly, teachers’ attitudes toward climate change are detailed.

4.2 Teachers’ Understanding of the Greenhouse Effect

This section explores the level of teachers’ knowledge and understanding of the natural and enhanced greenhouse effect. This represents an important aspect of investigation, as it could be suggested that teachers’ understanding of both the natural and enhanced greenhouse effect is vital for a full comprehension of climate change. These processes act as a foundation from which to grasp climate change and its related aspects (Shepardson et al., 2011).

In this section a brief outline of the mechanism of the greenhouse effect is first provided. Teachers’ knowledge of the gases involved in the greenhouse effect is then explored. This is followed by a discussion of teachers’ understanding of the functioning of the greenhouse effect. The discussion is accompanied by an explanation and justification of the considerations made when evaluating teachers’ knowledge of the natural and enhanced greenhouse effect. Finally the most prevalent misconceptions relating to the greenhouse effect held by teachers is outlined.

4.2.1 The Process of the Greenhouse Effect

The ‘natural greenhouse effect’ is a term used to describe the process by which the Earth is heated (IPCC, 2007a; Houghton, 2009). During this process incoming (short wave) radiation

makes contact with, and is absorbed by, the Earth's surface. Not all incoming radiation reaches the Earth, some is reflected back into space by clouds and dust particles before it reaches the Earth. A percentage is also reflected by "light-coloured areas of the Earth's surface..." due to the albedo effect (IPCC, 2007a, 96). In order to maintain a balance of energy, the radiation which is absorbed by the Earth is re-emitted back into space as long wave radiation (IPCC, 2007a; Houghton, 2009). Some of this outgoing radiation is trapped by greenhouse gases, such as carbon dioxide and water vapour, which are present in the Earth's atmosphere. This trapped heat is then re-emitted back to Earth. The greenhouse effect thus ensures that the Earth is suitable for life by keeping it at a constant warm temperature (IPCC, 2007a; Houghton, 2009).

The concentration of greenhouse gasses present in the atmosphere will greatly affect the amount of radiation trapped in the atmosphere, compared to that which is lost. The IPCC (2007a) asserts that due to a rise in certain anthropogenic activities, such as deforestation and the burning of fossil fuels, the level of greenhouse gases in the atmosphere has intensified. This has resulted in more radiated heat being trapped in the Earth's atmosphere (IPCC, 2007a; Houghton, 2009). This process has been named the 'enhanced greenhouse effect', and has caused a rise in average temperatures on Earth. This general rise in temperature has resulted in a myriad of differing changes in climate across various regions of the world (IPCC, 2007a, Houghton, 2009).

4.2.2 Teachers' Conceptions of the Gases Involved in the Greenhouse Effect

To ascertain which gases are perceived as contributing to the greenhouse effect, teachers were asked to name "...the major greenhouse gases" (*Appendix A*, Question 4). *Table 8* below, details the gases identified by teachers, and the percentage of teachers who identified those gases. It should be noted that the percentages displayed in *Table 8* do not total 100. This is because of the open-ended nature of the question which meant that some teachers offered more than one response.

Table 8: Greenhouse Gases Identified by Teachers

Greenhouse Gases Identified by Teachers	Percentage of Teachers who Identified Respective Greenhouse Gases (%)
Carbon dioxide	88
Methane	59
Water vapour	34
CFCs	31
Sulphur dioxide	22
Carbon monoxide	13
Ozone	9
Nitrogen	9
Nitrous oxide	6
Oxygen	6
Argon	6
Helium	3
Hydrogen	3
Smoke	3

In examining teachers' conceptions of the key greenhouse gases two major themes emerged: correct knowledge of the key greenhouse gases and limited or inaccurate knowledge of the key greenhouse gases.

4.2.2.1 Correct Knowledge of the Key Greenhouse Gases

Scientists have named several greenhouse gases. These include, but are not limited to, carbon dioxide (CO₂), chlorofluorocarbons (CFCs), methane (CH₄), nitrous oxide (N₂O), water vapour (H₂O(g)) and ozone (O₃) (Dove, 1996; Bozdogan, 2009; Coskun and Aydin, 2011). Of these gases, the most important or 'key' are considered to be: carbon dioxide; methane, nitrous oxide and water vapour (Dove, 1996; IPCC, 2007a).

As shown in *Table 8* (p. 61), 88% of individuals correctly named carbon dioxide as a major greenhouse gas. However, a significantly lower percentage named other important greenhouse gases such as methane, water vapour or CFCs. This finding suggests that teachers mainly attribute carbon dioxide to contributing to the greenhouse effect, but have little knowledge of the other greenhouse gases which play a role in this process. This finding is reflected in similar studies mentioned in the literature review (Dove, 1996; Khalid, 2003; Papadimitriou, 2004; Boon, 2010).

Information provided by the mass media is a possible reason for teachers being most aware of carbon dioxide as a greenhouse gas. Dove (1996) and Khalid (2003) both assert that the media has generally focused exclusively on carbon dioxide's role in the greenhouse effect

and has in many instances labelled it as the only greenhouse gas. As will be highlighted in *Section 4.2*, the majority of teachers stated that their knowledge of climate change and its related aspects is primarily acquired from the mass media. Thus, it is likely that many of these teachers are primarily aware of carbon dioxide as a greenhouse gas due to the influence of the mass media.

As shown in *Table 8* (p. 61), 31% of teachers named CFCs to be one of the major greenhouse gases. While the assumption is theoretically sound, it could be suggested that this ‘understanding’ may be driven by key misconceptions which exist in some of these teachers’ mental models of the greenhouse effect. Although CFCs are a greenhouse gas, they are mostly known for contributing to ozone layer depletion (Boyes et al., 1993). It could be suggested that participants ‘knowledge’ of CFCs as a greenhouse gas could be as a result of their conflation of the greenhouse effect and ozone layer depletion. This point is reinforced by the fact that all teachers who named CFCs as a greenhouse gas, also incorrectly linked the greenhouse effect and ozone layer depletion.

4.2.2.2 Limited or Inaccurate Knowledge of the Key Greenhouse Gases

Some teachers displayed limited knowledge regarding the primary greenhouse gases. These individuals either named gases which are not direct greenhouse gases as being primary greenhouse gases, or labelled gases which do not play any role in the greenhouse effect as being major greenhouse gases. Further to this, some teachers named a combination of incorrect and indirect gases in their response.

Carbon monoxide was named by 13% of teachers (*Table 8*, p. 61) to be one of the major greenhouse gasses. The IPCC (2007b) highlights that carbon monoxide can be considered an **indirect** greenhouse gas. This is because carbon monoxide reacts with other greenhouse gases and leads to an increase in ozone levels. In addition, carbon monoxide is defined as an indirect greenhouse gas as it enhances the lifespan of methane in the atmosphere (EIA, 2004). Sulphur dioxide was named by 22% of teachers (*Table 8*, p. 61) as being one of the major greenhouse gases. Sulphur dioxide is considered to be an indirect greenhouse gas as when “...**coupled** with “elemental carbon emissions”, contributes to the formation of aerosols which directly and indirectly affect warming and cooling in the earth’s atmosphere” (Satein, 2009, 5). Lastly, 3% of teachers (*Table 8*, p. 61) referred to hydrogen as being a greenhouse

gas. Hydrogen falls under the category of an indirect gas. Derwent et al. (2006) explain that hydrogen circuitously contributes to the greenhouse effect through increasing levels of both ozone and methane in the atmosphere. This occurs through hydrogen reacting with “...tropospheric hydroxyl radicals...” (Derwent et al., 2006, 65).

It could be argued that because carbon monoxide, hydrogen and sulphur dioxide are scientifically defined as *indirect* greenhouse gasses, the teachers who view these as a major greenhouse gases have incorrect knowledge with regard to the primary greenhouse gases, and/or no knowledge of the distinction between primary and indirect greenhouse gases.

Certain gases present in the atmosphere are not recognised by scientists as contributing to the greenhouse effect. Three gases (nitrogen, argon and oxygen) which form part of this group were incorrectly identified by six teachers as being major greenhouse gases. Of these six teachers, five were found to have incorrectly identified nitrogen, argon or oxygen as an important greenhouse gas, while one teacher named both oxygen and nitrogen as key greenhouse gases. However, alongside these incorrect assertions, each of these six teachers accurately named major greenhouse gases, such as carbon dioxide, water vapour and methane, in their responses. Thus, this finding suggests that these teachers hold a mix of both erroneous and correct knowledge concerning the key greenhouse gases.

4.2.3 Teachers’ Knowledge and Understanding of the Process of the Greenhouse Effect

To assess their level of comprehension of the greenhouse effect, teachers were asked to draw a diagram illustrating the process of the greenhouse effect, and write a brief paragraph explaining the diagram. The teachers’ knowledge and understanding of the greenhouse effect was then classified into three categories: adequate knowledge and understanding of the greenhouse effect; limited knowledge and understanding of the greenhouse effect; and no knowledge and understanding of the greenhouse effect. To place teachers’ understanding of the greenhouse effect into the above mentioned categories a diagram of the process (*Figure 4*, p. 63) provided by the IPCC (2007a) was used as an ‘ideal’ prototype from which to assess levels of knowledge.

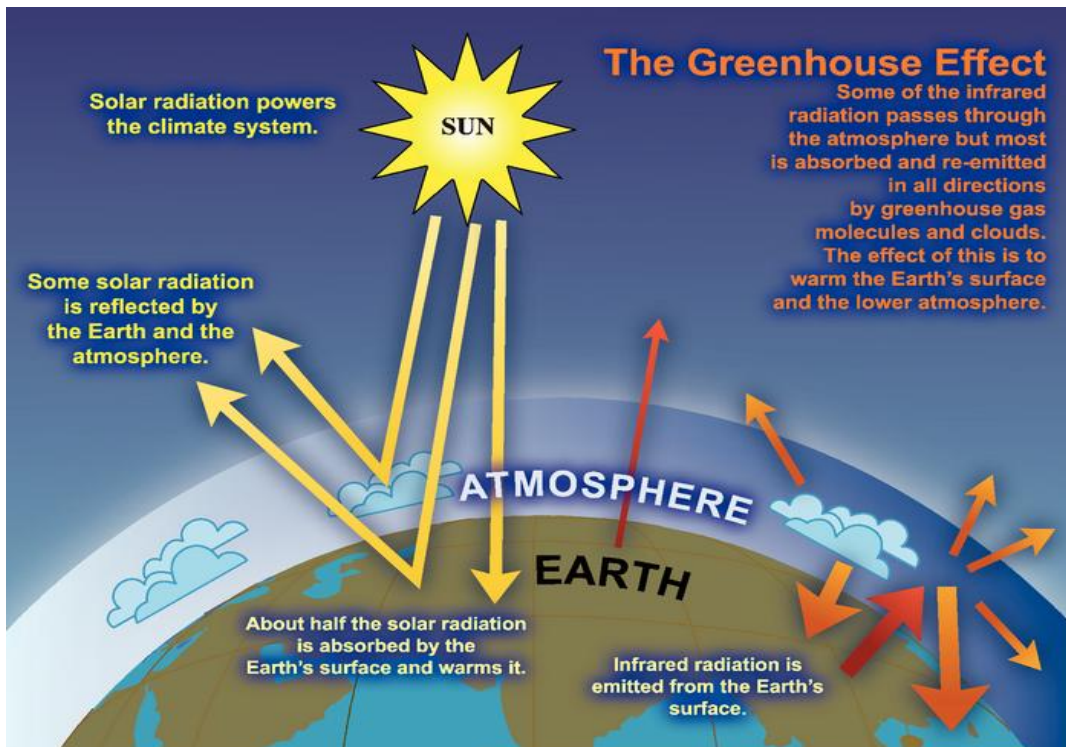


Figure 4: An Ideal Representation and Explanation of the Natural Greenhouse Effect (IPCC, 2007a, p. 98)

Figure 5, below, shows the percentage of teachers who fell into each of the above mentioned respective categories.

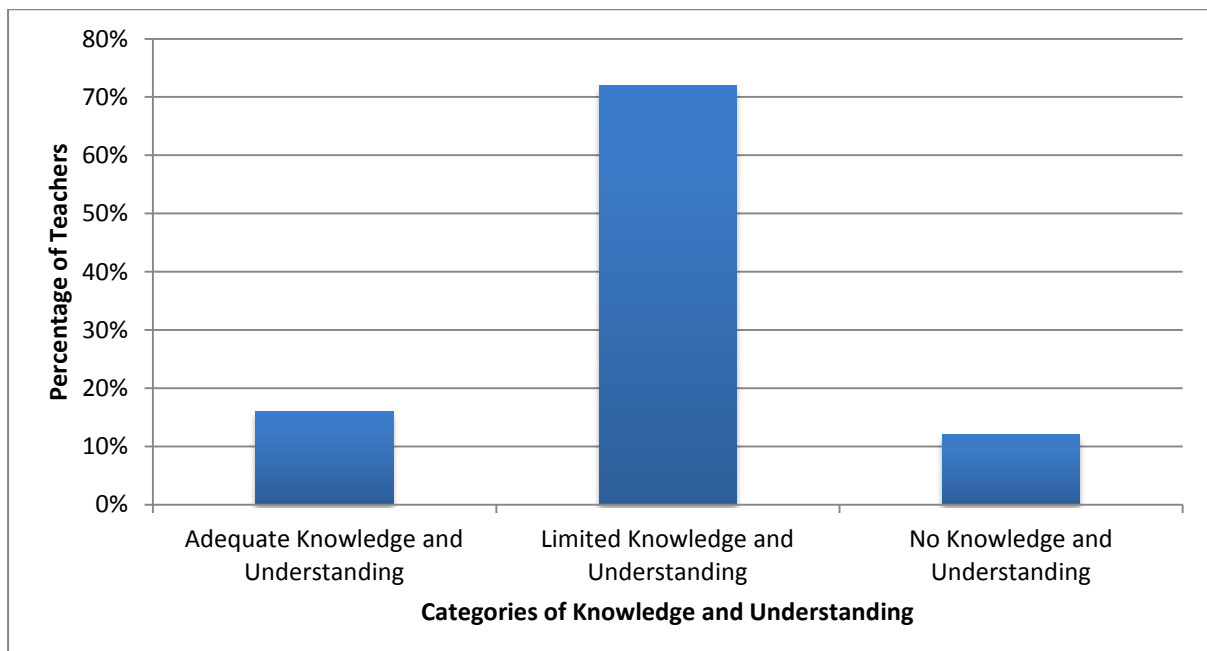


Figure 5: Teachers' Knowledge and Understanding of the Greenhouse Effect

In *Figure 4* (p. 63), the key components related and contributing to the greenhouse effect are represented and explained. These key components include: the process of incoming solar radiation and outgoing infrared radiation; the process of some outgoing infrared radiation escaping through the atmosphere; the process of the majority of infrared radiation being absorbed and re-emitted by greenhouse gases and clouds; and the overall warming effect of this process. The extent to which these components were present (or not) in teachers' diagrams, and adequately detailed in explanatory paragraphs, was the basis from which teachers' respective knowledge and understanding of the greenhouse effect was categorised.

4.2.3.1 Adequate Understandings of the Greenhouse Effect

As shown on *Figure 5* (p. 63), 16% of teachers displayed an adequate understanding of the greenhouse effect. This group acknowledged in both their diagrams and paragraphs that greenhouse gases absorb and re-emit heat toward Earth. In addition, these participants described and distinguished between the process of incoming short wave radiation and outgoing long wave radiation. Examples of these adequate understandings are illustrated in the figures and corresponding explanatory paragraphs, below:

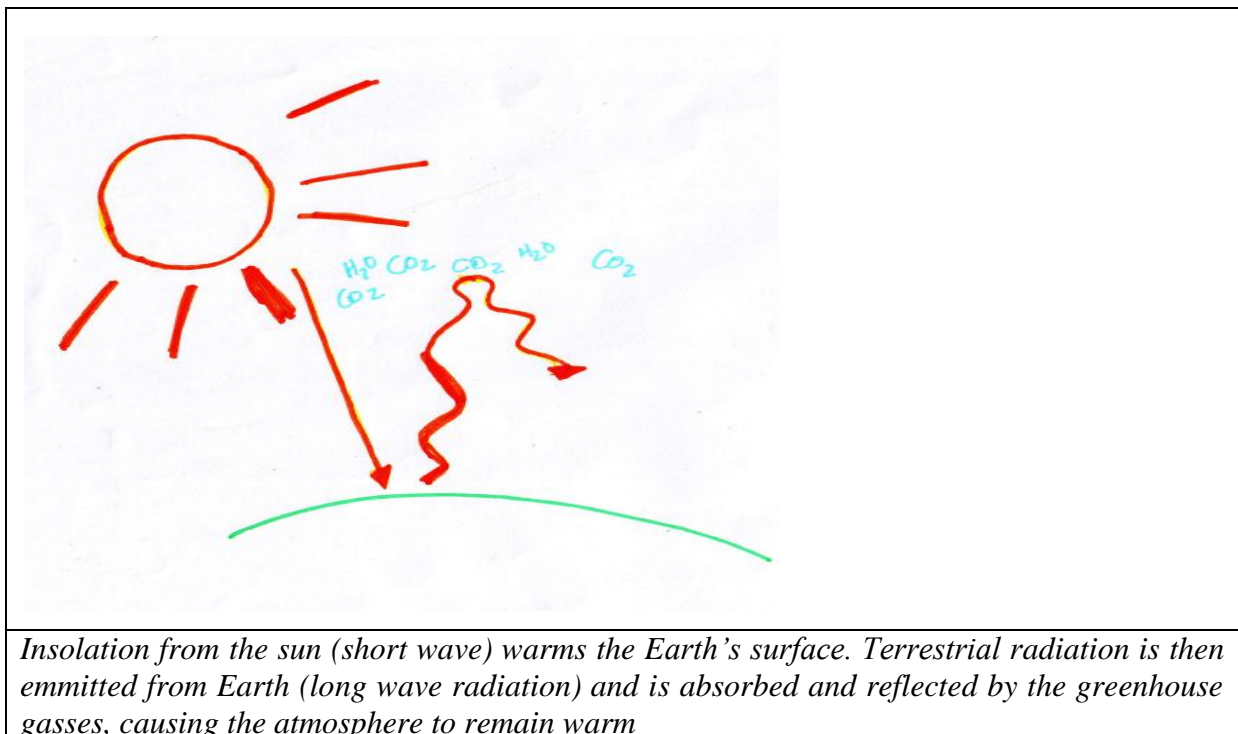


Figure 6 and Explanatory Paragraph: The Greenhouse Effect. (Government School 3, Teacher C)

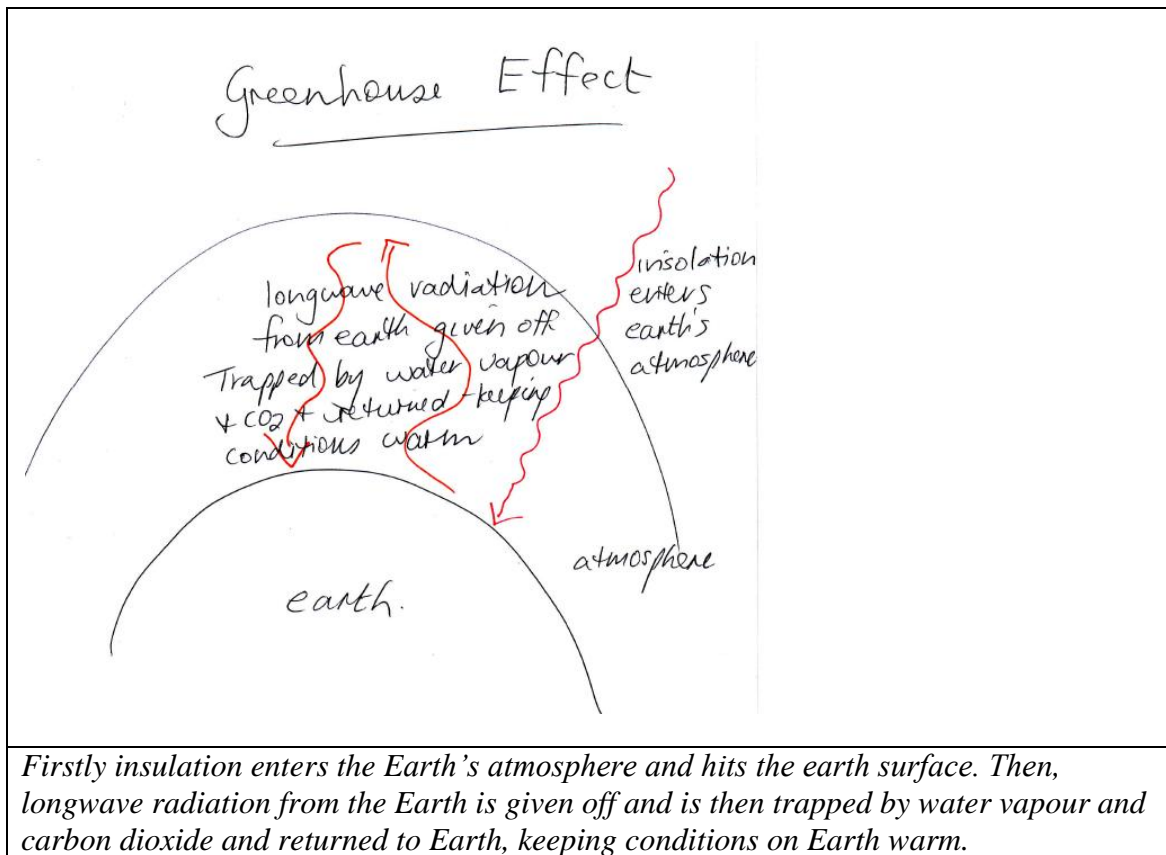


Figure 7 and Explanatory Paragraph: The Greenhouse Effect. (Private School 4, Teacher C)

It should be highlighted that despite these teachers demonstrating an adequate comprehension of the greenhouse effect, some do hold key misconceptions relating to the process. These misconceptions of the greenhouse effect will be discussed later.

4.2.3.2 Limited Understandings of the Greenhouse Effect

Figure 5 (p. 63) highlights that 72% of teachers hold a limited understanding of the natural greenhouse effect.

One limitation in knowledge which was prevalent among seven teachers from this group was view the greenhouse effect as a primarily anthropogenic process. In reality the greenhouse effect is a natural process which has been enhanced by human activity (IPCC, 2007a; Houghton, 2009). This was made clear by the fact that these teachers did not detail the natural greenhouse effect in their diagrams and paragraphs. Instead these teachers represented and explained only the enhanced greenhouse effect, detailing the process through which

greenhouse gases are released into the atmosphere through human activity. Examples of this can be seen in *Figure 8* and *Figure 9* below:

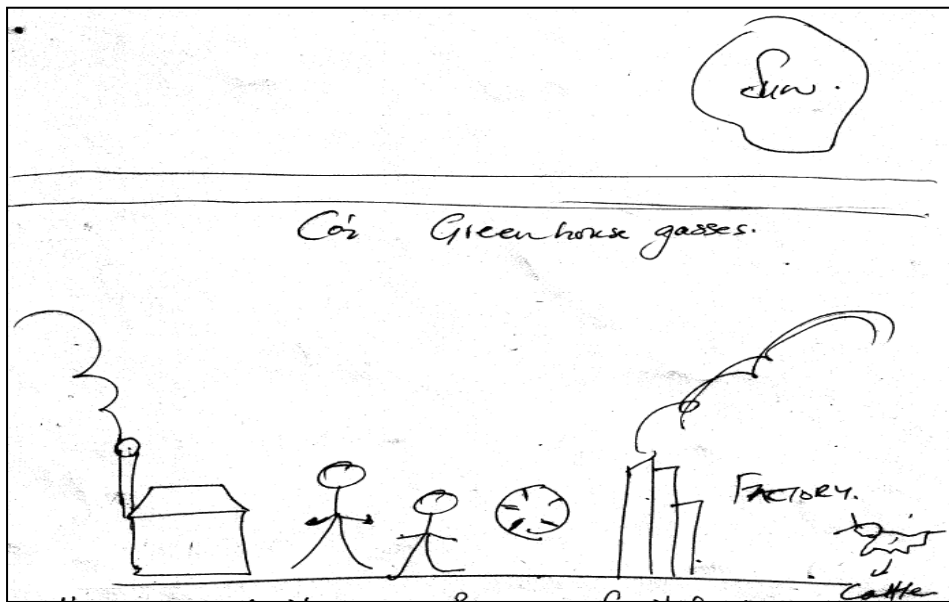


Figure 8: The Greenhouse Effect. (Government School 1, Teacher A)

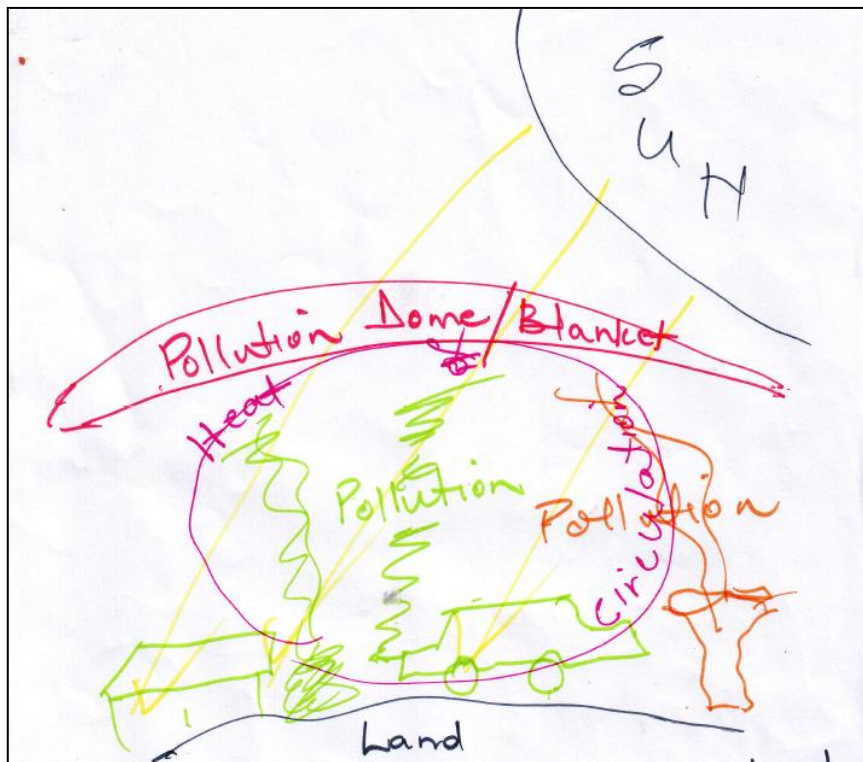


Figure 9: The Greenhouse Effect. (Township School 2, Teacher A)

Figure 8 and *Figure 9* (p. 66) appear to be illustrations of the enhanced greenhouse effect. Evidence of this is shown by the ‘causal’ representations drawn on the bottom of the diagram. These representations are all associated with anthropogenic activities which have been associated with driving the enhanced greenhouse effect. This suggests that these teachers have a limited knowledge of the natural processes which are the foundation of the greenhouse effect.

It is important to highlight that both teachers display additional limitations in knowledge of the greenhouse effect. In *Figure 8*, Teacher A (Government School 1) has inaccurately represented greenhouse gases as occurring in a type of ‘lid’ in the atmosphere. In Teacher A’s (Township School 2) diagram (*Figure 9*) and explanatory paragraph (demonstrated below), four additional limitations in knowledge of the greenhouse effect are apparent. First, this teacher inaccurately suggests that air pollution (in general) drives the enhanced greenhouse effect. Some forms of air pollution such as carbon dioxide and other greenhouse gases do contribute to the enhanced greenhouse effect. However, not all substances which form part of air pollution contribute to the enhanced greenhouse effect. Thus it is inaccurate for this teacher to attribute air pollution in general to the enhanced greenhouse effect. In *Figure 9* and the explanatory paragraph, below, it is clear that this teacher erroneously believes that outgoing heat is trapped under a ‘pollution dome/blanket’. In reality, outgoing heat is absorbed by greenhouse gases and then re-radiated toward Earth (IPCC, 2007a). In addition, although this teacher correctly represented incoming radiation on their diagram, this teacher displays key limitations in knowledge regarding the process of outgoing solar radiation. Lastly, as detailed in their explanatory paragraph, below, this teacher suggests that the enhanced greenhouse effect operates on micro-scales, raising temperatures only in specific areas.

‘The heat is absorbed by the earth and has to be reflected back into the atmosphere but because of the pollution blanket that is in the atmosphere the heat cannot be scattered. The heat is circulated in the same place raising temperatures in that area’
(Figure 9, Explanatory Paragraph: Township School 2, Teacher A)

As highlighted above, a prevalent flaw in Teacher A’s (Government School 1) understanding of the greenhouse effect is the perception that greenhouse gases occur in a type of ‘layer’ or

'lid' in the atmosphere. It was found that this is a common misconception held by a selection of other teachers. Examples of this incorrect perception are illustrated in the diagrams and corresponding explanatory paragraphs, below.

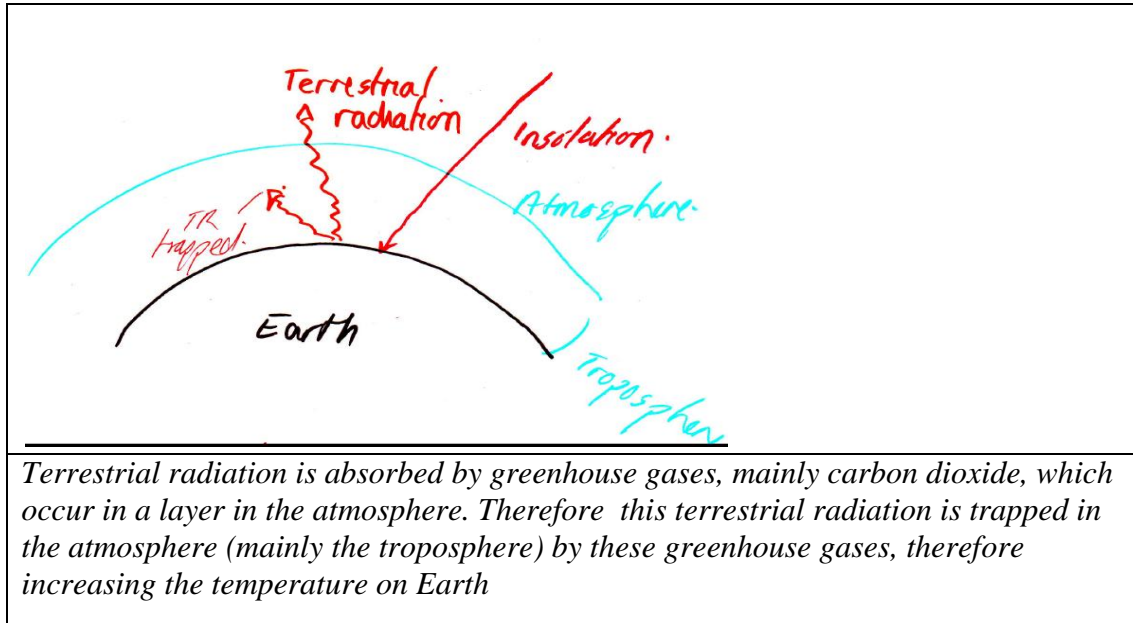


Figure 10 and Explanatory Paragraph: The Greenhouse Effect. (Government School 3, Teacher A)

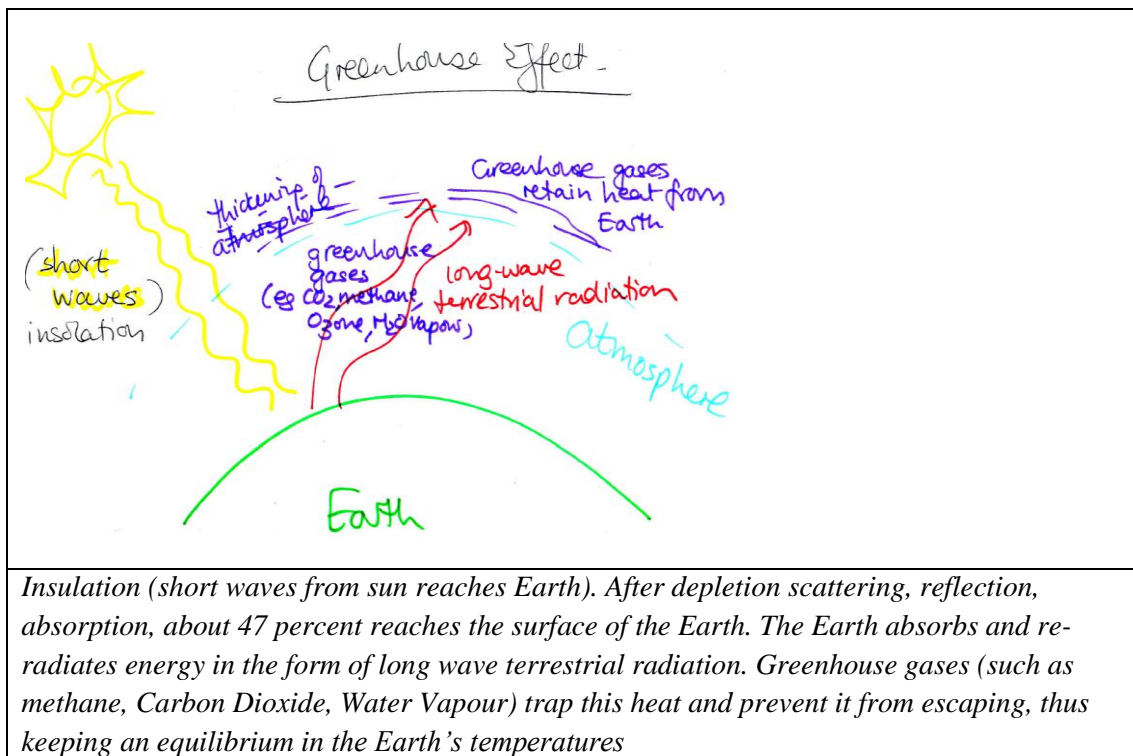


Figure 11 and Explanatory Paragraph: The Greenhouse Effect. (Government School 4, Teacher A)

As shown in the explanatory paragraphs, above, these teachers do not acknowledge that greenhouse gases re-emit heat energy toward Earth, and rather believe that greenhouse gases trap heat in the atmosphere thereby yielding warmer Earth surface temperatures. It is likely that this belief is tied to the perception that greenhouse gases exist in a layer in the atmosphere.

A fairly substantial number of teachers from the group classified as having limited knowledge and understanding of the greenhouse effect have either a partial or non-existent knowledge of the processes of incoming shortwave radiation and outgoing long wave radiation. These participants either identified incoming shortwave radiation or outgoing long wave radiation, while others did not detail any form of radiation in their diagrams or explanatory paragraphs. These radiation processes are crucial aspects which contribute to the functioning of the greenhouse effect (IPCC, 2007b).

In both *Figure 8* (p. 66) and *Figure 12* (below) it can be seen that the teachers who drew these diagrams did not represent either incoming shortwave radiation or outgoing long wave radiation.

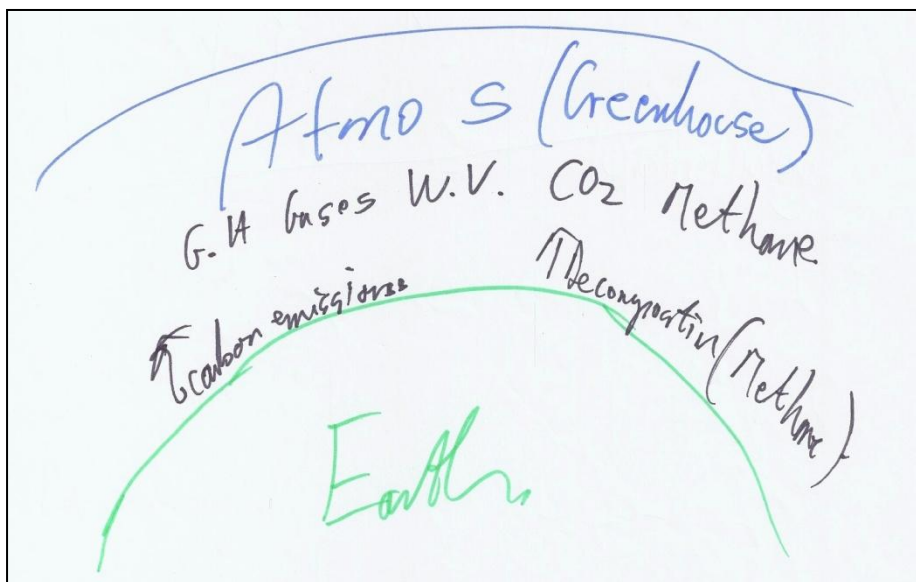


Figure 12: The Greenhouse Effect. (Government School 2, Teacher A)

In addition, in the required explanatory paragraphs neither of these teachers (Government School 1, Teacher A and Government School 2, Teacher A) mentioned incoming nor

outgoing radiation as playing a part in the greenhouse effect. Evidence of this can be seen in the explanatory paragraphs below:

'Human Activities (eg: burning fossil fuels) release greenhouse gases into the atmosphere. These gases absorb heat thus increasing temperature in the upper atmosphere. As a result temperature could increase over a longer period of time leading to global warming' (Figure 8, Explanatory Paragraph: Government School 1, Teacher A)

'Increase in greenhouse gases accelerate the greenhouse effect meaning rapid global warming' (Figure 12, Explanatory Paragraph: Government School 2, Teacher A)

It can be seen that Teacher B (Township School 5) who drew *Figure 13* (below) did not represent incoming shortwave radiation. However, this teacher did correctly include outgoing long wave radiation, annotated on the diagram as 'terrestrial heating'. A similar pattern can be seen in this teacher's (Township School 5, Teacher B) explanatory paragraph, where no mention of incoming shortwave radiation is made, but the process of outgoing long wave radiation is described.

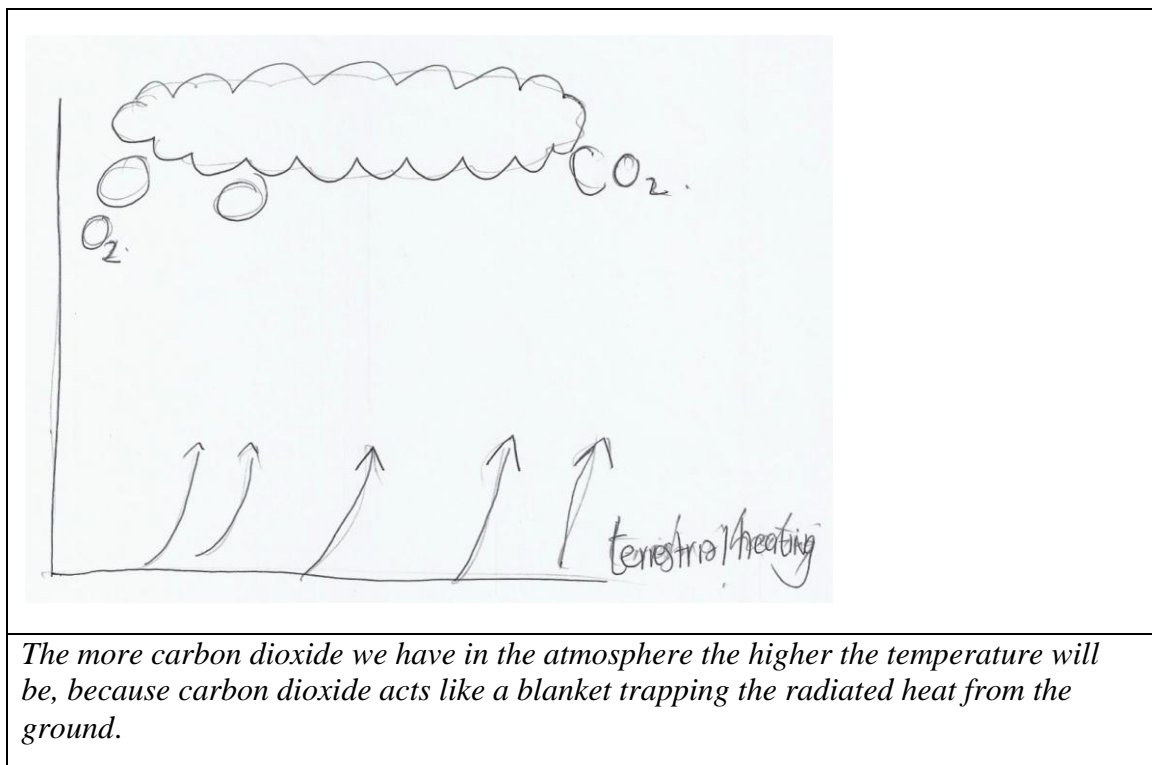


Figure 13 and Explanatory Paragraph: The Greenhouse Effect. (Township School 5, Teacher B)

As highlighted previously, a key aspect of the natural greenhouse effect is the process by which naturally occurring greenhouse gases absorb outgoing radiation and re-emit this heat energy towards Earth (IPCC, 2007a). Three teachers from the group (classified as having limited knowledge and understanding of the greenhouse effect) demonstrate no knowledge of the role of these greenhouse gases in the natural greenhouse effect. The first of these teachers erroneously believes that during the process of the natural greenhouse effect the Earth's surface is warmed as a result of **the atmosphere** trapping heat in a blanketing effect. This is illustrated in this teacher's diagram (*Figure 14*) and corresponding explanatory paragraph, below:

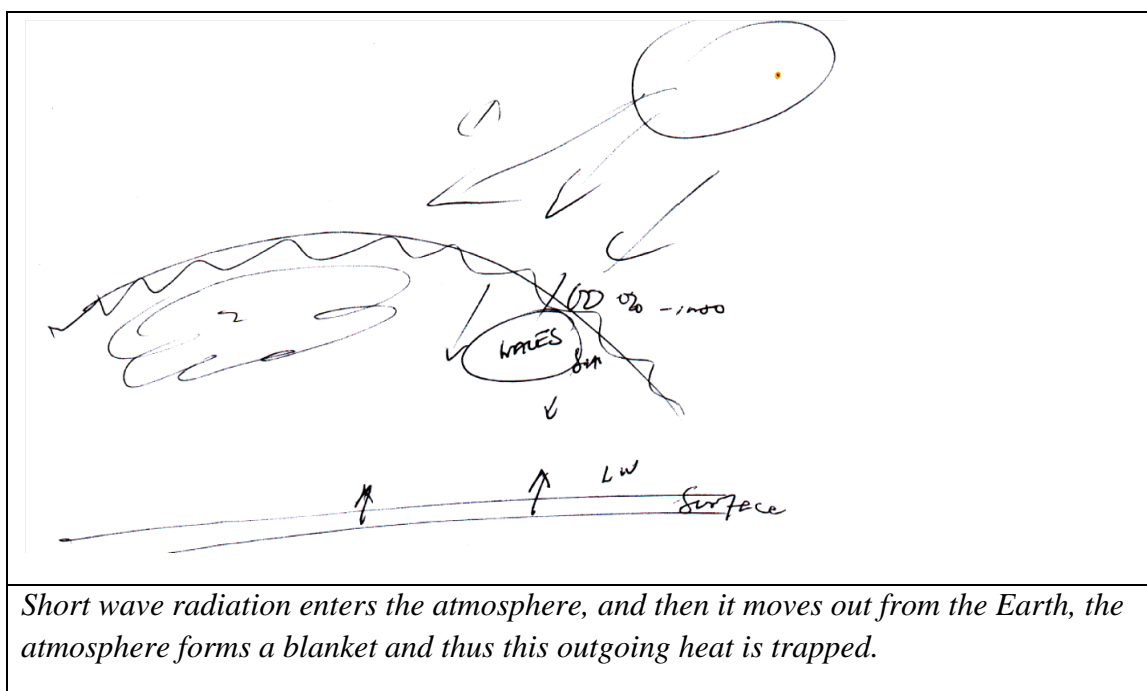
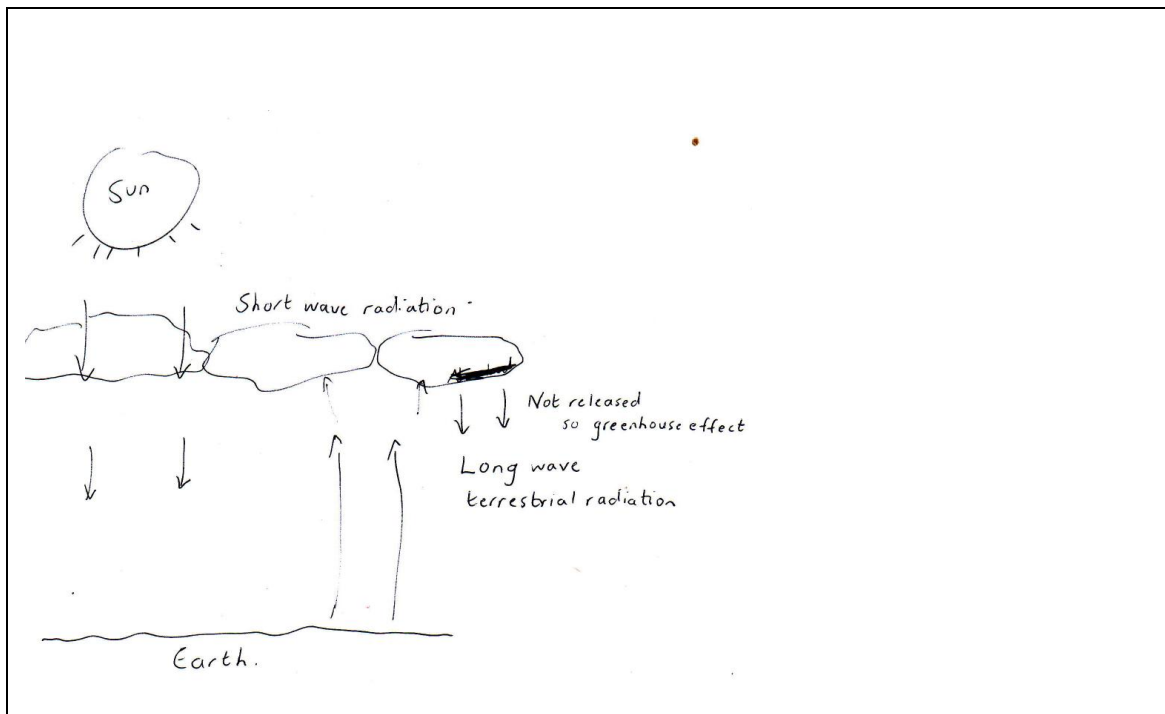


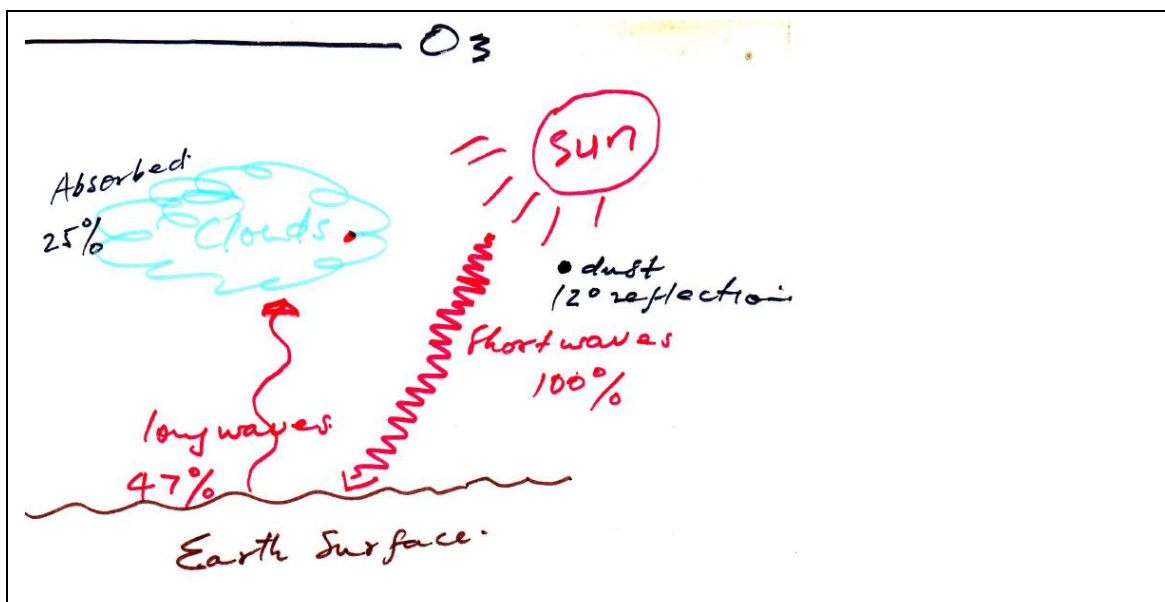
Figure 14 and Explanatory Paragraph: The Greenhouse Effect. (Government School 4, Teacher A)

Two teachers refer only to the role of clouds in absorbing and re-emitting heat energy toward Earth and did not represent or explain the contribution of greenhouse gases to the natural greenhouse effect (refer to *Figure 15* and *Figure 16* and the corresponding explanatory paragraphs, p. 72). It is important to highlight that, as shown in the explanatory paragraph below *Figure 16*, Teacher B (Township School 4) erroneously links and conflates **enhanced** greenhouse effect and ozone layer depletion.



Short wave radiation comes in, reaches Earth, and then is released back into the atmosphere as terrestrial radiation, clouds trap this radiation and turns to heat the atmosphere.

Figure 15 and Explanatory Paragraph: The Greenhouse Effect. (Private School 4, Teacher B)



Greenhouse effect is the process that occurs when clouds trap the longwave radiation, as a result warming the earth's surface. Greenhouse gases destroy or make worse the hole in the ozone, as a result the earth is being over heated. The steps we should take are to legislate (through fines), recycling, deforestation, education, solar panels.

Figure 16 and Explanatory Paragraph: The Greenhouse Effect. (Township School 4, Teacher B)

Included in this group of teachers who had limited knowledge of the greenhouse effect is a teacher who literally drew a greenhouse to illustrate the process (refer to *Figure 17*, below).

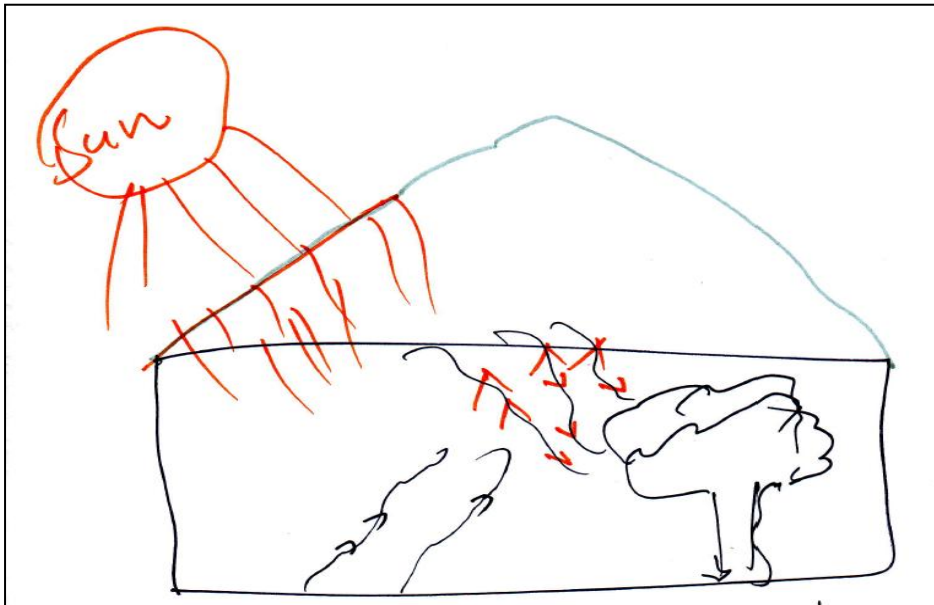


Figure 17: The Greenhouse Effect. (Township School 2, Teacher C)

Greenhouses are glass or plastic structures which provide the ideal environment for growing plants which are vulnerable to the cold, as they allow for the sun's incoming short wave radiation to freely enter the structure and do not allow the outgoing long waves to exit. In this way greenhouses trap the sun's heat in its confines (Power, 1980). The process of heat entering and being trapped in the greenhouse is similar to the mechanism of the greenhouse effect. Thus, the analogy of a greenhouse is often used by key information sources, such as textbooks and internet sites, as a basic explanatory tool to aid individual's comprehension of the greenhouse effect.

It could be suggested that this teacher (Teacher C, Township School 2: *Figure 17*) has been unable to develop and transfer his/her knowledge beyond the greenhouse analogy, and is thus unable to comprehend the more complex and intangible greenhouse effect. The primary function of an analogy is to help individuals comprehend "...new information in terms of already familiar information and to help them relate that new information to their already existing knowledge structure" (Orgill and Bonder, 2004, 16). Thus, for an analogy to be effective in concept development it must be based on a principle or notion which is already recognisable to individuals (Orgill and Bonder, 2004). Greenhouses can be generally

described as being a northern hemisphere phenomenon, as due to warmer climatic conditions in the inhabited southern hemisphere, countries such as South Africa tend to not use greenhouses to the same extent.

In light of this it could be argued that this teacher (Teacher C, Township School 2: *Figure 17*) may not have a clear grasp of the workings of a greenhouse due to lack of exposure and familiarity. Thus, while the teacher displays a basic understanding of the structure of a greenhouse (refer to *Figure 17* p. 73), he/she does not understand the technical functioning of a greenhouse. This is illustrated by the teacher's vague indication of incoming and outgoing solar radiation (refer to *Figure 17*, p. 73). Therefore, as a result of this gap in knowledge it could be proposed that this teacher has become rooted in the analogy and has been unable to extend his/her knowledge to the greenhouse effect.

4.2.3.3 No Knowledge or Understanding of the Greenhouse Effect

As shown on *Figure 5* (p. 63) four teachers have **no** knowledge or understanding of the process of the greenhouse effect. These participants stated during the interview that due to insufficient knowledge they could neither draw a diagram nor write a paragraph on the greenhouse effect. In addition to displaying inadequate knowledge regarding the process of the greenhouse effect, the majority of these teachers had gaps in their conceptual understanding of the process. This was seen in responses to questions pertaining to the greenhouse effect. These flawed responses included participants incorrectly linking ozone layer depletion to the greenhouse effect, and in some cases labelling pollution as a primary contributing factor to the process. These misconceptions which are held by this group and other teachers who took part in the research will be discussed in more depth, below. It is important to mention that one teacher from this group could not answer any question relating to the greenhouse effect during the interview.

4.2.4 Teachers' Misconceptions Concerning the Natural and Enhanced Greenhouse Effect

A large percentage of teachers display a number of key misconceptions in their understanding of the natural and enhanced greenhouse effect. First, it was found that 53% of teachers tended to incorrectly link ozone layer depletion to the greenhouse effect. In addition, some teachers

hold misconceptions regarding the contribution of general air pollution to process and functioning of the enhanced greenhouse effect.

4.2.4.1 Erroneous Linking of Ozone Layer Depletion and the Greenhouse Effect

The functions and properties of the ozone layer and greenhouse effect are not related (Coskun and Aydin, 2011). The greenhouse effect keeps the Earth at a warm liveable temperature through trapping some of the long wave radiation re-emitted from the Earth's surface via the greenhouse gases present in the atmosphere (IPCC, 2007a; Houghton, 2009; Coskun and Aydin, 2011). By contrast, the ozone layer serves to protect the Earth and its inhabitants from the sun's harmful ultra-violet rays (Coskun and Aydin, 2011).

A clear but incorrect connection between the greenhouse effect and ozone layer depletion was made by 53% of teachers. These teachers all stated that ozone layer depletion allows more of the sun's radiation to enter the Earth's atmosphere, thus contributing to the enhanced greenhouse effect by increasing temperatures on Earth. This can be seen in the extracts below:

'...the ozone layer protects us from the rays of the sun and once it is broken down those sun rays will contribute to the greenhouse effect by heating the Earth' (Township School 5, Teacher B)

'...there is a huge link between the greenhouse effect and ozone layer depletion... it means more of the sun's rays are coming through' (Private School 3, Teacher C)

'...ozone layer depletion plays a huge part in the greenhouse effect... because it means the sun is just coming through, there is nothing to stop it now, and that makes everything hotter' (Private School 4, Teacher A)

'[ozone layer depletion] is reducing that protective layer and playing a part in the greenhouse effect, allowing more heat to enter the atmosphere' (Private School 4, Teacher B)

'Ozone layer depletion has meant that more of the sun's rays come in, and so it is hotter. So, in that way it adds to the whole enhanced greenhouse effect' (Private School 2, Teacher A)

The incorrect linking of ozone layer depletion and the greenhouse effect among teachers is consistent with the finding from other studies of a similar nature (Dove, 1996; Groves and Pugh, 1999; Khalid, 2003; Papadimitriou, 2004; Boon, 2010; Coskun and Aydin, 2011).

There are a number of explanations which account for prevalence of this misconception in teachers' understanding of the greenhouse effect. First, ozone layer depletion and the greenhouse effect have similar overlapping concepts. For instance, the atmosphere, gases and solar radiation play key roles in both ozone layer depletion and the greenhouse effect but also there has been warming associated with ozone layer depletion (Rye et al., 1997). Thus, it could be suggested that these apparent similarities may have prompted some teachers to assume incorrectly that the two processes are related.

Another possible explanation for teachers incorrectly linking the greenhouse effect and ozone layer depletion could be attributed to the mass media (Boyes et al., 1993; Dove, 1996; Khalid, 2003, Daskolia et al., 2006). It has been asserted that the mass media often does not provide a definitive contrast of ozone layer depletion and the greenhouse effect, and in some cases has been found to fuse the phenomena into one. This may cause teachers to combine ozone layer depletion and the greenhouse effect into a single environmental construct, resulting in these teachers being unable to distinguish cognitively between the various processes which define the greenhouse effect and ozone layer depletion (Daskolia et al., 2006). As will be discussed in *Section 4.4*, many teachers named the mass media as their primary source of information on climate change and its related aspects. Thus it could be proposed that the mass media, due to its inaccuracies and lack of clarity, may be the key driver behind some participants conflating the greenhouse effect and ozone layer depletion.

A third explanation is that the prescribed textbooks may have fostered this misconception (Daskolia et al., 2006; Choi et al., 2010). In studies of a similar nature it was found that prescribed textbooks contained a variety of generalisations and inaccuracies regarding the two processes (Choi et al., 2010). Thus, it could be speculated that textbooks may, in some instances, be the cause of the erroneous linking of the greenhouse effect and ozone layer depletion by teachers. The likelihood of this explanation will be examined in more detail in *Chapter 5* where an in-depth analysis and assessment of a selection of geography textbooks

used by teachers in the classroom for climate change education and as a resource for information on climate change will be conducted.

Ten teachers attempt to explain the link between ozone layer depletion and the greenhouse effect. The first way in which some teachers try to establish a connection between the two phenomena is by stating that CFCs contribute to the greenhouse effect through contributing to the depletion of the ozone layer. This is demonstrated in the following quotes:

'We need to cut down on CFCs because they play a big part in ozone layer depletion...this process then allows more heat to be absorbed by the atmosphere and then increases the greenhouse effect' (Private School 4, Teacher B)

'They [CFCs] build up and affect the ozone layer, they destroy the ozone layer and that means that the greenhouse effect increases...the ozone layer protects is from the rays of the sun and once it is broken down those sun rays will contribute to the heating of the Earth' (Township School 5, Teacher B)

CFCs have had an effect on both the greenhouse effect and ozone layer depletion (Boyes et al., 1993). Thus, it could be suggested that this commonality shared by the two phenomena has allowed for some teachers to quantify and justify the link which they believe exists between ozone layer depletion and the greenhouse effect. It is important to note that following the establishment of the Montreal Protocol, the use of CFCs in developed and developing countries has been gradually phased out for over 15 years (Powell, 2002). Thus, teachers suggesting that CFC usage needs to be reduced, suggests a key gap in their knowledge.

A smaller percentage of teachers assert that greenhouse gases have played a role in ozone layer depletion which causes extra solar radiation to enter the Earth. This is illustrated in the extracts below:

'Greenhouse gases...affect the ozone layer and make the greenhouse effect'
(Township School 3, Teacher A)

‘...you must remember the part of the ozone layer in all of this [the greenhouse effect], because of all the negatives we put into the atmosphere...which are responsible for depleting the ozone layer, meaning more heat...’ (Government School 1, Teacher A)

The majority of greenhouse gases have been recognised as contributing to the greenhouse effect, but are not recognised as playing a role in ozone layer depletion (IPCC, 2007a; Houghton, 2009; EPA, 2010).

Finally, it is interesting that the majority of teachers who conflate the two phenomena did not indicate the ozone layer in their diagram on the greenhouse effect. Instead, the majority of these teachers either made an incorrect reference to the link during the course of the interview, or inaccurately referred to the role of the ozone layer in the greenhouse effect in their diagram’s explanatory paragraphs. A smaller percentage of participants from this group mentioned the link in both the interview and their explanatory paragraph. Three participants represented the ozone layer in their diagrams. An example of this can be viewed in Figure 16, (p. 72) as well as in *Figure 18*, below.

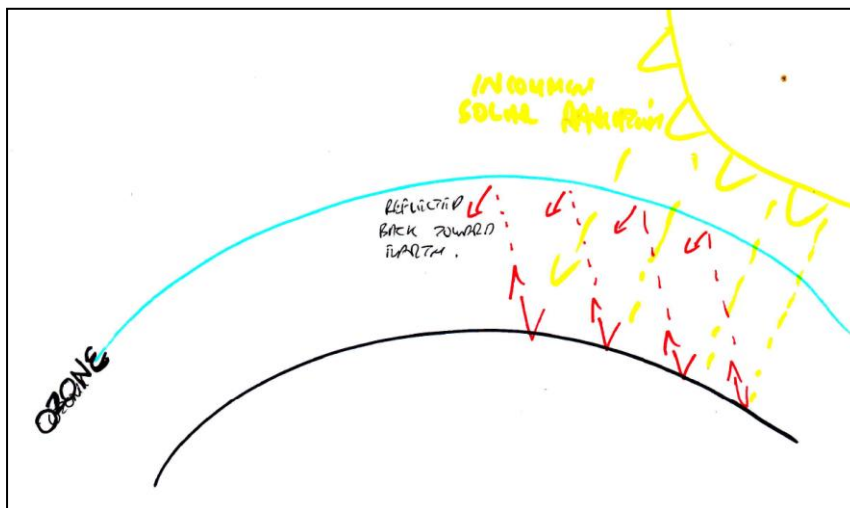


Figure 18: The Greenhouse Effect. Private School Teacher 3, Teacher C)

4.2.4.2 Inaccurate Conceptions of the Contribution of General Air Pollution to the Process and Functioning of the Greenhouse Effect

Six teachers referred broadly to ‘air pollution’ as contributing to the enhanced greenhouse effect. This can be seen in the following quotes:

'Well I think that pollution is a major aspect of the greenhouse effect and climate change, because it is what causes it. Air pollution I mean' (Government School 2, Teacher A)

'I think that if you look at the pollution in the air and what is happening there, that is making everything worse with the greenhouse effect' (Government School 2, Teacher B)

'...air pollution is one of the things that makes the this greenhouse effect and then climate change so bad' (Township School 5, Teacher B)

'And the change in temperature with this enhanced greenhouse effect it will become very high... because of the air pollution' (Township School 3, Teacher A)

The above teacher's descriptions of 'air pollution' as contributing to the enhanced greenhouse effect is not incorrect, but does indicate flaws or inaccuracies in knowledge. Air pollution is a broad term for any "...atmospheric condition in which certain substances are present in such concentrations that they bring undesirable effects on man and his environment" (Admassu and Wubeshet, 2006, 5). Examples of substances present in air pollution include greenhouse gases such as carbon dioxide and methane, particle matter such as dust or smoke, radioactive substances, sulphur dioxide and carbon monoxide. Certain substances found in air pollution such as greenhouse gases do contribute to the enhanced greenhouse effect. However, other forms of air pollution play a minimal/non-existent role in the process, but are a direct cause for a variety of other environmental issues such as acid rain (Admassu and Wubeshut, 2006). Thus, it could be argued as being inaccurate for teachers to refer broadly to air pollution as contributing to the enhanced greenhouse effect, as not all substances associated with air pollution will contribute to this process. This finding may indicate a lack of sufficient scientific knowledge or the framing of all environmental issues into a single construct.

4.2.5 Section Summary

The findings outlined in this section suggest that some teachers have fundamental inconsistencies and gaps in their knowledge regarding the greenhouse effect. These flaws in understandings may have adverse effects on their conceptualisation of climate change (Shepardson et al., 2009).

4.3 Teachers' Understandings and Perceptions of Climate Change

In this section teachers' knowledge and perceptions of climate change and its related aspects are examined. First, teachers' conceptions of the term 'climate change' are analysed. Second, teachers' perceptions of the global current and future impacts of climate change is examined. Following this, attention will be given to teachers' conceptions of the risks associated with climate change. Finally, teachers' knowledge and understanding of climate change mitigation strategies are explored.

4.3.1 Teachers' Understandings of the Term 'Climate Change'

The IPCC (2007c, 30) defines climate change as "...any change in climate over time [usually decades or longer], whether due to natural variability or as a result of human activity". This definition of 'climate change' differs from that provided by the UNFCCC, where 'climate change' refers to "...a change in climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability over comparable time periods" (IPCC, 2007c, 30). However, as the IPCC is widely acknowledged to be the current authority on climate change, it is likely that the definition of 'climate change' provided by the IPCC represents the most scientifically accepted, the most recognised and most widely used definition (Rodgers and Marres, 2000; Parmesan and Yohe, 2003; Tubiello et al., 2007; Rosenweig et al., 2008). It is for these reasons that the IPCC's definition will be used as a benchmark from which to explore the extent of accuracy of teachers' understandings of the term 'climate change'.

As can be seen in the IPCC's definition, climate change can be linked to natural causes (such as changes in the Earth's orbit or changes in solar output), or anthropogenic influences (IPCC, 2007b). In this research, all participants correctly acknowledged that through certain activities humans can, and do, influence climatic patterns. However, as shown in *Table 9* (p. 82), some teachers believe that human activities are the only force at play, while others recognize that natural forces are also a contributing factor. The majority of teachers (63.5%) incorrectly suggest that climate change occurs only as a result of human activity. It is extremely important for individuals to understand that changes in climate can stem from both natural variations and anthropogenic causes. It could be reasoned that individuals who are aware that the Earth's climate may alter due to natural variations may develop a greater

understanding of the extent and role of anthropogenic factors contributing to climate change (IPCC, 2007b).

Table 9: Teachers' Understanding of the Term Climate Change

Teachers' Understanding of the Term 'Climate Change'	Response Proportions
Climate change can only be naturally induced	0
Climate change can only be human induced	62.5%
Climate change can be both naturally and human induced	37.5%

Another important aspect of the IPCC's definition of climate change relates to 'time'. Changes in climate can either be short term and temporary (referred to as 'climate variability'), or long term (referred to as 'climate change') (USAID, 2007). Thus, in order for changes in climate to be quantified 'climate change', extensive scientific monitoring over an extended period of time, usually a minimum of a number of decades, has to occur (IPCC, 2007a). With this in mind, it can be argued that if considerations of 'time' do not form part of lay individuals understanding of climate change, there is a risk that short term changes in climate will incorrectly be linked to climate change (Stehr and von Storch, 1995).

Over half of the teachers correctly acknowledged that climate change occurs over time. This is demonstrated in the following quotes:

'[Climate change is] *The changing of climate over a long period of time...*' (Township School 3, Teacher B)

'[Climate change is] *Basically the change in patterns with regard to climate, over time*' (Private School 4, Teacher A)

'*Climate change is about long term change...*' (Private School 2, Teacher B)

'*You must remember that in order for a change to be called 'climate change' it must be sustained over 50 to 100 years...*' (Government School 2, Teacher C)

'*...with climate change you cannot look at it over a short space of time, you need to look at the changes over long time frames to see if it is climate change*' (Government School 5, Teacher A)

‘...climate change refers to the change of climate over a number of years...’ (Private School 1, Teacher B)

‘My understanding of climate change would be any difference or change of a climate of a region over a period of time...’ (Government School 1, Teacher A)

The above quotes suggest that there is awareness among this group that long term trends are important in considerations of climate change. However, despite this, 75% of participants refer to recent local and global weather events and natural disasters as evidence of climate change. A reason for these contrasting findings is that while some participants have a theoretical understanding that climate change occurs over significant timescales, in practice the majority of this group tends to attribute recent short-term weather anomalies to climate change.

4.3.2 Perceived Current and Future Global Impacts Resulting from Climate Change

A substantial number of teachers (97%) believe that climate change has had an effect on average weather globally, and affirm that global weather patterns will be affected by climate change in the future. The most frequently identified impacts of climate change include: global temperature increases, sea level rise, and an increase in the frequency and/or intensity of some extreme weather events. Generally teachers’ descriptions of these impacts of climate change were basic and did not take into account the scientific uncertainties and complexities surrounding these phenomena. In some cases, teachers’ conceptions of these impacts of climate change are similar to the findings and predictions of IPCC (2007b), albeit less scientifically complex. In a number of instances however, teachers’ knowledge of these impacts is inaccurate or flawed.

As highlighted previously, the majority of teachers interviewed link climate change to anthropogenic activity, and do not acknowledge the role of natural variations in climate change. Thus, when discussing the current impacts of climate change, teachers are generally only attributing impacts to anthropogenic climate change. This limits the scope and scientific complexity of their responses.

4.3.2.1 Global Temperature Increases as a Perceived Impact of Climate Change

The majority of teachers acknowledge that a key indication of climate change has been global temperature increases. This conception is supported by the IPCC (2007b), which states that there has been a general warming of global air temperatures over recent decades. While anthropogenic climate change has been found to have resulted in a general warming of the Earth, such warming is regionally variable, with anthropogenic influences causing some areas to experience a decrease in average temperatures (IPCC, 2007b). It was correctly acknowledged by 9% of teachers that climate change may result in the heating or cooling of certain regions. However, 79% of teachers held the misconception that the current trend of increasing global temperatures will continue in the future as a result of climate change. This is highlighted in the following quotes:

'Well basically, from what I know, you temperatures globally are going to increase because of climate change' (Government School 2, Teacher B)

'I mean, I think just warming, we are going to get warmer and warmer... So long term, I suppose just increases in temperature and general warming are what we cannot expect' (Private School 1, Teacher B)

'I think that temperature increases around the world because of climate change will be the biggest thing' (Township School 5, Teacher A)

'I think our temperatures, our temperatures is not going to be normal, it is going to be very hot, everywhere will feel the heat' (Township School 3, Teacher A)

'...everything will get hotter' (Government School 1, Teacher 1)

'...we are looking at an increase in temperatures globally, certain areas that were cold are obviously going to be warmer...' (Government School 3, Teacher C)

The misguided belief that anthropogenic climate change will cause continuous global temperature increases in all locations throughout the world could be attributed to two sources: the mass media and the textbooks used most frequently by interviewed teachers for climate change education and as a personal source of information on climate change. The mass media generally uses the term 'global warming' when referring to climate change. Similarly, as highlighted and discussed in further detail in *Section 5.3.3.3*, many of the geography

textbooks selected for analysis in this research frequently use the term in reference to ‘climate change’. Shome and Marx (2009) and Whitmarsh (2009) argue that the term, ‘global warming’, brings with it connotations of pervasive and continual temperature increases. In this research, all of the teachers who employed either the mass media or textbooks as a source of information on climate change, correspondingly used the term ‘global warming’ either interchangeably with, or as a sole term of reference to, climate change.

Connotations of pervasive rising temperatures associated with the term ‘global warming’ have been argued to cause some individuals to assume that the impacts of climate change are mostly heat related (Whitmarsh, 2009). Findings from this research confirm this hypothesis. All of the 59% of teachers who used the term ‘global warming’ during interviews acknowledged the effects and impacts of climate change which are associated with temperature increases. The quotes below highlight examples of the heat related impacts and effects of climate change as perceived by teachers:

‘I think that we are just going to see...more severe heat waves’ (Government School 3, Teacher A)

‘...these days we experience too much of heat and too much of floods, and that is simply meaning that there is a lot of evaporation that is taking place from all this heat’ (Township School 3, Teacher A)

‘If you just look at Africa, there are parts of Africa which are going to become drier...fires [will] impact on natural vegetation...’ (Private School 2, Teacher A)

‘...your temperatures globally will increase...’ (Government School 2, Teacher B)

‘...certain areas that were cold are obviously going to be warmer... your cold areas like Finland are going to become like San Tropez...’ (Government School 3, Teacher B)

4.3.2.2 Sea Level Rise as a Perceived Impact of Climate Change

Sea level rise was considered by 25% of teachers to be a current global effect of climate change, and 13% of teachers mentioned rising sea levels as a future impact of climate change. Sea level rise is listed/cited by the IPCC (2007b) as being one of the key existing impacts of

anthropogenic climatic change. It is predicted that sea levels will continue to rise in the future (IPCC, 2007c). Sea level rise is claimed to be one of the impacts of anthropogenic climate change which is discussed most frequently by key bodies of communication, such as the mass media (Rick et al., 2011). As the majority of teachers (91%) use mass media as a source of information on climate change, it is surprising that such a low percentage of teachers (25%) named sea level rise as being a current indication and/or future impact of climate change.

Teachers who described rising sea level as a current and/or future impact of climate change, all correctly suggested that sea level rise has been caused by melting of ice caps and glaciers prompted by increases in global air temperatures. This is highlighted in the following quotes:

“...we have melting glaciers and sea level rise because temperatures are getting to high” (Township School 4, Teacher A)

“There are signs, in terms of melting polar ice caps, so there is more water in the ocean” (Government School 4, Teacher A)

“...the ice is melting because of heat, raising the level of the sea” (Township School 3, Teacher B)

“As well as the level of the ocean, because of these high temperatures the level of water rises, especially in the ocean, because, for example, you will have the dissolving of the ice caps” (Township School 3, Teacher A)

“...melting of ice caps...and that causes sea level rise” (Private School 1, Teacher B)

Sea level rise is brought about as a result of melting glaciers, ice-caps and ice-sheets. However, another equally important cause of sea level rise is thermal expansion of sea water. Thermal expansion occurs as a result of warmer ocean temperatures induced by increasing global air temperatures (IPCC, 2007b). Interestingly, while all the teachers who identified sea level rise as an effect of climate change correctly attributed the effect to melting caps, only one teacher mentioned thermal expansion of ocean water as a cause for sea level rise. This indicates that the majority of these teachers may not be aware of the role which thermal expansion plays in increasing sea levels.

A possible reason for this finding may be linked to the visual representations of the effects of climate change depicted in the mass media. Smith and Joffe (2009, 652) state that images of melting ice caps and ice shelves are used frequently by the mass media to portray the “...scale and speed of the climate change problem”. Many teachers in this research use mass media as a source of information on climate change (refer to *Section 4.4*). Thus, it is likely that teachers may be more aware of melting ice caps and glaciers, as supposed to thermal expansion, as a cause for sea level rise as a result of these visual representations in the mass media.

Melting ice caps and glaciers were identified by 22% of teachers as a current impact of climate change. Melting ice caps and glaciers are an indication of regional warmer temperatures allowing for the regression of these ice masses and thus climate change (IPCC, 2007b). Interestingly, these teachers did not go further by identifying that melting ice caps and glaciers have led to rising sea levels. It has been emphasized that there is a strong and important link between melting glaciers and ice caps and the current trend of rising sea levels (IPCC, 2007b).

One reason for teachers not acknowledging sea level rise when discussing melting ice caps and glaciers may be attributed to the influence of mass media. As highlighted above, the mass media regularly employs images of melting ice caps and glaciers to tangibly represent the current effects of climate change to the public (Smith and Joffe, 2009). Images used by the mass media have been found to trigger greater emotional responses in individuals than textual information. So, lay individuals may be more likely to pay attention to visual images (Smith and Joffe, 2009). Therefore, although the mass media may discuss sea level rise in relation to melting ice caps and glaciers, the images of melting icecaps and glaciers are most easily recalled as an impact of climate change.

4.3.2.3 Increase in the Frequency and/or Intensity of Extreme Weather or Climatic Events as a Perceived Impact of Climate Change

Many teachers believe that another current effect of global climate change has been an increase in the frequency and/or intensity of some extreme weather and climatic events. A smaller percentage of teachers named increases in the frequency and/or intensity of certain extreme events as being a future impact of climate change. *Table 10*, below, shows which

extreme events teachers believe have altered and will continue to alter as a result of climate change.

Table 10: Teachers’ Perceptions of Present and Future Changes in Extreme Events as a Result of Climate Change

Extreme Event and Associated Changes	Currently	Future
Tropical cyclones (increase in severity and/or frequency)	44%	13%
Flooding (frequency/severity)	19%	6%
Drought (frequency/severity)	0%	13%
Increase in intense rainfall events	9%	9%
Changes in patterns of drought and flooding	13%	6%
Severe snow events	31%	13%
Tornado Events (increase in severity and/or frequency)	9%	3%
Earthquakes, tsunamis and volcanic eruptions	9%	6%
Increase in the intensity of heat waves	9%	6%

The IPCC’s observations and findings in the Fourth Assessment Report provide a good scientific foundation from which to assess the accuracy of teachers’ perceptions of the impacts of climate change on extreme events. However, it is important to note that teachers do not use IPCC documents and reports as a source of information on climate change (refer to *Section 4.4*). Thus, teachers’ perceptions of the ways in which climate change has impacted on extreme events are unlikely to directly correspond to, or be as scientifically complex as the findings and observations made in IPCC assessments.

Subsequent to the Fourth Assessment Report, the IPCC published a special report entitled ‘Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaption’ (IPCC, 2012). This latest special report provides a more in-depth analysis of changes in extreme events than the Fourth Assessment Report. In addition, in some cases, the levels of certainty and confidence in the variations of certain extreme events differ to varying extents from those in the Fourth Assessment Report. However, as the **special report** (IPCC, 2012), was published before teachers were interviewed it was not used as a baseline for assessing the accuracy of teachers’ perceptions of the changes in extreme events as a result of climate change.

4.3.2.3.1 Perceptions of the Effect of Climate Change on Tropical Cyclones

As shown on *Table 10* (p. 88), 44% of teachers believe that there has been an increase in intensity and/or frequency of tropical cyclones as a result of climate change. This is demonstrated in the following quotes:

'And we have also been having more intense tropical cyclones' (Private School One, Teacher A)

'We have had more tropical cyclones that are more destructive than in the past' (Township School 2, Teacher A)

'It is normal for cyclones to come, but to be so frequent and devastating, says to me that there has been a change' (Government School 1, Teacher A)

'...we have always had tropical cyclones... but the proportions and the intensity is becoming a lot more dramatic' (Private School 6, Teacher A)

The IPCC's Fourth Assessment Report states that there has been a recorded increase in intense tropical cyclone activity primarily over the North Atlantic with "...limited evidence of increases elsewhere" (IPCC, 2007b, 2). The majority of the group of teachers believe that climate change has resulted in more intense tropical cyclones at a global scale. This suggests a limited awareness among this group that changes in tropical intensity may be regionally specific. The mass media tends to sensationalise tropical cyclone events, and in some cases has erroneously linked particularly devastating tropical cyclones in various regions to anthropogenic climate change (Boykoff and Roberts, 2007). Many teachers are reliant on the mass media as a source of information on climate change. Thus it could be suggested that, through mass media misrepresentations, this group may have developed the opinion that the intensity of tropical cyclones has increased globally.

A few teachers (13%) believe that the **frequency** of tropical cyclones has increased as a result of climate change. The IPCC (2007b) emphasize that as a result of limited data it is difficult to ascertain whether or not there has been any general variance in tropical cyclone numbers as a result of climate change. However, it is important to highlight that a number of other scientifically reliable sources state that the occurrence of tropical cyclone events in North Indian and Atlantic oceans has increased as a possible result of climatic change

(Goldenberg et al., 2001; Emanuel, 2005; Webster et al., 2005; Mann and Emanuel, 2006). Increased reporting of extreme events in mass media has been attributed to many lay individuals developing the view that the number of weather-related extremes are rising, whether they have or not (IPCC, 2007b). Thus, increased exposure to the occurrence of tropical cyclone events through reports in mass media may have caused these teachers to believe that the frequency of tropical cyclone events has risen.

Three teachers state that climate change will, in the future, result in the increased **intensity** of tropical cyclones. This is in line with the reports of the IPCC (2007b) which highlight that as a consequence of warmer tropical ocean surface temperatures it is likely that tropical cyclones will carry “...larger wind peak speeds and more heavy precipitation...” (IPCC, 2007c, 46). Two teachers proposed that numbers of tropical cyclones would increase in the future due to climate change. This conception is not reflected in the reports of the IPCC (2007b).

4.3.2.3.2 Perceptions of the Effect of Climate Change on Drought and Flood Events

The IPCC (2007b) reports that the occurrence and intensity of droughts over most land areas has increased. In some, but not all areas, “...numbers of daily precipitation events that lead to flooding have increased...”, however, there is very little evidence for a wide-spread global change in flood events (IPCC, 2007b, 308). It is predicted that in the future many regions or areas will experience more frequent and/or severe floods and droughts at varying times (IPCC, 2007b). A number of teachers (31%) state that patterns of drought and flooding have become more intense and/or longer lasting as a result of climate change, while 13% teachers believe that, in the future, patterns of drought and flooding will continue to grow in severity and/or frequency. A misconception prevalent among two teachers was that climate change is a direct cause for the occurrence of droughts and floods. This is highlighted in the following quotes:

‘We get droughts and floods because of this climate change’ (Township School 2, Teacher B)

‘Climate change has caused us to have droughts and even the floods’ (Township School 5, Teacher A)

This conception is incorrect, as while anthropogenic activities have contributed to a change in the patterns and nature of floods and droughts, such events can occur as a result of natural variations in climate or climatic cycles (ie. El Niño and La Niña events), or due to other factors such as increased urbanisation or sea level rise (IPCC, 2012).

Some teachers identified only severe or more frequent flooding as a present or future impact of climate change. Furthermore, a number of teachers only mentioned changes in the occurrences and intensity of drought as a future impact of the phenomena. Arguably, this suggests that these teachers may hold incomplete knowledge of the effect which climate change has on both events.

4.3.2.3.3 Perceptions of the Effect of Climate Change on Intense Rainfall and Snowfall Events

Three teachers acknowledge that climate change has prompted an increase in intense rainfall events. These teachers' perceptions are consistent with findings from the IPCC (2007b) which show that as a result of increased convection tied to rising temperatures the frequency of heavy rainfall events has increased over most land areas. Ten teachers inaccurately state that climate change has prompted the occurrence of more severe snow events (*Table 10*, p. 88). This perception is not reflected in findings from the IPCC (2007b).

4.3.2.3.4 Perceptions of the Effect of Climate Change on Tornado Events

As exhibited in *Table 10* (p. 88), 9% of teachers believe that climate change has caused a general increase in the number and intensity of tornado events. A further 3% of teachers claim that, in the future, tornadoes will become more frequent and intense as a result of climate change. The IPCC (2007b) state that there is insufficient data to show that there has been an increase in the number or intensity of tornado events. As a result, it is also difficult for predictions to be made regarding how the nature of tornadoes may vary in the future (IPCC, 2007b). Thus, the above assumptions made by this group of teachers are incorrect. In the same month as many teachers were interviewed, two areas in Gauteng were hit and severely damaged by tornados. To date there is no scientific evidence which link these tornado events to climate change. Interestingly, the teachers who believe that climate change has resulted, or will result, in an increase in the intensity and number of tornado events globally, also inaccurately attributed the recent tornado events to being evidence of climate

change in Gauteng. Incorrect assumptions surrounding the effect of climate change on the nature of tornadoes may be as a result of these teachers inaccurately linking localised small-scale weather anomalies to global climate change.

4.3.2.3.5 Perceptions of the Effect of Climate Change on Tsunamis, Volcanic Eruptions and Earthquakes

There are a variety of misconceptions and inaccuracies embedded in some teachers' knowledge and understanding of the current and future effects of climate change on extreme events. However, a small percentage of teachers presented more obscure misconceptions. This included the belief that non-climatic natural disasters such as tsunamis, earthquakes and volcanic eruptions are a result of anthropogenic climate change:

'You can see climate change it is happening now because we are experiences the tsunamis, and the earthquakes. We are experiencing things like earthquakes because there is a change in climate' (Township School 2, Teacher B)

'Also the earthquakes and the volcanic eruptions, these are increasing and they are being caused by an increase in heat that we are receiving on a day-to-day basis' (Township School 5, Teacher B)

'...every month there is either an earthquake or a volcano. This is not just happening because of nature, we know very well that with something like volcanoes immediately the ground is extra hot, it means that the climate is full of things which are contributing to this' (Township School 2, Teacher C)

Volcanoes, earthquakes and tsunamis are natural disasters which are not related to climate change, but rather are of a geomorphological and seismic nature. This is highlighted by the fact that there is currently very little scientific evidence which points toward these natural disasters as being products of climate change (UNEP, 2012). The misconception that these geophysical events are impacts of climate change may be as a result of insufficient engagement with scientific information on climate change. This point is substantiated by the finding that generally teachers do not rely on scientific journals and articles for information on climate change, favouring less reliable and accurate sources such as the mass media and the internet (refer to *Section 4.4*). Another explanation for this misconception may be that

these teachers are ‘fusing’ environmental problems into one broad environmental construct. This shows that these teachers may not appreciate the complexity of the environment and its problems.

4.3.2.3.6 Perceptions of the Effect of Climate Change on Heat Waves

Heat waves are defined by the IPCC (2007b, 787) as “... the longest period in the year of at least five consecutive days with maximum temperature at least 5°C higher than the climatology of the same calendar day”. A few teachers (9%) state that heat waves have become more severe as a result of climate change. This assumption is flawed, as although heat waves have been reported to have become more frequent, there is little evidence which shows that heat waves have become more intense (IPCC, 2007b). Representations and reporting of heat wave events in mass media may be attributed to teachers’ incorrect perceptions that heat waves have become more severe. Mass media tends to sensationalise climate change related events to increase readership or viewership (Weingart et al., 2000). Thus, it could be speculated that the mass media may be portraying heat waves as being more severe than ever before.

It has been predicted that in the **future** climate change will cause heat waves to become more frequent, intense and longer lasting over most regions (IPCC, 2007b). A small proportion of teachers (6%) correctly state that heat waves **may become** more severe as a result of climate change. Possible future changes in the length and frequency of heat waves were not acknowledged by any teachers.

4.3.3 Teachers’ Perceptions of Risks Induced by Climate Change

All of the teachers interviewed believe that climate change is associated with a number of risks. In analysing teachers’ perceptions of risk, three major themes emerged: correct understandings of climate change induced risk; misconceptions of climate change induced risk; and alarmist perceptions of climate change induced risk.

4.3.3.1 Correct Understandings of Risks Induced By Climate Change

The majority of teachers display sound and accurate understandings of the risks which are associated with climate change. This is demonstrated by the identification of risks such as

food insecurity, flooding, drought, biodiversity loss, increased risk of water and vector borne diseases such as malaria and cholera, and increases of allergies and asthma among humans (Table 11, below). These are recognised by a number reliable scientific sources as being key risks of climate change (Beggs and Bambrick, 2005; IPCC, 2007b; IPCC, 2007d; Shea et al., 2008; Archer et al., 2010).

However, few teachers hold a deeper scientific knowledge of these risks. When discussing risks, none of the teachers considered some key scientific considerations which relate to risk such as uncertainty. The IPCC (2007b) highlights that there are a number uncertainties which surround climate change. As a result, scientists have been unable to make definite predictions surrounding key aspects of climate change but rather present likely findings together with an indication of the level of uncertainty. Another important aspect of the risks linked to climate change, is that they are expected to be regionally variable (IPCC, 2007b). One of the key reasons for this is that because the nature and extent of many of the predicted impacts of climate change are expected to differ from place to place, the nature and extent of the risks linked to these impacts will vary regionally. The majority of teachers did not consider this key aspect of climate change induced risk.

Table 11: Teachers' Understanding of the Risks Related to Climate Change

Climate Change Related Risks Identified by Teachers	Teachers who Identified Respective Risks (%)
Agricultural Decline	56
<u>Risks to Human Health:</u>	
Increases in Skin Cancer Instances	47
Increases in Malaria and Cholera	28
Increases in Allergies and Asthma	3
Other	19
Economic Decline	38
Food Insecurity	31
Coastal Flooding	31
Flooding	31
Drought	28
Extinction/decline of Flora and/or Fauna	28
Death of People	19
Water Insecurity	16
Increased Veld Fires	13
Desertification	13
Migration Leading to Overpopulation of Certain Regions	9
Lifestyle Compromise	9
Conflict Over Resources	9
Increased Poverty and Unemployment	9
Coral Bleaching	3
Desalination of Estuaries	3
Lack of Oxygen	3

4.3.3.2 Misconceptions of Risks Induced by Climate Change

Some teachers hold a number of misconceptions surrounding climate change induced risks. In most cases these misconceptions were held alongside correct understandings of risks, in few instances did teachers hold entirely erroneous perceptions of risk. The most prevalent misconceptions identified in teachers' conceptions of the risks related to the perceived impact of climate change on human health.

4.3.3.2.1 Misconceptions of the Risks of Climate Change to Human Health

A substantial percentage of teachers held misconceptions regarding the risks of climate change to human health. First, 47% of teachers incorrectly believe that climate change will increase the risk of skin cancer among humans. Skin cancer is largely associated with ozone layer depletion, while climate change has no known effect on the occurrence of the disease (Coskun and Aydin, 2011). Interestingly, the majority of teachers who linked skin cancer to climate change also conflated the enhanced greenhouse effect and ozone layer depletion. Thus, misconceptions of increased instances of skin cancer due to climate change may be as a result of these teachers conflation of the properties of the enhanced greenhouse effect and ozone layer depletion and hence they do not correctly understand that decreases in ozone will increase skin cancer.

Second, three teachers incorrectly believe that climate change has, or will cause increased instances of colds and flu among individuals. There is no scientific evidence which validates these assertions.

'...if you are experiencing a change in weather like it is hot one day, then cold, then it is raining, then it is windy, then we will have more diseases, it might be flu or other things...' (Township School 5, Teacher A)

"...people will fall sick with the colds and the flu and all that..." (Township School 2, Teacher A)

'Health wise it [climate change] is not healthy for us, that is why we are always coughing and sneezing with the colds and the flu, because the body is confused...today is warm, tomorrow is cold, the other day it is dusty, and then the wind is blowing' (Township School 2, Teacher B)

Two teachers held more obscure misconceptions about the risks of climate change to human health. One teacher stated that swine flu is a major associated risk, while another attributed instances of bronchitis and tuberculosis to climate change.

4.3.3.3 Alarmist Perceptions of Risk

A number of teachers hold alarmist perceptions of climate change induced risks. This is illustrated by one teacher who held the belief that climate change will cause a decline in oxygen levels.

‘Also, our natural grass will die and that will mean that there will be a shortage of oxygen in the air...’ (Township School 3, Teacher A)

Some teachers (22%) claimed that climate change will cause death among some individuals. This is highlighted in the following quotes:

‘[When my learner is]...looking at the changes[caused by climate change], she may think the world is going to end now, let me no longer pursue my studies, I don’t want to die studying but I want to die working’ (Township School 2, Teacher C)

‘People will definitely have to try and prepare themselves to survive...’ (Government School 3, Teacher B)

‘...our forefathers used to live to the age of eighty, but then if you look at the generation of my learners they have a very short life expectancy because of this climate change’ (Township School 3, Teacher A)

‘I think that human life will be lost...’ (Township School 5, Teacher B)

‘Yes, with climate change there are always risks because of where we live, so human life will always be at risk’ (Government School 4, Teacher B)

It could be suggested that alarmist perceptions of risk displayed among some teachers may be attributed to the mass media which tends to sensationalise the issue of climate change (Weingart et al., 2000). Many of the teachers who held alarmist perceptions of climate change induced risks also relied on the mass media as a source of information on climate change. In particular teachers’ perceptions that climate change may cause death among

humans may be linked to the mass media. To increase newsworthiness the mass media often links loss of human life to climate change related events and impacts in an extreme and over exaggerated manner (O'Neill and Nicholson-Cole, 2009).

Three teachers used examples from the mass media, particularly films and documentaries, when explaining the risks of climate change. As the examples used by these teachers were often extreme in nature, this finding reinforces the link between mass media's representations of climate change and the formation of alarmist understandings of the phenomena's risks. Examples used by the respondents are illustrated in the following quotes:

'...we are likely to face the same crisis that we see there in '2012' [movie]. There will be so many storms and the whole world will just be filled with water and we will be eroded away' (Township School 5, Teacher B)

'...we might be heading to being like the movies, with big aliens and space ships. At the end of the day if this [climate change] continues we might not be eating beef, we might be eating human flesh because that cow is not there anymore' (Township School 5, Teacher B)

'..if you watch that documentary 'Six Degrees that Could Change the World'...that paints a very bleak picture... you know, increased fires and irreconcilable damage...' (Government School 3, Teacher C)

4.3.4 Teachers' Knowledge and Understanding of Climate Change Mitigation

All of the teachers who participated in this research believe that steps need to be taken to alleviate climate change. *Table 12* (p. 98) displays the strategies which teachers identify as being important for the mitigation of climate change. It should be noted that the percentages displayed in *Table 12* (p. 98) do not total 100. This is because given the open-ended nature of the interview question, "Should steps be taken to alleviate climate change and if so which steps should be taken?" (*Appendix A*, Question 11) many teachers offered more than one response.

Table 12: Teachers' Perceptions of Mitigation Strategies for Climate Change

Mitigation Strategies for Climate Change Identified by Teachers	Teachers who Identified Respective Mitigation Strategies (%)
Use Alternative Energy/ Reduce Burning of Fossil Fuels	53
Use Public Transport/Reduce Car Use	41
Reduce Deforestation/Plant More Trees	38
Recycling	28
Energy Conservation	28
Filter/Reduce Industrial Emissions	25
Reduce the use of CFCs/aerosols	19
Education	16
Legislation or Policy Implementation	16
Use Unleaded Petrol	16
Reduce Dumping	9
Reduce Air Travel	9
Use Renewable Resources	6
Buy Eco-Friendly Products	6
People Should Become Vegetarians	6
Reduce Population Growth	3
Greening Cities	3
Seasonable Farming Practices	3
Buy Fair Trade Foods	3
Minimise Water Pollution	3

When analysing teachers' understandings of climate change mitigation approaches, two major findings emerged: correct understandings of mitigation strategies for climate change; and incorrect/poor understandings of mitigation strategies for climate change. The majority of teachers (50%) hold a combination of both correct and incorrect understandings of appropriate mitigation strategies for climate change, while 41% of teachers hold entirely correct understandings of appropriate mitigation strategies for climate change. A few teachers (9%) hold entirely inaccurate conceptions of mitigation strategies for climate change.

4.3.4.1 Correct Understandings of Mitigation Strategies for Climate Change

Many teachers hold relatively correct conceptions of some of the key strategies for mitigating climate change. This is demonstrated by the fact that the use of alternative energy sources, the use of public transport or reduction in car use, planting trees or a reduction in deforestation, energy conservation, the filtering or reduction of factory emissions, and recycling were among the most frequently identified mitigating strategies (refer to *Table 12*, above). Each of these strategies have been listed by a number of reliable sources as being appropriate and important for climate change mitigation (Ferguson, 2009; IPCC, 2007b; FAO, 2010; Gorte and Sheikh, 2010; UNESCO and UNEP, 2011b). Other indirect mitigating

strategies correctly named by a smaller percentage of teachers were education (16%) and legislation or policy implementation (16%).

Teachers who identified either, alternative energy (53%), planting of trees or the reduction of deforestation (38%), energy conservation (28%), or the filtering or reduction of factory emissions (25%) displayed a deeper understanding of why such strategies would help mitigate the threat of climate change:

'...we could move to cleaner energies so that we burn fewer fossil fuels... so like we could move away from running appliances that require a lot of electricity which then requires the burning of more fossil fuels to create electricity' (Private School 6, Teacher A)

'...every time we give off carbon dioxide like in the industrial processes, we are adding these particles into the atmosphere which are going to trap heat...so maybe the filtering of factory emissions will help' (Private School 4, Teacher C)

'I think we can mitigate climate change through reducing our carbon emissions...so they can embark on programmes where they don't allow such high emissions due to filters and all that kind of thing' (Government School 4, Teacher)

'It [climate change] can be slowed down through making people plant trees... trees really help us in the reduction of carbon dioxide...' (Township School 2, Teacher A)

'Also...we must reduce the number of trees that are being cut down, so that they can at least destroy some of the carbon dioxide' (Government School 5, Teacher A)

Among those teachers who correctly identified the use of public transport or a reduction in car use, it was not clear if there was an understanding as to why such activities would be helpful. In these instances teachers did not explain why or how such mitigating activities would be useful.

A number of teachers (28%) identified recycling as a mitigation strategy for climate change. Recycling is a broad mitigation strategy for a host of environmental problems including general land and air pollution (University of Massachusetts Amherst, 2006). However,

recycling has increasingly been recognised as an important means through which one can contribute towards reducing the threat of climate change (Yarrow, 2008; UNEP and UNESCO, 2011b). The majority of teachers who identified recycling did not provide explanation as to how or why recycling might contribute to climate change mitigation. Thus it was unclear as to whether these teachers have accurate conceptions of the use of this mitigation strategy in relation to climate change. However, four teachers from this group did offer explanations as to why recycling might be useful for climate change mitigation. Two of these teachers were accurate in their understandings, as shown below:

'...things like recycling, urge people to recycle rather than dumping, because that will take away some of the greenhouse gases' (Township School 3, Teacher B)

'They can do recycling, because then not as much stuff needs to be manufactured which then requires more energy consumption and that' (Private School 5, Teacher A)

However, the other two teachers displayed problematic flaws in their understanding of the importance of recycling for reducing the threat of climate change:

'We should recycle, don't litter everywhere because pollution destroys the atmosphere' (Township School 2, Teacher B)

'Like the handyman, they leave their rubbish everywhere, they don't know that whatever they are having it can be recycled to not cause this pollution' (Township School 2, Teacher C)

Education was correctly identified by 16% of teachers as a mitigation strategy for climate change. Education is believed to be one of the strongest means through which to raise public awareness about climate change (UNEP, 2006a,b; UNESCO and UNEP, 2011a,b). In addition, education is suggested to promote critical changes in attitudes and behaviours toward an array of environmental issues, such as climate change. The value of climate change education has been thought to lie in its ability to strengthen public support for and participation in various mitigating strategies and policies put in place by governments (UNEP, 2006a,b; UNESCO and UNEP, 2011a,b).

Among the majority of teachers who identified education regarding climate change as a mitigation strategy, it was unclear as to whether there is an awareness of why this approach is important. One teacher correctly stated that education would raise awareness of climate change. Another teacher stated that climate change education would teach people about the importance of the environment and the effects of greenhouse gases. However, the remaining teachers did not explain the value and usefulness of climate change education as a mitigation strategy.

Education regarding climate change has typically focused on two groups in society (Devine-Wright et al., 2004): the public (through means such as general awareness campaigns); and school children (through educational programmes and their school curricula). School children have been identified as being one of the most important societal groups to target as they represent the future generations and need to be equipped to make the best decisions for the planet, now and in the future (UNESCO, 2009a).

Of the teachers who identified climate change education as a mitigation strategy, the majority did not specify which societal groups this approach should target. Two teachers inferred that education regarding climate change should be aimed at the general public. Given their profession it is surprising that none of the teachers from this group referred specifically to the education of school children in their responses. It is also interesting that given their role as ‘educators’, that a relatively small percentage (16%) of teachers named education as a mitigation strategy. This finding suggests that teachers may not be aware of the importance of their own profession or the role that they may play in climate change mitigation.

4.3.4.2 Poor Understandings of Mitigation Strategies for Climate Change

Some teachers held incorrect conceptions of the mitigating strategies which are appropriate for climate change. In a few instances teachers named actions such as the use of unleaded petrol (16%), the use of eco-friendly products (6%), seasonal farming practices (3%), and a reduction of water pollution (3%) as being suitable strategies for climate change mitigation. While these actions are suitable approaches for addressing environmental and social issues in general, they are not directly related to reducing anthropogenic climate change. The lack of specific knowledge regarding strategies appropriate for climate change mitigation may be a result of insufficient interaction with scientific information on climate change

(Papadimitriou, 2004). Through basic analysis of association it became apparent that none of the teachers who suggested the above strategies use scientific journals and articles for information on climate change. Another factor which may contribute to this finding may be that teachers combine all environmental problems into a general environmental construct. In studies of a similar nature comparable results were yielded where some participants held incorrect knowledge of appropriate and specific mitigation strategies for climate change (Dove, 1996; Groves and Pugh, 1999; Papadimitriou, 2004; Bozdogan, 2010).

The inaccurate conception that a reduction in the use of CFCs or aerosol deodorants will help mitigate climate change is held by 19% of teachers. Each of the above mentioned mitigation strategies are typically associated with, and are well-known for contributing to, the reduction of ozone layer depletion rather than climate change (Bostrom et al., 1994). Therefore, it is likely that this conception has occurred as a result of these teachers erroneously linking the enhanced greenhouse effect and climate change to ozone layer depletion. This point is illustrated by the fact that each of these teachers had made clear connections between ozone layer depletion and the enhanced greenhouse effect during the course of the interview. As a result of drawing incorrect links between the two phenomena these teachers are incorrectly connecting and extending strategies known for contributing to lowering ozone layer depletion to climate change mitigation. This is clearly illustrated in the case of four teachers who made direct reference to 'ozone layer depletion' or the 'ozone' when explaining the usefulness of reducing the use of CFCs or deodorants for climate change mitigation:

'Like for instance we should stop using those spray deodorants because they are bad for the ozone layer' (Township School 1, Teacher B)

'Also another thing is the types of deodorants and perfumes that we are using, you need to check on the can that they say 'ozone friendly' (Township School 5, Teacher A)

'We must reduce CFCs, those are particularly important to target because they play such a big role in ozone layer depletion' (Private School 4, Teacher B)

'Try to reduce the CFCs, like the gases from fridges they make the hole in the ozone layer very bad' (Township School 5, Teacher B)

4.3.5 Section Summary

The findings detailed in this section highlight that teachers have fundamental limitations and misconceptions with regard to climate change. Limitations in knowledge were identified in many teachers' belief that climate change is solely as a result of human activity. In addition, while teachers were generally able to correctly identify the future and present global impacts of climate change, the majority hold limited and/or inaccurate deeper conceptual knowledge of these impacts. In a few instances some teachers named obscure past and/or present global impacts of climate change. It was found that the majority of teachers held a combination of both correct and poor understandings of appropriate mitigation strategies for climate change. However, despite these limitations in knowledge, teachers tend to display a generally sound and accurate understanding of the risks induced by climate change.

Another prominent finding regarding teachers' understandings of climate change is that they are unaware of the scientific uncertainties which accompany climate change and its related aspects.

4.4 The Sources of Information on Climate Change for Teachers

In this section the sources of information which teachers rely on for information on climate change are explored. A broad outline of the sources of information identified by all participants across all school categories is given, followed by an examination of the possible influences and effects of the sources found to be used most frequently by teachers on their knowledge and perceptions of climate change. As textbooks represent an important teaching resource, the effect of textbooks on teachers' knowledge and perceptions of climate change is also briefly examined.

The majority of teachers, across private, government and township schools, stated that their knowledge of climate change is primarily gained from the mass media, such as newspapers and television (refer to *Table 13*, p. 105). Another form of mass media used by some teachers is films and documentaries. The predominant films referred to by some teachers were 'An Inconvenient Truth' and '2012'. Four teachers referred to the National Geographic documentary 'Six Degrees that Could Change the World'.

Teachers tend to rely on the mass media as a major source of information on climate change because it is a readily accessible source from which knowledge on climate change can be accessed. This point is supported by the responses of a number of teachers:

'I really enjoy reading newspapers because they are so easily accessible...'
(Government School 1, Teacher A)

'I get most of my information from newspapers and DVD's... mainly because they are so easy to get my hands on...' (Private School 6, Teacher A)

'I get my information [about climate change] from different media's because they are so readily available... I can just turn on my TV and see a news segment about climate change or open up a magazine and read about it' (Private School 3, Teacher C)

'...because of their accessibility, I tend to rely on newspapers, television and DVD's for information on climate change' (Government School 3, Teacher A)

'...also, I get my knowledge from the television, the radio and the newspapers, because it is no problem to reach those sources, you know...' (Township School 5, Teacher B)

'I look at the medias because they talk about climate change all the time and they are so nicely accessible for me...' (Township School 3, Teacher A)

Another source frequently identified as a key contributor to teachers' knowledge of climate change is personal observation of day-to-day weather events. It could be suggested that teachers' reliance on day-to-day observation may be due to the relative accessibility associated with such a source.

The internet was also identified by a number of teachers as being a key contributor of information (refer to *Table 13*, p. 105). A smaller percentage of teachers identified textbooks, the 'South African Geography Teachers Network', word of mouth, presentations, workshops and conferences, books, scientific journals and articles, and colleagues as sources of information on climate change (refer to *Table 13*, p. 105). It should be noted that the percentages displayed in *Table 13* do not total 100. This is because given the open-ended

nature of the interview question, ‘Where do you find out information on climate change’ (Appendix A, Question 12), many teachers offered more than one response.

Table 13: Teachers’ Sources of Information on Climate Change

Teachers’ Sources of Information on Climate Change	Teachers Reliant on Respective Sources of Information (%)
Mass Media	91
Observation of day-to-day weather events	63
Internet	50
Textbooks	28
South African Geography Teachers Network	25
Word of Mouth	19
Presentations, Workshops and Conferences	16
Books	16
Scientific Journals and Articles	9
Colleagues	6

Teachers across each of the three school categories rely on the above sources to varying extents. First, it is noted that township school teachers are reliant on day-to-day observation of weather events to a far greater extent than private and government school teachers. Of the township school teachers interviewed, 90% named observation as a source of information, while 70% of government school teachers and 33% of private school teachers rely on this source. This difference could be attributed to affordability and availability, with more concrete and reliable sources generally being out of reach for teachers in less resourced areas and schools.

Compared with teachers in government and private schools, a far greater number of teachers from township schools identified textbooks as a source of information on climate change. Limited access to a variety of sources in less resourced township areas may make it necessary for these teachers to rely on textbooks to a far greater extent.

A number of teachers (25%) identified the ‘South African Geography Teachers Network’ as a source of information on climate change. The ‘South African Geography Teachers Network’ is an e-mail based group for interested geographers from across the country. The group sends a variety of emails offering the latest information, debates, pictures and videos on various environmental issues, including climate change, to registered members. Interestingly, all of the 25% of teachers who identified the ‘South African Geography Teachers Network’ as a source of information are those who teach in private schools. There may be a general lack of

awareness about the ‘South African Geography Teachers Network’ among township and government school teachers.

4.4.1 The Effects of Key Sources on Teachers’ Knowledge and Perceptions of Climate Change

As highlighted above, the mass media and day-to-day observation of weather events are the two most utilised sources of information on climate change by teachers across all school categories. Correspondingly these sources were found to have the most clearly identifiable effects on teachers’ perceptions and understandings of climate change.

4.4.1.1 The Effect of Mass Media on Teachers’ Perceptions and Understandings of Climate Change

A substantial number of teachers (91%) from the private, government and township school sample have primarily gained information about climate change through the mass media. Through often inaccurate, flawed, or alarmist, representations of climate change from the mass media have been found to have a variety of negative implications for many lay individuals understandings of climate change (Weingart, 2000; Daskolia et al., 2006; Carter, 2006). This finding is supported in this research where a number of inaccurate, flawed or alarmist perceptions of climate change held by some teachers could be attributed to mass media representations. A detailed account of the effect of mass media of teachers’ perceptions of climate change has been provided in previous sections within this chapter.

4.4.1.2 The Effect of Day-to-Day Observation of Weather Events on Teachers’ Perceptions and Understandings of Climate Change

Another way in which many teachers learn about climate change is through personal observation of day-to-day weather events. Many teachers (75%) across all school categories referred to recent events as evidence of climate change. Reference to recent events was most evident when teachers were asked about the impacts of climate change in Gauteng. This is illustrated in the extracts, below:

‘...our seasons are shifting, our winters are becoming shorter and more severe. I mean this year we saw rain in June. Our summer seems to be extending way into March and April’ (Government School 3, Teacher B)

'Well I think what is happening at the moment... look at the snow which we had'
(Government School 2, Teacher A)

'...from my observation... we don't experience a spring anymore, we move straight from winter to summer' (Township School 5, Teacher A)

'...we would never really experience the amount of rain here that we are now experiencing' (Private School 1, Teacher B)

'The recent thing... severe winter rains' (Township School 1, Teacher B)

'For the past two years we have had rain right into winter... that for me is indicative of a change in the climate' (Government School 1, Teacher A)

Three teachers were interviewed during a particularly hot summer period in Gauteng. Although the temperatures were high, there is no indication that this was due to climate change. The three teachers interviewed during this period stated that rising temperatures are evidence of climate change in Gauteng. This is illustrated in the following quotes:

'...we used to in Gauteng only experience temperatures of maybe 30 degrees, not 35 degrees!' (Township School 5, Teacher A)

'The temperatures in Limpopo are very high, and now you see those temperatures in Gauteng' (Township School 5, Teacher B)

'Again temperature, I think that we seem to each year, we have a greater number of days of temperature that are higher than what we would normally get' (Government School 4, Teacher B)

Furthermore, two teachers were interviewed during a day in spring where temperatures were lower than usual. Again, there is no evidence that this occurrence was as a result of climate change. However, both interviewees linked the drop in temperature to climate change. This is demonstrated in the extracts below:

'Especially now, this month, last year on this day it was extremely hot... but today is very cold' (Township School 2, Teacher C)

'You see that the temperatures are unpredictable now days... it is meant to be spring time but we are wearing jerseys' (Township School 3, Teacher B)

Finally, many teachers were interviewed in the same month as two areas in Gauteng were afflicted by tornadoes. To date there is no scientific indication that suggests that these events may be linked to climate change. Four teachers referred to the recent tornado events as being evidence of the effects of climate change in Gauteng.

'In Gauteng, for example we had tornadoes the other day, which I think in an indication of climate change' (Private School 1, Teacher A)

'Yes... Like the tornadoes here that we had, that's a major indication of climate change' (Private School 4, Teacher B)

'...like the tornadoes recently, we have never had something like a tornado before' (Private School 2, Teacher A)

'Another thing is that recently we have experienced tornadoes and those are things that we have not really experienced before, for me that is a sign of climate change' (Township School 5, Teacher B)

The above findings are evidence of teachers using day-to-day observation as a key source of information on climate change. In a study conducted by Papadimitriou (2004) similar results were yielded, as participants were found to use recently experienced local weather events as evidence of climate change.

Five teachers noted recent global events when asked about the impacts of climate change on a world-wide scale. The majority of these respondents tended to refer to recent natural disasters. In particular, the drought in Somalia, which was topical at the time when the interviews were conducted, was used as evidence of climate change. The drought occurred as a result of a prolonged El Niño event in the region (African Union, 2011). Although El Niño events are predicted to become more frequent and severe with the onset of climate change because they are driven by thermodynamic fluctuations in equatorial atmospheric and oceanographic conditions (UNEP, 2006b), there is little scientific evidence which suggests at this stage that the drought in Somalia was linked to climate change.

Climate can either have short term, periodic changes known as climate variability, or long term changes known as climate change (USAID, 2007). Usually climate variability occurs as a result of natural processes, while climate change can be influenced by anthropogenic activities (Jonsson, 2010). From the above findings it is clear that some teachers are not taking into account long-term trends when considering climate change, but are rather attributing short term weather anomalies or recent weather events to climate change. This finding is consistent with the writings of Stehr and von Storch (1995), who state that the long term and slow climatic changes associated with anthropogenic climate change are not generally recognised or noticed by the lay individuals. Instead, lay individuals automatically focus attention on more tangible short term, naturally occurring rare extremes or weather anomalies. As a result, events which are actually tied to climate variability are mistaken for climate change.

However, over half the teachers interviewed, many of whom cited day-to-day observation of weather events as a source of information on climate change, defined climate change as occurring ‘over time’. This suggests that although teachers have a theoretical understanding that climate change occurs over an extended period of time, in reality when teachers encounter a weather anomaly or hear about one (such as the drought in Somalia) they tend to attribute it to climate change.

4.4.2 The Effect of Textbooks on Teachers Knowledge and Perceptions of Climate Change

As shown on *Table 13* (p. 105), a fairly small percentage of teachers (28%) cited textbooks as a source of personal information on climate change. However, 91% of teachers stated that they primarily use textbooks as a source for teaching learners about climate change. Thus, these textbooks may play an active role in informing teachers’ knowledge and perceptions of climate change. In *Chapter 5* the extent to which a selection of textbooks used most frequently by interviewed teachers for climate change education provide relevant, accessible and accurate information on climate change, is analysed. It became apparent through this analysis that many of the recognised shortfalls in textbooks information on climate change mirror the primary misconceptions, limitations and inaccuracies identified in teachers’ knowledge and perceptions of climate change. This will be discussed and examined in more detail in *Chapter 5*.

4.4.3 Section Summary

The findings detailed in this section reveal that teachers rely on a broad range of sources for information on climate change. The sources of information found to be used most by teachers, are the mass media and day-to-day observation of weather events. These two sources were found to have key influences on teachers' perceptions of climate change. Frequent use of the mass media as a source of information is likely a cause of many teachers' inaccurate, flawed, and/or alarmist perceptions of climate change. Teachers who use personal day-to-day observation of weather events as a source of information on climate change tend to incorrectly name recent weather or climatic events as evidence of more long term climate change. The textbooks used most frequently by teachers for climate change education have a variety of impacts on teachers' knowledge and perceptions of climate change (this will be discussed in further detail in *Chapter 5*).

4.5 Teachers' Attitudes towards Climate Change

In this section teachers' attitudes toward climate change are discussed. Attitudes of disinterest and apathy toward climate change were identified among many teachers. This finding may have implications for the success of climate change education in schools and thus will be a focal point of this section.

4.5.1 Teachers' Feelings of Apathy and Disinterest toward Climate Change

Many teachers demonstrate feelings of disinterest and apathy toward climate change. This is demonstrated in the following extracts:

'I don't really take an active interest in the subject of climate change...' (Government School 4, Teacher B)

'I don't like the way climate change is being emphasized as being this all encompassing problem that if you deal with it that everything else will fall into place, because I have been around long enough to know that things go in and out of fashion.....so why is global warming being made into a special case... it's obviously because it is the catch of the day, it's what everyone is pushing at the moment and the scientific community and aid organisations need all these things for legitimacy and funding...' (Government School 2, Teacher C)

As a result of these feelings of disinterest and apathy, some teachers do not attempt to extend their knowledge beyond the basics.

'...I only have to teach the kids basic knowledge, so I don't feel why I have to go and extend my knowledge beyond what I need to teach them' (Government School 2, Teacher B)

'With teaching climate change I don't have the time or the interest in it to do extra research and to give my learners stuff about climate change that actually they don't need to learn about. If something comes my way then I will look at it for my lessons, but otherwise I just don't see the point' (Government School 4, Teacher B)

A possible explanation for these attitudes found among certain teachers could be the phenomenon known as 'green fatigue' (Haslett et al., 2011). Green fatigue refers to increasing attitudes of apathy and disinterest toward the issue of climate change among many of the lay individuals in society (Haslett et al., 2011). It is thought that this has come about predominantly as a result of climate being sensationalised by a variety of sources, such as the mass media and politics. This sensationalism and hype has led to overexposure to the issue of climate change among lay individuals, and results in the above mentioned feelings of apathy and disinterest (Thorne, 2009; Shields, 2010; Haslett et al., 2011). Some of the teachers interviewed had alarmist perspectives of climate change (*refer to Section 4.3.3.3*), often highlighting and focusing on the possible disastrous, hazardous and extreme impacts and risks of climate change. This alarmist perspective may lead teachers to feel despondent about climate change, and unable to do anything about it, due to its severity and scale (Swim et al, 2009).

In previous studies green fatigue has been identified among many learners in schools who display indifference toward the issue and a disinterest in learning about it (Haslett et al., 2011). Similarly, in this research, a number of teachers emphasized that many of their learners display boredom and a lack of interest in climate change.

'...they are so sick of hearing about it [climate change], they roll their eyes. Like ten years ago when we talked about AIDS, they are so sick of hearing about the environment and climate change...' (Private School 6, Teacher A)

'I think it is something that is becoming a lot more like the topic of AIDS, where it has been thrown in people's faces all the time that eventually, like with the kids, it goes in one ear and out the other, because they are so sick and tired of hearing about it' (Government School 2, Teacher B)

'You know, I would hate climate change to get to a topic like AIDS. Now I know that AIDS is vital, but for many of the students when you mention AIDS they groan and say 'not again'. So, I wouldn't like climate change to be seen like that, and I am worried that it is heading down that path' (Private School 2, Teacher B)

'...so to tell them [learners] they are heading for global warming and therefore must not go for technology and live simpler lives, and grow spinach instead of eating McDonalds, you will lose them. In fact, you have lost them long ago...' (Government School 2, Teacher C)

'The way kids are today, they have their interests, everything is now Facebook and they don't really care about learning about environmental things like climate change' (Government School 2, Teacher A)

This level of green fatigue amongst learners has resulted in them having very little deeper, meaningful or active interest in climate change beyond academics. This point is illustrated by a number of participants:

'I think that they are just interested in finding the answers, they aren't really going to research beyond that, they aren't really actively interested in it, they just want the marks' (Government School 2, Teacher B)

'...they only care about the marks, they want to get their matric and move on with their lives' (Government School 2, Teacher C)

'...from an academic perspective they are interested in it... you know, outside academics I am not convinced that they would take an active interest in it, or be really concerned about it' (Private School 1, Teacher A)

'At the end of the day all they want are the facts about climate change, they don't want to or have to go beyond that' (Private School 4, Teacher C)

It became clear during this research that, although sources such as the media and politics play a role in levels of green fatigue in learners, another main driver of green fatigue may be teachers themselves (Thorne, 2009). Teachers' knowledge of climate change has an influence over whether or not learners are educated about the issue in a way which inspires environmental attitude, behaviour, value and lifestyle changes (Khalid, 2003). However, another vital component of successful climate change education is teachers' attitudes toward the issue (Liu et al., 2012). Teachers have the potential to affect whether a learner is likely to meaningfully engage with a topic both inside and outside the classroom.

Teachers' own apathy toward the issue is likely to come across in their teaching of the topic, thus contributing to the identified disinterest in climate change which is displayed by learners. This point is further illustrated by the fact that many of the same teachers interviewed in this research who pointed toward green fatigue in learners, also displayed prominent levels of green fatigue themselves. This finding is an important one, as it illustrates the level to which teachers' perspectives and outlook on climate change can possibly impact on the interest and level of engagement of learners with the topic.

4.6 Section Summary

Teachers' attitudes of apathy and disinterest toward climate change were explored in this section. Such attitudes may be linked to a phenomenon known as green fatigue. Furthermore, it is likely that teachers' attitudes of disinterest and apathy in climate change are being passed onto learners in the classroom and having adverse effects on the extent to which learners meaningfully engage with climate change.

CHAPTER 5: A CRITIQUE OF TEXTBOOKS AVAILABLE TO FET GEOGRAPHY TEACHERS FOR CLIMATE CHANGE EDUCATION

5.1 Introduction

Climate change education in schools has increasingly been recognised as an important approach to address the issues of climate change (UNESCO, 2009a,b). Climate change education aims to increase awareness and understanding of climate change and its related aspects. Through improved awareness and understanding, climate change education seeks to inspire meaningful changes in behaviour, values and attitudes relating to the environment. In addition, climate change education seeks to ensure that learners are equipped to make informed decisions which aid climate change mitigation and to encourage awareness of and support for mitigating strategies and policies put in place by various governments (UNEP, 2006a). A final objective of climate change education is to provide learners with the tools to successfully adapt to the predicted effects and impacts of climate change (UNESCO, 2009a,b; UNESCO and UNEP, 2011b).

In the South African context, textbooks represent a crucial factor in the overall success of climate change education in schools. In this study it was found that textbooks are one of the primary resources used by 91% of teachers for teaching learners about climate change at the FET level. Thus, it could be suggested that textbooks represent a foundation from which learners are able to gain and/or enhance knowledge of climate change (Choi et al., 2010). Secondly, textbooks were listed by 28% of teachers as being one of the key sources of information relied on to enhance personal understanding of climate change. Oakes and Saunders (2002) highlight that often teachers will impart their own knowledge in conjunction with the information provided in prescribed resources when teaching learners about a topic. Therefore, textbooks may influence teacher perceptions of climate change which may in turn be passed on to learners in the classroom (Khalid, 2003, Choi et al., 2010). Ultimately, textbooks may affect both learner and teacher perceptions of climate change, which will in

turn determine whether the ultimate aims of climate change education are met (Choi et al., 2010).

This chapter assesses the value and suitability of textbooks used by a sample of thirty-two FET geography teachers for climate change education. Textbooks selected for analysis in this research were those used most frequently by the interviewed teachers, both as a source of personal information on climate change, and for climate change education in the classroom. These textbooks are listed below. All of the nine textbooks assessed were written in accordance with the stipulations and guidelines of the Republic of South Africa's Department of Educations' Revised National Curriculum Statement (RNCS) for Geography at FET level.

- Focus on Geography (Grade 10, Grade 11 and Grade 12)
- Geography for all (Grade 10, Grade 11 and Grade 12)
- Oxford In Search of Geography (Grade 10, Grade 11 and Grade 12)

Through the analysis of textbooks, it became clear that teachers' knowledge and perceptions of climate change (detailed in *Chapter 4*) may be tied to the representations of climate change identified in the textbooks. This represents an important finding, and thus is linked to the discussion in this chapter.

5.2 Criteria Used for Textbook Classification, Analysis and Evaluation

To critique the value of textbooks for climate change education, the extent to which textbooks provide relevant, accessible and accurate information was analysed. Textbooks were categorised according to a set of developed criteria (see *Table 14*, p. 116), based on the primary aims and objectives of climate change education. In addition, in developing this set of criteria, the criteria used to evaluate American Environmental Science and Earth Science textbooks in a similar study conducted by Choi et al. (2010), were incorporated and adapted. Based on these criteria textbooks were classified and analysed.

Table 14: Criteria for Evaluation of Textbooks

1.	Textbooks which enhance understanding of the greenhouse effect	Textbooks which do not enhance understanding of the greenhouse effect
2.	Textbooks with sufficient coverage of climate change	Textbooks with insufficient/scanty coverage of climate change
3.	Textbooks which contain entirely accurate information about climate change	Textbooks which contain inaccuracies in information about climate change
4.	Textbooks which make climate change relevant and applicable to the South African context	Textbooks which do not make climate change relevant and applicable to the South African context

For each criterion, parameters were set based on the considered opinion of the researcher. The set parameters allowed for textbooks to be categorised into respective criteria. The parameters used for each criterion will be outlined and explained in upcoming sections. It was not possible to use a definitive scale from which to measure the extent to which textbooks met each parameter and criterion. Thus, classification of textbooks was subjective based on the researchers' knowledge.

A detailed critique (based on the criteria and classification in *Table 14*, above) of each of the selected textbooks for climate change education is now provided.

5.3 Textbook Evaluation

5.3.1 Coverage of the Greenhouse Effect in textbooks

The first criterion (*Table 14*, above) classifies textbooks according to the extent to which these resources enhance understandings of the greenhouse effect which represents a crucial foundation from which to grasp climate change (Shepardson et al., 2011). To strengthen understandings of the greenhouse effect, textbooks need to provide sufficiently detailed information which is accurate of both the natural and enhanced greenhouse effect. To classify textbooks, an examination was undertaken as to whether these textbooks discuss the natural and/or enhanced greenhouse effect. If textbooks were found to include content on the natural and/or enhanced greenhouse effect, this content was then evaluated based on the extent to which the key components of the natural and/or enhanced greenhouse effect were sufficiently and accurately detailed. Textbooks should include an outline of the key components of the greenhouse effect: the process of incoming solar radiation and outgoing infrared radiation; the process of the majority of infrared radiation being absorbed and re-emitted toward Earth (and space) by greenhouse gases (and cloud); and the overall warming effect of this process.

A further aspect considered, was whether textbooks included visual representations (diagrams) of the greenhouse effect. The use of visual representations in textbooks has been identified as an important aid to enhancing learner understanding by making abstract concepts visually tangible and “...cognitively tractable...” (Uttal and O’Doherty, 2008, 54). To foster a complete understanding of the greenhouse effect, it is important that visual representations of the mechanism clearly illustrate all of its key components. It is also imperative that visual representations of the greenhouse effect are accurate, to prevent any inconsistencies in knowledge. Finally, it was considered important that textbooks show the relationship between the **enhanced greenhouse effect** and **climate change**.

Three of the textbooks selected for assessment included **no written or visual coverage** of either the **natural or enhanced greenhouse effect**. These texts were: *Geography for all: Grade 11*, *Geography for all: Grade 12* and *Focus on Geography: Grade 12*. A likely explanation for this finding is linked to the requirements and guidelines of the RNCS for Geography. The RNCS does not directly specify that the greenhouse effect needs to be examined in Geography at Grade 11 or Grade 12 level (DoE, 2008a; DoE; 2008b). Six of the remaining textbooks selected for assessment **did** contain coverage of the greenhouse effect to varying extents. The degree to which each of these six textbooks may serve to enhance understanding of the natural and enhanced greenhouse effect, according to the above described criteria, will now be outlined.

Focus on Geography: Grade 10 outlines the key components of the natural and enhanced greenhouse effect in a sufficiently detailed and accurate manner. In addition, the textbook makes clear links between the enhanced greenhouse effect and climate change. *Focus on Geography: Grade 10* does not provide a visual representation of the greenhouse effect. However, a diagram (shown in *Figure 19*, p. 118) illustrating the passage of the sun’s energy through the troposphere is provided. As shown in *Figure 19*, this diagram does include and represent components (such as the process of incoming and outgoing radiation) which drive the greenhouse effect. Thus, this diagram could strengthen understandings of the process of the greenhouse effect. However, the diagram is on a separate page from the explanation of the greenhouse effect. In addition, the textbook does not provide a clear written indication that the diagram can be linked to greenhouse effect. It may, therefore, be unlikely that those

making use of the textbook will refer to the diagram to further their knowledge of the greenhouse effect.

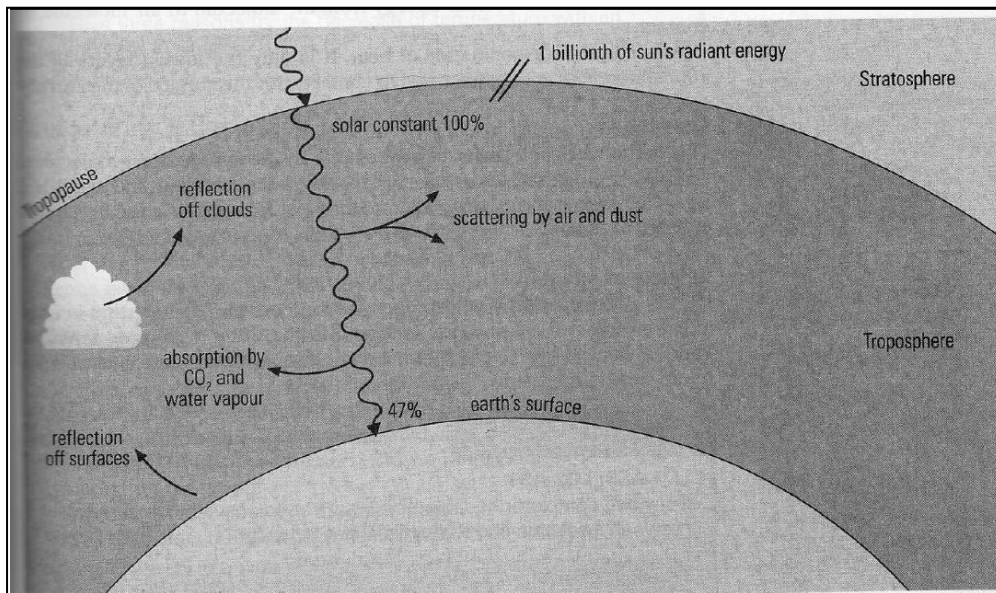


Figure 19: Focus on Geography: Grade 10 visual representation of the passage of the sun's energy through the troposphere (Dilley et al., 2008a, p. 65)

Focus on Geography: Grade 11 offers a brief description of the enhanced greenhouse effect. The information provided in this written explanation is limited and does not adequately detail all of the key components of the enhanced greenhouse effect. For instance, while the written paragraph correctly explains that greenhouse gases "...help to trap some of the heat energy reaching our planet from the sun" (Dilley et al., 2008b, 211), it does not specifically highlight the process of incoming solar radiation and outgoing infrared radiation. In addition, while it is accurately stated in this resource that greenhouse gases 'trap' heat, there is no indication that greenhouse gases then re-emit this heat energy toward Earth and outer space.

Focus on Geography: Grade 11 provides an annotated visual representation of the enhanced greenhouse effect, which adequately illustrates the key components, which were identified as being insufficiently described in the written paragraph (see *Figure 20*, p. 119). This may ensure that any inadequacies in knowledge arising from the scanty content present in the written paragraph are corrected. *Figure 20* (p. 119) illustrates the process of incoming short-wave radiation and outgoing long wave radiation, which were not mentioned in the written paragraph. In addition, the visual representation does illustrate, through the use of arrows,

that the heat energy trapped by greenhouse gases is re-emitted back to Earth. It is, however, important to note that neither the diagram, nor the written paragraph, suggest that some of the heat energy absorbed by greenhouse gases is emitted into outer space.

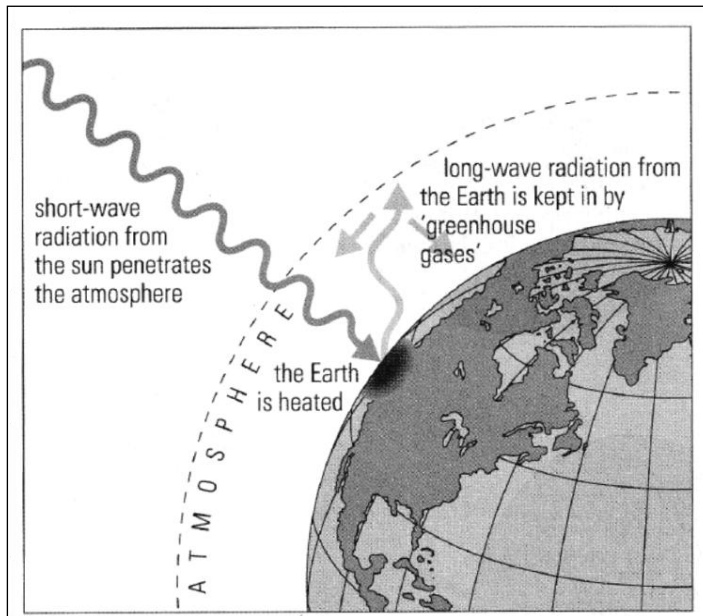


Figure 20: *Focus on Geography: Grade 11* visual representation of the Greenhouse Effect (Dilley et al., 2008b, p. 211)

Finally, although *Focus on Geography: Grade 11* provides a brief written outline and visual representation of the enhanced greenhouse effect, the textbook makes no reference to the natural greenhouse effect. This omission may result in limitations in knowledge, allowing the greenhouse effect to be viewed primarily as an anthropogenic process, rather than being a natural process enhanced by human activity. The textbook highlights the effect of the enhanced greenhouse effect on the rate and scope of climatic changes.

Oxford In Search of Geography: Grade 10 provides a sufficiently detailed account of both the enhanced and natural greenhouse effects. The description and explanation of the enhanced greenhouse effect is evident in two stages. First, an analogy describing the mechanism of a greenhouse is used to illustrate the basic functioning of the enhanced greenhouse effect. Analogies are generally used to facilitate understanding of a new concept by allowing individuals to relate unfamiliar information to an already understood concept (Orgill and Bonder, 2004). Thus, the success of an analogy in developing concept knowledge is dependent on whether it is based on a principle which is already familiar and understood.

In the Northern Hemisphere greenhouses are utilized frequently. However, in countries in the Southern Hemisphere, such as South Africa, greenhouses are not commonly used due to warmer climatic conditions. Thus, it could be argued that the concept of a greenhouse may not necessarily be familiar or known to those using *Oxford In Search of Geography: Grade 10*. As a result of this, the success of this analogy in promoting a sound foundation from which to understand the more complex functioning of the enhanced greenhouse effect may be compromised. Second, *Oxford In Search of Geography: Grade 10*'s account of the enhanced greenhouse effect includes a theoretical explanation of the key components of the mechanism. Overall these explanations are accurate, however, it is imprecisely stated that greenhouse gases cause heat energy to be "...trapped around the Earth's surface" (Winter et al., 2008, 52). Rather, greenhouse gases absorb heat energy and re-radiate this energy back to Earth and outer space (IPCC, 2007a).

Oxford In Search of Geography: Grade 10 also provides a visual representation of the enhanced greenhouse effect (*Figure 21*, below). As can be seen in *Figure 21*, most of the key components of the enhanced greenhouse effect are accurately illustrated. However, the diagram does contain one inaccurate depiction of a key component of the greenhouse effect, where greenhouse gases are erroneously represented as occurring 'in a layer' in the atmosphere. Despite this component being incorrectly represented in the diagram, the written explanation of the greenhouse effect emphasizes that "...carbon dioxide is not like a sheet or blanket around the Earth. Gases, particles, dust and water vapour are constantly moving about" (Winter et al., 2008, 52).

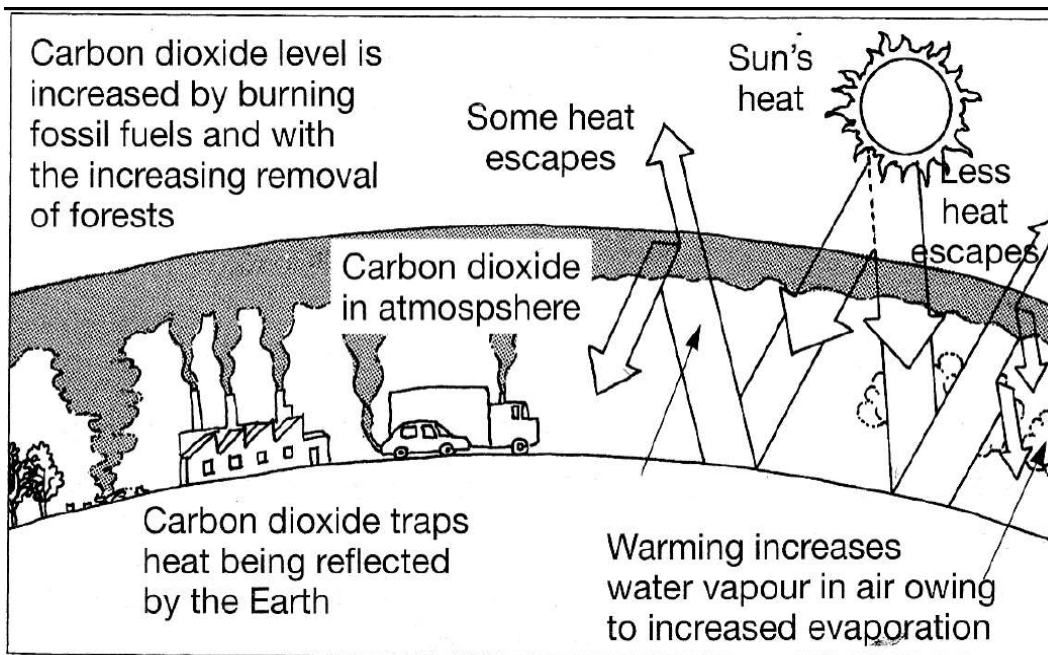


Figure 21: *Oxford In Search of Geography: Grade 10* visual representation of the enhanced greenhouse (Winter et al., 2008, p. 52)

Oxford In Search of Geography: Grade 10 discusses the enhanced greenhouse effect and climate change in different chapters. It is important that information regarding the enhanced greenhouse effect and climate change are placed in close proximity to ensure that the links between the two are recognised.

Oxford In Search of Geography: Grade 11 provides a sufficiently detailed and accurate written account of both the natural and enhanced greenhouse effect. In addition, the textbook creates clear and logical links between the enhanced greenhouse effect and climate change. *Oxford In Search of Geography: Grade 11* also presents an annotated visual representation of the natural and enhanced greenhouse effect, see *Figure 22*, below. Overall, in *Figure 22* all the key components of the natural and enhanced greenhouse effect are explained in a clear, understandable, and accurate manner. However, one key component of the greenhouse effect is incorrectly illustrated in *Figure 22*: greenhouse gases are inaccurately represented as occurring in a layer in the atmosphere. In addition, the label explaining this representation incorrectly states that outgoing radiation is "...trapped **beneath** the greenhouse gases" (Wilson et al., 2009, 242).

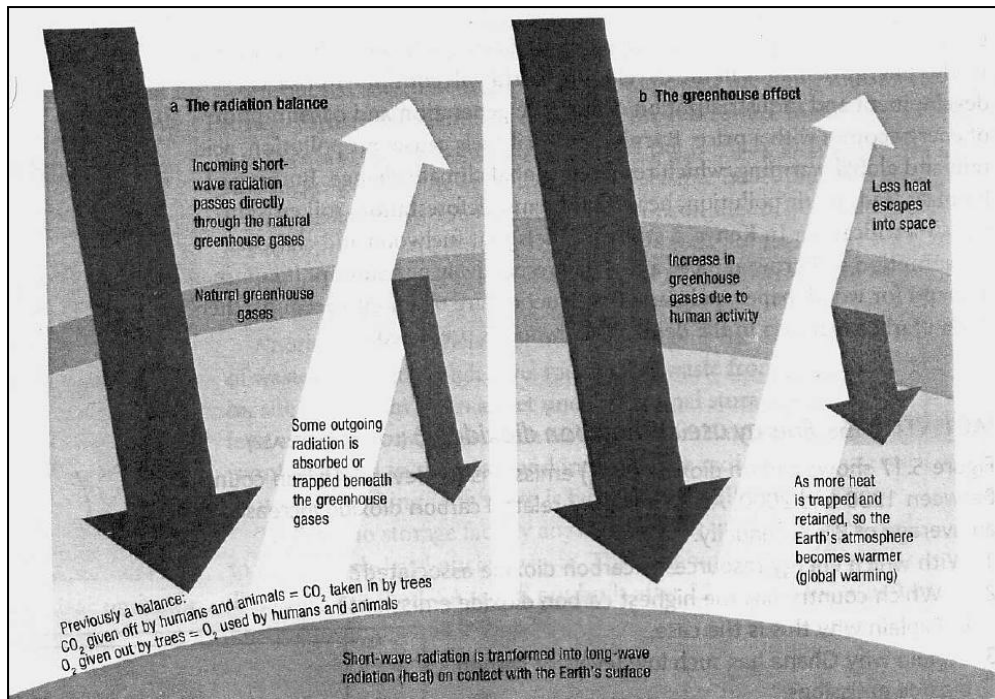


Figure 22: *Oxford In Search of Geography: Grade 11* visual representation of the natural and enhanced greenhouse effect (Wilson et al., 2009, p. 248)

Oxford In Search of Geography: Grade 12 provides an outline of both the natural and enhanced greenhouse effect in a brief paragraph. Despite the brevity, the key components of the natural and enhanced greenhouse effects are accurately highlighted. In this textbook, it is correctly stated that greenhouse gases “...absorb and re-radiate infrared radiation both upward and downward” (Wilson et al., 2007, 60). As mentioned previously, both *Oxford In Search of Geography: Grade 10* and *Oxford In Search of Geography: Grade 11* claim that greenhouse gases trap heat, neglecting to further explain that greenhouse gases re-radiate absorbed heat energy back to Earth. Thus, *Oxford In Search of Geography: Grade 12* is the only textbook in this series which correctly describes the interaction between greenhouse gases and heat energy. *Oxford In Search of Geography: Grade 12*, also correctly explains that the greenhouse effect is primarily a natural process which has been intensified due to an increase in anthropogenic activity.

Oxford In Search of Geography: Grade 12 does not provide a diagram explaining the greenhouse effect. Given the important role of visual representations in the consolidation of knowledge, this omission may have implications for the extent to which the process is understood by those using the textbook.

Geography for all: Grade 10 provides both an accurate and sufficient outline of the natural and enhanced greenhouse effect. *Geography for all: Grade 10* draws clear and logical links between the enhanced greenhouse effect and climate change. In addition, this textbook provides an annotated visual representation (*Figure 23*, p. 123) of the enhanced greenhouse effect, which is clear and easy to comprehend. The annotated visual representation correctly illustrates and explains all of the key components of the enhanced greenhouse effect, and is supported by an accurate written description of the mechanism.

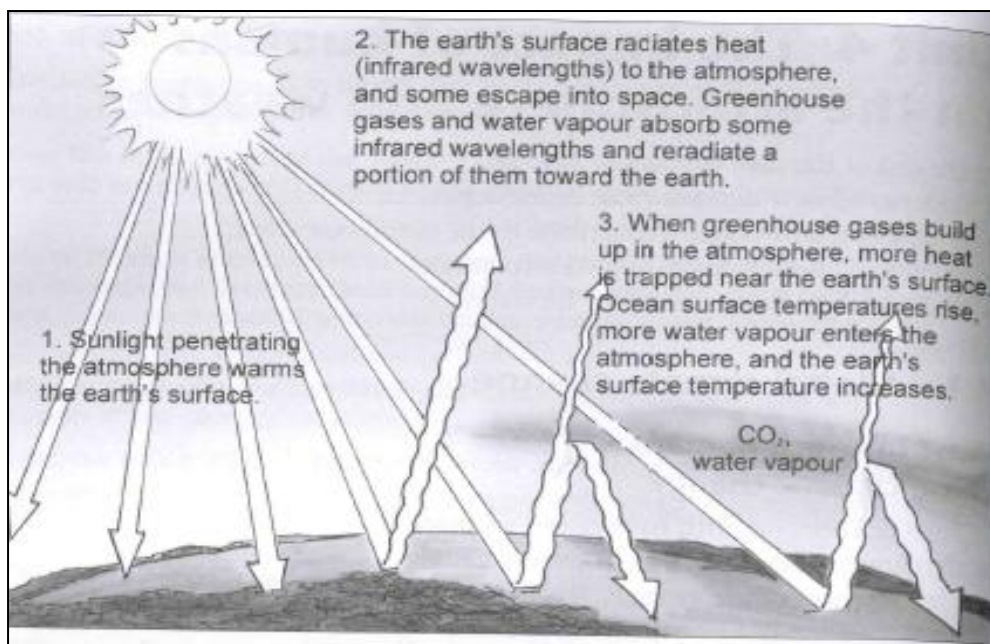


Figure 23: *Geography for all: Grade 10* visual representation of the enhanced greenhouse effect (Dube et al., 2008, p. 116)

5.3.2 Coverage of Climate Change in Textbooks

The second criterion establishes the extent to which textbooks cover the issue of climate change (*Table 14*, p. 116). Thus, the extent to which textbooks outline and discuss the following aspects of climate change was evaluated:

- the causes of climate change
- the current and predicted physical and social global impacts of climate change
- mitigation of climate change
- adaptation to climate change

Although there are a variety of aspects to climate change, these particular aspects were selected as their inclusion in textbooks was identified as being vital to meeting the key aims and objectives of climate change education. It was taken into consideration that textbooks, due to curriculum and publisher constraints, may not be able to focus on all of these aspects in detail.

All of the textbooks, with the exception of *Focus on Geography: Grade 12*, include content on climate change. However, the degree to which these textbooks cover each aspect of climate change differs. Any inadequacies identified in textbooks coverage of climate change may not necessarily be the fault of the textbook authors themselves, but rather due to the RNCS for Geography. One of the primary functions of the textbook, is to serve as the “...*written curriculum* that links the *intended curriculum* (articulated by the Revised National Curriculum Statements) to the...*implemented curriculum* (that is actually experienced in the classroom)” (Swanepoel, 2010, 59). Thus, textbook authors rely on, and have to adhere to, a prescribed curriculum as a guiding framework for the writing of these resources. The RNCS content framework for Geography at FET level calls for certain aspects of climate change, such as its causes, effects and consequences, to be explored (DoE, 2008a; DoE, 2008b). However, the RNCS does not give specific guidance as to the **extent** to which aspects of climate change should be detailed. This may ultimately result in limitations on the coverage of climate change in FET textbooks.

5.3.2.1 Textbook coverage of the causes of climate change

Climate change can be linked to both natural process (such as volcanic eruptions and sunspots) and anthropogenic activities associated with greenhouse gas emissions (IPCC, 2007a). However, with the onset of the industrial revolution and the associated rise in anthropogenic activities, human influences have been identified as playing a more pertinent role in current and future changes in global climatic systems (IPCC, 2007a; Houghton, 2009). The IPCC (2007a) states that many human activities have resulted in the increased release of a variety of greenhouse gases. The accumulation of these gases in the atmosphere has resulted in an overall warming of the climatic system (Houghton, 2009).

In terms of enhancing learners’ understanding of the causes of climate change, it is important that textbooks highlight both the natural and anthropogenic factors which drive climate

change. Individuals who are aware that the Earth's climate may alter due to natural variations may develop a greater understanding of the extent and role of people in contributing to climate change. Thus, to assess textbooks' coverage of the **causes** of climate change, two primary factors were taken into account: whether or not textbooks explain the role of natural variations in climate change; and the extent to which greenhouse gases and related anthropogenic activities which contribute to climate change are outlined. A wide variety of anthropogenic activities such as cement production, land use change, electricity production and use result in the emission of greenhouse gases (Chapman, 2007; IPCC, 2007b). However, it is unlikely that textbooks could highlight the majority of these anthropogenic activities due to limitations on climate change content recommended/enforced by the RNCS and publishing houses. So, for textbooks to be defined as adequately covering the human causes of climate change, texts should provide an outline of *at least* the **key** contributing anthropogenic activities associated with the release of **key** greenhouse gases.

The IPCC (2007b) identify three key greenhouse gases which have increased markedly since the onset of the industrial revolution: carbon dioxide, methane, and nitrous oxide. The anthropogenic activity which is responsible for the highest levels of carbon dioxide release is the combustion of fossil fuels (IPCC, 2007b). There are a wide range of human activities which require the burning of fossil fuels, such as air travel, industrial activity and coal-fired electrical production (Bureau of Meteorology, 2007; IPCC, 2007b). Increases in carbon dioxide levels in the atmosphere have been attributed to land use changes, such as deforestation, both as it reduces the photosynthetic potential to convert carbon dioxide into oxygen, but further as the trees removed are often burnt, releasing further carbon dioxide (Costa and Foley, 2000). Anthropogenic activities associated with the highest levels of methane emissions include: crop and livestock farming and the combustion of fossil fuels (Bureau of Meteorology, 2007; IPCC, 2007b). Nitrous oxide emissions are primarily associated with the burning of fossil fuels and the use of fertilizer in agriculture. Fossil fuel use, agriculture, and land use change have been a "...dominant cause of increases in greenhouse gases" (IPCC, 2007b, 81). The extent to which textbooks outline these key activities and their associated greenhouse gases was evaluated.

Based on the above considerations, textbooks were placed into one of two categories: **adequate** coverage of the causes of climate change, and **inadequate** coverage of the causes

of climate change. Textbooks placed in the former category, are those which include **adequate** coverage of the **majority** of the above outlined considerations. Textbooks placed into the latter category, are those which contain **scanty or limited coverage** of the **majority** of the above outlined considerations.

5.3.2.1.1 Textbooks Containing Adequate Coverage of the Causes of Climate Change

Of the eight texts which include coverage of climate change, four were classified as containing adequate coverage of the causes of climate change. These texts are: *Focus on Geography: Grade 10*, *Focus on Geography: Grade 11*, *Oxford In Search of Geography: Grade 11* and *Geography for all: Grade 10*.

Focus on Geography: Grade 10 lists a number of the key anthropogenic activities linked to driving climate change. Examples of these include: deforestation, increased industrialisation and fossil fuel combustion, and livestock farming. *Focus on Geography: Grade 10* also (correctly) highlights the respective key greenhouse gases, such as carbon dioxide and methane, which are released as a result of each of the listed key anthropogenic activities. In addition to the key activities, the textbook also mentions a number of other, less significant, anthropogenic activities which are linked to increased greenhouse gas emission levels. The inclusion of additional anthropogenic activities may broaden knowledge of the causes of climate change. However, one of the additional listed activities is inaccurate. It is suggested in the textbook that “The world’s population has increased, [and] therefore there is a larger intake of oxygen and release of carbon dioxide through respiration” (Dilley et al., 2008a, 69). In reality, the majority of carbon dioxide exhaled by humans is re-absorbed by plants during the process of photosynthesis (EPA, 2012). Furthermore, there is no peer reviewed scientific evidence to date which argues that an increase in levels of exhaled carbon dioxide as a result of population increase has contributed to anthropogenic climate change. It is important to highlight that the textbook names the release of CFCs through “...the use of aerosol sprays, refrigerants, air conditioners and industrial cleaning materials” as contributing to climate change (Dilley et al., 2008, 69). Although this assertion is theoretically sound, as CFCs do contribute to the enhanced greenhouse effect and climate change, they are primarily associated with ozone layer depletion (Boyes et al., 1993). Thus, the texts’ naming of CFCs as a cause of climate change may cause those using the textbook to establish erroneous links between ozone layer depletion and climate change. This point is validated by the finding in

this research, that many teachers' who established a link between ozone layer depletion and the enhanced greenhouse effect, justified this link through the commonality of CFCs shared by the two phenomena (refer to *Section 4.2.4.1*). The likelihood of those using the textbook incorrectly linking these two unrelated phenomena is made greater by the fact that *Focus on Geography: Grade 10* was found to, in other instances, directly link or conflate ozone layer depletion and climate change (this will be discussed in greater detail in *Section 5.3.3.1*). Despite providing adequate coverage of the anthropogenic drivers of climate change, *Focus on Geography: Grade 10* makes little reference to the role of natural processes in climate change.

Focus on Geography: Grade 11 was deemed to provide overall adequate coverage of the causes of climate change. First, the role of both natural and human processes in climate change is described in the textbook. This is illustrated in the following quote:

“There are theories that sunspot activity could be responsible for temperature changes on Earth, or cycles of volcanic activity. But it is the changing balance of gases in the air which is definitely the main cause of global warming” (Dilley et al., 2008, 211)

Second, *Focus on Geography: Grade 11* provides adequate coverage of the three key greenhouse gases which are primarily associated with driving the enhanced greenhouse effect. However, despite highlighting the role natural processes in climate change and offering sound coverage of the key greenhouse gases, *Focus on Geography: Grade 11* does not provide extensive coverage of the key anthropogenic activities associated with increases in greenhouse gas emissions. Rather, the textbook discusses only the role of the combustion of fossil fuels as contributing to climate change.

Oxford In Search of Geography: Grade 11 begins its coverage on the causes of climate change by providing definitions of long term climate change and short term climate change (*Figure 24*, p. 128). These definitions may serve to enhance overall knowledge and understanding of climate change though highlighting the important difference between climate variability and permanent climate changes. As shown in *Figure 24* (p. 128), the textbook states that long term climate change is driven by anthropogenic influences.

However, the textbook does not highlight the historical role which natural processes are known to play in long term climatic shifts.

Long-term climate change refers to the slow warming of the Earth since the early 1900s. This is being caused by the greenhouse effect. Atmospheric gases such as carbon dioxide are absorbing heat and the atmosphere is getting warmer. An increase in world population and human activities, especially industrial activity, has led to an increase in greenhouse gases. The impact of global warming on the Earth's climate is still being debated. Many people feel that action needs to be taken now to reduce global warming as the consequences of no action could be quite severe.

Short-term climate change refers to changes to the climate periodically. Examples of short-term climate change are El Niño and La Niña. Studies of these short-term climate changes indicate that they happen about every three to seven years.

Figure 24: *Oxford In Search of Geography Grade 11*: Definitions of long-term and short term climate change (Wilson et al., 2009, p. 86)

Oxford In Search of Geography: Grade 11 adequately highlights the three key greenhouse gases (methane, carbon dioxide and nitrous oxide) as examples of greenhouse gases which have increased as a result of human activity. The textbook also names sulphur dioxide as an example of a greenhouse gas contributing to the enhanced greenhouse effect and climate change. Sulphur dioxide is rather classified as an indirect greenhouse gas (Glade et al., 2012). Through naming an indirect greenhouse gas in conjunction with key greenhouse gases *Oxford In Search of Geography: Grade 11* may promote inaccurate conceptions of the key greenhouse gases which contribute to the enhanced greenhouse effect.

Oxford In Search of Geography: Grade 11 provides examples of a variety of key anthropogenic activities which have prompted a rise in key greenhouse gases:

“The burning of fossil fuels, increased fertilizer use and deforestation result in greater levels of CO₂, sulphur dioxide, nitrous oxide and methane in the atmosphere”
(Wilson et al., 2009, 247)

As shown in the above quote, examples of a selection of climate change inducing anthropogenic activities directly followed by a list of associated greenhouse gases is provided

in Oxford *in Search of Geography: Grade 11*. However, no indication of which anthropogenic activity is linked to the emission of which particular greenhouse gas (or gases) is evident. This may prompt those using the textbook to incorrectly assume that all of the listed greenhouse gases are associated with all of the listed anthropogenic activities. The linking of an anthropogenic activity to its associated greenhouse gas is important as it may serve to enhance knowledge of the causes and mitigation of climate change.

Geography for all: Grade 10 contains an outline of a number of greenhouse gases which have increased in atmospheric concentration as a result of anthropogenic activity, and which contribute to the enhanced greenhouse effect and climate change. Included in this outline are the key greenhouse gases of methane, nitrous oxide and carbon dioxide. Also included in the outline are CFCs. The textbook also highlights the percentage by which each of these gases contribute to the enhanced greenhouse effect through the use of a pie chart (*Figure 25*, below).

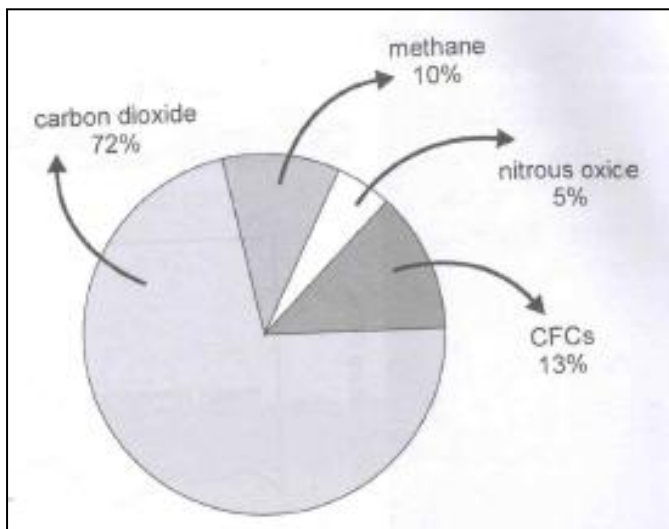


Figure 25: *Geography for all: Grade 10* pie chart representing percentage contribution of greenhouse gases to climate change (Dube et al., 2008, p. 115)

It is important to highlight that the percentages represented in the pie chart are not scientifically accurate. This is demonstrated in *Table 15* (p. 130), which illustrates The Bureau of Meteorology's (2007) ascribed percentages for greenhouse gas contribution to climate change which would have been calculated through air quality assessments.

Table 15: Greenhouse Gas Contribution to Climate Change (Adapted from: The Bureau of Meteorology, 2007, p.18)

Greenhouse Gas	Proportional Contribution to the Enhanced Greenhouse Effect (%)
Carbon Dioxide	60
Methane	20
CFCs	14
Nitrous Oxide	6

The pie chart does provide an accurate visual representation of the relative **extent** to which carbon dioxide and nitrous oxide contribute to climate change. However, the pie chart suggests that methane contributes less to climate change than CFCs, which contradicts the calculations provided by the Bureau of Meteorology (2007).

Geography for all: Grade 10 provides an outline of some of the human activities contributing to increased greenhouse gas emission levels, and thus climate change. Included in this outline are examples of many ‘key’ contributing anthropogenic activities, such as deforestation, burning of fossil fuels, agricultural activity, and increases in industrial activity. However, in one instance, the textbook inaccurately suggests that climate change is enhanced through human activities which result in increased water vapour content in the atmosphere. In reality anthropogenic activities have a minimal direct influence on levels of atmospheric water vapour (IPCC, 2007b). In addition, in some cases *Geography for all: Grade 10* highlights the greenhouse gas (or gases) associated with a named anthropogenic activity. This is demonstrated in the following quote:

“...CO₂ comes from the burning of fossil fuels and the destruction of forests. Methane and nitrous oxide come largely from agricultural activity” (Dube et al., 2008, 115)

However, this practice is inconsistent, and in most cases the textbook does not specify which greenhouse gas (or gases) is associated with each named human activity.

5.3.2.1.2 Textbooks Containing Inadequate Coverage of the Causes of Climate Change

Four textbooks were classified as containing inadequate coverage of the causes of climate change. These texts are: *Oxford in Search of Geography: Grade 10*, *Oxford in Search of Geography: Grade 12*, *Geography for all: Grade 11* and *Geography for all: Grade 12*.

Two textbooks, *Oxford In Search of Geography: Grade 10* and *Geography for all: Grade 12*, were found to contain limited coverage of the key greenhouse gases associated with anthropogenic activity and the enhanced greenhouse effect/climate change, and the anthropogenic activities associated with the increased release of such gases. In addition, these texts did not refer to the role of natural processes in climatic changes.

In *Oxford In Search of Geography: Grade 10* and *Geography for all: Grade 12* carbon dioxide is the only greenhouse gas described as being released through anthropogenic activities and playing a part in the enhanced greenhouse effect/climate change. These textbooks make no reference to the role of the increased emissions of methane, nitrous oxide, or even any of the other less direct greenhouse gases in driving the enhanced greenhouse effect/climate change. Carbon dioxide is widely regarded as being “...the most important anthropogenic greenhouse gas” (IPCC, 2007b, 2). This may account for the textbooks focus on carbon dioxide in explanations of the enhanced greenhouse effect and/or climate change. However, it is important that all key greenhouse gases associated with human activity are mentioned to ensure a well-rounded knowledge of the causes of climate change.

In addition, *Oxford In Search of Geography: Grade 10* and *Geography for all: Grade 12* both provide limited outlines of the key anthropogenic activities associated with increases in greenhouse gas emissions. In *Oxford In Search of Geography: Grade 10* only the anthropogenic activities which have prompted increases in carbon dioxide emissions are discussed. It is highlighted in the textbook that the combustion of fossil fuels “...in homes, industry and power stations...” will cause increases in carbon dioxide emissions (Winter et al., 2008, 52). The role of deforestation in causing increased levels of carbon dioxide in the atmosphere is briefly mentioned. Similarly, In *Geography for all: Grade 12* the combustion of fossil fuels is the only anthropogenic activity relating to climate change related anthropogenic activity. However, no reference to other key anthropogenic activities which have caused increases in the emissions of other key greenhouse gases is made.

Finally, in *Geography for all: Grade 12*, there is no reference to the role of natural processes in long term climatic changes. In *Oxford In Search of Geography: Grade 10* it is correctly explained that prior to anthropogenic forcings, long term shifts in climate were a result of

natural processes. However, the textbook does not further explain that natural processes **still** play a role in long term climate changes. This is exhibited in the following quote:

“... during the last Ice Age temperatures dropped and ice sheets formed over large areas of the Earth...Recent scientific research in the Antarctic shows there were periods of extreme warming and cooling long before industries and motor cars were invented...It is most likely due to a change in the amount of energy from the sun”
(Winter et al., 2008, 78 & 79)

Oxford in Search of Geography: Grade 12 and *Geography for all: Grade 11* both provide limited examples of the key anthropogenic activities associated with the release of key greenhouse gases. In explanations of the causes of climate change in *Oxford in Search of Geography: Grade 12*, only anthropogenic activities associated with increased concentrations of carbon dioxide in the atmosphere, such as the combustion of fossil fuels and deforestation, are detailed, whilst anthropogenic activities associated with the release of other key greenhouse gases, such as methane and nitrous oxide, are not. Similarly, in *Geography for all: Grade 11* anthropogenic activities linked to the emission of carbon dioxide are primarily listed. However, the textbook does state that “...other greenhouse gases are also released into the atmosphere by various forms of energy production” (Brett et al., 2006, 208). In addition, these texts do not detail the role of natural processes in climate change. Nevertheless, these texts **do** include adequate detail of the key greenhouse gases (released through anthropogenic activities) associated with driving the enhanced greenhouse effect and climate change.

5.3.2.2 Textbooks coverage of the global impacts of climate change

To evaluate coverage of the global impacts of climate change in the textbooks selected for analysis, a number of considerations were made. First, whether textbooks outline both the **current impacts** of climate change and the **predicted impacts** of climate change was assessed. By highlighting **current impacts**, learners (and teachers) may become aware of the immediate significance of climate change, which may inspire a meaningful contribution toward climate change mitigation. Through increased knowledge and awareness of the **future impacts** of climate change, learners (and teachers) may be better equipped to adapt and respond to such changes (UNFCCC, 2009; UNESCO and UNEP, 2011a).

Another consideration was whether textbooks provide an outline of both the physical and social impacts of climate change. An outline of both physical and social impacts of climate change may ensure that those using the textbooks gain a well-rounded knowledge of this aspect of climate change, and understand the degree to which it impacts on societies. The IPCC (2007b,e) has listed a number of observed and predicted global impacts of climate change to both natural and human systems. However, due to content and coverage limits placed on textbooks by publishing houses and the RNCS, it was considered unlikely that textbooks would detail **all** of the social and physical impacts linked to climate change. Therefore the provision of a **selection** of the predicted and observed impacts of climate change on both physical and human systems was considered to be adequate.

Third, the accuracy of the impacts listed in textbooks was considered. The observations and assessment of observed impacts and predicted future impacts of climate change, presented in the IPCC's latest Working Group II Fourth Assessment Report, were used as a foundation from which to assess the accuracy of impacts described in textbooks. However, understandably, the textbooks selected for assessment are aimed at FET level high school learners and their teachers, and thus the impacts reported textbooks may not directly correspond to, or be as scientifically complex as, those listed by the IPCC. In addition, the textbooks selected for assessment in this research were generally published either before, or in the same year as, the release of the Fourth Assessment Report. Thus, the impacts listed by textbooks may not entirely match the **latest** IPCC projections and predictions. At this point, it is important to suggest that it is impractical "...to consider that textbooks can adapt to the knowledge base that evolves with every IPCC assessment" (Choi et al., 2010, 896). Therefore, it could be suggested that other sources such as climate change teaching resources and guides provided by organisations such as UNEP and UNESCO should be used in teaching to supplement textbooks (Choi et al., 2010).

5.3.2.2.1 Textbook Coverage of Current Global Impacts of Climate Change

All of the textbooks selected for analysis highlight the observed increases in temperature associated with the enhanced greenhouse effect. However, *Focus on Geography: Grade 11* and *Geography for all: Grade 11* are the only two textbooks which outline the current global impacts associated with these temperature increases.

Focus on Geography: Grade 11 highlights a selection of impacts of climate change on both human and physical systems. *Table 16*, below, highlights the observed impacts of climate change listed by the textbook.

Table 16: The observed impacts of climate change as listed by *Focus on Geography: Grade 11* (Adapted from: Dilley et al., 2008b, p.212-213)

Observed Physical Impacts of Climate Change	Observed Social Impacts of Climate Change
Melting of ice caps, glaciers and ice sheets	Evacuation of people in Maldives as a result of sea level rise
Snow melt	Infrastructure at risk in North America as a result of thawing permafrost
Rising sea levels	
Flooding in America’s Gulf Coast and Egypt’s Nile Delta as a result of sea level rise	
Maldives are disappearing as a result of sea level rise	
Northern hemisphere summers are longer than in 1850. Spring starts 9 days earlier and autumn starts 10 days later	
Warming tundra	

The observed impacts of climate change listed by *Focus on Geography: Grade 11* are mostly accurate, and are supported by the IPCC reports and assessments (IPCC, 2007b,c,e). However, in a few instances, the impacts listed by *Focus on Geography: Grade 11* are inaccurate. For instance the textbook states that “...the Maldives are disappearing...” as a result of rising sea levels (Dilley et al., 2008b, 213). While the IPCC (2007e) highlights that sea level rise is an increasing threat to the Maldives, no suggestion is made by the scientific body that the island is ‘disappearing’.

Second, as shown on *Table 16*, above, it is suggested by the textbook that in the “...northern hemisphere summers are longer than in 1850. Spring starts 9 days earlier and autumn starts 10 days later” (Dilley et al., 2008b, 213). Although the IPCC (2007e) confirms that in the Northern Hemisphere there has been a shift in the timing of seasons, the number of days the textbook ascribes to the shifts in spring and autumn in the Northern Hemisphere are not reflected by the IPCC (2007e), and have been proven to be both species and location specific (Parmesan and Yohe, 2003). However, despite this inaccuracy, this impact, as described by *Focus on Geography: Grade 11*, may allow those using the textbook to gain an understanding of the implications of climate change on the timing of seasons.

Geography for all: Grade 11 does not detail observed impacts of climate change on human systems. However, the textbook does contain a newspaper article which provides examples of observed weather and climatic events which occurred as a result of climate change. These are illustrated in the following quote:

“The United Kingdom and the United States experienced severe flooding in 2004; Europe experienced severe heat waves; and North America was hit by a number of exceptionally strong hurricanes” (Adapted from: *The Star*, 10/12/2004 in: Brett et al., 2006, 207)

Reference to these events as direct evidence of climate change is scientifically flawed, as detailed in *Section 4.3.2.3.2*, and may lead those using the textbook to develop incorrect perceptions of climate change. While the events listed by the textbook **may** be broad indications of climate change, they cannot be identified as impacts directly resulting from climate change. The listing of ‘recent’ events as evidence of climate change in the newspaper article may cause those using the textbook to assume incorrectly that all short-term anomalies in weather and climate may be attributed to anthropogenic climate change.

5.3.2.2.2 Textbook Coverage of Future Global Impacts of Climate Change

The coverage of the future global predicted impacts of climate change on human and physical systems in textbooks varied. The majority of textbooks list a selection of both physical and social future impacts of climate change. However, *Oxford In Search of Geography: Grade 11* and *Oxford In Search of Geography: Grade 12* were found to detail only possible physical impacts of climate change and did not include coverage of possible social impacts. Lastly, two textbooks (*Geography for all: Grade 11* and *Focus on Geography: Grade 12*) contained **no** coverage of the future global impacts of climate change on either physical or human systems.

5.3.2.2.3 Textbooks Coverage of the Physical Predicted Impacts of Climate Change

Table 17 (p. 136) illustrates predicted physical impacts of climate change as outlined by the textbooks. It is important to highlight that three textbooks (*Focus on Geography: Grade 12*, *Geography for all: Grade 11* and *Oxford In Search of Geography: Grade 12*) do not feature on *Table 17*. *Geography for all: Grade 11* and *Focus on Geography: Grade 12* do not

include coverage of this aspect of climate, and thus could not be included in *Table 17. Oxford In Search of Geography: Grade 12* **did** provide an outline of the physical impacts of climate change. However, the impacts named in the textbook were broad and unspecific and therefore difficult to tabulate. The physical future impacts listed in *Oxford In Search of Geography: Grade 12* will be examined at a later point.

Table 17: Physical Future Impacts of Climate Change as Outlined in Textbooks

	Focus on Geography: Grade 10	Focus on Geography: Grade 11	Oxford In Search of Geography: Grade 10	Oxford In Search of Geography: Grade 11	Geography for all: Grade 10	Geography for all: Grade 12
Sea level rise	✓	✓	✓	✓	✓	✓
Melting icecaps/ice sheets/glaciers	✓	✓				✓
Rising sea temperatures	✓			✓		
Rising Earth surface temperatures	✓	✓	✓	✓	✓	✓
Increases in veld and forest fires		✓				
Biodiversity loss	✓				✓	✓
Increase in frequency of tropical cyclones	✓					✓
Increase in intensity of tropical cyclones		✓				
Heavier monsoons	✓					
Heat waves					✓	
Changes in drought and flood patterns	✓		✓			✓
Heat waves						
Altered rainfall patterns		✓		✓		✓
Agricultural decline			✓	✓		✓
Decline in water resources	✓		✓			
Destruction of Coral Reefs	✓					✓
Damage to process of photosynthesis and genetic structure of plants					✓	

The textbooks represented on *Table 17*, above, highlight **predicted physical** impacts of climate change through a variety of means. In most cases textbooks provide a list of physical impacts. Two textbooks (*Oxford In Search of Geography: Grade 11* and *Focus on Geography: Grade 11*) used annotated maps to represent key predicted physical impacts. One textbook (*Oxford In Search of Geography: Grade 10*) contains a newspaper article which outlines a selection of physical impacts of climate change. The newspaper article used by this textbook greatly sensationalises the future physical impacts of climate change. This is demonstrated in the following quote:

“Be warned- climate change will affect the way we live... while some changes may take a long time to happen themselves, many seem to promise more sudden and dramatic effects...” (Adapted from: Argus, 2001, in: Winter et al. 2008, 77)

Most textbooks listed an average of five **physical future** impacts of climate change. This is sufficient to provide those using the textbooks with a solid understanding of the nature and extent of the predicted physical impacts associated with climate change. The majority of future physical impacts of climate change listed by textbooks (*Table 17*, p. 136) are reflected in the projections made by the IPCC (2007b,e). However, in a few instances, the impacts described by textbooks are not reflected in these projections. For instance, each textbook erroneously suggests that in the future, global temperature increases linked to anthropogenic climate change will continue. However, scientists have highlighted that trends of rising temperatures are regionally variable, and thus some areas of the world are experiencing a decrease in average temperatures as a result of climate change (IPCC, 2007b). It is projected that these statistical trends are likely to continue in both direction and magnitude (IPCC, 2007b,e). Second, *Focus on Geography: Grade 10* and *Geography for all: Grade 12* both suggest that in the future climate change will cause an increase in the frequency of tropical cyclone events (*Table 17*, p.136). It has been scientifically projected that in future years the intensity and frequency of tropical cyclones may increase, however, the IPCC (2007b,e) does not suggest an overall increase in tropical cyclone occurrences as a result of climate change.

Many of the physical impacts listed by textbooks are expected to vary in nature and extent between different regions. This occurrence is known as ‘regional variability’. When reading the predictions made by the IPCC (2007b,e) it becomes apparent that the regional variability of certain impacts is often detailed and/or heavily scientific. It is unrealistic for textbooks, especially those aimed at FET level learners, to provide an analysis of the regional variability of listed physical impacts in a way which is similar to the IPCC (2007b,e). However, it may be useful for those using textbooks to gain a basic understanding of the regional variability of some of the physical impacts of climate change. Four textbooks **did** provide a basic and broad outline of the regional variability of **some** of the listed physical impacts.

As highlighted previously, the physical impacts of climate change outlined in *Oxford In Search of Geography: Grade 12* are not included in Table 17 (p.136). The impacts named by the textbook can be viewed in Figure 26, below:

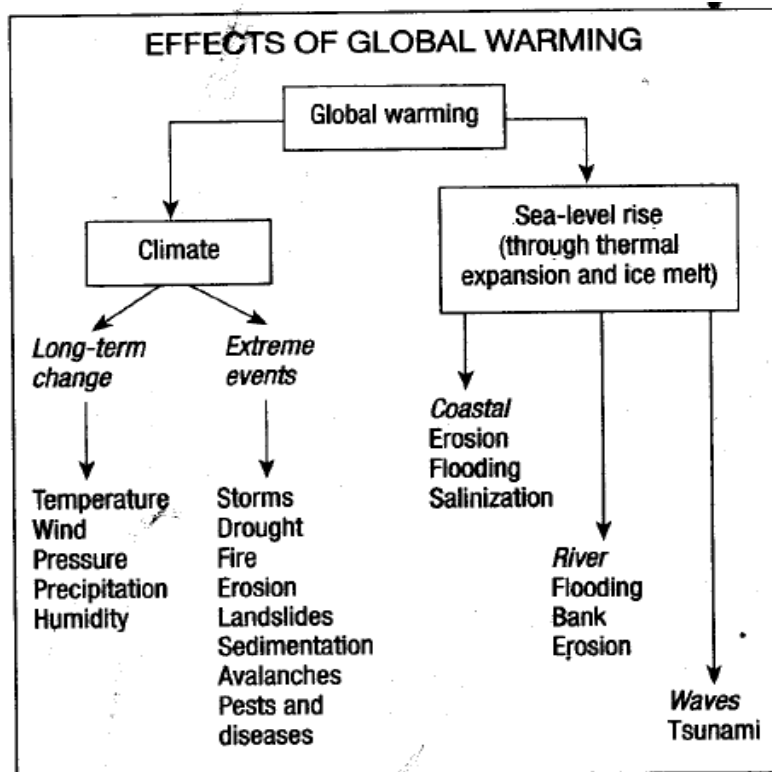


Figure 26: Effects of Global Warming (Wilson et al., 2007, p. 103)

As shown in Figure 26 (above), *Oxford In Search of Geography: Grade 12* identifies and outlines an extensive range of climate change related impacts. However, descriptions of these impacts contain a number of flaws. First, the impacts described by the textbook are broad and unspecific. For instance, the textbook suggests that long term changes in temperature, wind, pressure, precipitation and humidity will occur as a result of climate change (Figure 26). However, the textbook does not detail the extent and scale of such changes. In addition, although the majority of impacts named by the textbook are accurate and are reflected in the predictions of the IPCC (2007b,e), *Oxford In Search of Geography: Grade 12* notes tsunamis as a future effect of climate change. In reality, tsunamis occur as a result of earthquakes, caused by tectonic movement of plates, which is not recognised as a result of climate change (UNEP, 2012).

5.3.2.2.4 Textbooks Coverage of the Predicted Social Impacts of Climate Change

Five of the textbooks highlight the predicted global social impacts of climate change. The social impacts as outlined by textbooks are represented on *Table 18*, below. As discussed previously, three textbooks (*Geography for all: Grade 11*, *Oxford In Search of Geography: Grade 11* and *Focus on Geography: Grade 12*) **do not** consider global future social impacts of climate change, and are thus not included in *Table 18*. *Oxford In Search of Geography: Grade 12* is also not included in *Table 18* as this textbook refers only to future social impacts of climate change at a **regional scale** in the context of South Africa and Africa. While it is useful for textbooks to outline impacts of climate change relevant to the African and South African context, it is equally important that predicted **global** social impacts of climate change are discussed to provide those using textbooks with an understanding of the **global** significance and pervasiveness of climate change on human systems.

Table 18: Social Future Impacts of Climate Change as Outlined in Textbooks

	Focus on Geography: Grade 10	Focus on Geography: Grade 11	Oxford In Search of Geography: Grade 10	Geography for all: Grade 10	Geography for all: Grade 12
Increased deaths (linked to heat waves/ increased heat)	✓	✓	✓	✓	
Greater risk of epidemic infectious illness/disease (ie: malaria)	✓		✓	✓	
Starvation/undernourishment (linked to increase in droughts)	✓				✓
Increase in instances of eye cataracts				✓	
Increase in skin cancer instances				✓	✓
Increase in instances of weaker immune systems				✓	
Destruction/ disappearance of coastal property/land (linked to sea level rise)		✓	✓		✓
Greater risk to infrastructure in North America (due to thawing permafrost)		✓			

The accuracy of the textbooks with respect to the predicted social impacts of climate change is varied. The majority of textbooks (*Focus on Geography: Grade 10*, *Oxford In Search of Geography: Grade 10* and *Focus on Geography: Grade 11*) were accurate in terms of the impacts they identified. These include: increased deaths (linked to heat waves/ increased heat); greater risk of epidemic infectious illness/disease (ie. malaria); starvation/undernourishment (linked to increase in droughts); destruction of coastal property/land (as a result of sea level rise); and greater risk to infrastructure in North America (due to thawing

permafrost). Each of these future impacts of climate change is reflected in the predictions of the IPCC (2007e).

In *Geography for all: Grade 10* and *Geography for all: Grade 12*, some of the global social impacts of climate change are accurately outlined (*Table 18*, p. 139). However, *Geography for all: Grade 10* and *Geography for all: Grade 12* list some incorrect and/or inaccurate future social impacts of climate change. First, both texts incorrectly cite impacts which are scientifically associated with ozone layer depletion as being future impacts of climate change, such as increases in instances of skin cancer and eye cataracts. The conflation of the impacts of climate change and ozone layer depletion in textbooks and the implication of this for those using the textbooks will be discussed in greater depth in an upcoming sub-section (6.3.3.1). *Geography for all: Grade 10* also inaccurately lists weaker immune systems among humans as a further future impact of climate change.

Another key flaw identified in all of the textbooks (*Table 18*, p.139), is an inadequate selection of predicted social impacts related to climate change. Excluding the inaccurate impacts listed by *Geography for all: Grade 10* and *Geography for all: Grade 12*, textbooks outline approximately two to three (accurate) social impacts of climate change. In comparison to the average number of physical impacts listed in textbooks, the selection of social impacts is lacking, particularly as the IPCC predicts a far greater number of social impacts, as each physical impact is likely to result in numerous social impacts.

5.3.2.2.5 Textbooks Coverage of Climate Change Mitigation

For textbooks to contribute meaningfully to climate change education, it is important that these resources provide adequate and accurate coverage of climate change mitigation. As highlighted previously, a key aim of climate change education is to provide learners with a basis from which to develop the ability to make informed decisions which will benefit the environment, and thus minimise the impacts of climate change (UNESCO and UNEP, 2011b; UNESCO, 2009a,b). Textbooks which offer ‘small scale’ mitigation strategies applicable to the context and everyday life of those using the textbooks may provide learners with the knowledge, motivation, and guidance from which to make an informed personal contribution to climate change mitigation. Examples of such ‘small scale’ mitigation strategies may include: “...waste reduction, energy and resource efficiency and responsible shopping...”

(UNESCO and UNEP, 2011b, 61). In addition, textbooks could provide practical guidelines and tips relating to learners' personal contribution to climate change mitigation, and activities and case studies focusing on personal/'small scale' climate change mitigation. These may assist those using the textbooks in developing "...critical skills they need to address the challenges of climate change through their personal everyday actions and choices" (UNEP and UNESCO, 2012, 1).

Climate change education seeks to build an awareness of, and support for, mitigating strategies, policies, and legislation put in place by local governments (UNEP, 2006a). Thus, it is also important that South African textbooks used for climate change education highlight **some** of the climate change response strategies and policies put in place by the country's government. Textbooks could also provide activities and case studies which link to such strategies.

Three textbooks included no coverage of climate change mitigation or mitigation strategies. These texts were: *Focus on Geography: Grade 10*, *Focus on Geography: Grade 12*, and *Geography for all: Grade 12*. Six textbooks (*Focus on Geography: Grade 11*; *Geography for all: Grade 10*, *Geography for all: Grade 11*, *Oxford In Search of Geography: Grade 10*, *Oxford in Search of Geography: Grade 11* and *Oxford in Search of Geography: Grade 12*) provide coverage of this aspect of climate change to varying degrees and extents.

Four textbooks (*Geography for all: Grade 10*, *Oxford in Search of Geography: Grade 10*, *Oxford in Search of Geography: Grade 12* and *Focus on Geography: Grade 11*) list a broad range of 'small scale' climate change mitigation strategies (*Table 19*, p.142).

Table 19: Climate Change Mitigation Strategies as Outlined in *Geography for all: Grade 10, Oxford in Search of Geography: Grade 10, Oxford in Search of Geography: Grade 12* and *Focus on Geography: Grade 11*

	<i>Geography for all: Grade 10</i>	<i>Oxford in Search of Geography: Grade 10</i>	<i>Oxford in Search of Geography: Grade 12</i>	<i>Focus on Geography: Grade 11</i>
Reduce, Reuse and Recycle	✓	✓	✓	
Use Public Transport/Reduce Car Use	✓	✓	✓	
Support environmentally sustainable investments	✓			
Buy local goods	✓			
Do not buy goods with excessive packaging	✓			
Improve insulation of homes and/or geysers	✓	✓		✓
Use renewable energy sources	✓	✓	✓	
Eat less red meat	✓			
Eat more raw food				✓
Use less energy in industry		✓		
Reduce deforestation/protect forests/ Plant trees		✓	✓	✓
Reduce energy consumption		✓		
Use energy efficient light bulbs				✓
Use better heat sources for cooking				✓
Smaller baths and shorter showers				✓
Education			✓	

Each of the strategies listed in *Geography for all: Grade 10, Oxford in Search of Geography: Grade 10, Oxford in Search of Geography: Grade 12* and *Focus on Geography: Grade 11* (Table 19) are listed by a number of scientifically reliable sources as suitable and important for climate change mitigation (Ferguson, 2009; IPCC, 2007b; FAO, 2010; Gorte and Sheikh, 2010; UNESCO and UNEP, 2011b). Many of the mitigation strategies described in the four textbooks may be easily adopted at a personal level. For instance, the practice of ‘reduce, reuse and recycle’ outlined in three of the four textbooks is one strategy which has been recognised as being generally easy to adopt and practice across varying cultures, age groups and contexts (Bushnell et al., n.d.). In addition, although learners using textbooks may not be entirely in control of the electrical consumption of “the buildings they are in... they may control their own use of it” (UNESCO and UNEP, 2011b, 34). However, the mitigation strategies outlined by textbooks are brief, and do not provide solid or in-depth guidance on incorporating such mitigating activities into everyday life. This may discourage or inhibit these individuals from adopting such strategies. Furthermore, some learners using textbooks may be unable to realistically engage with the outlined mitigation strategies due to societal, financial or political barriers, particularly in a developing country such as South Africa (United Nations, 2010).

In addition to listing ‘small scale’ mitigation strategies, *Oxford in Search of Geography: Grade 10* and *Oxford in Search of Geography: Grade 12* provide an outline of government and international mitigation strategies through a description of the Kyoto Protocol. A similar description and outline was also provided by *Oxford In Search of Geography: Grade 11* and *Focus on Geography: Grade 11*. Briefly summarised, the Kyoto Protocol is an international treaty written in 1997 and requires member countries to reduce their greenhouse gas emissions through the implementation of legislation, policy and various other strategies (Whitmarsh, 2005; Halvorssen, 2008; UNFCCC, 2008). In this way the Protocol aims to minimise the growing threat of climate change (Whitmarsh, 2005; Halvorssen, 2008; UNFCCC, 2008). As shown in the Figures below, in the four texts the primary aims and objectives of the Protocol are briefly outlined:

At a meeting in Kyoto, Japan, in 1997, 38 industrialized countries signed an agreement to reduce carbon dioxide emissions. These countries included the United States, Japan and member states of the European Union. They agreed to reduce emissions by between 6% and 8% within the next 10 years. Despite these efforts, Figure 2.15 still shows that carbon dioxide emissions are expected to rise. Carbon dioxide emissions are difficult to predict because:

- Not all carbon dioxide will move into the atmosphere. The carbon cycle constantly absorbs and releases carbon at different times and places.
- Removing trees and plants for development upsets the balance of the carbon cycle. The rate of removal and destruction is unpredictable.
- New, cleaner technologies to generate power such as wind, solar and hydrological power are increasingly used in many developed countries. This could reduce carbon dioxide emissions.
- The global population is increasing. This places more demands on energy and food requirements.
- The oceans act as a carbon dioxide sink. This means that oceans absorb carbon dioxide. It is still too early to predict how much carbon dioxide is being stored on the ocean floor.

Figure 27: *Oxford in Search of Geography: Grade 10*: Outline of the Kyoto Protocol (Winter et al., 2008, p. 54)

The Kyoto Protocol

In order to reduce the emission of greenhouse gases many countries signed the **Kyoto Protocol**. The Protocol was introduced in Kyoto, Japan in 1997. Countries agreed to do the following:

- reduce their emissions of greenhouse gases
- use energy more efficiently and investigate the use of renewable resources of energy
- reduce emissions from the waste (methane) and transport sectors (fossil fuels)
- protect and develop sinks for greenhouse gases
- promote sustainable forms of agriculture
- all these activities must be undertaken in such a way that potentially adverse effects on developing countries are minimized.

Large developing countries including India, China and Brazil are not required to meet specific targets for reduced emissions for now. Two major countries are opposed to the Kyoto Protocol – Australia and the United States of America. The reasons for this are concerns that their industrial growth will be retarded and that the Protocol does not go far enough.

Figure 28: *Oxford in Search of Geography: Grade 12*: The Kyoto Protocol (Wilson et al., 2007, p. 103)

The Kyoto Protocol, Japan, 1997

The Kyoto Protocol was signed in Kyoto, Japan in 1997. The Protocol requires all signatories to reduce their greenhouse gas emissions and in this way reduce global warming. Countries are also committed to using energy more efficiently and investigating the use of renewable sources of energy. Countries also have to establish "sinks". Sinks are processes that help remove greenhouse gases from the atmosphere. The Protocol requires countries to reduce their greenhouse gas emissions according to specific targets. The targets have to be met between 2008 and 2012. Developed countries have larger targets as they have historically contributed more to the greenhouse gas emissions. Also, they are more able to pay the costs involved in cutting emissions. Developed countries will need to cut their emissions by about 5% by 2012. Developing countries do not have specific targets.

The Kyoto Protocol is viewed as a major step forward in reducing greenhouse gas emissions and therefore global warming. However, despite many countries signing the Protocol they have not yet created legislation to control emissions within their country. Also a major contributor to greenhouse gas emissions, the USA, has not agreed to the Protocol. The USA feels that the Protocol will limit economic development. It also feels that rapidly developing countries such as China, who are exempt from specific targets will gain an economic advantage.

Figure 29: *Oxford in Search of Geography: Grade 11*: The Kyoto Protocol, Japan, 1997 (Wilson et al., 2009, p. 252)

A potential solution: The Kyoto Protocol

Most countries were represented at the Kyoto Conference on global warming in 1997. A protocol was passed calling on the nations of the world to reduce their outputs of greenhouse gases by the years 2008–2012 to their 1990 levels. This is what was agreed:

- United States: 7% reduction
- European Union: 8% reduction
- Japan: 6% reduction
- 21 other countries: various targets

Developing countries were not asked to make binding commitments. China was considered to be a developing country at the time. But between 1996 and 2002, the number of private cars in China grew from 2 million to 16 million. By 2015–2020, China could have over 200 million cars and 500 more coal-burning power stations. At this rate China will replace the USA as the world's leading emitter of carbon dioxide and other greenhouse gases.

Another problem was that although many countries signed the documents, their governments have not ratified the agreement (passed the agreement into law). The world's two largest producers of greenhouse gases, the USA and Russia, have refused to ratify the Kyoto Protocol.

Figure 30: *Focus on Geography: Grade 11*: A Potential solution: The Kyoto Protocol (Dilley et al., 2008b, p. 214)

The description of the Protocol in *Oxford in Search of Geography: Grade 10*, *Oxford In Search of Geography: Grade 11*, *Oxford In Search of Geography: Grade 12* and *Focus on Geography: Grade 11* is valuable as it may provide learners with an awareness of the global significance of climate change and the widely recognised need to address the issue on a global scale. Furthermore, it is important that learners are made aware of the Protocol as it marks “..the cornerstone of the climate change regime” (Ling, 2012, 5).

In addition to providing a background and outline of the Kyoto Protocol, *Oxford in Search of Geography: Grade 11* and *Oxford in Search of Geography: Grade 12* both provide coverage

of the various strategies to reduce greenhouse gas emissions by countries which have ratified the agreement (*Figure 28 and Figure 29*, p. 142). South Africa represents one of the countries which have ratified the Protocol (European Commission, 2008). Consequently, some of the strategies listed in *Oxford in Search of Geography: Grade 11* and *Oxford in Search of Geography: Grade 12* have already been (or will be) adopted by the South African government to reduce greenhouse gas emissions in line with the requirements of the Protocol. An example of a strategy listed in the textbook which has been adopted by the South African government is a commitment to the use of renewable sources of energy in the country, as evidenced by the experimental Darling Wind Farm (DME, 2003; DEAT, 2010). Thus, in outlining these strategies the textbooks may contribute toward climate change education's aim of increasing **awareness** of climate change mitigation strategies instigated by local governments (UNEP, 2006a).

It is important to highlight that the Kyoto Protocol is also briefly discussed in *Geography for all: Grade 12*. However, the discussion of the Protocol does not occur in conjunction with the textbooks coverage of climate change, but rather occurs in an unrelated unit. In addition, in *Geography for all: Grade 12*, the Protocol is not described as being a specific mitigation strategy for climate change, but is referred to as being a broad strategy for the reduction of pollution.

Two textbooks (*Oxford In Search of Geography: Grade 12* and *Focus on Geography: Grade 11*,) include a classroom/homework activity which supports or accompanies their listed mitigation strategies. *Oxford in Search of Geography: Grade 12* includes an activity within its unit on climate change in which learners are required to work in groups and discuss how the South African energy and transport sectors can reduce greenhouse gas emissions. The activity provided in *Focus on Geography: Grade 11* calls for learners to "...outline actions that could be taken by individuals, local communities, power providers and the government to help reduce global warming" (Dilley et al., 2008b, 214).

The activities found in both *Oxford In Search of Geography: Grade 12* and *Focus on Geography: Grade 11* are valuable as they encourage learners to critically consider, and actively develop, appropriate mitigation strategies for various economic sectors and/or governmental and civil members of society. The activities found in both *Oxford In Search of*

Geography: Grade 12 and *Focus on Geography: Grade 11* require learners to work in groups. It has been recognised that group work plays a key role in promoting ‘deep’ and active learning (Davies, 2009). Thus, the group work centred activities found in these textbooks may further strengthen learners’ knowledge of climate change mitigation. In addition, through developing ‘their **own**’ mitigation strategies and strengthening knowledge of climate change mitigation, learners may develop a sense of empowerment. This sense of empowerment **may** motivate learners to take action to mitigate climate change (Schreiner et al., 2005). However, such a sense of empowerment may not entirely be fostered by the activities alone, and is dependent on a variety of factors such as the level of learner interest in climate change, and the extent of knowledge surrounding all aspects of climate change (Schreiner et al., 2005).

Geography for all: Grade 10 and *Geography for all: Grade 11* do not list climate change mitigation strategies relevant to the South African context, or ‘small scale’ mitigation strategies relevant to the personal everyday context of those using the textbook. However, these textbooks do include brief considerations and coverage of climate change mitigation through a case study, in the case of *Geography for all: Grade 10*, and an activity, in the case of *Geography for all: Grade 11*. In *Geography for all: Grade 10*, a case study is provided in which the efforts of the African Wildlife Foundation in introducing climate change mitigation strategies in Africa are outlined. The case study explains that through improving land management and encouraging the planting of trees and reduction of deforestation, the African Wildlife Foundation is contributing toward climate change mitigation in Africa. The activity found in *Geography for all: Grade 11* requires learners to select a form of energy production which releases greenhouse gases and suggest solutions to “...decrease the effects of [these] greenhouse gases on global warming” (Brett et al., 2006, 206).

5.3.2.3 Textbook Coverage of Adaptation to Climate Change

Climate change is acknowledged as having a variety of impacts on the lives of communities and individuals worldwide, and is likely to continue to impact these groups in years to come (UNESCO and UNEP, 2011a,b). Therefore, numerous scientific groups have stressed the importance of strengthening the adaptive capacities of communities and individuals to climate change (Brooks et al., 2005; Eakin and Luers, 2006; IPCC, 2007d; Ziervogel et al., 2008). A primary means through which to strengthen adaptive capacities in a variety of

contexts, and at a variety of levels, is thought to be through climate change education (Humanitarian and Policy Group, 2009; UNESCO and UNEP, 2011a). The importance of climate change education lies in its aims to equip individuals with “...critical thinking and problem solving skills” and increase awareness of the impacts of climate change and the relevant knowledge and skills which allow optimum response and adaptation to such impacts (UNESCO and UNEP, 2011a, 61).

It was deemed that for textbooks to usefully contribute toward meeting this aim of climate change education, resources should provide an outline of climate change adaptation, and adaptation strategies which are relevant and useful. Thus, the extent to which textbooks provide coverage of adaptive strategies which are applicable to both the South African (a developing nation) context, and to the personal level of the learner, was evaluated. However, it is important to emphasize that the role of textbooks in enhancing adaptive capacities is not entirely dependent on the extent to which climate change adaptation and adaptation strategies are outlined by these resources. The UNFCCC (2009, 4) highlights that enhancing overall understanding of climate change and “...the expected changes in climate and their effect at a local level” is key to strengthening adaptive capacities. Thus, the extent to which textbooks adequately and accurately outline other aspects of climate change, such as impacts on regional and local scales (evaluated in previous *Section 5.3.2.2* and upcoming *Section 5.3.3*) will also play a role in the enhancement of adaptive capacities.

In assessing the coverage of climate change adaptation, two themes emerged: textbooks containing coverage of climate change adaptation; and textbooks containing no coverage of climate change adaptation.

5.3.2.3.1 Textbooks Containing Coverage of Climate Change Adaptation

Four textbooks included coverage of climate change adaptation to varying extents. These texts are: *Focus on Geography: Grade 10*, *Oxford in Search of Geography: Grade 10*, *Oxford in Search of Geography: Grade 12* and *Geography for all: Grade 10*.

Geography for all: Grade 12 and *Oxford in Search of Geography: Grade 12* **do not** include **written** coverage of climate change adaptation and adaptation strategies. However, these textbooks contain activities where learners are required to engage cognitively in climate

change adaptation. As shown in *Figure 31*, below, *Geography for all: Grade 12* requires learners to suggest ways in which to ‘deal’ with various climate change related impacts. This activity is useful as it may prompt learners to consider how best to adapt to climate related changes in their own context.

Activity 28: Mapwork analysis of global warming

1. Use Figure 2.63 (a) and (b) on pages 53 and 54 in the colour section to complete Table 2.7.

Table 2.7: The effects of global warming

Climatic change	Where they occur	Risks for people	How to deal with this change
Increased droughts and desertification			
Increased storms			
Increased flooding			

2. Study Figure 2.63(a). Name three areas of the world where the following occur:
 (a) rising sea levels
 (b) carbon emissions per person that are higher than 2%.

3. Which country shown in Figure 2.63(b) contributes the most to world carbon emissions? Why do you think this is the case?

4. In your opinion, what can be done to try and stop such high carbon emissions? Why do you think this is difficult to do?

Figure 31: Activity 28: Mapwork analysis of global warming (Brett et al., 2007, p. 120)

A ‘possible research assessment task’ is also provided in *Geography for all: Grade 12*, which requires learners to select a climate change hazard and write a report which details the causes and effects of a selected hazard and “...**how to deal** with the hazard” (Brett et al., 2007, 120).

In *Oxford in Search of Geography: Grade 12*, the unit on climate change provides an activity in which learners are required to suggest adaptation strategies for a local farmer which will allow him to “...cope with increasing climate change” (Wilson et al., 2007, 106). Climate change is likely to have a broad range of implications for crop cultivation in South Africa, such as decreases in crop yields, changes in the timing of harvest, and changes in the regions suitable for the growth of various crops (Root et al., 2003; Porter and Semenov, 2005; Benhin, 2006). Therefore, the need for both commercial and subsistence farmers to adapt farming practices so as to lessen the impact of climate change on crop yields has been recognised as being of utmost importance (Benhin, 2006). Thus, the activity provided in *Oxford in Search of Geography: Grade 12* is useful, as it requires learners to consider an aspect of climate change adaptation which is both real and relevant to the South African context. However, in *Oxford in Search of Geography: Grade 12* adaption strategies which

may be relevant and applicable to the personal context of those using the textbook are not provided.

In *Focus on Geography: Grade 10*, a case study is included, in which climate change adaptation and adaptation strategies relevant to Sub-Saharan Africa are considered. The case study highlights that it is critical that adaptive strategies are put in place in Sub-Saharan Africa to protect the region and its citizens from the impacts and effects of climate change. In addition, it is emphasised that wealthier countries should contribute to strengthening Sub-Saharan Africa's adaptive capacity through contributing financially to a variety of large scale regional adaptation strategies. A list of such adaptation strategies are also outlined in the case study, examples of which include: "Expanding the continent's meteorological monitoring network so that farmers can access better information about climate patterns in the region"; "Improving national social insurance programmes to protect farmers and poor residents from the worst effects of climate related disasters" and "Building early warning systems" (Dilley et al., 2007, 72). Although the adaptation strategies listed in the case study reference a regional context of Sub-Saharan Africa, many of these strategies have been or will be implemented in South Africa (DEAT, 2010). However, the strategies listed in the case study may not be relevant or applicable to the personal or 'small scale' context of those using the textbook. Therefore, while the textbook does include adequate coverage of climate change adaptation and adaptation strategies at a regional scale, it is unlikely that this resource will contribute meaningfully toward strengthening adaptive capacities at an individual level among learners.

Geography for all: Grade 10 includes a case study in which brief and limited coverage of climate change adaptation efforts in Africa are outlined. In the case study it is noted that the African Wildlife Foundation is helping the people and wildlife of Africa adapt to the impacts of climate change through working alongside African communities.

5.3.2.3.2 Textbooks Containing No Coverage of Climate Change Adaptation

Five textbooks selected for evaluation were found to contain **no coverage** of climate change adaptation. These texts are: *Focus on Geography: Grade 11*, *Oxford In Search of Geography: Grade 10*, *Oxford In Search of Geography: Grade 11* and *Geography for all: Grade 11*. In addition, as highlighted previously, *Focus on Geography: Grade 12* contains no coverage of

climate change, and thus this textbook does not include coverage of climate change adaptation.

5.3.3 The accuracy of information on climate change presented in textbooks

The third criteria (*Table 14*, p. 116), categorises textbooks according to whether these resources provide accurate information on climate change. The inclusion of erroneous information may reinforce or generate a variety of misconceptions surrounding climate change (Daskolia et al., 2006; Choi et al., 2010). Misconceptions present in understandings and knowledge of climate change may make it difficult for individuals to adopt the correct mitigation and adaptation strategies or the appropriate changes in attitudes, behaviour and values (Khalid, 2003).

Dove (1999, 35) highlights that in some instances geography textbooks can be “...a source of misinformation and geographical inaccuracies”. In this research **all** of the textbooks analysed contained inaccuracies in information provided on climate change. The inaccuracies identified in textbooks’ coverage of climate change will likely minimise the value of these textbooks for climate change education. The key inaccuracies and flaws identified in the majority of textbooks are: the conflation and/or linking of climate change and ozone layer depletion; and the imprecise use of the term ‘global warming’ either interchangeably with, or as a sole term of reference to, climate change. A few textbooks contain other inaccuracies and flaws, such as the naming of incorrect impacts and effects of climate change and alarmist portrayals of climate change. These have been detailed and discussed in *Section 5.3.2.2.1*.

5.3.3.1 Textbooks which erroneously conflate or link climate change to ozone layer depletion

Five of the textbooks were found to conflate or even link ozone layer depletion and climate change. These textbooks are: *Oxford In Search of Geography: Grade 10*, *Focus on Geography: Grade 10*, *Focus on Geography: Grade 11*, *Geography for all: Grade 10* and *Geography for all Grade 12*. As highlighted from findings in this research, and the findings from studies of a similar nature, many teachers either hold the erroneous conception that ozone layer depletion and climate change (or the enhanced greenhouse effect) are associated or tend to conflate the properties of the two phenomena (Groves and Pugh, 1999; Khalid, 2003; Papadimitriou, 2004; Bozdogan, 2009). In a number of other studies, a

similar trend in conceptions has been identified among learners (Boyes et al., 1993; Bjorn and Wallen, 2000; Kilinic, 2008; Shepardson et al., 2009). Thus, by linking climate change and ozone layer depletion these textbooks may perpetuate these erroneous beliefs.

A common tendency identified in each of the above textbooks, was to place discussions of ozone layer depletion and climate change in the same section/unit. In most instances, these textbooks outline climate change and immediately progress to an explanation of ozone layer depletion. One textbook, *Focus on Geography: Grade 10*, referred to climate change and ozone layer depletion on the same page, within the same contexts. Evidence of this is provided in *Figure 32*, below, where in the ‘Key Questions’ box, questions regarding climate change (or ‘global warming’) are asked alongside (or in conjunction with) questions regarding ozone layer depletion. In addition, the quotes provided beneath the ‘Key Questions’ box refer to both climate change and ozone layer depletion respectively.

Unit 4: Climate change

Global warming

You learnt in an earlier unit that carbon dioxide and water vapour absorb the heat energy that is radiated from the Earth, creating a natural ‘greenhouse effect’ that keeps the atmosphere warm.

However, the amounts of carbon dioxide and other pollution gases such as carbon monoxide, nitrous oxide, chlorofluorocarbons and methane are increasing. This is causing a greater absorption of long-wave radiation and creating an increased ‘greenhouse’ effect. This is leading to an increase in temperature worldwide – global warming.

More and more of these ‘greenhouse’ gases are being released into the atmosphere for the following reasons:

- Increasing industrialisation and burning of fossil fuels result in greater amounts of carbon dioxide and nitrous oxide in the air.
- **Deforestation**, especially of the rainforests, means that there are fewer trees to take in the carbon dioxide and give off oxygen.
- The world’s population has increased, therefore there is a larger intake of oxygen and release of carbon dioxide through respiration.
- Increasing herds of cattle are producing more manure which gives off methane.
- Increasing rice production causes more methane to be released from paddy fields

KEY QUESTIONS

1. What is global warming?
2. Are climates changing?
3. What is ozone depletion?
4. What is being done to slow the process of ozone depletion and global warming?
5. What other forms of air pollution are there?

Global warming could melt many mountain glaciers

Gaping holes in ozone layer cause alarm

The Earth goes on sizzling

Figure 32: Unit 4: Climate Change (Dilley et al., 2008a, p. 69)

Although not drawing direct links between the phenomena, the above layouts of the texts may serve to prompt individuals to assume a relationship between ozone layer depletion and

climate change, or perpetuate existing beliefs that the two processes are associated. Furthermore, none of these textbooks provide any indication that the two processes are **not** linked.

In some cases textbooks **directly** link or conflate ozone layer depletion and climate change. For instance, in *Focus on Geography: Grade 10* it is erroneously stated that “...depletion of the ozone in the stratosphere is contributing to global warming” (Dilley et al., 2008a, 73). In addition, it is claimed in *Focus on Geography: Grade 11*, that a key impact of climate change may be increased amounts of ultra-violet (UV) radiation reaching the Earth’s surface. While an increase in levels of UV penetration is associated with the depletion of the ozone layer, it is not scientifically recognised as being an impact of climate change (Coskun and Aydin, 2011). Similarly, in *Geography for all: Grade 10* and *Geography for all: Grade 12* it is stated that one of the key predicted impacts of climate change for humans is skin cancer. Skin cancer is not associated with climate change, but is rather attributed to ozone layer depletion, when increased UV penetration has adverse effects on human skin (Coskun and Aydin, 2011). *Geography for all: Grade 10* also labels increases in eye cataracts as a future impact of climate change. Eye cataracts have not been scientifically linked to climate change, but are rather thought to occur due to a variety of other factors including increased UV radiation tied to ozone layer depletion (Bostrom et al., 1994; Boyes et al., 1999). This conflation between the impacts of ozone layer depletion and climate change may foster the erroneous belief among those using these textbooks that the two phenomena are linked.

There are a variety of explanations which may account for the above findings. First, textbook authors may be unaware of the prominent misconceptions regarding climate change held by learners and teachers (Choi et al., 2010). Thus, these authors may not have considered the implications of placing discussions of ozone layer depletion and climate change in such close proximity without specifying that the two phenomena are not linked. Another factor to consider is that textbooks authors themselves may hold the misconception that ozone layer depletion and climate change are associated.

The majority of textbooks which were identified as conflating or linking ozone layer depletion and climate change (directly or indirectly), are textbooks which have been written for Grade 10 classroom geography. It was recognised that a possible reason for this trend in

Grade 10 level geography textbooks may be due to the content framework of the Revised National Curriculum Statement. Under the content framework for Geography, the RNCS requires that one of the sub-themes to be explored when examining the topic of ‘atmosphere, weather and climate’ for Grade 10 level geography is the “...impact of humans on the atmosphere and weather” (DoE, 2008b, 22). The RNCS suggests that in covering this sub-theme, phenomena such as “global warming, ozone depletion...acid rain, greenhouse effect” are explored and examined (DoE, 2008b, 22). Thus, in the instance of Grade 10 level textbooks, this guideline may account for the identified flaws in layout where discussions around ozone layer depletion and climate change are placed in such close proximity.

5.3.3.2 Textbooks which erroneously link climate change and acid rain

Four of the textbooks selected for analysis were found to juxtapose the unrelated phenomena of acid rain and climate change. These textbooks are: *Focus on Geography: Grade 10*, *Oxford In Search of Geography: Grade 11*, *Geography for all: Grade 10* and *Geography for all: Grade 11*. In this research, teachers were not found to hold the belief that acid rain and climate change are linked. However, in studies of a similar nature, teachers were found to hold the misconception that acid rain causes climate change (Groves and Pugh, 1999; Papadimitriou, 2004). In addition, in studies where learners’ knowledge and perceptions of climate change were investigated, many learners attributed climate change to acid rain (Boyes et al., 1993; Boyes and Stanisstreet, 1997; Pruneau et al., 2001). Thus, textbooks juxtaposing of climate change and acid rain may cause those using the textbooks to believe that the two phenomena are linked or related. A possible reason for the Grade 10 level textbooks (*Focus on Geography: Grade 10* and *Geography for all: Grade 10*) placing these concepts in such close proximity may be tied to the content framework of the RNCS. As highlighted above (*Section 5.3.3*) the content framework recommends that the weather and atmospheric related issues of “global warming, ozone depletion...acid rain, greenhouse effect” are covered together (DoE, 2008b, 22)

5.3.3.3 Inaccurate use of the term ‘global warming’ in textbooks

The majority (eight) of the textbooks selected for analysis were found to use the term ‘global warming’ either interchangeably with climate change, or as a sole term of reference to the phenomena. The use of this term is problematic, as it may result in a number of negative

implications for teacher and learner perceptions of climate change. This is illustrated by the fact that it has been found that use of the term ‘global warming’ by sources such as the mass media has generated a myriad of misconceptions in lay individual’s knowledge of climate change. Whitmarsh (2009) suggests that the term has led many to assume that climate change may only be associated with global temperature increases and heat related impacts. However, in reality, it is projected that climate change may cause some areas to cool and other areas to warm. It has also been proposed that the term has prompted many individuals to incorrectly believe that the world will grow steadily warmer. However, scientists argue that “...each year might not be warmer than the previous one” (Shome and Marx, 2009, 2).

There are a variety of explanations which may account for use of the term ‘global warming’ as opposed to the more correct ‘climate change’ in textbooks. First, the time of writing may provide an explanation for the prominent usage of the term. The majority of the textbooks were published in the mid-2000s. In contrast, the negative implications of the term ‘global warming’ on perceptions of climate change have only been documented fairly recently. Thus, textbook authors may have been unaware of these findings at the time of writing. Another explanation may be that ‘climate change’ is a more neutral term in comparison to the more dramatic ‘global warming’ (Whitmarsh, 2009). Textbook authors may prefer to make use of a more dramatic term as a means of ensuring that learner interest in the topic is sparked.

Third, it could be suggested that mass media influence may account for textbook authors’ use of the term ‘global warming’. During the 1980s and 1990s, the term ‘global warming’ was used fairly frequently by scientists and politicians in both written and oral discussions of the phenomena. More recently these groups have moved away from this term, and now tend to favour use of the more correct and concise ‘climate change’ (Whitmarsh, 2009). However, ‘global warming’ is still used frequently by mass media. A reason for this may be that the term is more emotive and dramatic and is therefore an effective metaphor for “...capturing the public’s imagination about this global risk...” (Whitmarsh, 2009, 403). A more emotive term may be favoured by mass media which has been found to rely on alarmist and sensationalist portrayals of climate change to increase readership and viewership (Weingart et al., 2000; Whitmarsh, 2009). It could be suggested that textbook authors’ use of the term ‘global warming’ may have been influenced by the mass media’s frequent use of the term. This suggestion is partially confirmed by the fact that four of the teachers interviewed for this

research were co-authors of textbooks which have been selected for analysis. Each of these teachers stated that mass media was a key source from which information on climate change is obtained. However, a more thorough investigation of the sources which the majority of textbook authors use to gain or enhance knowledge of climate change needs to be conducted to confirm the validity of this argument.

5.3.4 The extent to which climate change is made relevant to the South African context in textbooks

To help meet the main aims and objectives of climate change education, it is important that textbooks, in addition to providing learners with an overall understanding of climate change at a global scale, should give information which is applicable to the country in which they live. Through this, textbooks may equip learners to successfully adapt to climate change and contribute to climate change mitigation within their local contexts (UNESCO and UNEP, 2011a,b). Thus, the fifth set of criteria (*Table 14*, p. 116) categorises textbooks according to the extent to which these resources present information on climate change which is relevant to South Africa. To categorise textbooks according to this criterion, the degree to which textbooks outline the predicted physical and/or social impacts, effects and/or risks of climate change in South Africa was taken into account.

Oxford In Search of Geography: Grade 11, *Focus on Geography: Grade 10*, *Focus on Geography: Grade 11*, and *Geography for all: Grade 12*, were classified as **not** presenting information on climate change which is relevant or applicable to the South African context. These textbooks were placed in this category as these resources did not, to any extent, meet the criteria discussed above. This finding highlights a key gap which may compromise the value of these textbooks for climate change education. It is important to reiterate that *Focus on Geography: Grade 12* included no coverage of climate change or its related aspects, and thus was not considered in the categorisation process.

Four of the nine textbooks were identified as providing information on climate change which was of direct relevance to the South African context. These textbooks are: *Oxford In Search of Geography: Grade 10*, *Oxford In Search of Geography: Grade 12*, *Geography for all: Grade 10* and *Geography for all: Grade 11*. Each of these resources met the above criteria to varying extents through a variety of approaches.

Oxford In Search of Geography: Grade 10 provides an outline of both the predicted physical and social impacts of climate change in South Africa. A number of diverse social and physical impacts are highlighted in the textbook. For instance, when examining how climate change may affect people living in South Africa, predicted impacts on a variety of factors such as water resources, biodiversity, and human and animal health are discussed. By emphasizing such a broad range of impacts, the reality of climate change and the extent of its impacts in South Africa may be recognised and understood by those using the textbook.

In its section on ‘climate change’ *Oxford In Search of Geography: Grade 12* examines the predicted effects and risks of climate change on Africa and its population. Although this section does not aim to focus specifically on climate change in the South African context, many of the effects and risks discussed may be easily applied to the country. For instance, in the discussion it is stated: “Households that earn their livelihoods by subsistence and small scale farming...are most at risk to hardship, hunger and even starvation as a result of climate change” (Wilson et al., 2007, 105). Subsistence and small scale farming are common in South Africa (du Toit, 2011). Thus, those using *Oxford In Search of Geography: Grade 12* may be easily able to identify the relevance of this risk to the South African context. In one instance the text makes a specific, albeit brief, reference to a predicted impact of climate change for South Africa. The resource accurately explains that “...the succulent plants of the Karoo could disappear almost entirely if CO₂ concentrations are doubled” (Wilson et al., 2007, 105).

In addition, within its unit on ‘climate change’ *Oxford In Search of Geography: Grade 12* includes a case study in which some of the current and future impacts of climate change in South Africa are outlined. This includes an activity where learners are required to answer a variety of questions related to the case study. The activity requires learners to cognitively engage with a variety of aspects of climate change in South Africa, such as impacts, risks and hazards.

Geography for all: Grade 10 includes a discussion within its section on climate change which briefly describes some of the anthropogenic activities in Africa which contribute to increasing the threat of climate change. In the discussion, a few examples of anthropogenic activities which contribute to climate change in South Africa are included. For instance, it is emphasized that in South Africa, the predominant use of coal-fired power stations greatly

contributes to climate change through emitting greenhouse gases. In addition, it is accurately stated that many individuals in the country “...use non-renewable energy sources...which emit harmful gases” (Jansen, 2012, 52). These are scientifically accurate claims which have been validated by a number of academic sources (Davidson et al., 2006; Tyler, 2009; Tait and Winkler, 2012). Highlighting this aspect of climate change may illustrate to those using the textbook that their actions and the decisions of governmental bodies may contribute directly toward enhancing climate change. This may create awareness that behaviour and lifestyle changes are required if the threat of climate change is to be reduced.

In *Geography for all: Grade 11*, climate change is made relevant to the South African context through the use of a newspaper article and an activity. In the newspaper article provided the effects of climate change on rainfall patterns in South Africa is a primary focus. In the article it is accurately stated that while some areas in the country are experiencing a rise in rainfall levels which can be linked to climate change, in the majority of the country’s regions rainfall has decreased as a likely result of climate change. It is emphasized that these changes in rainfall patterns will continue unless greenhouse gas emissions are lowered.

5.4 The Effect of Textbooks on Teachers’ Knowledge and Perceptions of Climate Change

As highlighted in *Chapter 4*, teachers hold a number of misconceptions, limitations and inaccuracies in their knowledge and perceptions of climate change. Although textbooks were not cited as a personal source of information on climate change by many teachers, it is likely that through using textbooks as a primary teaching material for climate change education, teachers’ knowledge and perceptions of climate change may be both consciously and/or unconsciously informed by these resources (Britton and Lumpkin, 1977; Choi et al., 2010). Correspondingly, through the analysis of textbooks in this chapter, it became clear that many of the inconsistencies or inaccuracies identified in teachers’ knowledge and perceptions of climate change may be linked to some of the inadequate or inaccurate representations of climate change and its related aspects presented in textbooks. The following table highlights the misconceptions, limitations and gaps in teachers’ knowledge and perceptions of climate change which correspond with common shortfalls identified in textbooks information on and representations of climate change.

Table 20: Corresponding Misconceptions, Inaccuracies and Gaps in Knowledge Held by Teachers and Presented in Textbooks

Teachers Prominent Misconceptions, Inaccuracies or Gaps in Knowledge Regarding Climate Change	Textbooks Shortfalls in Representing and Communicating Climate Change
Limited knowledge of both incoming and outgoing solar radiation	Limited representations/explanations of outgoing and/or incoming radiation among some textbooks
Inaccurate conceptions of greenhouse gases as occurring as a 'lid' or 'layer' in the atmosphere and incorrect conceptions of heat being trapped beneath greenhouse gases, causing temperature increases	Visual representations of greenhouse gases occurring as a 'lid' or 'layer' and no indication that greenhouse gases re-emit 'trapped' outgoing heat energy toward Earth in some textbooks
Limited knowledge of the key greenhouse gases	Scanty explanation of all of the key greenhouse gases among some textbooks
Incorrect belief that climate change is solely as a result of human activity	Limited explanation of natural forcings which may drive climate change
Conflation of ozone layer depletion and the greenhouse effect/climate change	Conflation or direct linking of climate change and ozone layer depletion among the majority of textbooks
Inaccurate use of the term 'global warming'	The use of the term 'global warming' either interchangeably with climate change, or as a sole term of reference to the phenomena, among the majority of textbooks
Inaccurate conceptions of pervasive global temperature increases linked to climate change	Inaccurate suggestion among the majority of textbooks that temperature increases on a global scale will continue as a result of climate change
Deeper conceptual inaccuracies/limitations in knowledge of correctly conceived impacts of climate change	Limited scientific explanation of correctly listed global current and/or future impacts of climate change
Limited knowledge of the regional variability of climate change	Limited explanation of the regional variability of climate change in most textbooks
Alarmist perceptions of climate change	Alarmist representation of climate change in one textbook
Inaccurately attributing short term weather anomalies to climate change	Listing of recent weather events as evidence of climate change in one textbook

The large extent to which misconceptions, inaccuracies and/or gaps in knowledge held by teachers correspond to textbooks shortfalls in representing and communicating information on climate change, demonstrated in *Table 20*, above, further validates the analysis of textbooks in this chapter and supports the argument that textbooks may influence teachers' knowledge and perceptions of climate change. Khalid (2003) highlights that teachers' knowledge and perceptions of climate change are passed on to learners in the classroom. Thus, for textbooks to be of value in climate change education, the shortfalls identified in textbooks provision of relevant, accessible and accurate information on climate change need to be addressed.

5.5 Section Summary

Textbooks selected for assessment in this research met the criteria detailed in *Table 14* (p. 116) to varying extents. The varying nature to which these textbooks met these criteria may compromise the ultimate value of these textbooks for climate change education. The first criterion classified textbooks according to the extent to which these resources enhance understandings of the greenhouse effect. Although the majority of textbooks included coverage of the natural and/or enhanced greenhouse effect, many of these textbooks contained flaws in their representation of key components of the mechanism. This may compromise learners' (and teachers') understanding of the greenhouse effect and thus by extension climate change (Shepardson et al., 2009). The second criterion evaluated the extent to which textbooks cover four key aspects of climate change: the causes of climate change; the current and predicted physical and social global impacts of climate change; mitigation of climate change; and adaptation to climate change. Textbooks coverage of these respective aspects differed, but overall, it was identified that none of the textbooks offer a consistent outline of **all** of these aspects. To contribute toward meeting the key aims and objectives of climate change education it is important that textbooks cover each of the key aspects of climate change sufficiently and accurately.

The third set of criteria assessed the extent to which textbooks contain accurate information of climate change. Each of the textbooks contained key inaccuracies or flaws in information surrounding and representations of climate change. These may foster new, or contribute to existing, misconceptions of climate change among those using the textbooks (Choi et al., 2010). The presence of misconceptions of knowledge and understanding of climate change may prevent those using the textbooks from acting and reacting to climate change in a way which is in line with the ultimate aims and objectives of climate change education. Thus, this finding severely limits the use of textbooks for climate change education. The fourth and final set of criteria assessed textbooks according to the extent to which these resources made the issue of climate change relevant and applicable to the South African context. Four textbooks did not relate climate change to the South African context.

It was identified that the textbooks selected for analysis in this research have a likely influence on interviewed teachers' knowledge and perceptions of climate change. Many of the shortfalls identified in textbooks representation and communication of climate change

correspond to the prominent misconceptions, inaccuracies or gaps apparent in teachers' knowledge and perceptions of climate change. This finding represents a further dynamic which compromises the value of textbooks for climate change education.

CHAPTER 6: KEY FINDINGS AND RECOMMENDATIONS

6.1 Introduction

The focus of this research was three dimensional. First, the research sought to investigate knowledge and perceptions of climate change held by FET level teachers in government and private schools in Gauteng. The research also aimed to identify whether these teachers hold misconceptions of climate change and its related aspects, and what these misconceptions are. Finally, this research sought to critique a selection of FET level geography textbooks available to teachers for the purposes of climate change education.

In this chapter the key results and findings of the research are presented. In addition, recommendations based on the key research findings for ways in which to improve teachers' knowledge and perceptions of climate change, and increase the value of some geography textbooks used for climate change education are made. This chapter concludes with suggestions for future research related to teachers' knowledge and perceptions of climate change and the critiquing of school textbooks for climate change education.

6.2 Overview of Teachers' Knowledge and Perceptions of Climate Change

This research has highlighted a number of key inconsistencies, misconceptions and gaps in teachers' knowledge and perceptions of climate change and its related aspects. The flaws in knowledge and perceptions have been discussed in detail in *Chapter 4* and are summarised, below. It is important to highlight that teachers' knowledge and perceptions of climate change are not, however, entirely dominated by flaws, inaccuracies and misconceptions.

- Gaps and inconsistencies were evident in the understanding of the greenhouse effect and its process for a majority of the teachers interviewed. Key examples of these gaps include: limited or inaccurate knowledge of the main greenhouse gases which drive the greenhouse effect; viewing the greenhouse effect as a primarily anthropogenic process; partial or non-existent knowledge of the processes of incoming shortwave radiation and outgoing long wave radiation; and conceptions of greenhouse gases as occurring in a type of layer or lid in the atmosphere, thereby trapping heat. The

majority of teachers were found to hold the erroneous belief that ozone layer depletion and the greenhouse effect are linked.

- The majority of teachers have a limited understanding of the term ‘climate change’. The most prominent example of this is the perception that anthropogenic forcings are the only cause of climate change
- While teachers understand that long term trends are a definitive feature of climate change, in practice many of these teachers tend to incorrectly attribute recent short-term weather events to climate change
- Many teachers displayed **correct** basic conceptions of the current and future impacts of climate change. However, deeper **conceptual inaccuracies or limitations** in knowledge of correctly named impacts were identified. Few teachers held entirely obscure or erroneous perceptions of the impacts associated with climate change
- The majority of teachers hold correct understandings of climate change induced risks. However, few of these teachers demonstrated deeper scientific knowledge and understanding of these risks. For instance, none of the teachers acknowledged the scientific uncertainties which form a key component of predictions of climate change risk, and did not consider the regional variability of such risks. In some cases teachers demonstrated misconceptions of risks alongside accurate conceptions. The most prominent misconception identified among a sizeable percentage of teachers, was the incorrect belief that climate change will cause increased instances of skin cancer. A likely cause of this misconception is linked to conflation of the properties of ozone layer depletion and the enhanced greenhouse effect
- A few teachers hold alarmist perceptions of the impacts and risks associated with climate change. It is likely that such alarmist perceptions are tied to teachers dependence on the mass media as a key source of information on climate change
- The majority of teachers hold a combination of both **correct** and **incorrect** understandings of appropriate climate change mitigation strategies. Few teachers hold misconceptions of appropriate mitigation strategies for climate change.

Teachers represent a key resource for learners in the classroom (Graves, 1982; Oakes and Saunders, 2002). Thus, it is likely that many of apparent limitations, inaccuracies and misconceptions of climate change identified in teachers' knowledge may be passed onto learners (Khalid, 2003). This may have ramifications for the ultimate success of climate change education in schools. This is illustrated by the fact that, in order for the key aims and objectives of climate change education to be met, it is important that learners have sound and accurate understandings of climate change and its related aspects (UNESCO and UNEP, 2011a,b; Choi et al., 2010). Many of the key inconsistencies, misconceptions and gaps present in teachers' knowledge and perceptions of climate change aspects were identified as being related to the sources on which teachers rely for information on climate change. The sources of information used most frequently by teachers, due to accessibility, are the mass media and observation of weather events. The textbooks used most frequently by teachers for climate change education, and as a personal source of information on climate change (and selected for analysis in this research), were found to have impacts on their knowledge and perceptions of climate change.

This research emphasizes the need to provide teachers with sufficient training to equip them with adequate understandings of climate change so that they may be "...in a better position to guide students' learning" (Choi et al., 2010, 896). In addition, teachers should be exposed to a variety of sources of information on climate change which are scientifically accurate and easily accessible. Ultimately, such sources may allow for correct understandings of climate change and its related aspects to be adopted by teachers. This in turn will contribute toward the success of climate change education in schools.

During interviews, the attitudes of some teachers toward climate change became clear. This represents an additional component to this research which was not anticipated. It was found that many teachers are apathetic and disinterested in climate change. It is likely that these attitudes are born out of a phenomenon known as 'green fatigue'. It is deemed likely that teachers' negative attitudes toward climate change may be passed on to learners in the classroom, and may compromise the extent to which learners engage with the issue (Liu et al., 2012). This is validated by the fact that many of the teachers identified as displaying negative attitudes toward climate change, stated during interviews

that learners are exhibiting boredom and a distinct lack of interest toward climate change both in and beyond the classroom context. Thus, it may be possible that attitudes of disinterest and apathy toward climate change among learners are tied to teachers' own apathy and disinterest in the topic. However, to ensure the validity and correctness of this assessment, further research and investigation is required. Negative attitudes toward climate change among teachers and learners alike may have undesirable consequences for the ultimate success of climate change education in schools (Liu et al., 2012).

6.3 Overview of the Critique Undertaken on Selected Textbooks for Climate Change Education

The extent to which the textbooks selected for analysis in this research have the potential to usefully contribute to climate change education is varied. Although the majority of textbooks **did** provide content on climate change, these texts **did not** provide consistently adequate, relevant and/or accurate information on climate change and its related aspects. It is important to highlight that one textbook (*Focus on Geography: Grade 12*) contains no content of climate change or its related aspects.

- Most textbooks included coverage of the enhanced and/or natural greenhouse effect. However, a number of limitations were identified in representations and/or outlines of the key processes associated with the greenhouse effect in these texts. The most common included: inconsistent written and/or visual representations of both incoming and outgoing radiation; limited explanation and/or visual representation of the process by which outgoing heat trapped by greenhouse gases is re-emitted toward Earth; incorrect visual representations of greenhouse gases occurring in a type of 'lid' or 'layer' in the atmosphere.
- In most cases textbooks did not provide consistently adequate explanations of **all** the key aspects of climate change. For instance, in some cases textbook/s provided a detailed explanation of the causes of climate change, but limited coverage of climate change mitigation and/or adaptation.
- Four textbooks provided information, activities and/or case studies which made climate change relevant and applicable to the South Africa context. However, an

equal number of the remaining textbooks selected for analysis did not make climate change relevant and applicable to the South African context

- Each of the textbooks selected for assessment contain, to varying extents, flaws and/or inaccuracies in information, portrayals, and/or representations of climate change. Examples of these include: linking or conflation of ozone layer depletion and climate change; alarmist portrayals and representations of climate change; and listing of incorrect or inaccurate impacts of climate change
- Many of the shortfalls identified in these textbooks representation and communication of climate change correspond with the inaccuracies, gaps and misconceptions highlighted in interviewed teachers' knowledge and perceptions of climate change. As these textbooks were selected for analysis based on their frequent use by teachers interviewed, both for climate change education and as a source of personal information on climate change, it is likely that these textbooks are influencing teachers' understandings of climate change

The findings from this research suggest a number of recommendations for improving the value of textbooks for climate change education. First, scientists, teachers, and publishers should work together in the writing and reviewing of textbooks. This would help to ensure that correct and up-to-date knowledge of climate change held by scientists may be combined with teachers and publishers knowledge of "...pedagogically appropriate educational approaches" for teaching climate change (Choi et al., 2010, 896), whilst meeting the publishers' requirements on length and content. In addition, it is suggested that textbook authors should immerse themselves in literature which details prevalent misconceptions of climate change among learners and teacher alike. This would ensure that these authors do not present information on or representations of climate change which could potentially enhance these misconceptions. However, it is important to highlight here the findings from this research indicate that limited or flawed representations of climate change prevalent in the textbooks may not necessarily be the fault of the textbook author themselves, but rather due to guidelines for coverage of climate change prescribed the Revised National Curriculum Statement (RNCS). As textbook authors follow curriculum guidelines when writing textbooks, this points to a need for the curriculum's guidelines to be reconfigured, so as to compliment the aims and objectives of climate change education.

6.4 Recommendations for Future Research

Research into teachers' knowledge and perceptions of climate change in the South African context is limited. There is, therefore, considerable scope for further research in this discipline. This research is based on a sample of 32 private and government school FET level geography teachers in Gauteng Province, South Africa. This sample size is relatively small. Thus, it may be valuable for future research to investigate the knowledge and perceptions of climate change among a more extensive number of FET level geography teachers. This may provide insight into the extent to which the trends identified in teachers' knowledge and perceptions of climate change in this research are representative of the broader community of FET level geography teachers. Such research may aid interventions to address inaccuracies and misconceptions in teachers' knowledge and perceptions of climate change. In addition, it may be useful for future research to replicate the methodology used in this research in other provinces in the country. This may provide an indication of the extent to which the key findings from this research are widespread to the broader South African context. Future research may also benefit from establishing the place of training and level of qualification of interviewed teachers. This will be useful as, through a process of cross-correlation and statistical analysis, the extent to which level and place of training may be linked to limitations and/or strengths in teacher knowledge and perceptions of climate change could be determined.

The geography textbooks selected for assessment in this research were those written according to the guidelines of the RNCS. As highlighted previously, the RNCS is currently being phased out (as of January 2012) and being replaced by a national Curriculum Policy Statement (CAPS) (DBE, 2011b). CAPS is not an entire departure from the RNCS, but rather represents a modified concise version of the RNCS (DBE, 2011b). However, textbooks written in line with the RNCS, including the majority of the textbooks selected for analysis in this research, are being (or already have been) rewritten in line with the requirements and modifications apparent in CAPS (DBE, 2011a). Many of these rewritten textbooks have already been introduced in schools and classrooms, and thus are already influencing teaching and learning. As CAPS is relatively new, there is scope for research which critiques CAPS geography textbooks for climate change education. Thus, it may be useful for a follow-up research to be conducted, in which the criteria used for the assessment of selected textbooks in this research is used as a baseline from which to critique CAPS, and any future, geography

textbooks for climate change education. This may allow for limitations in current CAPS textbooks to be identified and rectified in the future. In addition, it may create awareness among teachers of the aspects of these textbooks which may or may not be useful for climate change education.

This research provided a critique of **FET level geography** textbooks. It may be valuable for future research to extend the scope of this research. This may be achieved through critiquing textbooks in other subjects such as physical and natural science, which are required to cover climate change by the curriculum, for climate change education.

Lastly, Swanepoel (2010) highlights a variety of methods and criteria which have been used previously to assess a variety of textbooks coverage of numerous scientific topics. The criterion used in this research, although sound and useful, is open to improvement. Thus, it may be valuable for future research to focus on developing and enhancing the criteria employed in this research further. This would likely contribute toward improved assessments and evaluations of textbooks for climate change education in the future.

6.5 Conclusion

This research revealed a number of inaccuracies, misconceptions and gaps in teachers' knowledge and perceptions of climate change. It is likely that these will be passed on to learners in the classroom and will have ramifications for learners' understanding of climate change (Khalid, 2003). Insufficient or incorrect understanding of climate change among learners may adversely affect the extent to which they are able to develop appropriate environmental attitudes, behaviours and values which may contribute to reducing the threat of climate change and reduce the extent to which they are able to effectively adapt to the impacts of climate change. Thus, it is important that the trends in teachers' knowledge and perceptions of climate change are sufficiently addressed so as to ensure the ultimate success of climate change education in schools.

Textbooks represent a key classroom resource which can guide both learners' and teachers' knowledge and views of a variety of topics, including climate change (Choi et al., 2010). In this research, the analysis of textbooks used most frequently by a sample of FET level geography teachers' for climate change education indicated a number of shortfalls in these

textbooks provision of relevant, accessible and accurate information on climate change. Such shortfalls need to be addressed as they have significant implications for the extent to which these resources can usefully contribute toward the ultimate aims and objectives of climate change education.

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APPENDIX A: Standardised Semi-Structured Interview

Demographic:

Age: 20-30 30-45 45-60 60-75

Sex:

Number of years in teaching:

Level: Grade 10 Grade 11 Grade 12

Interview Questions:

1. What is meant by the term 'climate change'?
 - 1.1.Explain it to me?
2. What do you think the most important aspects of climate change are?
 - 2.1.Why are these important?
3. Draw a diagram showing how the greenhouse effect works. (*Piece of blank A4 paper will be provided to each participant*).
 - 3.1.Write a brief paragraph explaining your diagram.
4. What are the major greenhouse gases?
5. Can humans influence the greenhouse effect?
 - 5.1. Please explain your answer.
6. Can the greenhouse effect be slowed down or stopped?
 - 6.1. Explain your answer.
7. Has climate change affected the weather globally?
 - 7.1.Explain your answer.
 - 7.2.How do you know this?
8. Will climate change affect weather globally in the future?
 - 8.1.Explain your answer.
 - 8.2.How do you know this?
9. Has climate change affected the weather in Johannesburg?
 - 9.1.Explain your answer.
 - 9.2. How do you know this?

10. Are there major risks associated with climate change?
 - 10.1 If so, can you name a few?
11. Should steps be taken to alleviate climate change and if so which steps should be taken?
12. Where do you find out information on climate change?
13. Do you use any textbooks to facilitate your teaching of climate change?
 - 14.1 If yes, which textbooks do you use?

APPENDIX B: GDE Research Approval Letter



education
Department: Education
GAUTENG PROVINCE

For administrative use:
Reference no. D2012/104

GDE RESEARCH APPROVAL LETTER

Date:	7 July 2011
Name of Researcher:	Vujovic J.O.S.
Address of Researcher:	P.O. Box 41045
	Craighall
	2024
Telephone Number:	011 788 3266 / 083 596 3390
Fax Number:	011 880 7309
Email address:	jessvujovic@gmail.com
Research Topic:	An investigation of Gauteng Geography teachers' perceptions of climate change and an evaluation of textbooks provided to Geography teachers for climate change education at FET level
Number and type of schools:	TEN Secondary Schools
District/s/HO	Ekhuruleni South; Gauteng East; Johannesburg Central; Johannesburg East; Johannesburg North; Johannesburg South and Johannesburg West

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

1. The District/Head Office Senior Manager/s concerned must be presented with a copy of this

1

Making education a societal priority

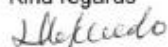
Office of the Director: Knowledge Management and Research

9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506
Email: David.Makhado@gauteng.gov.za
Website: www.education.gpg.gov.za

- letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.
2. The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.
 3. A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.
 4. A letter / document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.
 5. The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.
 6. Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.
 7. Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year.
 8. Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.
 9. It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.
 10. The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.
 11. The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.
 12. On completion of the study the researcher must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.
 13. The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.
 14. Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards



Dr David Makhado

Director: Knowledge Management and Research

2011/07/07

Office of the Director: Knowledge Management and Research

9th Floor, 111 Commissioner Street, Johannesburg, 2001
 P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506
 Email: David.Makhado@gauteng.gov.za
 Website: www.education.gpg.gov.za

APPENDIX C: Information Letter for Heads' of Schools

Dear Headmaster/ Headmistress,

I am a student from the University of the Witwatersrand, working towards completing my master's degree by dissertation in Geography.

For my dissertation I have chosen to explore Geography teachers' perceptions of climate change. In addition, my research also seeks to critique some of the textbooks provided to geography teachers for climate change education. Ultimately this study may shed light on the aspects of teacher's knowledge and understandings of climate change which may need to be broadened or clarified. Furthermore, this research may provide useful direction in uncovering the features of the textbooks used for climate change education which need to be improved upon or extended. An investigation of these two closely linked dimensions may assist in ensuring that learners are educated about the issue in a way which will inspire attitude, behaviour, value and perception changes

In order to assist with this research I would like to ask your permission to interview two educators who teach geography at FET level (grades 10- 12) in your school.

The interviews will take place after school hours at a time which is convenient to the teacher and each interview will last for 30 to 40 minutes. Before conducting the interviews all aspects of the study, such as what it hopes to achieve and how the findings will be used, will be explained to each participant. Educators will then be required to sign a consent form. The teacher will not be penalized for not participating, and will have the right to withdraw from the study at any time. It is also important to highlight that educators will not be remunerated for participating. Efforts will be made to safeguard their privacy (actual names and contexts will be disguised) so that issues remain anonymous. The information given during the research process will be written down and taped, however, names will not be disclosed. All data will be destroyed.

If you require more clarity on this research or have any questions, feel free to ask and I will try and answer your queries where possible.

Thank you for taking the time to consider allowing educators from your school to participate in this study. Looking forward to hearing further from you.

*Jessica Vujovic
jessvujovic@gmail.com*

APPENDIX D: Participant Information and Consent Sheet

Dear Educator,

I am a student studying at the University of the Witwatersrand towards my Masters in Geography. As part of my degree I am required to conduct research on a topic of my choice. I have elected to research geography teachers' perceptions of climate change. In addition to this my research also seeks to critique some of the textbooks provided to geography teachers for climate change education.

Through examining the above mentioned aspects this study may shed light on the areas of teacher's knowledge and understandings of climate change which may need to be broadened or clarified. Furthermore, this research may provide useful direction in uncovering the features the textbooks used for climate change education which need to be improved upon or extended. An investigation of these two closely linked dimensions may assist in ensuring that learners are educated about the issue in a way which will inspire attitude, behaviour, value and perception changes.

In order to assist with the research I would like to invite you to participate in this study through being interviewed. You will not be penalized for not participating, and you have the right to withdraw from the study at any time. It is also important to let you know that there will be no payments for participation. Efforts will be made to safeguard your privacy (actual names and contexts will be disguised) so that issues remain anonymous. The information that you give during the research process will be written down, however, your names will not be disclosed. All data will be destroyed.

The interview will be held at a time which is convenient for you, after school hours. The interview will last between 30 to 40 minutes.

If you require more clarity on this research or have any questions, feel free to ask and I will try and answer your queries where possible.

Thank you for taking the time to consider participating in the study.

Jessica Vujovic

University of the Witwatersrand

School of Geography, Archaeology and Environmental Studies

Consent Form for Participation in the Research

I agree to take part in the research project and I understand the purpose, conditions and procedures of the study as they have been explained to me. I understand that I am not going to get paid for my participation and that I have the right to withdraw from the study at any time during the study without a penalty. I understand that my identity will be protected.

Name of participant:

Date:

Signature:

I have explained the procedures, purpose and conditions of the study to my participants. I have explained to the participants what their rights are with regard to participation in the study as well as the limitations of confidentiality. I agree with the above mentioned conditions and will adhere to them.

Date:

Signature of the researcher:

APPENDIX E: Audio Taping Consent Form

Dear Educator,

You are invited to participate in this research process by participating in open-ended **audio-taped** interviews with the researcher. All data will be destroyed.

Thank you for your participation,
Jessica Vujovic
University of the Witwatersrand
School of Geography, Archaeology and Environmental Studies

Consent Form for Audio-taping of Interviews

I hereby willingly consent to the taping of my interviews as part of the research into educators' perceptions of climate change. I understand that all taped data will be destroyed.

Name of participant:

Date:

Signature: