Pre-Service Science Teachers' Understandings and Practices of Climate Change

By

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PREFACE

The work described in this dissertation was carried out in the Science and Technology Education Cluster, School of Education, University of KwaZulu-Natal, under the supervision of Professor Nadaraj Govender and co-supervision of Professor Angela James. Ethical clearance was granted for this study by the University of KwaZulu-Natal Research Office. The Ethics Clearance Approval Number is HSSREC/00005048/2022.

DECLARATION

This study represents the original work of the author except where otherwise indicated and has not been submitted in any form for any other qualification to any tertiary institution. Where use has been made of the work of others, it has been duly acknowledged in the text.

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SUPERVISOR'S SIGNATURE:  **DATE: 27th June 2024**

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DEDICATION

To my parents, Cheryl and Raymond Govender, who taught me the value of hard work and perseverance.

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- To God for providing me with knowledge, strength, support, and knowledge, for guiding me through all of the hardships faced, and for giving me the determination to pursue this study and make this research possible.

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- To my parents for their unwavering support.

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LIST OF ABBREVIATIONS

CCE	Climate Change Education
ESD	Education for Sustainable Development
FCCC	Framework Convention on Climate Change
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
PST	Pre-service teacher
SDG	Sustainable Development Goal
UNFCCC	United Nations Framework Convention on Climate Change

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ABSTRACT

This study explored pre-service teachers' (PSTs) understandings and practices before and after a Biological Science for Educators module regarding Climate Change. As Climate Change becomes an increasingly important issue, it is imperative that educators are well-equipped to teach this topic effectively. However, there is a dearth of literature regarding the effectiveness of teacher education programmes in adequately preparing PSTs to address Climate Change in their future classrooms.

Employing a qualitative approach, this research utilised questionnaires to assess PSTs' knowledge and practices both before and after the module. The sample consisted of 40 PSTs from the School of Education, University of KwaZulu-Natal. A questionnaire was used and adopted from a previous study to measure specific aspects of Climate Change knowledge, such as the understanding of climate processes and practical strategies. Additionally, post-module interviews provided qualitative insights into PSTs' understandings and practices of Climate Change.

The study indicated that while some students were aware that there are changes in our climate occurring due to Climate Change, there was no improvement in their conceptual understanding. This indicates that pre-service science teachers have a limited understanding of the deeper consequences and causes of Climate Change. Additionally, although some students engaged in behaviours that related to mitigating Climate Change, such as lowering energy consumption and burning of fossil fuels, these actions were often superficial and lacked a deeper commitment to sustainability practices. This suggests a need to use a holistic approach to Climate Change that not only increases awareness, but also deepens their conceptual understanding and fosters meaningful, sustained engagement in Climate Change mitigation efforts.The study proposes a content-pedagogical action oriented model that can be adapted and implemented across various educational levels, including schools, communities and tertiary institutions. This model also involves continuous reflection on and assessment of students' learnings, experiences and curriculum evaluations, including the involvement in Climate Change-related actions and a deeper understanding of the concept of Climate Change. The holistic approach suggested in the model will provide an enhanced,

important understanding of the effects of Climate Change. As this is a small case study with a particular socio-economic environment, the findings cannot be generalised across educational institutions or all PSTs.

Keywords: Climate change, climate change education, pre-service teachers' understanding of climatic change, mitigation, adaptation, effects of Climatic Change

CHAPTER 1

BACKGROUND / BRIEF MOTIVATION

1.1 Introduction

The Anthropocene era began in 1950. It is the period when people took over from nature as the most influential environmental force on Earth (Nixon, 2019; Ruddiman et al., 2015). Their human activities have been the primary influence in shaping the course of civilization (Lehtonen et al., 2019). The current state of the climate is a precarious situation that threatens future generations (Sanson et al., 2019). An analysis done by Cook et al. (2013, p. 1) of 11 944 scientific papers written by 29 083 authors and published in 1 980 journals demonstrates a greater than 97% consensus regarding anthropogenic global warming. The significance of climate for people, animals, and the environment is evident, given that food, fresh water, fibre, wood, and protection from threats are required in order to survive and thrive. Climate affects crop yield, disease, water scarcity and availability, and danger susceptibility (Islam & Winkel, 2017; Nhemachena et al., 2020; Sachs, 2015). Through Climate Change Education (CCE), Pre-service teachers (PSTs) are motivated and informed to make suitable choices and to rethink their position and practices about Climate Change. Climate Change Education also enables them to make knowledgeable choices. Pre-service teachers can be educated about adaptation, mitigation, and effects through classroom instruction that focuses on how lifestyles can be adjusted. It is, therefore, necessary to identify these activities so that, for example, by the use of renewable energy sources and the development of environmentally friendly technologies may influence consumption patterns.. Mitigating Climate Change requires education in order to learn how to change lifestyles, economies, and social structures that are based on excessive greenhouse gas (GHG) production. Education serves as a means to enlighten individuals about their role as conscientious consumers and as accountable members of society, empowering them to effect positive change.

In teaching about Climate Change, new knowledge, concepts, and processes are introduced in the schooling sector. Since educators are exposed to these for the first time, they may

experience difficulties in teaching about this issue. Several facets of Climate Change make it a complex topic to teach, but educators have made efforts to impart accurate knowledge through school and extension programmes. However, misconceptions about the causes of Climate Change exist, for example, Climate Change is natural and inevitable (Fleming et al., 2021; Lee et al., 2020; Sturridge & Holloway, 2022). The vast majority of learners do not comprehend the fundamentals of climate science (Leiserowitz et al., 2011; Monroe et al., 2019). Many science educators in the schooling sector are well aware of their challenges and believe that their role is restricted to disseminating factual knowledge on climate science. However, other educators hope to develop critical thinking skills in youth and to assist them in understanding the sources of conflict surrounding Climate Change (Monroe et al., 2019). As part of their efforts to assist young people in implementing local projects to adapt to and reduce the effects of Climate Change, some educators want to be able to prioritise the development of problem-solving abilities among their students (Azrai et al., 2022; Hudson, 2001; Monroe et al., 2019).

Pre-service science teachers encounter challenges in comprehending Climate Change mitigation and applying these and adaptation measures to the school curriculum (Competente, 2019; Jeong et al., 2021). There is still a dearth of evidence regarding the relationship between PSTs' understandings of the causes of Climate Change, and their knowledge of mitigation and adaptation strategies. The environmental measures currently taught and practised in schools and evident in textbooks are merely minor, simple, and ineffective actions. Therefore, it is necessary for additional studies to elucidate PSTs' understanding of Climate Change mitigation and adaptation. People have attempted to silence young climate change activists and retaliated against them due to the fact that they are expressing opinions that adults find uncomfortable (Hickman, 2020). Regardless, the youth are a logical target demographic for CCE because they will be responsible for addressing the negative impacts of Climate Change in the future (Feinstein & Mach, 2019).

In South Africa, CCE has not received the attention it deserves, despite its critical importance as a global challenge. This lack of attention can be attributed to the country's history of an education system plagued by inequalities and challenges. As a post-apartheid country, South Africa faces the enormous task of addressing the lack of access to basic education for a

substantial proportion of its population and addressing poor education quality among disadvantaged communities. In addition, the school science curriculum in South Africa has been criticised for being too theoretical and disconnected from the real world (De Beer, 2016). As a result, PSTs may not be adequately equipped to teach Climate Change, a complex and interdisciplinary subject that requires the integration of multiple sciences and an understanding of socio-economic and political factors. However, recent policy initiatives have acknowledged the importance of CCE in schools, and efforts have been made to integrate it into the curriculum. For example, the South African National Curriculum Statement (NCS) for Grade R to Grade 12 has included CC into some subjects but some of the challenges faced by South African teachers is that teachers have to cover large content in a limited time which results in some topics not receving as much attention (Du Plessis & Letshwene, 2020). Particular emphasis is placed on the life sciences, natural sciences, technology, and social sciences, which are expected to integrate Climate Change topics to provide learners with an understanding of the challenges, impacts, and possible responses related to Climate Change, such as the greenhouse effect (Department of Basic Education, 2011). Despite this policy directive, it is not clear how PSTs are responding to these initiatives and integrating CCE into their teaching practices. Therefore, this study sought to understand PSTs' understandings and practices of CCE in South Africa, with a view of supporting the successful integration of this important topic into the science curriculum.

1.2 Background

The Intergovernmental Panel on Climate Change (IPCC, 2014) refers to Climate Change as a long-term alteration in the climate's state that can be detected by variations in its mean or variability., typically decades or longer. Natural internal processes or external forces may cause Climate Change; for example, they may be caused by volcanic eruptions and by human interference. The United Nations Framework Convention on Climate Change (United Nations, 1992; UNFCCC, 2018) regards Climate Change as a climatic shift caused directly or indirectly by human action that modifies the composition of the global atmosphere in addition to the natural climatic changes observed over comparable periods.

Climate Change is one of the most pressing issues facing the world today. It is a complex phenomenon caused by a range of natural and human factors, and its effects are felt across the globe. As the scientific consensus on the causes and impacts of Climate Change continues to grow, there is an urgent need for individuals and institutions to take action to mitigate its effects and to adapt to its impacts. In this context, education has a vital role to play in helping individuals and communities to understand the science of Climate Change and to develop the knowledge, skills, and attitudes that are necessary to address Climate Change effectively. The next generation of students must be prepared to confront extremely complex sustainability issues such as Climate Change.

In South Africa, Climate Change is an especially pressing issue (Johnston et al., 2024) . The country is already facing the effects of Climate Change, which include floods, heatwaves, and other extreme weather events, and these effects are likely to become more severe in the coming years. Despite this, there is relatively little research on how CCE is taught in South African schools, and how PSTs understand and engage with this topic. Recent calamitous floods in KwaZulu-Natal, the Eastern Cape, and the Western Cape have demonstrated the need for a more effective response to disasters that are the consequence of Climate Change. There should be more education on Climate Change because early weather warning signs are insufficient for people to prepare and understand the situation. Climate Change Education is necessary for adapting and preparing people as well as ecological, social, and economic systems for a changing environment. We need to raise awareness regarding important issues in South Africa such as pandemics, floods, and droughts. We must provide information for those who need it most, so that they can prepare and adapt and can comprehend that it is a shared obligation. Hence, the crucial role of education in Climate Change must be acknowledged.

Climate Change Education is fundamentally about acquiring knowledge regarding mitigation and adaptation at both the local and global levels amid danger, uncertainty, and rapid change (Stevenson et al., 2017). In other words, CCE refers to the activities that focus on improving the extent to which an educational system is prepared for Climate Change and is reactive to these issues. Nations are instructed under Article 6 of the UNFCCC to regard education, training, and awareness campaigns as fundamental components of their responses to Climate

Change (Mochizuki & Bryan, 2015). Climate Change Education is closely linked to environmental education but is an aspect that has been challenged in obtaining a position in the curriculum and practices of educational institutions. This is the case even though environmental education has been on the international education agenda ever since the 1972 United Nations Conference on the Human Environment (Reimers, 2021). Moreover, CCE should creatively prepare teachers, PSTs, and adolescents for a swiftly changing, uncertain, risky, and potentially perilous future. Climate Change Education must provide critical thinking skills, scientific understanding, and ethical frameworks that will assist these groups in mitigating, adapting to, and reversing the consequences of Climate Change (Reimers, 2021).

This study is timeous and essential as it seeks to understand what and how PSTs are learning about Climate Change in order to prepare for an unpredictable future caused by the dangers of the human and ecological consequences of Climate Change. Since we can no longer guarantee young people a stable environment during their lifetimes, this study explores what should be taught about Climate Change and how PSTs should currently be engaged in CCE, thus keeping ahead of this uncertain future. Pre-service science teachers must be familiar with the concept of Climate Change and its causes, impacts and mitigation and adaptation techniques so that the education can aid in disseminating the information to the rest of society. Integrating CCE for PSTs into formal education systems could be a critical and effective strategy for strengthening the capacity for tackling the climate problem. This is because of the multiplier effects that occur when individuals share what they have learnt with their families and communities (Mochizuki & Bryan, 2015; Parth et al., 2020). This is especially true in Climate Change adaptation and mitigation. As a result, it is critical to educate PSTs and their students using Climate Change concepts in order for them to develop pro-ecological attitudes.

1.3 Problem Statement

Climate change has become one of the most urgent global challenges in recent years, affecting economies, ecosystems, and societies on a global scale. Pre-service teachers of science are essential in providing future generations with the knowledge and skills necessary to

effectively address climate change, as they are the future teachers. However, there is a growing concern that preservice science teachers may lack a comprehensive understanding of climate change and may not be adequately prepared to integrate climate change education into their teaching practices.

Previous studies have highlighted gaps in science education programs, revealing inconsistencies in how climate change concepts are taught and understood (Monroe et al., 2019). These gaps can lead to misconceptions and inadequate teaching practices, which ultimately hinder students' ability to grasp the complexities of climate change. Moreover, the varying levels of climate change literacy among preservice science teachers raise questions about the effectiveness of current teacher education programs in addressing this critical issue.

The problem this research addresses is the lack of understanding and appropriate actions of climate change education among preservice science teachers. By exploring preservice science teachers' perceptions, misconceptions, and instructional approaches to climate change, this study aims to provide insights that can inform the development of more effective teacher education programs, ultimately enhancing the quality of climate change education in schools.

The research objectives of this study are:

1. To explore pre-service science teachers' understandings of Climate Change before completing a Biological Science for Educators module.
2. To explore pre-service science teachers' practices of Climate Change before completing a Biological Science for Educators module.
3. To explore pre-service science teachers' understandings of Climate Change after completing a Biological Science for Educators module.
4. To explore pre-service science teachers' practices of Climate Change after completing a Biological Science for Educators module.

The research questions are:

1. What are pre-service science teachers' understandings of Climate Change before completing a Biological Science for Educators module?

2. What are pre-service science teachers' practices in relation to Climate Change before completing a Biological Science for Educators module?
3. What are pre-service science teachers' understandings of Climate Change after completing a Biological Science for Educators module?
4. What are pre-service science teacher's practices of Climate Change after completing a Biological Science for Educators module?

This study is structured as follows: Chapter 2 provides a review of existing literature related to Climate Change and education identifying key themes, theories, and gaps in the current knowledge, thus developing the foundation for the above mentioned research objectives. The research design and methodology used in this study will be discussed in chapter 3, which includes the qualitative approach, data collection methods, sampling, paradigm, and ethics. Chapter 4 provides the analysis of the collected data and discusses the findings in the context of the research questions, comparing the findings with existing literature, and portraying the themes. Finally, chapter 5 summarises the data analysis, providing conclusions and recommendations, discussing the implications of the findings for future research, and addressing the limitations of the study.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

Climate Change is a natural phenomenon; however, its effects are social because every human being is affected. The phenomenon of Climate Change necessitates adaptation because it results in alterations to the seasons, vegetation, precipitation, weather conditions and people's livelihoods. If Climate Change is inevitable, the only option for policymakers and executors is to devise policies and programmes that can be implemented to combat any short- and long-term negative effects of the changes (Isah, 2021).

2.2 Climate Change

The UNFCCC and the IPCC both have their own distinct definitions of the phenomenon known as Climate Change. According to the UNFCCC, Climate Change is characterised as a modification in the climate system that can be ascribed either directly or indirectly to human activities (UNFCCC, 2007, 2022). This alteration affects the composition of the Earth's atmosphere on a global scale and is distinct from natural climate variations observed over similar timeframes. In contrast, the definition of Climate Change provided by the IPCC encompasses a wide range of climatic alterations occurring over a period of time, regardless of whether they arise from natural fluctuations or from human-induced factors.

2.2.1 Evidence of Climate Change

Climate Change has risen to prominence as a critical global concern. The focus of the global media on Climate Change increased at the end of the previous decade, with the coverage of climate issues currently being at an all-time high (Kunelius & Roosvall, 2021). This new high tide of media attention on Climate Change brought with it a fresh sense of urgency regarding the future stability of the Earth's climatic system (Kunelius & Roosvall, 2021). Consequently, the rise of the climate catastrophe debate is not only a subject on the political and public

agenda but also a systemic problem that nations must confront—from ordinary life decisions to the very foundations of the economy, social interests, and power relations.

Although both natural and artificial forces can influence Climate Change, humanity's influence on the climate began with the Industrial Revolution. Washington and Cook (2011) state that Climate Change is a perplexing issue of our time and, according to Vukelić et al. (2022), Climate Change is a complicated subject and a global concern with uncertain implications. In South Africa, the effects of Climate Change represent a serious risk to the country's water resources, food security, health, and infrastructure, in addition to its ecosystem services and biodiversity. These effects present obstacles to the progress of the South African nation, particularly in view of the high levels of poverty and inequality that exist in the country. However, similar to numerous other regions across the globe, the original investigations on Climate Change in South Africa were predominantly approached from an environmental perspective rather than being viewed as a developmental concern (Ziervogel et al., 2014).

It is undeniable that anthropogenic emissions of GHGs are influencing the climate of the Earth. Human activities have presently elevated atmospheric carbon dioxide (CO_2) concentrations to a magnitude that has not been surpassed in the past 400 000 years according to the Earth's geological record (Wheeler & Watts, 2018). Since 1880, there has been a notable global average rise in the Earth's temperature, amounting to more than 0.85°C (Wheeler & Watts, 2018). These increasing temperatures, facilitated by climatic systems, lead to intensified and more frequent occurrences of extreme weather events, alterations in precipitation patterns affecting arable land, accelerated ice melting, and disturbances in several other environmental processes (Wheeler & Watts, 2018).

2.2.2 Global Response to Climate Change

The majority of the world's nations, particularly the developed nations, have adopted Climate Change policies. For instance, many developed nations have reflected on curriculum reviews and the adoption of new learning methods because the concept of Climate Change requires unlearning what has been previously learnt and learning an entirely new concept. Many

countries have adopted strategies to respond to Climate Change. The Chinese have disseminated the learning process on Climate Change to public forums in order to equip every Chinese citizen with the fundamentals of combatting Climate Change, while the United States has created organisations for adults, adolescents, and children (Isah, 2021).

2.2.3 Climate Change Adaptations and Mitigation

In addressing Climate Change and its consequent implications on various earthly systems, people employ two distinct approaches: mitigation and adaptation. According to the United Nations Educational Scientific and Cultural Organization (UNESCO, 2021), mitigation measures encompass the many efforts implemented to diminish and control the release of GHG emissions effectively. Adaptation efforts are implemented with the objective of mitigating vulnerability to the impacts of Climate Change.

Approaches to mitigate the impacts of Climate Change are diverse; however, the selection of appropriate adaptation techniques is contingent upon individual contextual factors. In general, adaptation techniques can be classified into two distinct categories: (1) measures aimed at mitigating sensitivity to the adverse effects of Climate Change, and (2) measures aimed at capitalising on the possible advantages that may arise from shifting climatic circumstances (Abbass et al., 2022). The reduction of vulnerability may encompass various approaches, including enhancing infrastructure resilience to withstand adverse weather conditions and applying risk management strategies to safeguard the availability and accessibility of food and water resources. The prospective advantages arising from alterations in climatic circumstances include strategies such as the advancement of crop varieties that are resilient to drought and the establishment of novel ecosystems that are more compatible with the evolving environment (Abbass et al., 2022).

Mitigation techniques aimed at addressing Climate Change generally encompass the reduction of GHG emissions and/or the augmentation of carbon sinks in order to counterbalance GHG emissions. Several examples of mitigation strategies can be observed, including the utilization of renewable energy sources, including solar and wind power, and the use of energy efficiency regulations, the improvement of transportation infrastructure to

decrease dependence on fossil fuels, and the encouragement of sustainable land-use practices that promote carbon sequestration. In addition, the implementation of afforestation and reforestation initiatives aimed at augmenting the quantity of carbon sequestered inside forested areas and soils have proved to be efficacious measures for mitigating Climate Change (Abbass et al., 2022). Rousell and Cutter-Mackenzie-Knowles (2020) concur and state that mitigation strategies are designed to minimise the anthropogenic factors that are contributing to Climate Change. These strategies commonly involve the reduction of GHG emissions, the enhancement of energy efficiency, the adoption of renewable energy sources, the promotion of sustainable transportation, the improvement of waste management practices, and the implementation of carbon capture and storage techniques, among other measures. Collaboration of several sectors, active involvement of the public, and endorsement from governmental entities are necessary to achieve the effective execution of these mitigation initiatives.

2.3 Climate Change Education

2.3.1 Climate Change Education in South Africa

The current school curriculum in South Africa lacks comprehensive coverage of Climate Change, particularly in relation to the human health implications of this phenomenon. This omission is evident in the official documentation provided by the South African Department of Basic Education in 2011 (Department of Basic Education, 2011). There is a pressing need for curriculum reform within tertiary level institutions. The acquisition of increased awareness regarding Climate Change has the potential to incite a sense of activism within the youth population of South Africa that is akin to the influential activism witnessed in several other regions globally. The Department of Agriculture in the Western Cape Province of South Africa has introduced an electronic book about Climate Change in three indigenous languages. This initiative offers an additional avenue for promoting a future in the education sector that is robust with regard to the impacts of Climate Change (Trautman, 2021).

2.3.2 Climate Change Education in Higher Education

The type of knowledge pertaining to Climate Change that university students obtain can have an impact on their overall quality of life. To elaborate, the data, in whatever manner it may be presented, moulds their sense of capability and responsibility to effect positive change in their neighbourhoods (Mugambiwa & Dzomonda, 2018). University students exhibit a strong inclination towards using technology and possess the capacity to make contributions towards the mitigation of Climate Change (Mugambiwa & Dzomonda, 2018). Research by Monroe et al. (2019) says that interventions that utilise technology to educate and encourage individuals to take action on Climate Change can be empowering. While the developing world experiences more pronounced consequences of Climate Change, it is crucial for university students in developing nations to possess a profound understanding and awareness of Climate Change impacts (Mugambiwa & Dzomonda, 2018). This knowledge on Climate Change will enable them to formulate effective strategies for mitigating Climate Change.

2.3.3 Climate Change Education and Teacher Professional Development

Professional development initiatives in the field of Climate Change are specifically designed to enhance teachers' knowledge and pedagogical abilities in teaching this subject matter (Johnson et al., 2008). These initiatives strive to cater to a broad range of educators who possess varied personal and professional limitations and various preferences in terms of their learning styles. To bridge the gap between understanding and practice, teacher education programs must incorporate experiential learning opportunities that allow pre-service teachers to engage with real-world climate issues.

Johnson et al. (2008) compiled a list of observations regarding the professional development of teachers in the context of Climate Change:

1. Educators require reliable scientific information on Climate Change and suitable, practical activities that are applicable to contemporary science classes rather than hypothetical science classrooms. To ensure optimal use of these resources within educational settings, it is imperative for teachers to possess prior experience in employing them during professional development endeavours, hence fostering a sense of proficiency and assurance in handling the materials. There is notable

enthusiasm among educators across many professions and educational levels to incorporate the topic of Climate Change into their school curricula.

2. The field of Climate Change science exhibits a strong multidisciplinary nature, extending its relevance beyond the confines of the earth science classroom. Its significance is evident in several academic disciplines such as biology, chemistry, and physics in addition to the realms of geography, history, and ethics. While the instructional focus may vary, students have the opportunity to acquire knowledge about Climate Change at many educational levels, ranging from primary school to graduate studies. According to educators, learners across academic levels exhibit a high level of motivation to acquire knowledge regarding Climate Change and actively engage in efforts to address this pressing issue.
3. Instead of focusing solely on global averages, educators value local perspectives on Climate Change. This tool facilitates the process by which educators can effectively illustrate the tangible effects of Climate Change to their learners while concurrently offering a platform for active learner participation through the act of observation.
4. The significance of teachers' involvement in a community of learners and practitioners cannot be overstated. Following the completion of the professional development activity, teachers frequently return to solitary classroom settings, devoid of opportunities for collaboration with their peers. Online tools such as online forums serve as valuable resources for individuals to sustain their connection to a community. Peer mentorship is an additional beneficial strategy for fostering a sense of community within the context of online courses.
5. Educators express apprehension regarding the potential psychological impact on learners when exclusively emphasising the negative and alarming facets of Climate Change. Focusing on the actions that students and communities can undertake to generate a positive influence is of utmost significance.
6. In recent times, professional development initiatives targeting teachers have placed less emphasis on the need to substantiate the existence of Climate Change. However, it remains crucial to furnish substantiation, including Climate Change observations and model outcomes, in order to enable educators to explicate the scientific principles with precision. Maintaining a neutral educational environment in which the exclusion of ideology and politics is emphasised is of utmost significance. The primary

emphasis should be placed on presenting factual information and exploring potential measures to enhance forthcoming climate scenarios.

7. Educators have the opportunity to use Climate Change science as a means to cultivate advanced cognitive abilities in their students such as critical thinking, the ability to analyse and interpret information from diverse sources, comprehension of uncertainty and its practical implications, and the development of a comprehensive understanding of systems and models.
8. In order to engage participants effectively, it is imperative that online professional development incorporates a diverse range of resources. These resources may encompass multimedia materials, internet pages, engaging tasks, surveys, and discussion boards.
9. It is essential for professional development programmes to incorporate a cyclical process of enhancement in what they offer, thus enabling continual improvement through the evaluation of outcomes and breakthroughs in science and technology.

The early stage of development of CCE reveals problems in the education sector's response to Climate Change. Plutzer et al. (2016) have reported that recent research has revealed a variety of approaches, which has led to different levels of implementation and acceptance. Nevertheless, educators are trying to confront the issue of Climate Change by revising established norms and practices, which has resulted in the emergence of new educational models (Shea et al., 2016).

The professional development model for science educators in the United States is designed to enhance teachers' knowledge and communication skills in accurately conveying the scientific concepts to their students. In the study conducted by Drewes et al. (2018), the focus was on examining the installation and execution of a professional development model for science instructors that addresses Climate Change. The primary objective was to assess the influence of this model on student learning outcomes. The findings of Drewes et al. (2018) indicated a notable enhancement in students' comprehension of the amplified greenhouse effect and the consequential ramifications of human activities on Climate Change. However, the students exhibited only modest improvements in their understanding of the potential consequences of Climate Change, and their ability to propose practical solutions to mitigate

these issues was lacking (Drewes et al., 2018). These shortcomings could be attributed to deficiencies in both professional development and the implementation of teaching strategies by educators.

A growing realisation among educators and scholars is that the way in which Climate Change is addressed may differ from the way other environmental challenges are approached. Indeed, the topic's complexity and uncertainty necessitate careful consideration and attention. However, even more than ethical controversies regarding hazardous waste disposal or declining biodiversity, the topic of Climate Change appears to resonate with values to the point where adults respond by safeguarding their social identity and lifestyle. (Nation & Feldman, 2022).

Beyond the difficulties inherent in the complicated nature of Climate Change, educators dealing with a variety of audiences, ranging from learners in schools to adults in communities, have reported additional difficulties in offering effective CCE to their learners. Teachers have expressed reluctance to teach Climate Change because of the possible reactions of their learners to Climate Change as it is a controversial topic, making them unwilling to teach the subject (Nation & Feldman, 2022; Seroussi et al., 2019; Wise, 2010). Some educators have voiced concerns that speaking out about Climate Change in their community will diminish their credibility and efficacy (Long & Tyson, 2014). As a result, they avoid discussing Climate Change in their classrooms. Moreover, some educators believe that they lack the requisite skills and knowledge to give sufficient Climate Change training to their learners (Monroe et al., 2013).

The education sector represents a previously untapped resource in the fight against Climate Change. There is a clear education agenda in place in the UNESCO *Education for Sustainable Development Goals: Learning Objectives* for Climate Change adaptation and mitigation strategies. These strategies necessitate the acquisition of new knowledge and skills and the modification of behaviour in order to mitigate the risks associated with Climate Change. Successful Climate Change adaptation and mitigation require proper knowledge, skills, and behavioural change, which education can deliver. Specifically, education can empower

individuals and communities to make educated decisions and take action towards sustainable development (Rieckmann, 2018).

The Earth has never been in the condition in which it is currently (Stevenson et al., 2017) and hence this study is guided by the definition of CCE of Stevenson et al. (2017), which concerns learning in times of risk, uncertainty, and swift change. The definition focuses particularly on mitigation, adaptation, and effects. The most prevalent solutions try to lessen the effects of Climate Change (mitigation) and adapt to those effects (adaptation). Simply, mitigation seeks to avoid the uncontrollable while adaptation seeks to manage the inevitable such as the rise in temperatures, wildfires, and droughts. Limiting the production of GHGs, particularly CO_2 and methane (CH_4), to prevent further anthropogenic Climate Change is referred to as mitigation (Ayers & Dodman, 2010). Rethinking the ideas that support developmental imbalances and our unsustainable relationship with nature is possible through adaptation to climate change (O'Brien et al., 2014). However, this conclusion is by no means assured, and mounting evidence suggests that adaptation is frequently conceived of as a non-political, specialised area and is implemented with a defensive rather than a progressive attitude. Adaptation has been conceptualised in terms of recognising what must be retained and what can be discarded as opposed to what can be reformed or gained (Pelling, 2010).

2.5 The Importance of Climate Change Education for Future Generations

The importance of CCE lies in its ability to enhance learners' comprehension of the environmental consequences of human activities and their role in exacerbating Climate Change . The implementation of effective educational strategies has the potential to influence the attitudes and behaviours of learners, leading to a greater propensity for taking proactive measures to mitigate their individual environmental footprint and fostering a culture of environmental responsibility among their peers (Monroe et al., 2019). A comprehensive analysis of 49 studies revealed that CCE programmes that proved effective exhibited distinct attributes such as personal relevance and compelling instructional approaches. These themes can be used by educators to guide their selection of curriculum and instructional approaches when addressing the topic of Climate Change (Aliyu et al., 2015). Furthermore, Molthan-Hill et al. (2019) state that the objective of CCE is to provide knowledge and awareness for

upcoming leaders and the general population regarding the scientific, social, environmental, and political complexities associated with Climate Change mitigation strategies and adaptation measures. Leal Filho and Hemstock (2019) assert that CCE aims to enhance individuals' comprehension of the multifaceted aspects pertaining to Climate Change while concurrently equipping societies with the necessary tools to address and adapt to the challenges posed by Climate Change effectively, thus fostering increased resilience. The acquisition of knowledge and understanding regarding Climate Change holds value in the formulation and execution of endeavours aimed at enhancing public consciousness about Climate Change and its consequences. Additionally, CCE plays a crucial role in the creation and dissemination of educational programmes and resources. Understanding the various CCE tactics implemented by higher education institutions worldwide and examining how these institutions enhance their efforts in addressing this pressing issue are crucial endeavours Molthan-Hill et al. (2019).

2.6 Climate Change Education, Climate Literacy, and Environmental Literacy

Since addressing the climate crisis requires climate-literate citizens and students from all segments of global society, CCE should incorporate a variety of disciplinary perspectives, translate and develop climate literacy, empower educators and students, and contextualise climate science so that it is understandable and credible. Climate Change Education is based on scientific Climate Change concepts, and its aim is frequently defined as the act of developing, encouraging, and shaping pro-environmental values and attitudes., and behaviours. Bofferding and Kloser (2015) determine and define three domains of declarative Climate Change knowledge: 'system knowledge' (mechanistic understanding of the climatic system and the drivers and impacts of Climate Change), 'action knowledge' (understanding of mitigation actions and behaviours), and 'effectiveness knowledge' (understanding and evaluating the potential of specific mitigation activities). According to Bofferding and Kloser (2015), a climate-literate person is one who:

- understands the fundamentals of anthropogenic Climate Change and the greenhouse effect;
- is aware of the effects of anthropogenic Climate Change and is able to provide examples of local impacts;

- knows the main contributors to anthropogenic Climate Change and can provide examples of daily activities that contribute to it;
- knows the effectiveness of various anti-climate-change strategies;
- understands the carbon footprint concept;
- is aware of the significance of implementing Climate Change solutions;
- believes in one's own capacity to participate in combatting Climate Change and achieve success (self-efficacy); and
- participates in activities that will likely aid in combatting Climate Change (on an individual, society, and political level).

Knowledge, affect, skills, and behaviours are the four primary components in environmental literacy (Kolenatý et al., 2022). The expression of environmental literacy can be seen in the form of observable environmentally responsible behaviour. Although behaviour is one of the components that make up environmental literacy, it is also the ultimate objective (Kolenatý et al., 2022). Daniš (2013) adds that environmental literacy (the goal of environmental education in other publications) comprises dispositions, knowledge, and competencies that may be applied with the aim of responsible environmental behaviour in certain circumstances. In addition, Ephraim (2019) defines environmental literacy education as a way of demonstrating a set of knowledge, skills, attitudes, and mental habits that enables individuals to have a positive relationship with their environment and to take daily and long-term actions to preserve and rebuild sustainable relationships with other individuals and the biosphere.

2.7 Education and Sustainable Conduct

In an effort to increase environmental literacy with the eventual objective of eliciting sustainable behaviour on a national and global level, many educational institutions, including universities, have incorporated some sort of environmental education into their course offerings (Reddy, 2021; Woodworth et al., 2011). Research conducted on these programmes has revealed that simply educating university students on environmental issues is enough to raise their environmental concerns and shift their worldviews in a way that is congruent with their concerns (Pe'er et al., 2007).

Education in environmental literacy as a possible tool is urgently needed in matters that concern the environment since it takes an individual who is environmentally literate to comprehend environmental issues. According to the African National Congress (ANC), in order for the environment to be free from degradation, there must be quality education that includes environmental education (Ephraim, 2019). This approach would assist individuals in acting and promoting an environmental ethic and in taking an active role in the responsible use of natural resources and effective management of the environment. The acquisition of environmental literacy through environmental education is the basis. Consequently, the components of environmental literacy, awareness (awareness of environmental issues), knowledge (knowledge of natural history and ecology; knowledge of the environment), and attitudes, skills, and action are necessary.

Teaching students about Climate Change can shift their worldviews into becoming more sustainable (Brennan, 2017; Shephard, 2010). Institutional mandates for CCE are based on the premise that "educators must take the lead in sustainability so that our graduates can be encouraged and supported to promote sustainable practices in their chosen career" (Shephard, 2010). As future leaders, students should be taught about Climate Change issues to create a biocentric worldview (Kopnina, 2020). Hence, it is appropriate to teach Climate Change at the university level in order to alter the values and behaviours of future leaders. This may be even more justified when educating future educators who may proceed to advocate sustainable practices in their future jobs (Evans et al., 2018; Shephard, 2010).

Despite the necessity of preparing science teachers to include sustainability education in their future professions, research indicates that such teachers have received inadequate training in this area (Pe'er et al., 2007; Reddy, 2021). The degree to which CCE has been included into beginning-teacher education curricula is either unknown (Evans et al., 2018) or requires significant change (Brennan & Widdop Quinton, 2020). It has been reported that PSTs in Australia have an unacceptably low level of knowledge and understanding of Climate Change. This includes secondary specialists who cite science and environmental studies as their focus of study (Boon, 2010; Groves & Pugh, 1999). Similar findings have been demonstrated in pre-service teachers in Canada (Puk & Stibbards, 2012) and the United States

(Lambert & Bleicher, 2013). These types of troublesome knowledge and comprehension gaps are not exclusive to pre-service teachers. According to research carried out with a demographically diverse group of university students in the United States this population is also home to a variety of misconceptions on the fundamental causes and effects of Climate Change (Wachholz et al., 2014).

2.8 Pedagogy of Climate Change

Scientific evidence and consensus exist regarding the origins and consequences of Climate Change on the future of humanity (Intergovernmental Panel on Climate Change [IPCC], 2021). From a scientific standpoint, the mitigation of human-induced global warming to a predetermined threshold necessitates the restriction of cumulative CO_2 emissions (IPCC, 2021). This entails achieving a state of net zero CO_2 emissions in addition to implementing substantial reductions in other emissions of GHGs. Effective and long term reductions in CH_4 emissions would additionally serve to restrict the warming impact arising from the increase in aerosol pollution while simultaneously enhancing air quality. According to Gatersleben et al. (2010), a number of people demonstrate a high level of materialism while expressing concern about Climate Change. They concluded that behavioural changes are delayed despite the fact that society has begun to perceive Climate Change as an important issue (Gatersleben et al., 2010).

Given its social and contentious nature, Climate Change is the most critical socio-scientific subject that teachers of all age groups should address. This is critical because those with a slight understanding of Climate Change are more inclined to accept untrustworthy sources of information and are unable to distinguish between relevant and irrelevant factors when evaluating the trustworthiness of sources (Competente, 2019). The role of universities in CCE is critical in addressing the world's scientific, environmental, social, and political issues. It is crucial that CCE in higher education institutions is expedited so that more people can engage with and adapt to Climate Change on a worldwide scale.

Teaching about Climate Change is complex and a number of factors play crucial roles. For example, the delivery of a climate change curriculum is hindered by the ongoing debate

regarding the reality of climate change. This indicates that it is necessary to reevaluate the issue of sustainability education in broader social contexts. (Perkins et al., 2018). An obstacle to the implementation of teaching Climate Change is the ongoing debate regarding the veracity of Climate Change. This factor, together with others, suggests that education for sustainability must be reconsidered in broader social contexts. Climate Change Education should aim to empower students to apply the knowledge and skills acquired in the classroom to real-world contexts by means of diverse extracurricular engagements. In a broader context, it is imperative to direct the focus towards the structure and administration of comprehensive CCE, with the aim of providing guidance for the establishment and advancement of environmental associations inside academic institutions. One notable example is the resurgence of bike sharing in China, which can be attributed to the implementation of comprehensive carbon education initiatives on university campuses.

Ultimately, it is imperative that CCE not only fosters students' capacity for practical application but also serves to heighten public consciousness regarding environmental matters beyond the confines of academia. A comprehensive education on global Climate Change should aim to foster collaboration among students, facilitate research endeavours, and promote the exchange of experiences with governmental entities such as the Ministry of Environmental Protection and the Ministry of Science and Technology. Additionally, engagement with non-governmental organisations and enterprises such as BP, Shell, and Toyota should be encouraged. In a broader context, due to the multifaceted nature of Climate Change, it is imperative to integrate CCE with various fields for enhanced effectiveness (Perkins et al., 2018).

Numerous members of the public disagree with the anthropogenic causes of Climate Change (Perkins et al., 2018). In general, people accept that the planet is warming with a degree of certainty, but they frequently reject the notion that human actions are altering the planet's climate. The reality is that Climate Change is occurring, and society must learn how to adapt.

Universities have begun to collaborate with local communities by educating their graduate and undergraduate students about climate adaptation in order to equip them with the skills necessary to deal with the emerging threats posed by a changing climate (Perkins et al., 2018).

According to Perkins et al. (2018), a curriculum on Climate Change must be comprehensive, fostering students' capacity to contribute to a more sustainable future and taking into account the four thematic areas of the UNESCO (2021) Climate Change Initiative: scientific, educational, environmental, and ethical. This requires individuals to have both the willingness and ability to collaborate, irrespective of cultural or disciplinary differences. differences (Eilam, 2022; Glasser, 2007). Educators' primary responsibility is to help students become better thinkers and lifelong learners. This endeavour is not a single activity but rather a collection of practices such as the ability to recognise facts and to evaluate new ideas and issues from multiple perspectives. Teaching students to become better thinkers and lifelong learners is not neutral in terms of content or context. In other words, it has nothing to do with how well students comprehend the subject matter in their respective classes. Students enter the classroom with concepts and ideas about the world that are already profoundly rooted within them. The incorporation of complex, controversial, and politically charged topics such as Climate Change presents teachers and a sustainable development curriculum with a number of challenges.

The political dynamics surrounding Climate Change are among the most contentious, involving competing values and interests. According to Perkins et al. (2018) to effectively teach social-scientific concepts like Climate Change and sustainable development, educators must understand the students' assumptions, areas of misunderstandings, as well as their logical thinking methods. Additionally, to enhance the practice of education for sustainable development (ESD), it is essential to consider the potential complexities that are inherent in a curriculum for CCE.

Approaches to integrating CCE are limited, disorganised, and frequently discipline-specific (Wall et al., 2017). Even within a particular subject of study, research on how CCE could be embedded is limited. The relationship between CCE and ESD has been explored in numerous articles. Mochizuki and Bryan (2015) argue that Climate Change should be taught as part of ESD:

> CC [Climate Change] has far-reaching implications for where people can settle, produce food, maintain built infrastructure, and rely on functioning ecosystems. Consequently, it impacts [*sic*] on multiple aspects of sustainable development,

including human migration, food security, economic growth, and biodiversity loss. Given that CC incorporates environmental, political, social, and economic factors, ESD's holistic framework is the optimal framework for advancing CCE.

Mochizuki and Bryan (2015) propose that CCE could be taught using one of the well-known ESD frameworks—the four pillars of education as conceptualised in the known 1996 'Delors Report' to UNESCO of the International Commission on Education for the Twenty-First Century (Delors, 1996), with a particular emphasis on two of the pillars:

1. Learning to know: Students must comprehend the causes and effects of Climate Change in addition to the mitigation and adaptation tools.
2. Learning to do: Students must develop transferable skills, for example, managing emotions such as anxiety, adapting quickly to new situations and learning contexts, comprehending systems, and imagining various solutions and future scenarios.

Wals and Benavot (2017) and Wolff (2011) found that, despite decades of efforts to establish effectual environmental education and ESD, gaps remain between education and sustainability. Challenges have arisen due to the gap between the reality of educational practices and the ideology of environmental education (Wolff, 2011). The critical challenges between sustainability and education can be caused by today's mixed understanding of human nature and worldview (Wolff, 2011). In order to identify sustainable education strategies that are effective, it is necessary to comprehend how modernisation continues to influence prevalent societal and cultural practices and education despite the emergence of new and more sustainable modes of thought (*Education for sustainability*, 2014; Wolff, 2011).

2.9 The Significance of Pre-Service Teachers' Understandings and Practices of Climate Change Education

The understandings and methodologies employed by PSTs on CCE have considerable importance since PSTs bear the responsibility of instructing and advocating for sustainable development education (Karpudewan et al., 2013). Nevertheless, the findings of a survey administered to PSTs enrolled in a science teaching methods course indicate that their comprehension and awareness of fundamental principles related to sustainable development

are comparatively limited when juxtaposed with conventional environmental notions (Karpudewan et al., 2013). Therefore, it is crucial to disseminate knowledge on sustainable development through the process of education and learning. Furthermore, Jeong et al. (2021) assert that the comprehension and methodologies employed by PSTs regarding CCE play a pivotal role in effectively tackling the scientific, environmental, social, and political complexities associated with Climate Change. The authors examined the impact of a flipped classroom intervention on the level of Climate Change awareness among PSTs. The findings of their study indicate that the intervention had a positive influence on both the awareness of Climate Change and the inclination of PSTs to participate in CCE (Jeong et al., 2021). Hence, enhancing the comprehension and implementation of PSTs regarding comprehensive civic education can make a substantial contribution towards mitigating current limitations and enhancing the professional growth of these individuals in the field of teaching. The comprehension and implementation of CCE among PSTs hold substantial importance because they directly affect PSTs' inclination to acquire the scientific knowledge necessary for comprehending this intricate matter.

Moreover, the research by Lambert and Bleicher (2017) revealed that towards the completion of the course observed a notable rise was observed in the proportion of PSTs who held the perception that human activity is the primary cause of global warming. This perception was found to be positively associated with an augmented level of worry regarding the detrimental effects of Climate Change on both the environment and human beings. Furthermore, it stimulated their enthusiasm for endorsing both national and individual initiatives targeted at alleviating the consequences of Climate Change (Lambert & Bleicher, 2017). While numerous studies have explored the impact of climate change education on students, few have focused specifically on pre-service science teachers' understandings and practices. This gap shows the need for further investigation in this area.

Competente (2019) also evaluated the incorporation of CCE among pre-service teachers at the College of Education of the University of Nueva Caceres. The study examined the attitudes, perceptions, and levels of Climate Change knowledge of pre-service teachers on Climate Change and the potential implications of this knowledge on their future instructional practices. The findings indicated that PSTs had notably elevated levels of literacy pertaining

to Climate Change science. However, certain deficiencies in the teachers' understanding of Climate Change science were also apparent. Furthermore, although the individuals in question demonstrated a thorough comprehension of the measures necessary to mitigate global warming and were suitably equipped to educate their students on these matters, their effectiveness as role models might have been undermined if their personal conduct failed to align with their professed knowledge.

2.10 Climate Change Education in Pre-Service Teacher Programmes

There is a lack of adequate science-topic understanding among pre-service teachers when dealing with intricate socio-scientific matters. Namdar (2018) suggests that it would be beneficial for teacher education programmes to offer additional opportunities for teachers to enhance and broaden their understanding of scientific information. This would enable them to address students' perspectives and ideas effectively regarding scientific knowledge. Additionally, the use of inquiry-based methodologies in traditional teacher preparation programmes might enhance teachers' science-topic understanding and provide a model for effectively teaching complex socio-scientific concerns in science classrooms.

According to Competente (2019), PST programmes exhibited a deficiency in integrating CCE within its professional disciplines. Nevertheless, there is the assertion that higher education assumes a pivotal role in the preparation and provision of the leadership necessary to address and overcome issues in these domains (Competente, 2019). Universities are strategically situated to optimise research and development initiatives pertaining to Climate Change. Additionally, they play a crucial role in cultivating a skilled workforce capable of providing technical expertise, educating the public, and equipping the nation to engage in Climate Change policy-making processes effectively (Competente, 2019).

The study conducted by Competente (2019) found that the PST programme exhibited a deficiency in incorporating CCE into their professional topics. Despite being emphasised by the Commission on Higher Education (CHED) in its Higher Education Reform Agenda, CCE was not expressly incorporated into the PST curriculum. The research also revealed that,

while the majority of teachers had basic knowledge in the field of Climate Change, certain deficiencies in their understanding of Climate Change were apparent (Competente, 2019).

Additionally, it is critical to identify and examine methods with which higher education institutions could effectively address Climate Change. Pre-service teachers and their learners of the future must be prepared to deal with sustainability concerns that are more complicated such as Climate Change, food scarcity, a growing global population, and biodiversity loss. Climate Change caused by humans has the potential to degrade and even reverse progress towards the United Nations Sustainable Development Goals (SDGs) (see Figure 2.2), posing one of the most fundamental hurdles to the international community in achieving sustainable development long-term (Anderson, 2012).

There are some differences between adaptation and mitigation, particularly in terms of their objectives. Mitigation focuses on reducing the causes of Climate Change, for example, reducing the burning of fossil fuels. In contrast, adaptation focuses on adjusting to the effects of Climate Change (e.g. drought); Climate Change has been seen to affect hydrological processes, leading to their heightened intensity and expedited onset. This phenomenon has resulted in numerous implications, among which is the heightened danger of wildfires (Mukherjee et al., 2018). A combination of both approaches is required to manage Climate Change. On the one hand, even with mitigation measures, the climate would continue to change in the following decades, necessitating the need for ongoing adaptation. On the other hand, adaptation would not be able to avoid all the negative consequences completely and thus mitigation would be necessary to keep Climate Change to a minimum (Locatelli et al., 2011).

Sustainable development is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Commission, 1987, p. 43). In ESD, which is widely regarded as a framework for improving the response to Climate Change issues, it is imperative for PST to demonstrate a willingness to act in response to the numerous issues and challenges of sustainable development, particularly Climate Change.

Climate Change is a long-term shift in temperature patterns and weather conditions on Earth. It is likely that human activities are the primary cause of global warming, with more than 95% of scientists agreeing to its cause (Intergovernmental Panel on Climate Change [IPCC], 2007). Initially, it is, therefore, necessary to identify these activities in order to influence human thinking and actions. This includes the education of citizens involving how to alter their lifestyles, economies, and social structures that produce excessive GHG production. The notion of education is often regarded as a powerful tool for supporting informed adaptations, mitigation, and responses to the impacts of Climate Change. One example of this is the potential for enhancing adaptive capacity through the strengthening of general education. As mentioned earlier in a report by Boon (2010), pre-service teachers in Australia were found to have a lack of knowledge as well as awareness of Climate Change, with similar findings demonstrated by pre-service teachers in Canada (Puk & Stibbards, 2012) and the United States (Lambert & Bleicher, 2013). Furthermore, Poortinga et al. (2019) conducted a study on global awareness of environmental issues. They determined that the citizens of developing countries have lower levels of awareness than the citizens of industrialised countries, despite the fact that both have been directly affected by Climate Change.

The SDGs, also referred to as the Global Goals, are a collection of global objectives designed to promote equitable and long-term health on all scales, from the biosphere of the planet to the health of individual communities. Their objective is to ensure a peaceful and prosperous future for all people while also ending poverty and conserving the environment in the present (Morton et al., 2017).

Figure 2.1

Graphical Illustration of the Sustainable Development Goals

Note. By UNESCO (2015). The 17 Sustainable Development Goals to be achieved by 2030

Quality Education, Goal 4 of the 17 SDGs, is to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (UNESCO, 2016, p. 7). In addition, the 2030 Agenda places education at the centre of the achievement of many of the other sustainable development objectives, for example, Goal 13: Climate Change Mitigation. The notion of education in terms of these many objectives is possibly based on the underlying values of a substantial amount of adult and lifelong education and learning practice. Educators and researchers in various national contexts must consider how their field of knowledge and practices are represented or included in the monitoring and reporting processes for the SDGs since lifelong learning is identified explicitly within SDG 4 and integrated into many other SDGs.

Regmi (2015) contends that the least developed countries have been harmed by restricted human capital models regarding educational development and by their conception of lifelong learning. Goal 13, as indicated in Figure 2.2, focuses explicitly on Climate Action, with the United Nations calling for immediate action to combat Climate Change and its effects and

Target 13.3 aiming to "improve education, awareness raising and human and institutional capacity on Climate Change mitigation, adaptation, impact reduction, and early warning" (UNESCO, 2016, p. 8).

In a study by Spiteri (2024), Maltese pre-service teachers have a basic awareness of Climate Change , but they also have certain misconceptions. Their comprehension, or absence thereof, is influenced by the accumulated knowledge of their culture and their personal perception of themselves. The participants selected personal life experiences and actions that held significance and worth to them, and employed these as cultural resources to develop their comprehension and identity in relation to Climate Change.

2.11 Education for Sustainable Development and Climate Change Action

Youth education is one of the most effective strategies to address Climate Change, as mentioned in a 2019 European Parliament resolution (Vukelić et al., 2022). Learning to co-exist with Climate Change establishes a new pedagogical discipline, confirming that Climate Change is not merely "a state for which we should be ashamed" or "a problem that must be solved" (Hulme, 2009, p. 364). While climate education and ESD alone will not solve the problem, they will play a critical part in the transition to a post-carbon reduction future. People have never encountered a situation that is comparable to what they are confronted with now, and this presents the issue of how to educate the youth about it. It is critical to recognise that Climate Change is not merely a scientific issue but a complicated social issue that demands more than content knowledge (McKeown & Hopkins, 2010). Teachers and PSTs must have a thorough understanding of the issue and the strategies for resolving Climate Change in order to incorporate essential modifications into school curricula. School students calling for Climate Change action stated unequivocally (Guardian, 2019):

> Our educational system has failed us. Our classrooms do not effectively teach us about the climate crisis. Schools do not prepare us for the world into which we are about to enter; rather, they train us for jobs and a society built on the system that caused the crisis.

Irwin (2020, p. 504) shares the view that we should be seeking an "immediate overhaul of the national curriculum, as well as a refocus on the ecological problem as our primary educational objective". The importance of PSTs demonstrating a willingness to act in the direction of sustainable development and a willingness to implement ESD is emphasised because ESD is one of the critical areas in which progress can be made in the context of Climate Change mitigation (Rauch & Steiner, 2013). As a result, this study addresses the critical topic of the elements that influence the readiness of PSTs to understand and practise Climate Change.

2.12 Practices of Climate Change Education

Climate Change is a vital and time-sensitive issue that necessitates prompt and decisive measures. Moreover, despite the recognition of the issue by various stakeholders including consumers, governments, and businesses, there has been a persistent upward trend in global carbon emissions over the last decades (Le Quéré et al., 2018; Liu et al., 2024). Since 1990, Europe has placed considerable emphasis on mitigating production-based emissions, although there has been a lack of substantial progress in reducing consumption-based emissions within the region (Schulze et al., 2019). Multiple scholarly investigations suggest the existence of a phenomenon commonly referred to as the 'blame-game' wherein individuals exhibit a tendency to shift accountability to other parties. Tolppanen and Kärkkäinen (2021) indicate the presence of intergroup attribution bias among individuals wherein they tend to perceive their own social group as being less accountable for Climate Change than an external group. According to Chang et al. (2017) and Lorenzoni and Pidgeon (2006), there is the perception among individuals that the government bears greater responsibility than individuals. Additionally, Feucht and Zander (2018) argue that there is a growing demand for increased accountability from the business sector.

Relatedly, policymakers perceive Climate Change mitigation as a challenging endeavour, given that the introduction of novel policies may encounter obstacles posed by the entrenched interests of industries and other governmental entities (Jordan & Matt, 2014). Businesses may assign responsibility to external parties because of their perception that consumers lack

sufficient awareness of environmentally friendly products and are unwilling to pay a premium for them (Tolppanen & Kärkkäinen, 2021). It has been argued that businesses may have the perspective that governments ought to provide increased subsidies in order to facilitate and promote environmentally sustainable industrial practices (Tolppanen & Kärkkäinen, 2021). While it is acknowledged that there may be elements of truth in the aforementioned perspectives, it is important to note that they often exhibit bias and evade accountability.

Chapter 2 has provided a detailed review of the literature surrounding various aspects of Climate Change and Climate Change Education. Key themes explored include evidence of Climate Change, global responses, adaptations and mitigations, Climate Change Education, sustainable development goals, and the critical role of teacher professional development. Education, especially Climate Change Education, is crucial for promoting sustainable development goals. Climate Change education for future generations is crucial. The literature portrays a need for a strong pedagogical approach that empowers pre-service teachers with the knowledge, skills, and attitudes necessary to effectively teach climate change topics.

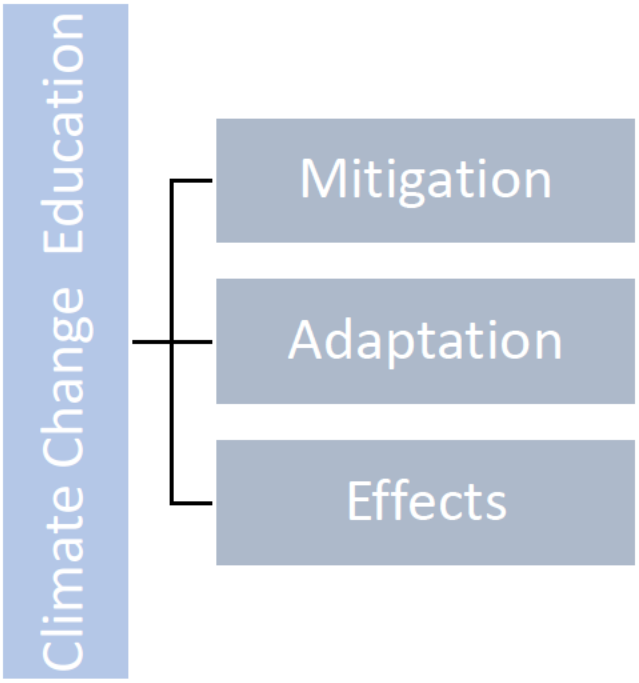
Development of an environmentally aware and scientifically knowledgeable population is dependent upon this. It is also important for future teachers to understand and teach about Climate Change, which shows the need for continuous professional development programmes. For effective Climate Change Education, these programmes should improve teachers' conceptual knowledge.

CONCEPTUAL FRAMEWORK

Climate Change Education is a combination of various knowledges. In order to understand CCE it is important for the knowledge about mitigation, adaptation, and effects to be explored (Stevenson et al., 2017) (see Figure 2.1).

Figure 2.2

Conceptual Framework: The Relationship Between Climate Change Education, Mitigation, Adaptation, and Effects



The conceptual framework provides a means to explore how pre-service teachers perceive the effects of climate change on the environment and society, and how these perceptions influence their understandings and practices to teach about climate change. By exploring their comprehension of mitigation, the framework allows for the assessment of the level of understanding that the pre-service science teachers' have. Furthermore, the practices that are undertaken for mitigation purposes may be revealed, including those that are used. In adaptation the meaning of how this is understood may be unpacked and in doing this the links to practices carried out, may be made. Since Climate Change is an abstract concept for many people, authentic evidence of it, as revealed by the effects provides further knowledge re understandings and possible practices, which may be undertaken.

Overall, the conceptual framework could be used to identify gaps in understanding and

practice, thereby, providing an in-depth analysis of pre-service science teachers' knowledge abouth the climate change topic.

In conclusion, chapter 2 provided literature on the features of climate change and the crucial role that education plays in addressing this worldwide issue. The following chapter will address the research design and methodology.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter outlines the research methodology used in this study, focusing on pre-service science teachers' understandings and practices related to climate change. This study was conducted in a specific educational setting with an intervention designed to engage participants with climate change education. The research objectives and questions are aligned with the interpretivist paradigm, which emphasizes understanding the personal experiences of participants. This paradigm, combined with a qualitative research approach, allows for a nuanced exploration of the complex perspectives of pre-service teachers. Through methods and instruements such as questionannaires and interviews, detailed insights into the pre- service science teachers' interactions with climate change topics may be obtained.

Further to this, a case study methodology was adopted. The most common definition of a case study is by Yin (2009, p. 18) who states that a case study:

> … investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.

The use of an exploratory case study in this research is essential for thoroughly investigating the nuanced understandings and practices of pre-service science teachers regarding climate change. This approach allows for an in-depth exploration of a complex and relatively unexplored area, which uncovers specific gaps in knowledge and educational practices that might not be evident through other methods (Swedberg, 2020). By focusing on a specific group within a particular educational context, the study can provide diverse contextual insights into how factors such as curriculum, teacher training, and personal beliefs influence teaching strategies related to climate change. Additionally, the findings from this case study can serve as a foundation for further research, identifying key variables and areas that warrant more detailed investigation in the future (Swedberg, 2020). This makes the exploratory case study approach particularly relevant and effective for addressing the aims of this research.

The chapter also discusses the sampling methods, data collection techniques, and research rigour to ensure the study's validity and reliability. The chapter emphasizes trustworthiness, dependability, and transferability to strengthen the study. The research design is comprehensively reviewed in Chapter 3, which establishes the foundation for the analysis and findings that will be presented in the subsequent chapters.

3.2 Location and Intervention of the Study

The university chosen for the study is well resourced and is located in the Pinetown area of KwaZulu-Natal. Pre-service science teachers enrolled for a science education module in the School of Education were in their final scientific majors and are currently pursuing their career path in science teacher education. Because of the scarcity of schools that accommodate PSTs, this study focused exclusively on PSTs at the University of KwaZulu-Natal.

This study's intervention, "Biological Science for Educators", had the aim of developing appropriate knowledge, theories, skills, attitudes and values with regard to the environment in students who wished to specialise in Biological Science Education. The module covers a range of topics, including Environmental Education, Biodiversity, Ecosystem Ecology, Southern African Biomes, detailed Energy Flow, Environmental Issues on both global and local scales (such as human impact on Climate Change, water issues, food security, and biodiversity loss), Biogeochemical Cycles, Population Ecology and Population Dynamics, Community Ecology (encompassing interactions in the environment and ecological succession), and Behavioural Ecology (including social organisation in animals). Through three fieldwork/practical sessions at Edgewood Campus and a three-day fieldwork at Twinstreams, which offers practical experience and direct interaction with environmental studies, practical learning is promoted. The module is assessed equally on coursework (50%) and an exam (50%). Coursework also consists of tests, reports from campus fieldwork, worksheets and associated reports from Twinstreams fieldwork, research projects, presentations, and understanding of biogeochemical cycles. The module makes use of theoretical and practical skills to help develop teachers' understandings and practices.

3.3 Research Objectives

The objectives of this study were

1. To explore pre-service science teachers' understandings of Climate Change before completing a Biological Science for Educators module.
2. To explore pre-service science teachers' practices of Climate Change before completing a Biological Science for Educators module.
3. To explore pre-service science teachers' understandings of Climate Change after completing a Biological Science for Educators module.
4. To explore pre-service science teachers' practices of Climate Change after completing a Biological Science for Educators module.

3.4 Research Questions

1. What are pre-service science teachers' understandings of Climate Change before completing a Biological Science for Educators module?
2. What are pre-service science teachers' practices in relation to Climate Change before completing a Biological Science for Educators module?
3. What are pre-service science teachers' understandings of Climate Change after completing a Biological Science for Educators module?
4. What are pre-service science teacher's practices of Climate Change after completing a Biological Science for Educators module?

3.5 Paradigm

A paradigm influences researchers' thinking and is "a way of perceiving the world that frames a study topic" (Hughes, 2020, p. 35). Educational research uses three distinct approaches: positivism, critical theory and interpretivism. Positivism is a philosophical stance embraced by natural scientists who examine the observable aspects of reality in society and formulate generalisations based on their observations. Furthermore, positivism places great importance on accurate data, while striving to exclude any influence from subjective interpretation or human prejudice (Alharahsheh & Pius, 2020). The purpose of the critical theory paradigm is not limited to explaining or comprehending society but to transforming it (Patton, 2002). Critical theorists take an ontological perspective that is consistent with historical realism, which has the belief that reality as we know it is produced intersubjectively through socially and

experientially established meanings and understandings (Aliyu et al., 2015). Although a reality exists, it has been shaped by cultural, political, ethnic, gendered, and religious forces that interact to form a social system. Critical theory is subjective epistemologically in that it assumes that no object can be investigated without affecting the researcher.

Interpretivism was used for this study because it allows for multiple perspectives and understandings. According to Thanh and Thanh (2015), interpretivism generally aims at understanding a specific context, and the fundamental belief of the interpretive paradigm is that reality is socially constructed. Since it acknowledges the validity of multiple perspectives held by a variety of individuals and groups, interpretivism is a method that is more open-minded. Interpretivism acknowledges that the validity of multiple viewpoints typically results in a deeper and more comprehensive comprehension of a given scenario (Thanh & Thanh, 2015). Rather than being discovered, truth and reality are constructed; in the current study, these were constructed through a questionnaire (see Annexure A) to understand PSTs' understandings of Climate Change. Reality cannot be entirely known since it is always mediated by our senses. Because interpretive epistemology is subjective, external reality cannot be accessed directly by observers without it being contaminated by their worldviews, concepts, and backgrounds, among other factors. As '*A companion to qualitative research'* (2004, p. 89) state, "Perception is seen not as a passive-receptive process of representation but as an active constructive process of production" in which individuals engage with one another and with society, attributing meaning and labels to various social processes.

3.6 Research Approach

Qualitative research looks at how to use and gather different kinds of real-world data that is non-numerical, for example, using case studies and personal experiences (Aspers & Corte, 2019). This research methodology is used to develop new ideas or build deep understanding of a particular matter. In this study, questionnaires provided an overview, while individual interviews and focus groups offered a more detailed analysis of the data. In this study, data was generated using a comprehensive questionnaire designed to explore pre-service science teachers' understandings and practices related to climate change. The questionnaire consisted of a combination of open-ended, closed-ended, and multiple-choice questions. The open-ended questions allowed participants to express their thoughts and experiences in their own words, providing rich qualitative data. The closed-ended questions enabled the collection of specific

information while the multiple-choice questions offered structured response options, facilitating the comparison of responses across participants. This approach ensured a well-rounded understanding of the participants' perspectives on climate change.

Qualitative research is also a form of social research that explores how individuals interpret and understand their personal experiences and surroundings. This study utilised qualitative data to analyse the behaviour of pre-service teachers (PSTs) in science and to gain insight into the motivations and emotions that influence their practices concerning Climate Change. The qualitative methodology was appropriate for this study as it provided realistic and detailed information obtained through non-quantitative data sources (Johnson & Christensen, 2014). Furthermore, this approach also shows how complicated and unpredictable human behaviour is, focusing on how different people are and what their specific needs are.

3.7 Sampling

Sampling is defined as the process of selecting a subset (called a 'sample') of a population of interest in order to draw conclusions or formulate solutions regarding the population (Taherdoost, 2016). There are two types of sampling techniques: probability or random sampling and non-probability or non-random sampling. This study applied two non-probability sampling strategies: convenience sampling and purposive sampling. These sampling methods are used to discover and choose people in order to acquire rich data with low resources (Nechval & Nechval, 2016). Convenience sampling includes participants of the target group who meet specific criteria such as simple accessibility, geographical closeness, availability at a particular time, and willingness to participate. Purposive sampling, often known as 'judgement sampling', is a type of sampling aimed at generating situations with a plethora of data for subsequent inquiry (Taherdoost, 2016). Because participants are deemed to hold the appropriate position or training or are acknowledged as possessing the required skills and competencies, they are able to supply the necessary information to the researchers. In the current study, the PSTs could provide information regarding climate education and curriculum enhancement.

The PSTs were given a questionnaire before and after completion of the module and, thereafter, ten PSTs were selected through random selection to participate in in-depth interviews. In this sampling technique, sample participants are chosen arbitrarily and entirely by chance. Because

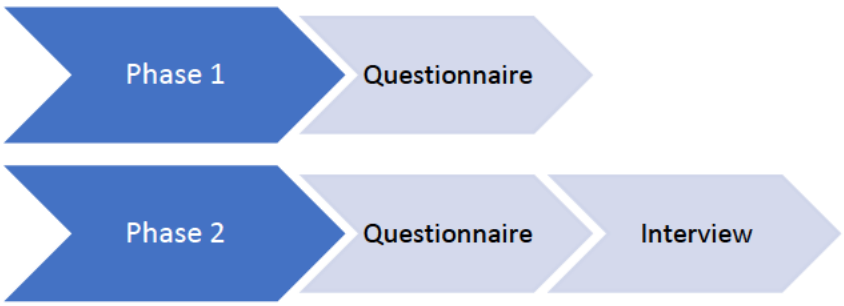
each participant has an equal probability of being selected, the sample quality is unaffected, and the accuracy of the collected data is increased. This form of sampling is ideal for relatively uniform populations (Bhardwaj, 2019). In addition, the data obtained can yield results that can be generalised to the larger population (Bhardwaj, 2019).

3.8 Data Collection / Data-Generation Methods

This study was conducted in two phases, Phase 1 and Phase 2 (see Figure 3.1). As part of Phase 1, a questionnaire (see Annexure A) was administered at the beginning and at the conclusion of the study. During these phases, the responses were examined to determine the PSTs' comprehension and implementation of Climate Change instruction. In Phase 2, the same questionnaire was re-administered to the entire class after the Climate Change section of the module had been completed. Thereafter, ten of the respondents were chosen through random selection to participate in an interview. The responses of the PSTs at the beginning and the end of the study were compared to explore if the module had an impact on the PSTs' understandings and practices of CCE.

Figure 3.1

Plan for Data Collection



The analysis of the quantitative data was carried out according to the instructions that were presented in the questionnaire. The responses of the respondents were grouped before being compared with each component. Analysing the qualitative data entailed noticing patterns, themes, categories, and regularities, in addition to arranging, accounting for, and making sense of the data in terms of the participants' understandings of the situation (Cohen et al., 2001).

A qualitative descriptive analysis technique was adopted. This involved reading the interview transcripts, selecting the portions of the interview transcripts that were the most detailed and most extensive, listing the key findings, and clustering them into themes. Thereafter, the data underwent content analysis in which a search was made for repeating notions, patterns of views, keywords, and statements (Cohen et al., 2001).

Table 3.1

Summary of Data Collection Process

Research Question	Instrument	Method	Analysis
1. What are pre-service science teachers' understandings of Climate Change before completing a Biological Science for Educators module?	Questionnaire (RQ1)	The questionnaire is presented before the topic of climate change is taught.	Analyse the content for important themes or categories
2. What are pre-service science teachers' practices in relation to Climate Change before completing a Biological Science for Educators module?	Questionnaire (RQ2)	The questionnaire is presented before climate change is taught.	Analyse the content for important themes or categories Examine the instruments and keywords to identify themes

3. What are pre-service science teachers' understandings of Climate Change after completing a Biological Science for Educators module? 4. What are pre-service science teachers' practices in relation to Climate Change after completing a Biological Science for Educators module?	All data sources (Questionnaire; Interview)	Consider the data sources for RQ1 and RQ2 Analyse the respondents' responses to determine which aspects of development would be considered beneficial Analyse the positive and negative aspects that the respondents have pointed out Determine the aspects that contribute to the PSTs' understandings of Climate Change Consider the guiding concepts and purposes underlying the respondents' answers	Analyse and compare the data from RQ1 and RQ2 from a variety of perspectives Examine the transcripts of the interviews and identify themes Focus on issues related to conflicting results, difficulties, political disunity, time, and educational constraints

3.9 Research Rigour

Validity and reliability are terms used in quantitative research, while trustworthiness is used in qualitative research. A valid study must show what exists, and a valid instrument or measure must accurately measure what it is intended to measure. There are numerous types of validity,

and numerous terms have been used to describe them. Cahit (2015) proposed two broad categories of validity that contain numerous subcategories, thus making distinctions between 'internal' and 'external' validity. Internal validity is a term that indicates the level to which research findings are an accurate reflection or representation of reality, instead of to the level resulting from unrelated variables (Slack & Draugalis J. R., 2001; Streefkerk, 2019, May 15). This study ensured internal validity through the random selection of the interview participants. Moreover, a specific protocol was followed to ensure that all respondents received the same questionnaires and attended the same module. External validity is concerned with the degree to which such representations or reflections of reality can be adopted between groupings (Findley et al., 2021; Lucas, 2003; Streefkerk, 2019, May 15). The external validity of the current study was achieved by ensuring that the data reflected the degree of resemblance between distinct groups of individuals, mitigation strategies, adaptation techniques, and the effects that were faced. Additionally, external validity was also achieved by studying the diverse situations in which these variables originated through random sampling.

Trustworthiness ensures rigour while maintaining the study's relevance to the qualitative research (Lincoln & Guba, 1985). The terms 'dependability', 'credibility', 'confirmability', and 'transferability' of qualitative research are the four pillars on which the trustworthiness of this type of study is built (Ponelis, 2015). In the current study, the findings were shown to be trustworthy through employing in-depth questionnaires, close engagement content analysis, and interviews, which confirmed that the findings reflected the participants' understandings and practices. The credibility of the study was also ensured by the questionnaire that was presented before and after the module. In this study, the respondents and participants remained anonymous, and the questionnaire was repeated to ensure consistency, stability, and repeatability. Ensuring that the reported findings represented the data that was obtained from the participants guaranteed dependability. This was demonstrated with the assistance of a recording, documentation, and transcripts. Moreover, a different researcher analysed the data further, and the results were compared to determine whether or not they were consistent. Furthermore, participants were given an informed consent form (Annexure B) that contained information about the study, thus providing the participants with content to understand the implications of partaking in the study and make an informed decision. Additionally, participants were free to withdraw at any time if they felt uncomfortable, and all information was kept strictly confidential.

The research design and methodology used in this study have been described in this chapter. The chosen research design, which is qualitative, is based on the nature of the research questions and the objectives of the study. The chapter also described the specific methodologies employed, such as questionnaires and interviews, and provided an explanation of the rationale behind their selection. Additionally, it provided the data collection procedures, sampling techniques and instruments that were used to collect relevant data. By adopting purposive sampling, this study ensured an accurate and reliable sample, which contributes to its reliability and validity of the findings. Furthermore, the chapter addressed the ethical considerations taken into account to protect the rights and well-being of the participants. These included obtaining informed consent, ensuring confidentiality, and maintaining transparency throughout the research process.

Overall, the research design and methodology presented in this chapter provide an effective framework for answering the research questions and achieving the study's objectives. The subsequent chapters will present the data and analysis of the study, followed by a discussion of the findings in relation to the existing literature.

CHAPTER 4

DATA AND ANALYSIS

4.1 Introduction

Chapter 4 reveals the findings and analysis of the data from this study, exploring how a biology for educators' module influenced 40 pre-service science teachers' understandings and practices regarding Climate Change. Through the administration of questionnaires (Appendix A) before and after the module, as well as interviews done after the module, insights were gathered into the participants' understandings and practices with regard to Climate Change. The "Biological Science for Educators" module which served as the intervention provided pre-service science teachers' who wanted to specialize in Biological Science Education with environmental knowledge, theories, abilities, attitudes, and values. Environmental Education, Biodiversity, Ecosystem Ecology, Southern African Biomes, detailed Energy Flow, Global and Local Environmental Issues (such as human impact on Climate Change, water issues, food security, and biodiversity loss), Biogeochemical Cycles, Population Ecology and Population Dynamics, Community Ecology, and Behavioural Ecology are covered in the module. Practical learning is fostered through three Edgewood Campus fieldwork/practical sessions and a three-day Twinstreams fieldwork that provides environmental studies experience. Coursework includes tests, campus fieldwork reports, Twinstreams worksheets and reports, research projects, presentations, and biogeochemical cycle knowledge. Both theoretical and practical abilities are used to assist teachers learn and practice.The participants' choices, understandings and practices of Climate Change are presented in this chapter.

The research was guided by the following questions and responded to in this chapter:

1. What are pre-service science teachers' understandings of Climate Change before completing a Biological Science for Educators module?
2. What are pre-service science teachers' practices in relation to Climate Change before completing a Biological Science for Educators module?
3. What are pre-service science teachers' understandings of Climate Change after completing a Biological Science for Educators module?
4. What are pre-service science teachers' practices in relation to Climate Change after completing a Biological Science for Educators module?

Forty five (45) questionnaires were distributed and 40 were responded to. Five questionnaires were excluded - two non-responses and three cases with substantial missing data.

The data collected from the questionnaire was analysed looking at the highest frequency of occurrence (i.e., the number of times a specific response occurs) was calculated by adding the responses of the subjects to each individual question. The quantified responses to the questions are subsequently presented as percentages. The analysis is displayed in a tabular format below (Tables 4.1 to 4.16). The data analysis in this chapter is deeply anchored in the conceptual framework outlined earlier in the study, which serves as a guiding structure for interpreting the findings related to pre-service science teachers' understandings and practices concerning climate change. The framework, which is based on major concepts of climate change, provides a lens through which the data concerning the PSTs, their understandings and practices, is explored ensuring that the analysis remains focused on the study's core objectives.

Questions 1 to 10 as well as 12 examined pre-service science teachers' understandings of Climate Change. This included participants explaining their understandings as well as knowledge. This study depicted the comprehension of Climate Change among pre-service science teachers based on their personal experiences and knowledge. The quantitative questions are summarised in the tables below. While some tables contain a maximum of 40 responses, others depend on the responses given by participants in the preceding question. For instance, participants who responded negatively to a specific question may be exempted from answering the subsequent question. This resulted in varying total numbers of responses for each individual question.

Participants were asked to choose three environmental issues from a list of six options in the questionnaire (pollution, flooding, poor waste management, Climate Change, traffic, overpopulation) that they experienced most. Two participants made only two choices.

Table 4.1

Environmental Concerns Experienced by Participants Before Completing a Biology for Educators' Module

Combination of major environmental concerns	Number of Participants
Pollution, poor waste management, and Climate Change	3
Pollution, traffic, and overpopulation	1
Pollution, flooding, and Climate Change	11
Pollution, flooding, and traffic	3
Flooding, traffic, and Climate Change	3
Flooding, traffic, and overpopulation	1
Pollution, flooding, and overpopulation	3
Pollution, poor waste management, and traffic	1
Pollution, flooding, and poor waste management	5
Pollution, poor waste management, and overpopulation	1
Pollution, traffic, and Climate Change	2
Flooding, Climate Change , and overpopulation	4
Pollution and flooding	2

The majority of participants (32 participants) identified pollution as one of the major environmental concerns. Additionally, Climate Change often co-occurred with pollution, especially when accompanied by flooding. Other concerns such as traffic (seven participants) and poor waste management (ten participants) were observed with a considerably lower frequency when compared to occurrences of pollution and flooding. The issue of overpopulation was also identified less frequently (ten participants). These findings indicate that pollution is the primary environmental concern, followed closely by Climate Change and flooding.

Participants were then asked if they had experienced drastic environmental conditions in the past ten years.

Table 4.2

Did Participants Experience Drastic Environmental Conditions in the Past Ten Years

Responses	Number of participants
Yes	32
No	3
I don't know	5

The responses indicated that the most drastic environmental issues experienced are flooding and drought. Floods were considerably more prevalent due to personal experiences, with 23 respondents reporting flooding, compared to only four mentioning drought. Additionally, five participants reported extreme weather conditions, including excessive heat or cold, heavy rainfall, and strong winds. Individuals affected by floods reported property damage, including houses, gardens, and crops, resulting in adverse effects on food security, housing stability, and overall well-being. In addition to this, six responses emphasised the connection of floods with infrastructure difficulties, sanitation issues, and contaminated water sources. Although occurring less frequently, droughts also present dangers by impacting water availability for consumption, sanitation, and agriculture. Respondents reported lower agricultural productivity and the risk of food scarcity due to drought, with one participant also noting the effects of temperature fluctuations. In addition to these six primary categories that were chosen earlier in table 4.1, other responses indicated incidents involving storms and lightning resulting in destruction, concerns about water pollution, and challenging climatic conditions characterised by extreme temperature variations and limited water availability.

Table 4.3

Participants Felt a Change in Weather Patterns Before Completing the Biology for Educators' Module

Responses	Number of participants
Yes	38
No	1
I don't know	1

Regarding whether participants felt a general change in weather patterns, the responses from the first questionnaire showed a high degree of agreement. Most participants associated these changes with Climate Change or global warming, which suggests a link between the two concepts by participants. Moreover, participants (62%) acknowledged that anthropogenic activities such as deforestation, pollution, and the combustion of fossil fuels contributed to a change in weather patterns with no greater detail. Participants (23%) also mentioned that they had personal encounters with severe weather phenomena, including heatwaves, floods, and droughts.

Different human activities were specified, for example, deforestation and air pollution. Different participants supported their observations with a range of personal experiences, with some mentioning specific weather events and others making collective examples that were discussed, seen or heard of.

Participants were also questioned about why the general weather pattern was changing, and it was noted that 20 of the participants attributed it to human activities. Burning of fossil fuels, industrial emissions, and car emissions were mentioned by participants as being responsible for emitting harmful gases such as carbon dioxide as well as causing deforestation. Thirteen participants connected these changes to global warming or Climate Change, attributing them to factors such as pollution, the combustion of fossil fuels, and the release of greenhouse gases. There was also a common response that indicates that human activities, such as deforestation and industrial processes, are primarily responsible for Climate Change and the resulting changes in weather patterns. Participants provided personal experiences, such as changes in temperature and precipitation, to contribute to their points of view. A comparison was also

made regarding the changes in weather patterns compared to those experienced by previous generations.

Further to this, participants were asked if they had heard of the term ‘Climate Change’ before and what they understood about it.

Table 4.4

How Many Participants Heard of Climate Change Before Completing the Biology for Educators’ Module

Responses	Number of participants
Yes	40
No	0
I don’t know	0

Pre-service science teachers' knowledge of Climate Change showed a range of understandings. 92% recognised human activities as contributors, with 64% specifically mentioning practices such as burning fossil fuels by businesses and deforestation. 46% recognized shifts in weather patterns, but only 23% directly associated this with global warming or the greenhouse effect and none mentioned natural causes.

Participants were then asked where they heard of Climate Change and were given the following options to choose from:

Table 4.5

Where Participants Heard of Climate Change Before Completing the Biology for Educators' Module

Source of knowledge	Number of participants
University, TV, Internet, Other	2
University, TV, YouTube, Other	1
University, Radio	1
Internet, Other	1
TV, Radio, Internet	1
TV, Other	1
University, TV, Radio, Internet, YouTube, Other	1
University, TV, Internet, YouTube, Other	1
Other	7
No response	2
University, TV, Radio, Internet, YouTube	5
University, TV, Radio, Internet	3
Radio	3
University, TV, Internet	1
University, TV, Radio, Internet, YouTube, WhatsApp, Other	1
University, Radio, Internet	1
University, TV, Other	1
University, TV, Internet, YouTube	2
Internet	1
University, Internet, Other	4

Fourteen participants heard of Climate Change from their secondary school education with five saying specifically in geography, while one participant mentioned being introduced to the topic during primary school and two participants mentioned general schooling. One respondent mentioned the church as a source of information on Climate Change. Emerging social media platforms, such as TikTok, were highlighted by one participant. One participant chose the 'other' option from the list without specifying a source.

Pre-service science teachers in this study (n=40) acquire information on Climate Change beyond traditional classroom learning. Universities, the internet, and television serve as their primary sources, followed by radio, YouTube, and educational institutions. Notably, newer platforms like TikTok and WhatsApp are emerging as potential information sources too, although their influence was less pronounced in this sample. These diverse media platforms show the importance of knowledge access, as evidenced by Participant AA's statement: "Knowledge is power. Knowing about Climate Change would change many doings."

When asked what they thought were the causes of Climate Change, participants revealed a dominant theme: human activity as the primary driver. Participants attributed Climate Change to anthropogenic factors, for example, activities such as the combustion of fossil fuels ("coal for electricity", Participant II), which release greenhouse gases like CO_2 ("greenhouse gases like CO_2", Participant C). Deforestation, was also mentioned by participants like Participant H, who viewed it as another detrimental human action that increases the carbon dioxide in the atmosphere. The increased presence of cars and their associated emissions were mentioned in responses like Participant FF's, while Participant EE specifically mentioned "industries" as major contributors to atmospheric carbon loading. Even indirect drivers like population growth were acknowledged, with Participant KK suggesting its potential to elevate global temperatures but not how it does so. Although the depth of understanding regarding specific mechanisms varied, with some participants delving into the greenhouse effect (Participant AA) and others focusing on broader concepts like pollution (Participant O), the consensus remained: human actions are actively altering the Earth's climate. This understanding often prompted expressions of concern for the associated consequences, with participants mentioning global warming (Participant G), extreme weather events (Participant V), and ecosystem degradation (Participant U).

When asked about the impacts of Climate Change in the next five years, participants discussed extreme weather events such as intensified floods, droughts, and heatwaves. Participants such as J and BB expressed concerns about the destruction of infastructure and communities in potential flooding scenarios. Participants like D and KK expressed concerns about the economic impact and depletion of essential resources due to droughts; however, they did not mention what essential resources. Heatwaves were also discussed by participants K and X, who anticipated increased temperatures and associated health hazards. Participants were also aware of biodiversity loss as an issue, emphasising the impact of "species extinction" and the

degradation of habitats that are crucial for the sustainability of the environment, in addition to climatic concerns. Furthermore, Participants P and S voiced concerns about potential consequences such as dry fields and famine, emphasising the growing risk of food insecurity. Moreover, certain participants expressed worries about particular outcomes, such as "increasing sea levels" and "changes in weather patterns", indicating the wider systemic effects of Climate Change.

Table 4.6

Did Climate Change Affect Participants Before Completing the Biology for Educators' Module?

Responses	Number of participants
Yes	35
No	3
I don't know	2

When questioned about the impact of Climate Change on them personally, the most common themes (20 out of 35 respondents) were about experiencing or expecting extreme weather events, including increased temperatures, flooding, and changes in precipitation patterns. Participants A, H, and W described first hand encounters with increased heat, while participants O, AA, and EE expressed concerns about the negative effects of floods on buildings and infrastructure. Furthermore, participants such as I, V, and HH observed deviations in conventional weather patterns, suggesting Climate Change. Additionally, seven out of 35 respondents linked Climate Change to health issues such as heat-related illnesses and skin problems caused by increased UV exposure, as reported by participants M, T, K, and LL, among others.

While the main emphasis was on weather extremes, participants also showed an understanding about food security, economic consequences, and the possibility of losing family members. Participants D, L, and F expressed concerns about food scarcity, while participants O and BB discussed possible economic consequences. Participants BB and GG expressed concerns about losing loved ones due to severe weather events, showing a variety of worries among respondents.

However, two participants were unsure about how Climate Change would affect them personally, while three denied experiencing any impacts.

Table 4.7

According to Participants, Did They Think Climate Change Could be Addressed Before Completing the Biology for Educator's Module

Responses	Number of participants
Yes	35
I don't know	2
No	0
No response	3

Participant feedback on addressing Climate Change showed a common belief in human accountability and capability. The majority (28/37) agreed that humans are responsible for Climate Change and have the ability to address it. Participants such as Participant B, who emphasised "save this land for the next generation", and Participant Y urged for us to "change our ways".

Education and awareness have been identified as possible solutions, as noted by a large number of participants (18 out of 37). This involves informing individuals about the impact they have on the environment and the effects of Climate Change. Furthermore, 12 out of 37 responses emphasised the importance of both individual and collective action. This involves implementing sustainable practices such as reducing pollution and participating in wider initiatives, as suggested by Participant II.

Although the main emphasis was on education and awareness, a few participants suggested particular actions.

Participants noted the importance of reducing greenhouse gas emissions by limiting activities that produce high levels of carbon dioxide. Additionally, sustainable practices were discussed by participants such as Participant A, who suggested conserving electricity, and Participant J, who suggested reducing the use of items that emit harmful gases.

Participants like Participant Q ("strategies to manage the damages") and Participant R ("focus on indigenous knowledge") went further and explained that exploring policy changes and alternative approaches are needed. Whereas a small number of participants were uncertain (2/40) or did not provide a response (3/40), most showed confidence in the potential to address Climate Change through shared responsibility, education, and both individual and collective actions.

Table 4.8

Who Participants Think Should be Responsible for Addressing Climate Change Before Completing the Biology for Educators Module

Responsbility to address Climate Change	Number of participants
International government, national government, local government, businesses	1
International government, national government, local government businesses, individuals	5
local government businesses, individuals	2
Individuals	10
National government, local government	1
International government, businesses, individuals	3
Others	3
International government	1
International government, businesses, individuals, other	1
International government, national government, local government businesses, individuals, other	2
Businesses	1
National government, businesses, individuals	1
International government, national government, local government, individuals	2
National government, local government businesses, individuals	1
International government, local government businesses, individuals	1

The participants were asked about who should take responsibility for addressing Climate

Change. A total of five participants left this unanswered while most selected (28 out of 35) was that all individuals have a role to play in addressing Climate Change. Participants such as Participant C and Participant EE agreed on the concept of shared responsibility.

When asked why, ten out of 35 participants suggesed education for addressing Climate Change. This involves providing education on Climate Change to individuals and businesses. While many recognised a shared responsibility, some mentioned particular groups such as Participant B ("UN and national government") and Participant Z ("national government can implement laws") who considered governments to be essential factors. Participants such as Participant J and Participant W highlighted the importance of individual responsibility. Participant Q emphasised the detrimental impact on the climate; further to this Participant HH focused on the responsibility of industries and businesses for causing climate problems. Participants also suggested that the local governments and individuals engage in community action. There was also an awareness of how responsibility is linked. They believed that responsibility should be distributed among individuals, governments, and businesses, as exemplified by Participant A's statement: "all of the above".

Five participants (NN, E, I, N, DD) did not provide reasons for their selections. Three participants selected "other" and articulated their perspectives on the distribution of responsibility among different entities, including schools, teachers, and individuals. There is also a belief that addressing Climate Change is a communal challenge that demands shared accountability from individuals, governments, and businesses.

Table 4.9

How Many Participants Took Action to Address Climate Change Before Completing the Biology for Educators' Module

Response	Number of participants
Yes	19
No	16
I don't know	5

Nineteen participants (47.5%) took action, 16 (40%) did not, and 5 (12.5%) were unsure. The majority of reported actions (13 out of 19) centred on individual decisions, such as using public

transportation (F, BB), refraining from littering (II, MM), and minimising waste (W, Z). Four out of nineteen participants discussed community-based actions, such as recycling programmes and clean-up initiatives. This shows an increasing recognition of the combined influence of community endeavours. Two out of nineteen participants associated their actions with gaining knowledge about Climate Change. Some participants discussed waste reduction through recycling and avoiding unnecessary items. Utilising public transportation and refraining from burning were also suggested as methods to decrease resource consumption. Reported actions mainly centred on personal decisions and community efforts. Participant B's statement "avoid using my mother's car" exemplifies a transition towards more environmentally friendly modes of transportation. Participant CC showcased community engagement in addressing Climate Change by promoting a clean environment in the school and community. Participant O illustrated the power of education in motivating individuals to take action, as they are learning about EDBS 330 and implementing it.

After the module, particpants were given the same questionnaire to identify any changes in their understandings and practices in relation to Climate Change .

Table 4.10

Environmental Issues Experienced by Participants After Completing a Biology for Educators' Module

Combination of major environmental concerns	Number of participants
Pollution, flooding, Climate Change	15
Pollution, flooding, traffic	5
Pollution, flooding, poor waste management	6
Flooding, traffic, Climate Change	2
Pollution, flooding, overpopulation	2
Flooding, poor waste management, Climate Change	3
Pollution, poor waste management, overpopulation	1
Pollution, Climate Change , overpopulation	4
Pollution, traffic, Climate Change	1
Pollution, traffic, overpopulation	1

When participants were asked to identify three environmental issues experienced after completing the Biology for Educators module, "pollution" was most frequently selected (35 participants). The term ‘flooding’ was chosen by a total of 33 participants, which accounts for 82.5% of the combined participants. The term ‘Climate Change’ was selected by 25 participants, representing 62.5% of the total.

Based on the data, it can be inferred that pollution, flooding, and Climate Change are the primary environmental concerns among the participants in this study. The frequent occurrence of ‘pollution’ choices emphasises its widespread presence in their encounters. Likewise, the prevalence of ‘flooding’ shows a collective worry about this particular environmental problem.

Less frequently, the options of "poor waste management", "traffic" and "overpopulation" were selected. Nevertheless, the fact that they are present indicates that they are still major concerns for certain participants.

Table 4.11

How Many Participants Heard of Climate Change After Completing the Biology for Educator’s Module?

Responses	Number of participants
Yes	36
No	0
I don’t know	0
No response	4

Participants' responses regarding what they know about Climate Change after completing the Biological Science for Educators module revealed distinct patterns, similarities, and variations.

There is an agreement among participants that Climate Change involves changes of weather patterns over a period of time. For instance, Participant A supported this, stating, "I know that Climate Change is the gradual change in the weather patterns over time." Participant D agreed, stating that the change in weather patterns is caused by various factors such as pollution and global warming.

Furthermore, there is acknowledgment of human activities as major contributors to Climate Change, specifically the release of greenhouse gases. Participant G asserted that Climate Change is caused by greenhouse gases. Similarly, Participant DD added, "Climate Change is primarily caused by human activities like the burning of fossil fuels, deforestation, and the release of greenhouse gases into the atmosphere."

Additionally, a number of participants were aware of the detrimental effects of Climate Change, including severe weather phenomena and increased temperatures. Participant E expressed the view that Climate Change refers to the phenomenon of a gradual and sustained rise in atmospheric temperature over an extended period of time. Participant S also expressed this apprehension, stating, "The emissions of greenhouse gases, such as carbon dioxide, have a detrimental impact on the Ozone layer." These factors contribute to extreme environmental conditions such as elevated temperatures, heavy precipitation, flooding, and sea level rise.

Participant LL provided an explanation, stating that Climate Change refers to the change of temperature and unusual weather patterns over an extended period of time. In agreement, Participant H stated that Climate Change refers to alterations in weather patterns and temperature over a specific duration.

Furthermore, there were instances where participants expressed fear or concern regarding Climate Change , while others showed a sense of urgency in addressing it. Participant A mentioned, "I am terrified of it." Similarly, Participant LL voiced concern, stating, "I am concerned about Climate Change and its impact on the planet and its inhabitants." Conversely, Participant A exhibited a proactive stance, suggesting, "Since we are the perpetrators and the root cause of Climate Change, I think we also can fix our mess before it’s too late."

Overall, while there are differences in the level and specificity among participants' responses, a common response emerges regarding the understanding of Climate Change as a long-term alteration in weather patterns, driven primarily by human activities and with consequences for both the environment and human society.

Table 4.12

Where Participants Heard of Climate Change After Completing the Biology for Educators' Module

Source of knowledge	Number of participants
Internet	4
University, Internet, YouTube	1
University, tv, Internet, YouTube	4
Other	2
No response	2
University, tv, Internet	3
TV	2
University, tv, radio, Internet, WhatsApp	1
University, Internet, YouTube	1
University, Internet	2
Tv, other	1
Tv, radio	1
University, YouTube	2
University, other	2
University, tv, radio, Internet	2
University, Internet, other	1
University, radio, Internet, YouTube, WhatsApp	1
Tv, Internet, YouTube, WhatsApp	1
Radio	1
Tv, radio, Internet	1
University, tv, radio	1
University, tv, Internet	1
Tv, YouTube	1
University, tv, radio, Internet, YouTube, other	1
University, radio, Internet, YouTube	1

The group of 40 participants were surveyed once more to determine their sources of information regarding Climate Change. A multitude of participants acquired knowledge about Climate Change from multiple sources, indicating the widespread nature of the subject across

diverse platforms. While 60% of respondents continued to mention universities as a prominent source, emphasising the crucial role of higher education in spreading knowledge about climate science, traditional media outlets, such as television and radio, continue to have a great impact on increasing public awareness. The ubiquity of the internet is apparent, as indicated by 25 participants who cited it as a source, with some specifically mentioning YouTube (12) as their preferred platform. The impact of social media seems to be less in this dataset, with only two mentions through WhatsApp. However, it could still have a role in disseminating Climate Change information within social networks. Schools were prominently identified as a provider of Climate Change Education, with five mentions. Additionally, a religious institution and other miscellaneous sources were mentioned once each.

This data suggests that learning about Climate Change occurs through diverse channels. Although formal education is important, both traditional and digital media play a significant role.

After completing the biology module participants were asked again what they thought causes Climate Change . Eight participants did not respond; the remaining data (n=32) revealed that the majority (27/32) of participants recognise human activities as the primary cause behind Climate Change . Participants mentioned specific actions such as the combustion of fossil fuels, which results in the emission of greenhouse gases (Participant A). They also mentioned deforestation again as a contributing factor to Climate Change (Participant N). Additionally, the release of greenhouse gases into the atmosphere through human activities, such as the burning of fossil fuels, was emphasised (Participant I). This shows the effectiveness of the biology module in emphasising human impact on the environment.

Many participants (19/32) grasped the critical role of greenhouse gases, particularly carbon dioxide, in retaining heat and contributing to global warming (participants G, U, DD, EE). Participant U represents this understanding: "Greenhouse gases...the main driver of Climate Change is the greenhouse effect...These gases trap the sun's heat and stopping it from leaking back into space and causing global warming."

Several participants (D, J, X, AA) discussed the depletion of the ozone layer, attributing it to human activities and Climate Change .

Participants also explained Climate Change as atmospheric changes; a portion (23/32) explained Climate Change from this perspective. Participants described how human activities alter the atmosphere, leading to global warming and impacting weather patterns. Participant S drew correlations between deforestation and the rise in carbon footprints, vehicle emissions, and air pollution, all of which contribute to Climate Change .While Participant I provided brief descriptions, participant LL offered more extensive explanations that included a range of human activities and their respective contributions.

The data suggests that the biology module successfully instilled in a majority of participants the concept of human activities as the primary driver of Climate Change, particularly through greenhouse gas emissions.

When asked about the potential effects of Climate Change in the next five years after completing the Biology for Educators module, seven participants did not respond to this question (n=33), while the primary focus of concern, as expressed by 20 out of 33 participants, focused on an increase of severe weather phenomena. Participants like Participant Q anticipated a worsening situation, fearing "floods...earthquakes...these will be even more severe" in the coming years. Similarly, concerns regarding the increasing sea levels and their impacts on coastal communities were widespread (13/33). Participant N, for instance, noted the risk of "flooding in coastal areas...sea salt contaminating the soil...crops not being able to grow."

The potential influence on ecosystems and biodiversity was also noted (12/33). Participants acknowledged the risks associated with Climate Change, with Participant KK expressing concerns about the potential harm to ecosystems and the increased endangerment of species. Moreover, the possibility of adverse effects on human health has attracted attention (11/33). Participant M expressed apprehensions regarding the heightened probability of "intense storms and extreme temperatures...respiratory ailments" due to Climate Change.

A consistency among the responses (27 out of 33) was the emphasis on the effects that directly impact human beings. The concerns encompassed worries regarding severe weather phenomena, the stability of food supplies, and matters pertaining to public health. Nevertheless, the level of comprehension and the precision of predicted outcomes differed. Participant BB,

for example, outlined a chain reaction, including an "increase in extreme weather events...water scarcity...decline in food production." Certain participants discussed repercussions, such as the depletion of natural habitats (Participant H) or the destruction of infrastructure (Participant O).

Based on the data, it can be inferred that the biology module had an influence on participants' comprehension of the possible outcomes of Climate Change in the next five years. A wide range of participants identified various potential consequences, primarily centred on severe weather events, increasing sea levels, risks to ecosystems and human well-being, and the security of food supply.

Table 4.13

Will or Does Climate Change Affect Participants?

Response	Number of participants
Yes	29
No	1
I don't know	3
No response	7

Following the Biology for Educators module, participants were once again queried about the impact of Climate Change on them. Participants C, D, I, N, P, and Y frequently mentioned direct encounters with extreme weather events. Participant P said, "During the floodings...roads were destroyed...children could not go to school." In addition, a number of participants expressed concerns regarding health complications that may arise due to heat or air pollution. These participants included C, E, M, N, T, and V. Participant N described the situation: "My grandmother deals with health problems related to the heat...rising temperatures can also lead to food shortages." Participants N, O, and P expressed concern about the disruptions to livelihoods caused by Climate Change. Participant O also raised awareness of the economic ramifications, stating that Climate Change is adversely affecting the agricultural sector, leading to a rise in food prices. Participants reported instances such as property destruction caused by floods (Participants D, P), health problems exacerbated by extreme heat (Participants C, M, N), and concerns regarding food security (Participants L, N, O).

There were also similarities in responses with regard to health issues. A number of participants (8/29) voiced concerns regarding the adverse health effects linked to Climate Change , such as heatstroke, respiratory ailments, and skin conditions (Participants C, E, M, N, T, V). Participant T verbalised a specific concern: "I might experience my respiratory illness (asthma) in severity if the air gets more polluted." Participants also expressed concerns about their livelihood, specifically mentioning potential repercussions on their sources of income. Participant O emphasised this concern: "Climate Change is affecting the agricultural industry which increases the food price."

While certain participants (D, N, S) exhibited a distinct comprehension of the cause-and-effect connection between Climate Change and their individual encounters, others (C, E, V) described the effects without explicitly referencing Climate Change. Several participants also noted the immediate repercussions, such as Participant P who mentioned the destruction of houses due to floods. On the other hand, Participant LL expressed apprehension about future dangers, specifically warmer temperatures that could potentially result in the spread of diseases.

Table 4.14

According to Participants, Did They Think Climate Change Could be Addressed After Completing the Biology for Educator's Module?

Response	Number of participants
Yes	34
No	1
I don't know	3
No response	2

The perspectives of the participants on addressing Climate Change were gathered again from the group of 40 individuals, with four participants who did not provide a response. Out of the total number of participants (34), most of them expressed a positive outlook towards addressing this problem, explaining a wide range of strategies while one said "No" and another said, "I don't know." A number of participants emphasised the significance of educational campaigns and increasing awareness (Participants NN, A, D, H, P, S, V, GG, HH, II, JJ). Participant NN

suggested putting Climate Change Education into the school curriculum, noting that it would "teach them in depth about the effects" (NN).

In addition, the participants highlighted the importance of taking personal measures to decrease carbon footprints, such as conserving energy, opting for walking or biking instead of driving, and reducing meat consumption. The presence of support for large-scale initiatives was apparent, as indicated by investments in renewable energy sources, sustainable practices, and improvements to infrastructure (B, K, FF, MM, C, N, O, AA, BB).

Participant AA recommended "reducing greenhouse gas emissions, switching to renewable energy sources, adapting to the effects of Climate Change , and removing carbon dioxide from the atmosphere".

Particular solutions were also emphasised by participants: promoting recycling of materials and carpooling (I); encouraging public transportation and carpooling (K); advocating for educational programmes and tree planting (O); proposing government regulations and public awareness campaigns (BB); and placing emphasis on the transition to clean energy and forest protection (MM).

While there was a general sense of optimism, there were also dissenting views that were observed. Participant DD expressed doubt regarding the possibility of completely reversing the situation, asserting that "we have reached a point of no return as a species" (DD). Participant Q expressed a firm belief that the situation was irreversible, explicitly stating, "No, it cannot be undone" (Q).

Although there is a widespread belief in the possibility of addressing Climate Change, the participants recognised the difficulties and put forward different solutions, with a focus on education, the adoption of renewable energy, sustainable practices, and collaborative endeavours.

Table 4.15

Who Participants Think Should be Responsible for Addressing Climate Change After Completing the Biology for Educators Module

Responsbility to address Climate Change	Number of participants
Individuals	17
International organisations	6
Businesses	3
Individuals, other	1
Local government, businesses, individuals	3
Other	1
International organisations, national government, local government, businesses, individuals	4
Businesses, individuals	1
Local government, individuals	1
International organisations, national government, local government, businesses	1
Local government	1

An analysis of participants' understandings of responsibility for addressing Climate Change after the Biology for Educators module (39 responses, 1 no response) suggests shared responsibility.

The theme of individual action was dominant. When asked for reasoning, participants felt that there is a need for personal accountability, specifically mentioning behaviours such as decreasing energy usage, utilising public transportation, and minimising waste (Participants NN, A, B, E, F, G). Participant NN exemplified this sentiment, stating, "It's no use pointing at others...each one of us has contributed". Additionally, participants recognised the necessity of taking personal initiative in addition to the collective endeavours of other groups (Participants D, N, W, Z). Participant D emphasised the notion that if everyone is worried, we might come up with various strategies to address the problem.

The significance of businesses was also recognised. Several participants (11 participants) recognised businesses as main contributors to Climate Change and, as a result, crucial agents

of change. Participant H's perspective can be summarised as follows: "Given that they are primarily responsible for the majority of the negative impacts caused by industries, they should possess the necessary resources and methods to mitigate Climate Change."

The potential of local governments to implement policies and advocate for sustainable practices was acknowledged (ten participants). Participant N proposed several concrete measures that local governments could implement, such as allocating funds towards the development of solar and wind power, enhancing the standards and availability of public transportation, and advocating for the construction of infrastructure that supports recycling.

Participants also feel that the role of international organisations in orchestrating worldwide endeavours and executing efficient policies need to be enhanced (Participants C, M, AA, DD, FF, GG, II, MM). Participant MM captured this view, highlighting their role in facilitating international cooperation, offering economic and technological support, and executing strategies to mitigate greenhouse gas emissions.

Several participants provided alternative perspectives. Participant O highlighted the significance of educators in promoting consciousness, while Participant P emphasised the necessity of collaborative efforts involving all groups.

While businesses, local governments, and international organisations all have important responsibilities, people are perceived as needing to change the way they behave. The issue's diversity shows how connected it is, and various parties need to work together to find meaningful solutions.

Table 4.16

How Many Participants Take Action to Address Climate Change After Completing the Biology for Educators Module

Response	Number of participants
Yes	20
No	17
I don’t know	3

Following the Biology for Educators' module, the 40 participants were asked if they ever took or regularly take action to address Climate Change. A total of twenty participants indicated that they have taken measures to address Climate Change, either by adopting existing strategies or by developing a new understanding of the issue. The actions undertaken by the participants included tree planting (Participants B, W, FF), recycling (Participants F, M, R, V), utilising public transportation (Participants F, K, BB), and educating others (Participants C, E, P). Participant M and Participant Z both discussed community recycling projects, emphasising the possibility of collective action. They mentioned how they took the initiative to start recycling plastic bottles and made it essential for everyone to participate.

Three participants (Participant NN, Participant J, and Participant S) felt uncertainty regarding their actions by choosing "I don't know", suggesting the need for additional educational or clarifying initiatives.

A total of 17 participants, namely A, D, G, H, I, L, Q, T, U, X, Y, AA, CC, DD, GG, HH, and KK, indicated that they did not take any action. Participant II also expressed restrictions caused by limited resources. They mentioned using fire for cooking at home and the negative impact of cutting down trees. However, they expressed a desire to explore alternative options once they have the means to do so.

Participant O explicitly connected the module to their change in behaviour ("after studying EDBS 330, I recognised the significance of individuals actively taking action..."). This evidence indicates that the module has the ability to promote a feeling of control and accountability.

CHAPTER 5

DISCUSSION, CONCLUSION, RECOMMENDATIONS, AND LIMITATIONS

5.1 Introduction

In this chapter, a discussion on the findings will portray how pre-service science teachers understand climate change as well as their practices to address it. Furthermore, this chapter will emphasize the studies key themes and practices of pre-service science teacher's climate change education. Based on the research, recommendations are provided. Additionally, it will discuss the limitations of the study that may have influenced the research outcomes, this is to contribute to the ongoing development of effective climate change education strategies and to offer an objective viewpoint on the findings and propose opportunities for further research.

5.2 Discussion

The findings of the study showed the impacts of the Biological Science for Educators' module. The qualitative data collected from the questionairres (Appendix A) shows themes of personal experiences, causes, effects, communication and roles as contributing factors.

This discussion will interpret these findings in the context of existing research. The discussion is focused on the main themes that were identified in the results, linking them to the broader research done which will be discussed further. To systematically analyze the data, the generated data is catergorized into themes that correspond to the major components of the conceptual framework. These components include the pre-service science teachers' knowledge of climate change, as well as their adaptation and mitigation strategies. Each theme was carefully coded to reflect these categories, enabling a nuanced exploration of science pre-service teachers' understandings and practices before and after completing the Biological Science for Educators module that served as the intervention. As the data was analyzed, patterns emerged that were consistent with, yet also extended beyond, the initial conceptual framework. For instance, while the framework anticipated that a solid scientific understanding of climate change would correlate with more effective practices, the data revealed complexities in how PST's translate their knowledge into action and understanding. Some participants demonstrated strong conceptual understanding but struggled to effectively practice adaptation and mitigation strategies, highlighting a gap that the initial framework did not fully anticipate.

1: What are pre-service science teachers' understanding of Climate Change before completing a Biological Science for Educators module?

The participants offered valuable perspectives on their choices, perceptions and experiences related to major environmental issues (Table 4.1), specifically pollution, flooding, poor waste management, Climate Change, traffic, and over-population. Their responses reflect the complex nature of environmental issues, emphasising not only the impacts at a local level but also the interconnections between the various environmental issues.

The Impact of Pollution on the Environment

Pollution was identified as the main environmental concern by most participants, with a majority stating that it was the most frequent issue. Ukaogo et al., (2020) say that, despite being a widely known issue, environmental pollution continues to be the most global challenge and is the leading contributor to environmental-related illnesses and fatalities. The participants commonly mentioned factors such as littering, burning of fossil fuels, emissions from vehicles, inadequate waste management practices, and insufficient awareness and education regarding environmental impacts. These responses show how human activities affect environmental degradation and how urgently effective mitigation strategies are needed.

Moreover, the responses provided by the participants highlighted the various effects of pollution on human health, ecosystems, and societal well-being. Frequent mentions were made of firsthand encounters with water pollution, health problems linked to air pollution such as respiratory illnesses (Participant T: "pollution, air and water, affects communities on a daily basis and as a person living with asthma, air pollution is a huge problem for me and people like me"), and the observation of land and water bodies that have been contaminated by human activities (Participant F: " I experienced water pollution in the past few months. Due to water shortage we have to fetch water from rivers, however that was challenging as people throw dirt there"). In addition, the participants emphasised the interconnections between pollution and other environmental issues, such as Climate Change and flooding, underlining the interconnectedness of environmental challenges.

Local Flooding Effects

Aldardasawi and Eren (2021) discuss the diverse concerns associated with floods, which include not only physical injuries but also economic destruction, damage to the environment, and psychological effects on those who survive.

Participants consistently mentioned the severe consequences of flooding events, including the tragic loss of lives, destruction of livelihoods, and forced displacement. Participant NN described a floods in KwaZulu-Natal (KZN) that resulted in loss of life, while Participant P emphasised the susceptibility of KZN residents, stating that they are "victims of floods". These responses support the claim made by Aldardasawi and Eren (2021) that floods present a substantial threat to life on earth.

The participant responses expressed the economic ramifications of flooding and the displacement of communities. Participant C discussed the displacement of residences in their community, while Participant M emphasised the detrimental effects on infrastructure. These responses show that floods have a negative impact on economic stability, cause difficulties for affected communities, and result in forced displacement. A study conducted in South Africa (Naidoo et al., 2022) found that floods have the potential to displace a large number of individuals, interrupt educational activities, and place excessive strain on social services.

Furthermore, Participant F explained that floods have the effect of destroying gardens and destroying food sources, which in turn leads to an increase in food insecurity. The Food and Agriculture Organization of the United Nations (FAO, 2020) recorded the adverse effects of floods on agricultural output, resulting in food scarcity and malnutrition. Participant O highlighted the impact of floods on infrastructure, which is further discussed by Aldardasawi and Eren (2021) provide a detailed account of the destruction inflicted upon roads, bridges, and other vital infrastructure. In addition, flooding has the potential to pollute water sources and disrupt sanitation systems, which can result in the occurrence of waterborne diseases (Okaka & Odhiambo, 2018).

Participants also established a connection between flooding and Climate Change. Participant M ascribed the adverse effects they encountered to Climate Change, while Participant DD expressed apprehension that recurrent flooding could be a repercussion of a shifting climate. These observations align with the expanding body of research that establishes a connection

between human activity, Climate Change, and the rise in occurrences of flooding events, for example, Intergovernmental Panel on Climate Change (IPCC, 2022). Consequently, Climate Change leads to intense precipitation events, rising sea levels, and changes in weather patterns, all of which together increase the probability of floods (Dube et al., 2022).

Participants reasoning depicts the extensive damage caused by flooding, and some responses also portray a lack of knowledge in certain areas such as the causes and mitigation strategies. Participant CC expressed a desire to comprehend the factors contributing to flooding, indicating a need for educational endeavours that enhance public consciousness regarding Climate Change and its impact on severe weather occurrences (Dhal, 2019; UNFCCC, 2007).

Furthermore, experiences of participants expressed the impacts of flooding, including casualties, economic hardships, forced migration, and potential psychological consequences. Moreover, the data indicates a correlation between flooding and Climate Change, as stated earlier, in enhancing the public consciousness.

Waste Management and Recyling

There is also a rise in urbanisation, population growth, and economic development, which have led to enhancements in human welfare (Nyika et al., 2020). Additionally, resource consumption has increased, leading to a rise in solid waste production (Chen, 2018). This issue poses as a challenge in developing nations with limited ability to handle such waste. Compared to developed nations, these countries generate less waste per capita; however, the capacity to properly and effectively manage, landfills, recycle, and reuse this waste presents a challenge. Waste handling capacity fluctuations result from the linear resource consumption model that developing countries adhere to, which encompasses the entire life cycle of products from processing to disposal in nature (Garcés-Ayerbe et al., 2019). Through greenhouse gas (GHG) emissions, contamination of land and water resources, as well as exacerbated Climate Change impacts, the model negatively impacts the environment (Nyika et al., 2020).

Poor waste management was also selected as a major environmental concern by ten participants before completing the Biological Science for Educators module. Nyika et al. (2020) highlight that particularly in rural regions, poor waste management practices are common, compelling inhabitants to resort to environmentally harmful alternatives like burning and unauthorized dumping, and having areas with insufficient waste disposal infrastructures. Participants

identified various contributions to poor waste management, including overcrowded landfills, littering, the burning of waste in the open, and inadequate waste collection services. For example, as said by Participant A, "… poor waste management in rural communities, in my community per say, we do not have the municipality coming to collect the waste, people just dispose waste anyhow and are not informed about the [correct] disposal." According to Nyika et al. (2020) there are two legally defined categories of waste in South Africa. Waste is any substance that is unnecessary, thrown away, rejected, or unwanted. According to Dlamini et al. (2019) this definition regards waste as being devoid of value and does not acknowledge its potential for causing pollution. The broad nature of this definition discourages the action of reusing and recycling. As per the second definition, "waste as any solid substance transported, dissolved or suspended in water such as sediment and that is deposited or spilled into water or on land in such a manner, volume and composition that causes pollution (Nyika et al., 2020). Nyika et al. (2020) say that by this definition all waste is deemed detrimental unless it undergoes treatment and is re-categorized and that the stringent definition of waste in SA may hinder the successful implementation of reusing and recycling programmes. These factors collectively contribute to environmental pollution and pose risks to public health. The responses highlighted the necessity for enhanced waste management practices, active involvement of the community, and comprehensive public awareness initiatives to effectively tackle this problem. The Department of Environmental Affairs in South Africa has a National Waste Management Strategy to address the poor waste management, despite their short supply of resources (Africa, 2024). Their goals which include encouraging waste minimisation, re-use, recycling and recovery of waste, ensuring the effective and efficient provision of waste services, increasing the contribution of the waste industry to the green economy and making sure that people are aware of the effects of waste on their health, well-being and the environment.

Health Issues of Climate Change

Participants expressed their concerns about various health issues that are worsened by Climate Change. Participant T stated, "When temperatures get really high, I will be one of those who will get sick as my immune system is not that strong," while Participant LL described "extreme temperatures caus[ing] irritation to my skin and lots of respiratory problems, specifically sinusitis." These instances emphasise the immediate health consequences of Climate Change, including illnesses caused by high temperatures, the transmission of diseases by vectors, and the impact of air pollution. According to Rocha et al. (2022), Climate Change presents

substantial threats to health and well-being, including but not limited to heat-related disorders and the transmission of vector-borne diseases. Significantly, emphasising the effects on individual well-being can operate as a compelling incentive for taking action on Climate Change (Edmondson et al., 2022).

Participant BB reported that a teacher ascribed their skin cancer to Climate Change. Recent studies show the possible link between excessive sun exposure and higher risk of skin cancer among South Africans; estimates place up to 72% of skin cancer cases in the nation to be caused by UV radiation exposure. Though there has not been much change in the ozone layer over South Africa in recent decades, its recovery could assist to shield against the development of skin cancer. The ozone layer acts as a shield against solar UV-B radiation. Ambient temperature may also affect the incidence of skin cancer; data points to a rise in this temperature possibly encouraging cutaneous carcinogenesis (Pillay et al., 2023; Wright et al., 2020; Wright et al., 2021). Although additional research is needed, this raises apprehension regarding potential health ramifications associated with Climate Change, such as heightened vulnerability to ultraviolet radiation resulting from the depletion of the ozone layer. Participant LL highlighted the distress caused by Climate Change, expressing that, recently, Climate Change has emerged as the predominant environmental concern they are confronting, with temperatures becoming unbearably high. This stresses the influence of Climate Change on everyday existence and wellbeing.

Concerns for Food Security

Participants also went deeper than the immediate physical effects of Climate Change. Participant D explained that climate-induced changes have resulted in rising temperatures and the loss of crops, which will ultimately lead to food scarcity. On the other hand, Participant O expressed concern about the potential for Climate Change to cause floods, disrupt the geographical areas where they reside, and have various negative impacts on our economy. The above responses show the progressive impacts of Climate Change on people's means of living, the availability of food, and their overall social welfare (IPCC, 2022).

Several interviewees indicated ambiguity or even refuted experiencing personal ramifications of Climate Change. This fluctuation highlights the significance of developing a strong understanding of climate science. Participants like AA, who described "More flooding in my area causing loss of many assets", could benefit from a deeper understanding of the scientific

mechanisms behind such extreme events. It is essential to actively involve those with little knowledge and correct any misunderstandings in order to cultivate a generation of future educators who are well-versed in scientific matters (Leiserowitz, 2005; Stevenson et al., 2017).

The Effects of Climatic Change and its Education

Although selected by a smaller percentage of participants, Climate Change was still recognised as an urgent global challenge with severe consequences. Ziervogel et al. (2014) and Nhemachena et al. (2020) emphasise expected alterations in Southern Africa, such as increasing temperatures, increased drought, and a rise in the occurrence and severity of extreme weather phenomena. Participants responses align with these research papers, providing reasons for their choice of Climate Change.

Participants also continued to report first hand experiences that correspond to the impacts of Climate Change (Table 4.6). Participant H noted "drastic changes to weather each day", while Participant I mentioned experiencing "extreme weather conditions such as dangerous thunderstorms and lightning, heavy rain, hot and cold days". These observations are consistent with the patterns reported by Nhemachena et al. (2020) and Ziervogel et al. (2014) regarding the rise in temperature variability and the occurrence of more severe weather events. Participant U elaborates on these, stating, "with Climate Change I have experienced the sun reaching 43 degrees and cold that is below 0 degrees, which is unpleasant and had made me sick."

Participant F describes the impact of Climate Change on their environment, noting, "change in climate left us with floods after that heat was experienced which caused the land to be dry." This narrative shows the vast consequences of Climate Change. Higher temperatures can result in increased evaporation, which can lead to arid conditions and potentially more vigorous rainfall episodes during precipitation events. In agreement with this is research conducted by Ziervogel et al. (2014) and Trenberth (2011) which points out the correlation between Climate Change and changes in precipitation patterns.

Participant O emphasised the need for "raising awareness" about Climate Change, and going further was Participant CC who expressed a desire to "share awareness". This viewpoint was also shared by Participant JJ who highlighted the importance of educating people about Climate Change. Participant NN directly connected Climate Change to extreme weather events, stating, "[it is the]reason for floods". If the climate is not changing, we would not have fatal

and destroying events that took lives and changed [our life] the for the worse." The urgency for action and education is essential, as public comprehension is vital for catalysing efforts towards Climate Change mitigation and adaptation strategies.

Responses from participants also exemplify the real-world consequences of Climate Change, including alterations in weather patterns, occurrences of severe weather, potential health ramifications, and disruptions to life. The data also emphasises the need for increased public awareness and education regarding Climate Change.

Understanding Complex Environmental and Climate Change Issues

Environmental concerns, specifically in urban areas, included traffic congestion and overpopulation. Participants emphasised the negative impacts of pollution caused by traffic, the expansion of urban areas, the strain on infrastructure, and the pressures from population growth on both the environment and public health. These discussions highlighted the intricate interplay between urbanisation, transportation systems, and demographic trends that contribute to environmental challenges.

Overall, the viewpoints of the participants offered understanding into the varied and connected character of environmental issues confronting communities. The discussions highlighted the necessity of comprehensive strategies in environmental management, policy interventions, community involvement, and scientific research to effectively tackle the challenges of pollution, flooding, inadequate waste management, Climate Change, traffic, and overpopulation.

Participants responses confirmed a general awareness of Climate Change among participants. However, the depth of understanding varied considerably. While 92% recognised human activities as contributors, as highlighted by Participant A who mentioned "burning of fossil fuels, overpopulation and use of vehicles", only 64% could pinpoint specific activities that can contribute to Climate Change. Recent research by Ofori et al. (2023) indicates that the majority of individuals possess a restricted grasp, misconceptions, and a lack of comprehension regarding Climate Change. Sub-Saharan Africa is expected to face a greater impact from Climate Change compared to other regions, yet there is a lack of information about the level of Climate Change understanding in the area. Further to this, Khatibi et al. (2021) say that insufficient information and awareness provide obstacles to passive involvement in Climate

Change matters. According to the research, attitudes can change and good behavioural shifts can result from actively participating in and understanding the consequences of Climate Change.

The pre-service teachers lack of specific understanding and absence of scientific knowledge can be seen in the following manner. Only forty-six percent (46%) of participants recognised shifts in weather patterns as a key feature of Climate Change. Participant Y exemplifies this with their statement, "Climate Change is about the changing weather patterns." However, only 23% directly linked these patterns to global warming or the greenhouse effect. Participant F demonstrated partial understanding, stating, "it is about change in weather conditions due to global warming. Our contribution to Climate Change by producing large amounts of CO_2." This highlights a need for educational efforts that bridge the gap between human activities and greenhouse gas emissions, and their resulting impact on weather patterns. Studies like Seroussi et al. (2019) support this notion, suggesting that many people struggle to grasp the complex mechanisms behind Climate Change. Specifically, not all in-service teachers have a comprehensive understanding of the greenhouse effect. Climate Change is a subject that in-service teachers have misunderstandings about, particularly when it comes to the reasons behind it and the resulting effects.

The IPCC (2021) emphasises the critical role of scientific communication in bridging this knowledge gap. Effective communication methods should use relevant examples and correct misconceptions to simplify difficult scientific ideas into understandable language, as explained by Howarth et al. (2020) that scientific explanations must be compelling and understandable. Furthermore, it is unreasonable to expect everyone to comprehend and grasp science accurately. Communication has to relate the issue to the interests and worries of the audience. We must remember that diverse audiences will read the same message differently and develop numerous points of view. Given the diversity of opinion surrounding Climate Change, it is crucial that we move away from alarming people and instead emphasise the advantages of making lifestyle changes. Only then can we hope to inspire long-term engagement and decisive action. Though misinterpretation and postponed decision-making are to be expected, stories can assist people to overcome perceived obstacles to change and enhance audience comprehension of Climate Change.

While many participants focused on weather pattern changes, some recognised the wider impact of Climate Change. Participant V mentioned food insecurity as a consequence, while Participant DD highlighted the threat to biodiversity. This aligns with the Intergovernmental Panel on Climate Change report and others (Gaware, 2024; IPCC, 2022; Ready & Collings, 2021) which details the multifaceted consequences of Climate Change, encompassing everything from food security and biodiversity loss to rising sea levels and extreme weather events. Raising public awareness about these broader impacts is crucial for garnering support for climate action, as highlighted by Khatibi et al. (2021).

A noteworthy aspect of the data is the concern expressed by participants like Participant O, who emphasises, "what I think about Climate Change is that it is an issue that should be taken into consideration and we must raise awareness about it before it's too late." This sentiment was echoed by Participant CC who pondered solutions, stating, "I think about what causes it, the negative impacts about Climate Change in our environment and what can we do to reduce it." These calls for action and education echo recommendations by UNESCO (2021), which emphasises the importance of public engagement and education in driving climate action. Educational initiatives should not only focus on scientific understanding but also empower individuals to take action in their daily lives and advocate for broader systemic changes.

The data from this study suggests a general awareness of Climate Change among participants, with many recognising human activities as a contributing factor. However, there are gaps in understanding, particularly regarding the mechanisms linking greenhouse gas emissions to weather pattern changes and the broader environmental consequences of Climate Change. The data also highlights a public call for action and education. By addressing these knowledge gaps, fostering public engagement, and implementing effective educational strategies, we can empower communities to participate in solutions and work towards mitigating the effects of Climate Change.

Communication of Climatic Change Issues and Climatic Change Education

Many participants indicated that they acquired knowledge about Climate Change (Table 4.5) through conventional media outlets such as television (TV) and radio. This shows the ongoing significance of these mediums in distributing information, especially for reaching people who may not actively search for climate-related content on the internet. Nevertheless, a few participants, specifically Participants E and M, exclusively referred to the internet, indicating

a possible transition towards online sources of knowledge, particularly among younger age groups.

The choices also show us the increasing impact of the internet as a platform for accessing Climate Change information. Participants such as Participant C, who specifically indicated "internet", and Participant T, who cited "internet and other", highlight this pattern. The internet provides a wide range of sources for information; however, the reliability and precision of this information can vary significantly. Research such as that conducted by Abbas et al. (2019) indicates that social media has both positive and negative effects. It can increase public knowledge and also contribute to the spread of false information.

An important finding is the contribution of institutions in promoting awareness regarding Climate Change. Many individuals, including Participant A and Participant K, cited the university as an important source of information. These findings indicate that educational institutions have a vital role in providing students with the essential knowledge and analytical skills to comprehend intricate environmental matters such as Climate Change. This supports the viewpoint of Eilam (2022), who says there is a need for incorporating Climate Change Education into many academic subjects to cultivate an educated population capable of tackling this worldwide issue.

According to the findings of this research, conventional media, the internet, and academic establishments are among the channels through which pre-service teachers obtain knowledge regarding Climate Change as 52% of participants chose the internet. Although traditional media continues to be a way of obtaining information, the internet's impact is steadily increasing. Universities have a substantial impact in increasing awareness. These findings emphasise the necessity of employing comprehensive communication strategies that take into account the varied information environments individuals encounter.

Students' Understandings of the Causes of Climate Change

It is acknowledged by the participants that Climate Change is predominantly caused by human activity. This statement is consistent with the accepted scientific consensus on Climate Change, as emphasised by the IPCC (2021). The IPCC report categorically asserts that human activities, specifically the combustion of fossil fuels and the destruction of forests, have been the primary factor behind the observed increase in temperature since the middle of the 20th century. Human

activities are largely responsible for the problem. This study revealed a dearth of understanding among participants on the natural factors contributing to Climate Change, such as the Milankovitch cycle, oceanic processes, gravitational forces, forest fires, solar activities, volcanic eruptions, and greenhouse gases (GHG). Although other variables have an impact on Earth's climate over extended periods, the prevailing agreement strongly indicates that human activity is the main cause of the current rapid warming. These forces, which arise from the planet's natural cycle, can cause both immediate and gradual changes in the planet's condition (Aktar, 2022; Berlie, 2018). However, the participants did not acknowledge nor point out the existence of them.

The participants' focus on behaviours such as the burning of fossil fuels, as indicated by Participant II, and the clearing of forests, as mentioned by Participant H, coincide with the primary causes of Climate Change caused by human activity, as recorded by the IPCC (2021). Participant C correctly identified that the combustion of fossil fuels results in the emission of greenhouse gases, with carbon dioxide (CO_2) being the primary gas released. Greenhouse gases, which include carbon dioxide and methane, have the ability to retain heat in the Earth's atmosphere. This phenomenon, known as the greenhouse effect, is responsible for global warming. Participant G shares the same concern about this issue.

Participant AA exhibited a comprehensive understanding of the greenhouse effect, while Participant O employed more general phrases such as "pollution". More educational programmes that explore the scientific basis of Climate Change might be needed to help people understand it in a more complex way than just seeing human action as the cause.

The cascading consequences of Climate Change were also reported by the students as follows. Participant V expressed concerns about extreme weather occurrences, while Participant U was concerned about ecological degradation. These concerns are in line with the many implications discussed in the IPCC report of 2021. Climate Change encompasses more than just increasing temperatures; it has far-reaching impacts on weather patterns, ecosystems, and human societies. The participants' apprehensions over the ramifications of Climate Change are noteworthy.

This study corroborates the findings of prior research conducted by Leiserowitz (2005) and Capstick et al. (2015), which revealed that a number of individuals acknowledge the influence

of human activity on Climate Change. However, their understanding of the precise factors contributing to Climate Change may be limited. It is essential to make efforts to close this gap in understanding. Using relatable examples and clearing up common misunderstandings (such as Climate Change is just about warmer weather or there is a hole in the ozone layer causing warming), educational efforts can use a variety of communication methods to break down difficult scientific ideas into language that is easy to understand. Moreover, as recommended by UNESCO (2021), public engagement initiatives should not solely concentrate on enhancing scientific comprehension, but also enable citizens to actively participate in their everyday activities and advocate for more extensive systemic transformations.

The data from this poll indicates that participants generally acknowledge that human activity is the main catalyst for Climate Change. Nevertheless, the level of comprehension regarding particular systems differs. These findings emphasise the necessity of employing diverse educational approaches to improve public comprehension of the scientific principles underlying Climate Change and its extensive ramifications. By promoting a higher level of knowledge and awareness among the general population, we can enable individuals to actively participate in finding answers and striving towards a future that is environmentally and socially sustainable.

Participants, when asked about the impacts of Climate Change in the upcoming five years, centred on three key themes that align with widely recognised scientific predictions. The major concern is the intensification of extreme weather occurrences. Participants anticipated an increase in the frequency of floods, droughts, and heatwaves, in line with the findings of the IPCC. The IPCC report indicates a direct association between Climate Change and the intensification of extreme weather events (IPCC, 2021).

Another concern is the potential for ecological decline. Many of the participants voiced concerns about the consequences of Climate Change on habitats and the potential extinction of species. Research conducted by Kolenatý et al. (2022), identifies Climate Change as a contributor to species extinction. The modification of meteorological patterns and the devastation of habitats provide a substantial peril to the delicate balance of ecosystems, perhaps leading to a reduction in biodiversity.

The responses also emphasised food security as a crucial topic. Participants expressed

apprehensions over the possible disturbance of agricultural productivity and the subsequent rise in food insecurity as a result of Climate Change. This concern is supported by studies, such as the study undertaken by Malhi et al. (2021), which discusses the negative impacts of Climate Change on agricultural productivity. Severe droughts, floods, and changes in weather patterns have the capacity to greatly impact agricultural productivity, potentially leading to food shortages.

The discussion also centred on the economic consequences of Climate Change. Participants voiced apprehensions on the adverse impacts of extreme weather events and interruptions to agricultural operations. Batten et al. (2020) agree with the substantial financial burden Climate Change can impose.

While there was a consensus on these essential subjects, there were some inconsistencies on specific details. There were multiple viewpoints regarding features of anticipated weather patterns. Certain individuals forecasted persistent precipitation, while others anticipated alternating periods of severe aridity and extensive rainfall. Furthermore, although participants acknowledged the concern of rising sea levels, it was not given importance during the interviews.

When asked if Climate Change will affect or is affecting them, the participants focused on severe weather events, highlighting an increasing feeling of urgency and personal significance about Climate Change. For instance, Participant W described their experience of "...extremely hot weather conditions, sometimes leading to flooding", while Participant I noted, "There are extreme weather conditions currently. It is currently too cold and it will be too hot in summer." These accounts align with the well-established link between Climate Change and the increasing frequency and intensity of heatwaves, droughts, and floods (Weber, 2010). Research indicates that individuals often perceive Climate Change primarily through observable alterations in weather patterns (Weber, 2010). Although individuals may acknowledge these changes, they may not fully establish a correlation between these occurrences and the fundamental scientific principles that drive Climate Change.

Personal encounters with scientific explanations in pre-service teaching programmes can have a profound impact. The statement by Monroe et al. (2019) highlights how human experiences are closely linked to the larger global processes that drive Climate Change. Pre-service teachers

might take advantage of this situation to highlight the scientific aspects of extreme weather occurrences, such as the impact of rising greenhouse gases on heat trapping and precipitation patterns. This can enhance pre-service teachers' comprehension of the causes of Climate Change (Monroe et al., 2019). This could enable them to equip their own students with a more comprehensive understanding of these phenomena in the future.

The table below summarises the responses of pre-service teachers' understandings of Climate Change before the Biological Science for Educators module into nine themes (Impact of pollution, Local flooding effects, Waste management and recycling, Health issues of Climate Change, Concerns for food security, The effects of Climate Change and its Education, Understanding complex environmental and climatic change issues, Communication of Climate Change issues and Climate Change Education, and Students' understanding of the causes of Climate Change) that were identified.

Table 5.1

Pre-Service Teachers' Understandings of Climate Change Before a Biological Science for Educators' Module

Themes	Understandings
Impact of pollution	Participants view pollution as the major environmental issue and link it to behaviours like burning fuel and littering. They also understand its immediate environmental and health impacts, and understand how pollution affects Climate Change.
Local flooding effects	The participants have an understanding of the effects of floods, such as the mental impacts, economic harm, damage to the environment, and physical harm. Participants recognise the link between inundation and food insecurity due to crop damage, as well as the link between flooding and Climate Change.

Waste management and recycling	Participants understand the environmental impacts of poor waste management, especially when urbanisation, population, and economic development increase. They also understand that this increases greenhouse gas emissions and environmental pollution, worsening Climate Change.
Health issues of Climate Change	Participants are concerned about Climate Change 's health effects. Direct implications include being more likely to get sick in extreme temperatures and having respiratory difficulties worsen.
Concerns for food security	Participants understand that Climate Change impacts more than the local ecosystem, pointing out in particular its effects on food security. Climate Change and flooding cause crop loss and food shortages.
The effects of Climate Change and its education	Although a small percentage, participants identified that Climate Change is a major concern. They linked personal weather fluctuations and severe weather like heatwaves and rainfall to Climate Change. Climate Change was also linked to skin cancer. Participants said more people should know about and act on Climate Change due to its consequences.
Understanding complex environmental and climatic change issues	Participants stated the importance of effective solutions for pollution, urbanisation, and population growth for the environment as well as public health. Many identified human activities as contributors to Climate Change, but the processes tying greenhouse gas emissions to weather pattern changes were unclear.

Communication of Climate Change issues and Climate Change Education	Participants usually get information about Climate Change from TV and the internet, demonstrating their continued importance. Universities are crucial informative sources, and several participants stressed the importance of education in helping students comprehend and address Climate Change.
Students' understanding of causes of Climate Change	Participants understand that Climate Change is caused by human activities like burning fossil fuels and deforestation. Natural causes like volcanoes and oceanic activity are unfamiliar to them. Additionally, the greenhouse effect and gases are well-known, but the process and gases are not.

2. What are pre-service science teachers' practices in relation to Climate Change before completing a Biological Science for Educators module?

Indvidual Action

The data portrayed a variety of how pre-service teachers put into action what it takes to address Climate Change. While many recognise individual actions like conserving electricity, there was also a call for systemic changes, such as policy shifts or industry regulations, Participant L said that "The national or local government cannot control how people live their lives, but it should be a choice made by an individual to change their bad lifestyle habits to tackle Climate Change." There is a reflection of awareness of the issue's complexity and the need for solutions at both individual and societal levels (Table 4.5) from pre-service teachers.

The recognition of multiple levels of action (Participant H: "I think the governments, both local and national, firstly have to implement the Climate Change Education to South African communities to raise awareness of the Climate Change issue and come up with ways to reduce it") shows the importance of systems thinking in Climate Change Education. The statement highlights the importance of comprehending the interdependence between individual actions,

economic frameworks, and systems of government while tackling intricate environmental issues (Kioupi & Voulvoulis, 2019).

Education as Empowerment

Education and awareness are identified as key priorities for Climate Change (Monroe et al., 2019). Participants see education as a way to promote public support for policies and help individuals change their own behaviour (Participant O: "Teachers can be the agent that could educate people about taking action for Climate Change). The pre-service teachers' aspirations to educate others indicates their perception of themselves as prospective catalysts for change in both formal and informal contexts. The focus on the transformational power of education aligns with studies on climate literacy. Climate education that is effective goes beyond simply imparting knowledge and instead focuses on fostering individuals' ability to take action and think critically (Monroe et al., 2019).

Although there is some disagreement among specific individuals, the majority of participants hold the idea that humans have the capability to address Climate Change. This is potentially a turning point in our understanding of climate, moving from merely realising how humans affect it to believing that we can all work together to change things.

Acting against Climate Change requires agency. Studies show that a lack of interest or involvement follows a feeling of powerlessness which results in a lack of involvement or interest (Woroniecki et al., 2019). Climate Change educators should give priority to fostering optimism and promoting a mindset focused on finding answers too.

Shared Responsibility

The viewpoints of the pre-service teachers regarding the responsibility for addressing Climate Change demonstrated a sophisticated and developing comprehension of the nature of the issue. Participants (H, B, C, P, BB, EE, MM) strongly believed in the concept of shared responsibility, in line with the international principle of common but differentiated responsibilities (Hormio, 2024; United Nations, 1992; UNFCCC, 2018). Their reasons for holding this view varied, for example, participant A expressed that all of the options possess influence and authority to educate individuals about and implement strategies to address the issue of Climate Change.

Participants expressed the need of education, seeing knowledge as an encouragement for both individual and group action. Education was deemed crucial at every level of society, as emphasised by the participants, including the need for group cooperation to make the endeavour easier and more realistic as well as the global effects of Climate Change.

Still, there remained a conflict between putting individual actions first and pushing for structural change through corporate and governmental policies, reflecting a broader debate over who should be responsible for solving Climate Change. Participant Z portrayed the conflict when they said there should be laws to stop Climate Change which can be implemented by the national government and the monitoring of these laws' compliance is possible by the local government.

Multi-level Collaboration

Participants supported the idea of using a multi-level strategy, emphasising the importance of cooperation among individuals, communities, enterprises, and governments (Table 4.8). In agreement are Fisher and Leifeld (2019) who support using the concept of polycentric governance, such as global climate politics and the Paris Agreement. In other words, many times policy innovation is seen to result from independent forms of bargaining, shared understandings, and the creation and execution of solutions involving individuals at various levels and locations within the relevant political system. This methodology concludes that diverse actions at different levels create multiple benefits.

The range of reactions, which include individual action, systemic change, and multi-level collaboration, highlights the significance of developing a comprehensive perspective of responsibility in pre-service teacher education. By providing future educators with the necessary tools and knowledge to understand and address the nature of climate action, we can empower them to guide their students in becoming proactive catalysts for change. This will result in a generation that is well-equipped to effectively tackle the pressing issue of Climate Change. .

The methods indicated by pre-service teachers in addressing Climate Change demonstrate a combination of involvement, reluctance, and a primary emphasis on individual efforts. Although a considerable proportion (47.5%) of the participants stated that they had taken action, a substantial segment (40%) had not yet initiated measures to address Climate Change.

The participants' statements, such as "avoid using my mother's car" (Participant B) and appropriate disposal of waste such as recycling, demonstrate a conscious endeavour to reduce their environmental footprint through individual decisions. This implies that being comfortable or familiar with individual behaviours can serve as a starting point for addressing Climate Change. The module can prepare future teachers to become versatile agents for change, enabling them to not only embrace sustainable behaviours themselves but also motivate future generations to address Climate Change through an in-depth approach.

However, the focus on personal choices also reveals a possible dearth in understanding the broader complexities of Climate Change. Even while individual acts are important, the systemic causes of the problem might not be adequately addressed by them.

Although the majority of participants focused on individual acts, a small number of participants also noted community-based initiatives such as recycling programmes and clean-up campaigns. This indicates an increasing acknowledgment of the significance of communal effort in tackling Climate Change. In addition, two individuals correlated their acts with acquiring knowledge about Climate Change, emphasising the significance of education in stimulating pro-environmental conduct. The participants' engagement in community-based activities, such as participant FF who stated, "If it is done this way, everyone will understand. It starts from the world to the whole community and to all the individuals to make a change. If it is done this way there will be a very big change" and the influence of education as said by Participant H, "I think the governments, both local and national, firstly have to implement the Climate Change Education to South African communities to raise awareness of the Climate Change issue and come up with ways to reduce it" align with studies on climate action competency, which emphasises the significance of individuals not only understanding Climate Change but also feeling empowered to engage in proactive measures (Kolenatý et al., 2022).

The absence of community involvement and the limited engagement in broader societal resolutions raise concerns regarding the extent and efficacy of existing Climate Change Education initiatives. It suggests that pre-service teachers could need more help to understand the complex and interconnected features of Climate Change as well as the need for action at different levels, such promoting laws and putting systemic reforms into place. Teacher education programmes should prioritise the significance of not only instructing about Climate Change but also enabling students to become proactive contributors in discovering and

executing solutions. This may entail integrating systems thinking into educational programmes, involving students in projects that benefit the community, and motivating them to actively engage in climate advocacy campaigns.

Table 5.2 shows the participants responses that were divided into four identified themes (Individual action, Shared responsibility, Education as empowerment, Multi-level collaboration) regarding practices in relation to Climate Change before completing the Biological Science for Educators module.

Table 5.2

Pre-Service Teachers' Practices in Relation to Climate Change Before a Biological Science for Educators Module

Themes	Practices
Individual action	Pre-service teachers practice different actions to address Climate Change. The participants focus on individual actions which are limited to avoid using personal cars, lowering electricity consumption and recycling.
Shared responsibility	Participants discussed shared responsibility for Climate Change. They believe that individuals, businesses, and governments have essential roles. Participants also thought education was important because it encourages individual and group action. They emphasised education at all levels and group cooperation to make climate actions more practical and effective.
Education as empowerment	Participants agreed that there is a need to educate people about Climate Change. Education can help people support laws and improve their actions.
Multi-level collaboration	Participants support a multi-level Climate Change strategy that included individuals, communities, businesses, and governments to address Climate Change.

3. What are pre-service science teachers' understanding of Climate Change after completing a Biological Science for Educators module?

The impact of Pollution on the Environment

Before the Biological Science for Educators module, most participants named pollution as their main environmental concern and continued to choose this after the module. The uniformity in the choices made by participants before and after the programme indicates that the module may not have had a substantial impact on their impression of the extent of pollution. However, it is possible the module deepened their understanding of its causes and consequences, for example, participant K's response became more detailed stating that "Pollution is one of the world's environmental issues, as there are many types of pollution such as air, water, land, etc. In urban areas, there is high rates of air pollution due to industrial activities releasing dust to the atmosphere, which causes carbon emission to affect global greenhouse gas."

Considering that the participants consistently identified pollution as a major environmental concern both before and after the module, it is clear that addressing environmental issues such as Climate Change is a difficult task. Even while educational modules can offer insightful knowledge, it takes constant work and a variety of strategies to change deeply rooted beliefs and actions.

Local Flooding Effects

Flooding remained a prominent concern after the module (82.5% of participants selecting it). This could be attributed to local variables or recent weather occurrences. Although the module might not specifically discuss floods, it may have provided them with the knowledge to comprehend its correlation with more extensive matters such as Climate Change. The reasoning provided by participants for selecting flooding continues to be because of the personal encounter with flooding. Participant G said, "I chose flooding because it's also one of the environmental issues that I have come across in my own home. I also saw this issue happening in the different communities." According to a study done in South Africa (Busayo et al., 2022), several severe floods have occurred over the past decade, resulting in substantial infrastructure damage, loss of life, and disruption of livelihoods. Importantly, environmental changes that are currently being observed are the result of human activities. Additionally, participant O mentioned, "in our Province KZN we faced devastating floods". The environmental issue of floods has been chosen as it has a huge impact on environmental aspects as well as the economy

and socially. For instance, during the floods that we had in KZN many people were left with no homes, many lost their jobs and others lost their relatives. The floods is an aspect that needs serious attention such as having adaptation, disaster response plans and building proper infrastructure that will help us prepare for them.

Waste Management and Recycling

The continued presence of "poor waste management", "traffic" and "overpopulation" (though less frequently chosen) suggests these remain concerns for some participants. The module might not have explicitly targeted these issues, but it could have provided them with a foundation for further exploration.

There was an increase in the number of participants selecting poor waste management as a major environmental concern. Participant G stated that "I chose poor waste management because it is one of the issues that is not yet addressed to many informal settlements. I have seen many different places where there is poor waste management." Waste management procedures in South Africa are often ineffective due to a lack of waste management services and societal resistance to waste separation at the point of source (Adeniran et al., 2022). Waste collection services are obtained by a mere 66% of the population through municipal contracts or private corporations. There have been reports of inefficiencies in waste collection programmes across various regions of the country.

Health Issues of Climate Change

The study indicates that pre-service teachers have a heightened knowledge of Climate Change and its long-term effects. However, their general comments on health issues such as sinus problems and skin cancer reveal a possible lack of understanding of the wider range of health implications. Participant BB mentioned that "Some people have skin cancer due to high temperature" while Participant GG said that "it is because it one of the things I get to experiences and see as in like every day, back home we have heavy industries who contribute to air pollution and as for me a person who's always had sinus issues, I get affected a lot in terms of breathing and my eyes tend to each a lot."

Concerns for Food Security

Although participants readily established a connection between Climate Change and environmental concerns with all of its potential repercussions in mind, food security was not

explicitly brought up but rather as an impact of flooding encounters that washed away crops (Participant BB: “my community is vulnerable to flooding due to heavy rains and storms. Last year we’ve experience lot of flooding in KwaZulu-Natal which had negative impact to a lot of people, some were left homeless, some passed away, some lost their properties like cars, businesses were damaged and crops died”). Studies show that there is a gap between the level of public knowledge regarding Climate Change and the enduring consequences it has on agricultural systems. It is critical to incorporate explicit food security considerations into Climate Change Education. Weather patterns are disrupted, the risk of extreme weather events is increased, and agricultural (United Nations Economic Commission for Africa. African Climate Policy Centre [UNECA-ACPC], 2011; Thornton et al., 2018) productivity is disrupted as a result of Climate Change which may result in food shortages and price fluctuations (O'Neill et al., 2022). The aforementioned repercussions exhibit an uneven distribution, rendering more susceptible developing nations and regions that are profoundly dependent on agriculture (Mirzabaev et al., 2023). By incorporating food security concerns into Climate Change Education modules, pre-service teachers can acquire a more comprehensive understanding of the matter. This understanding will enable them to equip forthcoming generations with the necessary skills to champion sustainable agricultural methodologies that exhibit resilience amidst the impacts of Climate Change.

The Effects of Climate Change and its Education

Following the module, there was a minor change in participants' comprehension and emphasis on Climate Change. Remarkably, the proportion of participants who selected Climate Change as their major environmental concern increased to 62.5% in comparison with their initial responses, 57.5%, before the module. Participant NN said, “The third choice I chose is because I have not only heard and learned about it, but I have now seen it. I have seen people losing their homes, dying, drowned in the same water that we prayed for since we also had shortages of water because of high temperatures and low rainfalls. It is real and it threatens my, our future. And to be entirely honest I am afraid. Can we do it? Can we change the climate? but only positively this time around.” This shift can be ascribed to the module improving their capacity to differentiate between Climate Change and other environmental concerns, such as pollution, or the compulsory prioritisation in a three-choice format leading some individuals to choose flooding instead of Climate Change.

Although prioritising decreased, there was an evident rise in the level of comprehension on the effects of Climate Change . The participants' accounts of their personal encounters with floods and the catastrophic consequences they experienced emphasised the tangible and imminent dangers presented by Climate Change. These views emphasise the immediate necessity to tackle Climate Change in accordance with the IPCC (2021) predictions of increasingly frequent and intense extreme weather occurrences. Recent studies discovered that individuals' direct encounters (Sezen-Barrie et al., 2019) with severe weather have a substantial impact on their understanding of Climate Change (Bergquist et al., 2019; Demski et al., 2017). This implies that the module effectively assisted participants in linking their personal experiences with scientific reasons.

The module seemed to broaden participants' understanding beyond their initial concerns. After completing the session, participants displayed a heightened understanding of the wider socioeconomic impacts of Climate Change. Comments that consider the effects of Climate Change on human health, livelihoods, and global well-being demonstrate a comprehensive understanding of the problem. This is consistent with the objectives of Climate Change Education, which aims to promote global citizenship and environmental accountability (International Bureau of Education-United Nations Educational, 2018).

Ultimately, although the initial emphasis on Climate Change among pre-service teachers may have diminished following the module, their comprehension of the issue's intricacy and pressing nature was notably enhanced. The improved understanding, together with a strengthened dedication to increasing consciousness, emphasises the crucial function of education in providing future educators with the necessary knowledge and drive to effectively address Climate Change.

Understanding Complex Environmental and Climatic Change Issues

Pre-service teachers demonstrated a notably enhanced and sophisticated comprehension of intricate environmental and climatic change matters after the module. The data presented in Table 4.10 demonstrates an increased understanding, highlighting a wider appreciation of the interconnectedness and magnification of different environmental issues.

Following the module, the strongest change was in the heightened recognition of the interconnectedness between pollution, flooding and Climate Change. Out of the 40

participants, pollution was recognised as a problem, while 33 individuals identified flooding and 25 participants acknowledged Climate Change. This suggests that there is a broader and more comprehensive understanding of these issues. This consciousness is consistent with the systemic approach promoted by Garg and Dhiman (2022), which highlights the significance of examining environmental issues from a comprehensive perspective in order to promote impactful education and action. The heightened details in participants' responses indicate a greater ability to comprehend and address environmental concerns from a comprehensive perspective. The recurring choice of combinations such as pollution, flooding, and Climate Change demonstrates an understanding of the complex and interconnected nature of these issues. Having a comprehensive understanding is crucial in order to create efficient tactics for reducing and adjusting to the effects of something.

Post-module responses from participants indicate that they now have a heightened understanding of the far-reaching consequences of these concerns. For example, flooding, which is often worsened by Climate Change, can result in pollution as garbage and toxins are spread around. Moreover, inadequate waste management directly contributes to environmental contamination, hence intensifying Climate Change by causing a rise in greenhouse gas emissions. Participant G expressed in the interview that the module provided them with insight into the connection between inadequate waste management and pollution. They further noted that this not only has negative effects on local environments but also adds to the issue of global Climate Change. This realisation emphasises the significance of tackling environmental concerns together rather than individually (Kopnina, 2020).

After the implementation of the module, topics such as traffic congestion and overpopulation were chosen with less frequency, possibly because participants did not acknowledge their importance in worsening environmental and climatic problems.

The participants' lack of acknowledgement of the impact of human actions, such as overpopulation and transportation, in worsening environmental problems highlights the need for greater comprehension. The lack of recognition of overpopulation by more participants after the module highlights misunderstanding of how population pressures might result in escalated pollution, amplified waste generation, and heightened susceptibility to climate-related catastrophes.

The module supports pre-service teachers in linking personal experiences with scientific explanations, which is consistent with the findings mentioned earlier (Bergquist et al., 2019; Demski et al., 2017). The researchers argue that these connections are essential for influencing views and behaviours related to Climate Change.

The data from the post-module indicates some transition towards a comprehensive and broad understanding. For example, their thoughts after completing the module demonstrated a stronger understanding of the link between human activities, greenhouse gas emissions, and the subsequent effects on weather patterns. Most (23/33) voiced worries about the rising sea levels and the intensity of weather occurrences (e.g., Participant Q), which is consistent with a study by Wang et al. (2018) that shows individuals' tendency to pay attention to outcomes that are immediate and local for them.

The findings of the study indicate the changes that the PSTs' experienced as a result of their engagement in the Biological Science for Educators module. They showed understanding of elements generated by humans, fundamental scientific ideas like greenhouse gases, and possible urgent repercussions. A comparison of pre- and post-module data also indicates a possible change in their comprehension. Although the first statistics were on harsh weather and rising sea levels, the post-module comments showed a wider range of issues, such as food insecurity, economic effects, and biodiversity loss. This raises the possibility that the module helped to clarify long-term consequences more fully.

This shows that the module may have successfully expanded on existing knowledge and prioritised human-driven causes, establishing a solid basis for future learning.

There was also an increased focus on personal connections to Climate Change after completing the module. Participants directly associated Climate Change with their own encounters with extreme weather phenomena. This is consistent with the findings of Khadka et al. (2021) who suggest that place-based learning works well for teaching about Climate Change because it includes visible, local effects that relate human activity to the phenomenon. The module appeared to enable a transition from theoretical ideas to actual experiences, encouraging participants to establish a connection between Climate Change and tangible occurrences in their personal lives. Having a broadened viewpoint is essential for future teachers since they will be responsible for equipping learners with the necessary skills to navigate a continuously

changing environment. Some participants (e.g., D, N, S) demonstrated a clear grasp of the cause-and-effect relationship between human activities and Climate Change. This implies a comprehensive understanding of climate science and the capacity to draw parallels between individual experiences and more extensive ecological changes. This connection is crucial for future educators who will need to effectively communicate the complex science of Climate Change to their students.

Participants also voiced scepticism over the possibility of fully reversing Climate Change (DD, Q). This emphasises the need for developing critical thinking skills and encouraging open conversations about the complexities of Climate Change solutions in teacher preparation programmes (Reimers, 2021). Future teachers must be equipped to address both the pressing nature of the climate crisis as well as the diverse viewpoints regarding possible solutions.

Students' Understanding of the Causes of Climatic Change

The module data before suggests the participants possessed some understanding of the complex and interconnected nature of environmental issues, while the post-module data suggests potential shifts in their focus, particularly regarding Climate Change.

Participants' awareness of Climate Change is almost universal (36 out of 40 responded "Yes" when asked whether they had heard of it). Venghaus et al. (2022) reports that there is a growing public awareness of Climate Change. However, awareness doesn't necessarily equate to scientific understanding (Sezen-Barrie et al., 2019). The module probably did not introduce the topic for the first time, but instead sought to enhance their pre-existing knowledge and clarify any possible misunderstandings. The consistency with the findings of Venghaus et al. (2022) indicates that the module may have successfully stressed these key components of Climate Change.

The responses show that the participants had a common understanding of key Climate Change concepts. They recognise it as a long-term shift in weather patterns (e.g., Participant A: "gradual change in weather patterns over time"). Many correctly identified human activities, particularly greenhouse gas emissions, as key contributors (e.g., Participant G: "caused by greenhouse gases"). These findings correspond with the research conducted by Lehtonen et al. (2019), which indicates that successful Climate Change Education should focus on highlighting the role of human activities in causing Climate Change and the long-term impacts it will have.

Pre-service teachers also recognised the adverse effects of Climate Change. These included rising temperatures (e.g., Participant E: "gradual and sustained rise in atmospheric temperature") and extreme weather events (e.g., Participant S: "heavy precipitation, flooding, and sea level rise"). These responses also agree with the scientific consensus on Climate Change impacts by the IPCC (2022).

Although the participants had a common knowledge of fundamental ideas, their responses differed in terms of thoroughness and precision. Some, like Participant LL, offered detailed explanations. Participant H offered more succinct explanations. This indicates a spectrum of existing knowledge and different degrees of involvement with the subject matter.

Responses from participants also revealed emotions in relation to Climate Change. Some expressed fear (Participant A: "terrified of it") or concern (Participant LL: "concerned about Climate Change"). Conversely, some participants demonstrated a sense of urgency in addressing the issue (Participant AA: "we also can fix our mess before it's too late"). These emotional responses highlight the personal significance many participants attach to Climate Change, echoing the call for Climate Change Education that fosters feelings of empowerment and agency (Lehtonen et al., 2022).

Out of the 40 participants, 32 demonstrated knowledge of the concept of Climate Change, showing a consistently high level of awareness throughout the module. This is important because it shows how well the module engages participants and keeps the topic at the centre of their educational experience. Nevertheless, it is crucial to differentiate between the state of being aware and the state of comprehending. As mentioned earlier, being aware of something does not necessarily mean that one is scientifically literate.

An important accomplishment of the module was strengthening the recognition that human actions play a large role in causing Climate Change. The primary factors mentioned by participants were greenhouse gas emissions (19/32) and their function in heat entrapment (e.g., Participant U) resulting from the combustion of fossil fuels and deforestation; however, they did not mention which greenhouse gases and how. Acquiring such knowledge is essential as it equips teachers to effectively communicate precise information to their future students, potentially influencing the comprehension and actions of the next generation in relation to Climate Change.

The participants' enhanced comprehension of the implications of Climate Change, including escalating temperatures, severe weather occurrences, intense rainfall, flooding, and the rise in sea levels, aligns with the conclusions drawn by the IPCC (2022). Having a thorough awareness of the extensive and profound effects of Climate Change is crucial, as it enables future educators to effectively convey the gravity of the issue to their students. By recognising these effects, the participants are more prepared to engage in discussions on the repercussions of Climate Change in a manner that is both scientifically precise and applicable to everyday life.

The gap in levels of comprehension among participants shows us the challenges found in Climate Change Education. While certain individuals, such as LL, showed a profound understanding of the topic, others offered more rudimentary comments. This gap implies that a universal solution may not be effective. Varied educational tactics are necessary to accommodate different levels of prior knowledge and involvement. This may entail the provision of customised learning experiences, specific feedback, and supplementary resources for individuals requiring further assistance.

The participants' emotional reactions to Climate Change, which encompass dread, concern, and a sense of urgency, demonstrate a personal attachment to the subject. The emotional involvement might serve as a potent catalyst for taking action. According to Lehtonen et al. (2022), Climate Change Education should have the dual purpose of providing information and enabling citizens to take proactive measures. By recognising and dealing with these emotional reactions, educators can assist pre-service teachers in transforming their concerns into productive activities, promoting a feeling of empowerment and accountability.

The module effectively aided participants in identifying human activities as the main driver of Climate Change. This is shown by the fact that 27 out of 32 participants mentioned problems including deforestation and combustion of fossil fuels, which are acknowledged as major contributors by the scientific consensus (IPCC, 2022). This change of perception implies that the module addressed possible misunderstandings on the reasons for Climate Change but not necessarily how they contribute to Climate Change. Future teachers who will have to successfully explain this complex issue to their students must grasp the basic science underlying Climate Change too.

Future educators must develop their critical thinking skills, give the next generation a strong grasp of climate science, and provide opportunity for open discussions in order to enable them to address Climate Change issues. Furthermore, the module helped participants to understand the need for addressing Climate Change more fully. The participants are aware of the need for people embracing sustainable behaviours and the critical role that businesses, local governments, and international organisations play in promoting systemic change. Future educators need to have a thorough grasp of collective responsibility as well in order to train the next generation to address this global issue.

Communication of Climatic Change Issues and Climatic Change Education

Prior to the module, participants depended on traditional media platforms like television and radio to obtain their Climate Change knowledge (Table 4.5). These conventional methods continue to play a crucial role in spreading knowledge to wide-ranging audiences, particularly those who may not actively search for climate-related content on the internet. However, the analysis of post-module data indicates a transition towards more organised and dependable sources of information (Table 4.12).

Upon finishing the module, 24% of the participants identified universities as their main providers of scientific information. This demonstrates a dependence on higher education institutions for obtaining comprehensive and reliable climatic knowledge. According to Molthan-Hill et al. (2022) and Valentín et al. (2015), it is crucial to incorporate thorough Climate Change Education into the official curriculum of higher education institutions in order to cultivate a knowledgeable teaching workforce. The transition from conventional media to scholarly sources demonstrates a heightened level of comprehension and the capacity to analyse intricate environmental matters in a discerning manner.

The study found that the internet remains a widely accessible and comprehensive platform for obtaining information. It specifically identified 25 instances when the internet was mentioned, with 12 of those instances directly referring to YouTube. This shows the internet's function in offering a wide array of resources and viewpoints on Climate Change. As said earlier, Meel and Vishwakarma (2020) warn that the reliability and partiality of online information might differ greatly which emphasises the significance of providing pre-service teachers with the necessary abilities to critically evaluate material and distinguish between credible and misleading sources.

Although the internet is widely used, social media sites like WhatsApp had a small direct influence, being mentioned only three times. This indicates that, although social media is widely used for communication, its utilisation for educational objectives in the field of climate science is restricted among pre-service teachers. This emphasises an earlier statement of Natarajan (2017) who asserts that the capacity of social media for network-based knowledge transfer should not be undervalued. Hence, it is imperative for teacher preparation programmes to investigate methods for efficiently utilising social media to disseminate reliable climate science knowledge and foster substantial dialogues among prospective educators.

The importance of formal education in improving understanding of Climate Change was further emphasised by five participants who identified schools as crucial sources of information. This is consistent with the research conducted earlier by Eilam (2022), which emphasises the importance of incorporating Climate Change Education into different academic disciplines. Offering pupils a thorough Climate Change Education through official institutions guarantees that they acquire the essential analytical abilities and information to understand and tackle environmental problems with effectiveness.

The statistics from the post-module clearly demonstrate that the comprehension of Climate Change issues among pre-service teachers greatly improves following their participation in a specialised training module. Higher education institutions play an important role in enabling this advancement by offering a well-organised and thorough learning environment. The need for formal education continues and the growing emphasis on reliable academic resources highlight the critical role that well-designed academic courses play in shaping informed and proactive future teachers.

The improvement in the comprehension of Climate Change among science teachers in training following the completion of the module showcases the effectiveness of well-organised educational interventions. Universities and formal education institutions are essential for delivering comprehensive and rigorous climate education.

Although traditional media and the internet are still significant sources of information, the increasing emphasis on academic institutions highlights the necessity of offering instructional content that is of superior quality and reliability.

Educational programmes can improve the capacity of pre-service teachers to obtain, disseminate, and instruct reliable climate science knowledge by promoting critical assessment skills and utilising different communication channels. This holistic strategy will enhance the knowledge and proactive nature of the teaching community, enabling them to effectively tackle the urgent global concerns presented by Climate Change.

The table below summarises the responses of pre-service teachers' understandings of Climate Change after the Biological Science for Educators module into the same nine themes (Impact of pollution, Local flooding effects, Waste management and recycling, Health issues of Climate Change, Concerns for food security, Effects of Climate Change and its Education, Understanding complex environmental and climatic change issues, Communication of Climate Change issues and Climate Change Education, and Students' Understanding of causes of Climate Change) that were identified before the module.

Table 5.3

Pre-Service Teachers' Understandings of Climate Change After Completing a Biological Science for Educators Module

Themes	Understandings
Impact of pollution	Participants consistently identify pollution as one of the major environmental issue. Some participants attribute this to industrial activities that releases dust and carbon emissions that contribute to global greenhouse gas levels, polluting air.
Local flooding effects	Recent local events and personal experiences have raised participants' awareness of floods as a major environmental threat. They understand that flooding is an impact of Climate Change but not how.

Waste management and recycling	The participants recognise that poor waste management is one of the major environmental concerns and the possible effects this have on the environment.
Health issues of Climate Change	Participants have an awareness of the health consequences of Climate Change. However, their understanding of its health implications seems limited, as they primarily mention issues like sinus problems and skin cancer.
Concerns for food security	Participants are aware that floods can affects the growing of crops, but they did not specifically address food security and Climate Change.
The effects of Climate Change and its education	Participants' Climate Change understanding improved substantially. While they understood Climate Change 's risks, such as harsh weather destroying homes and life, they learned to distinguish Climate Change from pollution and its socioeconomic implications on livelihoods, health, and weather in the module.
Understanding complex environmental and climatic change issues	Participants understood environmental and Climate Change topics more effectively after the module. They understood how pollution, flooding, and Climate Change interact. Participants also acknowledged Climate Change's impact on health, livelihoods, and global well-being. They concluded that humans cause Climate Change by combining personal and scientific evidence.
Communication of Climate Change issues and Climate Change Education	Participants turned to more dependable sources of information regarding Climate Change following the module. After the

	module, universities were chosen as the primary source of Climate Change Education for participants.
Students' understanding of causes of Climate Change	After the module, participants had an improved and comprehensive understanding of Climate Change. They understood its sources, such as greenhouse gas emissions, and effects, like rising temperatures and harsh weather. Most participants could link Climate Change to human activity. The module improved participants' comprehension of sustainable behaviour and Climate Change mitigation entities; however, participants were unable to explain their responses on a deeper level, for example, what are the natural causes of Climate Change or what are the greenhouse gases?

4. What are pre-service science teachers' practices in relation to Climate Change after completing a Biological Science for Educators module?

Individual Action

The optimistic perspective and varied suggestions put forth by the participants, such as individual endeavours to decrease carbon footprints and educational campaigns indicate that the module potentially instilled a sense of ownership and responsibility in the pre-service teachers. Their encouragement of solutions that focus on renewable energy (B, K, FF), sustainable habits (MM, C, N), and infrastructure improvements (O, AA, BB) also possibly shows a grasp of the necessity for systemic change alongside individual efforts. This broader perspective is crucial for future educators who will need to equip their students with a comprehensive understanding of climate action (Monroe et al., 2019; Stevenson et al., 2017).

The participants acknowledged individual responsibility for modifying behaviour (e.g., reducing energy usage, utilising public transportation) while recognising the significance of collaborative efforts (D, N, W, Z). The importance that Participant D places on collective action underscores the potential of the module to cultivate a feeling of empowerment and unity. This is consistent with the demand to instil in future generations, who will be required to collaborate in order to tackle Climate Change, a sense of collective agency (Hormio, 2023; Trott, 2019) .

Education as Empowerment

Although 17 participants indicated that they did not take any action, the clarification provided by Participant II illuminates possible obstacles. The reliance of certain individuals on limited resources, such as charcoal for domestic use, impedes their ability to adopt particular sustainable practices. Literature suggests that socioeconomic constraints influence the adoption of sustainable practices (Hampton & Whitmarsh, 2023; Tschakert et al., 2017). However, their willingness to explore alternative options indicates that they are prepared to take action when the situation demands it, resonating with Ajzen (1991) Theory of Planned Behaviour, which asserts that perceived behavioural control and intention are crucial determinants of behaviour.

The explicit correlation that Participant O establishes between the module and a change of their actions is notable. The fact that pre-service teachers attribute an increased awareness of the significance of individual action to the module implies that it might enable them to assume responsibility for their environmental impact. Monroe et al. (2019) provide further support for this discovery by emphasising the significance of environmental education in developing environmentally conscious behaviour by enhancing awareness and understanding.

The pre-service teachers exhibited a nuanced comprehension of climate action, placing equal emphasis on systemic change, individual accountability, and collaborative endeavours. This statement exemplifies the multi-level strategy endorsed before by Fisher and Leifeld (2019), which emphasises the necessity for coordinated endeavours at the individual, societal, and institutional levels in order to achieve successful climate action. Through the cultivation of a sense of agency and the provision of a multifaceted perspective, this module has the ability to effectively prepare future science teachers to enable future generations to confront the complex challenges associated with Climate Change. This follows the pedagogical framework suggested by Salazar et al. (2022) and *Across the spectrum: Resources for environmental educators* (2016), which says there is a need to equip educators with the necessary expertise and resources to comprehensively tackle intricate environmental challenges.

Shared Responsibility

A total of seventeen participants selected individual accountability as the sole responsibility for addressing Climate Change. The remaining participants selected various combinations of responsibility, such as enterprises, international organisations, all levels of government, and individuals.

The distribution of responsibilities in this manner is consistent with the principles outlined in Taylor (2016), which assert that in order to effectively mitigate Climate Change it is necessary to involve a wide range of stakeholders. The acknowledgment of corporations as contributors and potential agents of change (Participant H) is indicative of the increasing focus on corporate environmental accountability, as explicated by Morgera (2020).

With this comprehension, pre-service educators are equipped to assess corporate practices with a critical eye and promote sustainable business models in the classrooms of the future. Shabalala (2023) highlights the criticality of integrating this viewpoint into educational frameworks, emphasising the need to educate students about the wider socioeconomic systems that impact environmental consequences. Pre-service teachers have the ability to promote a critical awareness in their students, thereby empowering them to not only embrace sustainable behaviours on an individual level but also to actively participate in more extensive systemic transformations.

In addition, the multi-stakeholder approach is consistent with the conclusions drawn earlier by Betsill and Bulkeley (2021) and Fisher and Leifeld (2019), which emphasise the interrelated responsibilities of international organisations, governments, and businesses in tackling worldwide environmental issues. Future educators will be able to effectively convey to their students the significance of collective action due to their enhanced comprehension of the complexities of climate governance, which is ensured by incorporating these perspectives into teacher education.

Overall, the diverse perspectives expressed by the participants regarding accountability for climate action emphasize the need for an all-encompassing educational strategy that considers the involvement of corporations, governments, individuals, and the international community. This is consistent with current scholarly works that support the use of integrated approaches in environmental education (Damoah et al., 2024). As a result, pre-service teachers will be in an ideal position to effectively drive transformation in their classrooms.

Multi-level Collaboration

The discussion around local governments promoting sustainable practices suggests that the module equipped participants to consider the role of local governments in creating a more sustainable future. The mention of international organisations facilitating global initiatives

(Participant MM) also acknowledges the need for coordinated international action, such as agreements like the Paris Agreement. This global perspective is needed for future educators who will need to prepare students to engage in collaborative solutions across international borders.

The emphasis on the interconnectedness of the climate crisis (Participants O, P) aligns with the notion that comprehensive solutions require collaboration between individuals, businesses, governments, and international organisations. A holistic understanding enables pre-service teachers to become effective change agents, fostering collaboration within their schools as well as with their communities.

In addition, the increase in personal climate action among 20 participants indicates that the module potentially served as a catalyst for a shift in behaviour. Still, the confusion of the three participants shows the need for more educational initiatives that provide practical guidance and clarify effective approaches. Examples, case studies, and opportunities to develop action plans could be incorporated into future iterations of the module. Leal Filho et al. (2023) say that the UN Sustainable Development Goals (SDGs) must be included into higher education, so that new teaching and learning approaches that might transform education can be implemented together with a recognition and understanding of educational goals. Innovative techniques that seek to advance education for sustainable development include unconventional, student-centred teaching and learning approaches such problem-based learning, inquiry-based learning, games, or case studies. However, further educational initiatives are necessary to provide hands-on training and clarify successful approaches.

Table 5.4. summarises the participants' responses that were divided into the same four identified themes (Individual action, Shared responsibility, Education as empowerment, Multi-level collaboration) regarding practices in relation to Climate Change after completing the Biological Science for Educators module.

Table 5.4

Pre-Service Teachers' Practices in Relation to Climate Change After Completing a Biological Science for Educators Module

Themes	Practices
Individual action	Participants emphasised the need for individual Climate Change efforts like lowering carbon footprints, energy use, and public transportation. Their encouragement of renewable energy, sustainable practices, and infrastructure improvements demonstrates an awareness of the need for systemic change in addition to individual efforts.
Shared responsibility	Participants stated the need for shared responsibility among individuals, businesses, international organisations, and governments for addressing Climate Change.
Education as empowerment	Socioeconomic restrictions, such as relying on few resources like charcoal, restricted many participants from implementing sustainable practices. However, alternatives are considered wherever possible. Some participants felt the module impacted their behaviour and increased their awareness and responsibility. Pre-service teachers understood climate action, suggesting systemic change, individual responsibility, and collaboration.
Multi-level collaboration	Participants suggest that local governments are crucial for sustainability. They also emphasise cooperation between individuals, businesses, governments, and international organisations. Some people are inspired to take climate action,

	while others are still unsure and require more practical support and education.

Tables 5.5. and 5.6. shows a comparison of pre-service teachers' understandings and practices before and after completing a Biological Science for Educators module.

Table 5.5

Pre-Service Teachers' Understandings of Climate Change Before and After a Biological Science for Educators Module

Themes	Understandings before the module	Understandings after the module	Participants and interview snippets
Impact of pollution	The main environmental problem connected to a variety of human activities like burning fuel and trash is understood by participants to be pollution. They know that pollution has instant consequences for the environment and human health, including respiratory illnesses and contaminated rivers. Furthermore understood is the connection between pollution and other environmental problems such as Climate Change. The participants also stress the need for increasing public knowledge and understanding of pollution and the part that preservice science teachers have in developing Climate Change Education.	Participants invariably recognise pollution as a major environmental concern, classifying it into three distinct categories: air, water, and land pollution. They recognise that urban areas suffer from high levels of air pollution due to industrial activities, which release dust and cause carbon emissions, contributing to global greenhouse gas levels. This development in knowledge is a result of a more precise classification of pollutant kinds and a concentrated awareness of the major effects of industrial activity in metropolitan regions. Further evidence of a more sophisticated understanding of the effects of pollution is the gro	Participant T:" pollution, air and water, affects communities on a daily basis and as a person living with asthma, air pollution is a huge problem for me and people like me." Participant F: " I experienced water pollution in the past few months. Due to water shortage we have to fetch water from rivers; however, that was challenging as people throw dirt there."

		wing knowledge of how local pollution leads t o more general global problems like greenhou se gas emissions.	
Local flooding Effects	While participants have an awareness of the effects of flooding, which included injuries, financial losses, psychological impacts and environmental damage, they placed emphasis on displacement and loss of livelihoods. Participants understand the connection between food insecurity and flooding as a result of their own loss of agriculture. Additionally, participants made a connection between Climate Change and flooding, stating that the change of weather patterns have negative impacts.	The participants' understanding of flooding as a major environmental concern has increased as a result of recent local events and personal experiences. They have now gained a deeper understanding of the relationship between flooding and broader issues, such as Climate Change. The impact of floods on infrastructure, livelihoods, and social well-being was noted by participants in their communities. They now look at the importance of infrastructure development, emergency response strategies, and adaptation to mitigate the effects of flooding.	Participant NN, Participant P: "victims of floods" Participant C Participant M, Participant F, Participant O, Participant DD, Participant CC Participant G: “I chose flooding because it’s also one of the environmental issues that I have come across in my own home. I also saw this issue happening in the different communities.”

			Participant O: “In our Province KZN we faced devastating floods.”
Waste management and recycling	Participants have an understanding of the environmental concerns that are associated with poor refuse management, particularly in the context of population growth, urbanisation, and economic development. They realise that solid waste is increasing, especially with inadequate waste management facilities. This contributes to the effects of Climate Change and contributes to the emission of greenhouse gases and pollution to the environment. Participants identify numerous factors that, especially in rural regions, contribute to the overcrowding of landfills, inadequate waste collection services, and littering. Cleanup, reuse, and recycling initiatives are suggested by participants.	Although at a lower rate, participants continued to recognise that poor waste management is a major environmental concern, with a particular focus on informal settlements. They are aware that these regions frequently lack formal waste management systems, which results in higher health risks and environmental degradation. Although the module may not have described the process and actions in detail, it may have assisted students comprehend that they are a contributing factor to Climate Change.	Participant A: “poor waste management in rural communities, in my community per se, we do not have the municipality coming to collect the waste, people just dispose waste anyhow and are not informed about the [correct] disposal.” Participant G: “I chose poor waste management because it is one of the issues that is not yet addressed to many informal settlements. I have seen many different places where there is poor waste management.”

			Participant T: "When temperatures get really high, I will be one of those who will get sick as my immune system is not that strong."
Health issues of Climate Change	Participants are concerned about the potential negative health impacts of Climate Change. They note the immediate effects of extreme weather, such as a greater chance of suffering from illness during hot weather and an increase in breathing difficulties. Their experiences show the connection between health challenges, including heat-related illnesses and Climate Change.	The participants gained an improved understanding of the effects of Climate Change. However, their understanding of its health consequences seems limited, as they solely mention issues like sinus issues and skin cancer.	Participant LL: "extreme temperatures causing] irritation to my skin and lots of respiratory problems, specifically sinusitis." Participant B Participant BB: “Some people have skin cancer due to high temperature.” Participant GG: “it is because it one of the things I get to experiences and see as in like every day. Back home we have heavy industries who contribute to air pollution and as for me a person who’s always had sinus issues, I get

			affected a lot in terms of breathing and my eyes tend to each a lot.”
Concerns for food security	Participants understand that Climate Change impacts more than the ecosystem around them, and in particular its effects on food security. Participants expressed concern regarding the potential broader consequences, including negative effects on the economy and the communities they live in.	The participants remained aware that floods can impact the growth of crops; however, they did not specifically address food security and adaptation to Climate Change.	Participant D, Participant O, Participant AA: "More flooding in my area causing loss of many assets." Participant BB: “my community is vulnerable to flooding due to heavy rains and storms. Last year we’ve experience lot of flooding in KwaZulu-Natal which had negative impact to a lot of people: some were left homeless, some passed away, some lost their properties like cars, businesses were damaged and crops died.”
			Participant H: "drastic changes to weather each day”

The effects of Climate Change and its ducation	Participants had an understanding that Climate Change is a worldwide problem. They linked personal experiences of changes in the weather and severe events, such as heatwaves and rainfall, with Climate Change. Certain individuals associated health issues, such as skin cancer, with Climate Change. Participants also agreed that it is important to increase awareness and education regarding Climate Change.	Participants showed an improvement in their understanding of Climate Change. They acknowledged the potential risks caused by Climate Change, including the loss of lives and homes as a result of severe weather. The module helped them differentiate between Climate Change and other concerns, such as pollution, to form links with one another and to comprehend the broader socioeconomic consequences.	Participant I: "extreme weather conditions such as dangerous thunderstorms and lightning, heavy rain, hot and cold days" Participant U: "with Climate Change I have experienced the sun reaching 43 degrees and cold that is below 0 degrees, which is unpleasant and had made me sick." Participant F: "change in climate left us with floods after that heat was experienced which caused the land to be dry." Participant NN: “The third choice I chose is because I have not only heard and learned about it, but I have now seen it. I have seen people losing their homes, dying, drowned in the same

			water that we prayed for since we also had shortages of water because of high temperatures and low rainfalls. It is real and it threatens my, our future.”
Understanding complex environmental and climatic change issues	Participants showed understanding of environmental concerns but did not always understand the links or impacts on each other. They expressed the importance of actions to deal with the challenges of pollution, flooding, and population increase on the environment and public health. Although many acknowledged that human activities were contributing to Climate Change, there were gaps in understanding, particularly with respect to the processes that connect greenhouse gas emissions to changes in weather patterns. Participants also encouraged education and action in order to raise public awareness and	After the module, participants showed an improved understanding of environmental and Climate Change issues. They understood the relationship of pollution, flooding, and Climate Change, grasping the influence of these issues. The participants also expressed their awareness of the extensive consequences of Climate Change, which included living conditions and health. They concluded that human activity is the cause of Climate Change by combining personal experiences with scientific explanations. The module aided their transition from theoretical knowledge to practical actions. A number of participants	Participant A: "burning of fossil fuels, overpopulation and use of vehicles" Participant Y: "Climate Change is about the changing weather patterns." Participant F: "it is about change in weather conditions due to global warming. Our contribution to Climate Change by producing large amounts of CO_2." Participant V Participant DD

	systematic changes that will mitigate the effects of Climate Change.	showed uncertainty about the possibility of reversing Climate Change.	Participant O: "what I think about Climate Change is that it is an issue that should be taken into consideration and we must raise awareness about it before it's too late." Participant CC: "I think about what causes it, the negative impacts about Climate Change in our environment and what can we do to reduce it." Participant G
Communication of Climate Change issues and Climate Change Education	Conventional media channels, such as television and radio, were the primary sources of participants' Climate Change knowledge, suggesting the continuing value of these mediums. The internet's growing importance was also reflected by the participants.	Following to the module, participants chose more reliable sources of information concerning Climate Change as universities became more frequently mentioned.	Participant E Participant M Participant C Participant T Participant A Participant K

	Universities were identified by many participants as critical informational sources, emphasising the necessity of education in equipping students with the necessary knowledge and skills to understand and address Climate Change.		
Students' understanding of the causes of Climate Change	Participants understand that human activities, such as the combustion of fossil fuels and deforestation, are the primary causes of Climate Change. Nevertheless, they are not aware of the natural causes, such as oceanic activities and volcanic eruptions. They are aware of the greenhouse effect and greenhouse gases, but they are not as informed about the process and the various gases.	Participants gained a more in-depth understanding of Climate Change after completing the module. They acknowledged its causes, particularly human activities such as greenhouse gas emissions, and its consequences, including extreme weather and rising temperatures. The majority of participants were able to establish a connection between human activities and Climate Change, but were still unsure of natural causes and processes regarding greenhouse gases despite the fact that their levels of knowledge varied. The module's expansion of the participants'	Participant H Participant II Participant C, Participant AA Participant U Participant A: "gradual change in weather patterns over time" Participant G: "caused by greenhouse gases"

		understanding of the need for sustainable behaviours and the roles of various entities in mitigating Climate Change was evident.	Participant E: "gradual and sustained rise in atmospheric temperature"

Table 5.6

Pre-Service Teachers' Practices in Relation to Climate Change Before and After a Biological Science for Educators Module

Themes	Practices before the module	Practices after the module	Participants' and interview snippets
Individual action	In an effort to respond to Climate Change, pre-service teachers implement different actions. In addition to supporting systemic changes, such as stronger industry regulations, the participants concentrate on individual actions, such as reducing their own electricity consumption and other personal measures. They understand that in order to effectively address Climate Change , individual initiatives are necessary.	The importance of individual actions, including the reduction of carbon footprints, usage of energy, and the use of personal cars, was emphasised by the participants in order to address Climate Change. Their level of awareness for individual action remained similar which was evident in their detail of sustainable practices.	Participant L: "The national or local government cannot control how people live their lives, but it should be a choice made by an individual to change their bad lifestyle habits to tackle Climate Change." Participant B Participant K Participant FF Participant MM Participant C

			Participant N Participant O Participant AA Participant BB Participant D Participant W Participant Z
Shared responsibility	Participants expressed the need for shared responsibility for addressing Climate Change. Many participants agreed that governments, businesses, and individuals all play important roles. The participants also believe that education is crucial, as it develops both individual and collective action. They emphasised the importance of education at all societal levels too and group collaboration in order make Climate Change initiatives more realistic and effective.	Participants emphasised the importance of shared responsibility after the module, which involves not only individuals but also businesses, international organisations, and all levels of government, in order to address Climate Change. They identified the major part that businesses play in both causing and addressing environmental issues.	Participants H Participants B Participants C Participants P Participants BB Participants EE Participants MM Participant H

Education as empowerment	The participants have raised the need for increasing public awareness and education regarding Climate Change. They believe that education can increase the likelihood of individuals supporting laws and changing their actions. The majority of the participants are of the opinion that society is capable of reducing the effects of Climate Change.	Many participants were unable to implement sustainable practices due to socioeconomic constraints, such as the necessity of relying on scarce resources like charcoal. Nevertheless, there is a tendency to find alternative options when possible. A small number of participants reported that the module had a direct impact on their behaviour, fostering an increased sense of personal responsibility and awareness. Pre-service teachers continued to emphasise their understanding of climate action by emphasising personal responsibility, collaboration, and systemic change.	Participant O: "Teachers can be the agent that could educate people about taking action for Climate Change." Participant II Participant O
			Participant B: "avoid using my mother's car"

Multi-level collaboration	Participants called for a multifaceted strategy to address Climate Change that prioritised partnerships among governments, businesses, communities, and individuals. However, they failed to mention specific actions and what impact they would have on addressing Climate Change.	Participants emphasised the importance of collaboration among governments, businesses, international organisations, as well as individuals. While some participants are motivated to take personal climate action, others are unsure how, and others feel unsure and see a need for more practical education and support.	Participant FF: "If it is done this way, everyone will understand. It starts from the world to the whole community and to all the individuals to make a change, If it is done this way there will be a very big change." Participant H: "I think the governments, both local and national, firstly have to implement the Climate Change Education to South African communities to raise awareness of the Climate Change issue and come up with ways to reduce it." Participant MM Participant O Participant P

The results above discussed the responses from the questionnaires which included personal experiences, causes, effects, communication, and roles as contributing factors to the understandings and practices of climate change. This showed a superficial understanding and practices of Climate Change. Additionally, there were several key themes that were noted: these themes were summarised into tables, which portray pre-service science teachers' understandings and practices of climate change before and after the module, such as the impact of pollution, local flooding effects, waste management and recycling, health issues related to climate change, concerns for food security, the effects of climate change and its education, understanding complex environmental and climatic change issues, communication of climate change issues, and students' understanding of the causes of climate change.

The following section summarises the findings, providing a conclusion, recommendation, implications, and the study's limitations.

5.3 Findings

The main findings from this study on the influence of a Biological Science for Educators module on the understandings and practices of pre-service teachers (PSTs) regarding Climate Change are summarised in chapter 5. The findings of the study emphasise the importance of the findings previously discussed. Furthermore, it provides suggestions for improving teacher education as well as the gaps found. The chapter concludes with recommendations for future research that will address the limitations identified in this study.

This study aimed to explore the understandings and practices of pre-service teachers (PSTs) regarding Climate Change. By assessing PSTs' knowledge and actions through a comprehensive qualitative approach, this research sought to identify gaps and opportunities within existing teacher education programmes.

The findings showed the importance of teacher training in preparing future teachers with both the theoretical understanding and practical skills necessary to effectively teach Climate Change concepts and make a difference. While the study showed little improvements in PSTs' understandings of Climate Change and confidence to teach, it also showed the need for enhanced and interactive education modules.

By addressing these educational gaps, this research contributes to the the goal of developing stronger and more flexible science education curricula. This will empower teachers to more effectively teach their students about Climate Change, thus developing the next generation of learners who will be more informed and engaged with one of the most critical issues of our time.

5.4 Summary of Results and Findings

The study began by exploring PSTs' basic awareness and understanding of Climate Change which will be summarised below. Participants were asked various questions to explore their Climate Change understandings, which included where they had heard about Climate Change, how they defined it, its causes and effects, and the actions they took to address it. The results showed that all participants (100%) had heard of Climate Change. However, the depth of their understandings varied. Some PSTs revealed a strong grasp of Climate Change, while others showed only a simple awareness.

Additionally, the study revealed that, despite their awareness, there was a limited range of actions taken by PSTs to address Climate Change. This gap between understanding and action shows an important area for improvement in teacher training programmes. While PSTs may be aware of Climate Change and its importance, they often lack the practical skills to integrate effective Climate Change Education and mitigation strategies into their teaching practices.

Question 1: What are pre-service science teachers' understanding of Climate Change before a Biological Science for Educators module?

The participants' views on major environmental issues, including pollution, flooding, waste management, Climate Change, traffic, and overpopulation was explored. Pollution was the most chosen concern due to its frequent occurrence and impact on human health, ecosystems, and societal well-being. Participants also noted the interconnectedness between pollution and other issues like Climate Change and flooding. Flooding was also identified as having severe consequences due to their personal encounters, including loss of life, economic destruction, and displacement. Participants linked flooding to Climate Change and emphasised the need for better mitigation strategies. Furthermore, poor waste management, particularly in rural areas,

was another major concern. Participants were aware that poor waste collection services lead to environmentally harmful practices like burning and unauthorised dumping.

Although a smaller percentage of participants highlighted Climate Change, it was recognised as an major concern. Climate Change was recognised for its health impacts, such as heat-related illnesses, respiratory problems, and cancer. The participants' responses were aligned with research that predicted increasing temperatures, droughts, and extreme weather in Southern Africa (Nhemachena et al., 2020; Ziervogel et al., 2014). Additionally, personal encounters from participants that mentioned drastic weather changes, such as dangerous thunderstorms, extreme heat and cold, and flooding emphasised the need for raising awareness and educating our future teachers on Climate Change to foster effective mitigation and adaptation strategies.

Furthermore, while many recognised human activities as major contributors, there were gaps in their understanding, for example, in comprehending the specific mechanisms linking greenhouse gas emissions to weather pattern changes. This lack of detailed understanding shows the need for enhanced educational efforts that bridge these gaps and promote a more deeper understanding of Climate Change. Effective strategies, including the use of relatable examples and correction of misconceptions, are important to enhancing understandings and encouraging participation in climate action.

Participants' were also aware of the interconnected nature of environmental issues, Climate Change and the importance of education in addressing them. The role of traditional media, the internet, and educational institutions in sharing Climate Change information was also important as the findings showed that these were the most common platforms that participants use to obtain their information.

Question 2: What are pre-service science teachers' practices in relation to Climate Change before completing a Biological Science for Educators module?

The pre-service teachers' practices related to Climate Change before completing the Biological Science for Educators module reflect a mix of individual actions and calls for systemic changes. While many participants recognised the importance of individual efforts, such as conserving electricity and proper waste disposal, there was also a strong emphasis on the need for policy

shifts and industry regulations. Participants showed awareness of the challenges of Climate Change and the need for solutions at both individual and societal levels.

Education and awareness were common responses from the participants when asked about what action could be taken. They emphasised the power of education as well to promote public support for climate policies and help individuals adopt more sustainable behaviours. These responses portray the importance of both individual and collective action and are supported with studies on climate literacy, which advocate for education that not only imparts knowledge but also empowers individuals to take action and think critically about climate issues.

The participants' awareness of shared responsibility in addressing Climate Change acknowledged the need for multi-level collaboration involving individuals, communities, businesses, and governments. Despite the strong focus on individual actions, the participants also recognised the importance of community-based initiatives and the need for systemic reforms to address the broader challenges of Climate Change. The findings suggest that pre-service teacher education programmes should prioritise equipping future educators with the knowledge and tools to foster comprehensive climate action, enabling them to guide their students in becoming proactive agents of change.

Question 3: What are pre-service science teachers' understanding of Climate Change after a Biological Science for Educators module?

After completing the Biological Science for Educators module, pre-service teachers showed a consistent understanding of Climate Change-related issues with a deeper understanding of its various forms and consequences, particularly pollution, flooding, and waste management. Their recognition of pollution as a primary concern persisted. Participants acknowledged the severe impact of local flooding, relating it to both recent weather events experienced and their Climate Change knowledge. This understanding suggests that, while the module reinforced their awareness, changing deeply rooted views calls for ongoing effort and extensive educational strategies.

While participants showed an deeper understanding of the long-term effects of Climate Change, particularly in terms of health issues and food security, there remains a need for more in-depth education to be able to understand the processes and how they contribute to impacts,

for example, why they contribute to health issues. Addressing these gaps will empower pre-service teachers to better educate future generations on the broad impacts of Climate Change and the importance of sustainable practices.

The number of participants who identified Climate Change as their primary environmental concern increased slightly, which could indicate an improved understanding to distinguish it from other environmental issues. The module deepened their awareness of the broader socioeconomic impacts of Climate Change, including its effects on livelihoods and globally. Participants also linked their personal experiences with severe weather to scientific explanations, which created the urgency of addressing Climate Change.

Furthermore, the module also broadened participants' views on the interconnectedness of various environmental issues. They acknowledged the ways in which Climate Change is caused and linked it to pollution and inadequate waste management. Additionally, participants had an increased understanding of the role of human activities in driving Climate Change, the significance of greenhouse gas emissions, and the long-term impacts on weather patterns. However, participants still did not provide further details on the processes and natural causes but they did mention a few different greenhouse gases which was a challenge before the module.

Question 4:. What are pre-service science teachers' practices in relation to Climate Change after completing a Biological Science for Educators module?

Pre-service teachers, after completing the Biological Science for Educators module, showed a slight shift in their practices related to Climate Change. They portrayed a strong sense of ownership and responsibility, with many participants mentioning individual actions to reduce carbon footprints, promote renewable energy, and adopt sustainable habits. Along with a sense of personal responsibility, participants also knew that systemic changes were needed. This showed that they had an understanding of taking action on Climate Change but they struggled with bigger actions or different actions outside of lowering emissions at home, avoiding littering and using cars less.

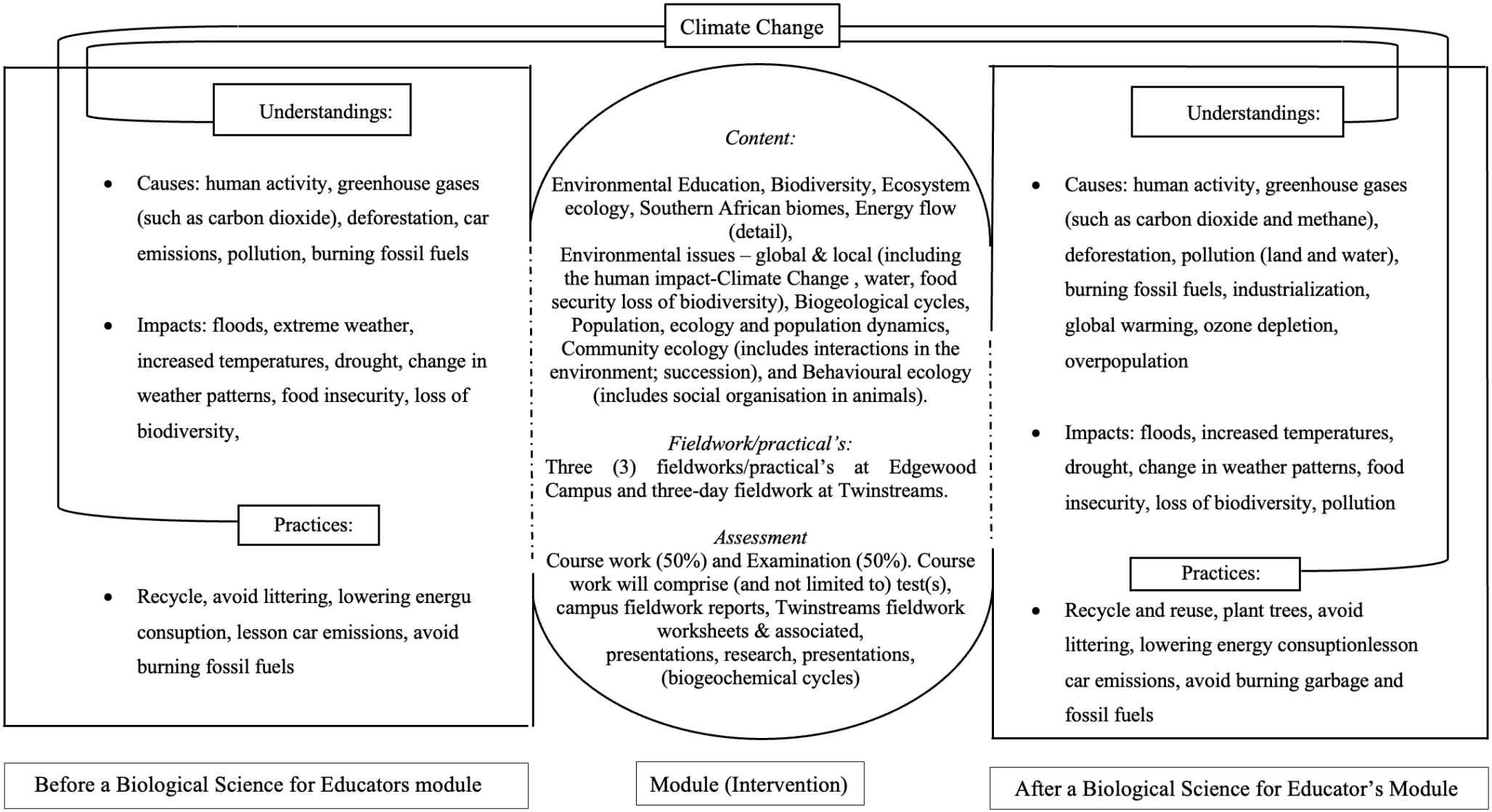
The module also contributed to participants' understanding of a shared responsibility in addressing Climate Change, with participants recognising the roles of individuals, businesses,

governments, as well as international organisations. This multi-stakeholder approach aligns with contemporary environmental education frameworks that emphasise the importance of coordinated efforts across different sectors. The participants' increased focus on local government and international initiatives also shows an enhanced awareness of the need for both local and global collaboration to address the Climate Change effectively. Moreover, the module's impact is portrayed in the increased mentions of personal climate actions reported by the participants, such as lowering energy consumption, creating community gardens, avoiding littering and burning of fossil fuels.

In conclusion, the module had little effect on enhancing pre-service teachers' conceptual understanding of Climate Change and the interconnectedness of individual and collective actions as well as the different causes and processes. This can be seen in the table summary below (Table 5.1 Figure) that shows a comparison of pre-service teachers' understandings and practices of Climate Change before and after completing the module.

Figure 5.1

A Model of Pre-Service Science Teachers' Understanding and Practices Before and After Completing the Module That Served as the Intervention


Climate Change
Understandings:
Causes: human activity, greenhouse gases (such as carbon dioxide), deforestation, car emissions, pollution, burning fossil fuels
Impacts: floods, extreme weather, increased temperatures, drought, change in weather patterns, food insecurity, loss of biodiversity,
Practices:
Recycle, avoid littering, lowering energu consuption, lesson car emissions, avoid burning fossil fuels
Content:
Environmental Education, Biodiversity, Ecosystem ecology, Southern African biomes, Energy flow (detail),
Environmental issues – global & local (including the human impact-Climate Change , water, food security loss of biodiversity), Biogeological cycles, Population, ecology and population dynamics, Community ecology (includes interactions in the environment; succession), and Behavioural ecology (includes social organisation in animals).
Fieldwork/practical's:
Three (3) fieldworks/practical's at Edgewood Campus and three-day fieldwork at Twinstreams.
Assessment
Course work (50%) and Examination (50%). Course work will comprise (and not limited to) test(s), campus fieldwork reports, Twinstreams fieldwork worksheets & associated,
presentations, research, presentations, (biogeochemical cycles)
Understandings:
Causes: human activity, greenhouse gases (such as carbon dioxide and methane), deforestation, pollution (land and water), burning fossil fuels, industrialization, global warming, ozone depletion, overpopulation
Impacts: floods, increased temperatures, drought, change in weather patterns, food insecurity, loss of biodiversity, pollution
Practices:
Recycle and reuse, plant trees, avoid littering, lowering energy consuptionlesson car emissions, avoid burning garbage and fossil fuels
Before a Biological Science for Educators module
Module (Intervention)
After a Biological Science for Educator's Module

5.5 Recommendations

The purpose of this study was to explore pre-service science teachers' understandings and practices regarding Climate Change. The aim was not to identify mistakes in the module but rather to explore pre-service teachers' knowledge on Climate Change to effectively teach future students. This section will discuss the gaps in understandings and practices and provide recommendations based on the findings of this study.

Though most of the participants are aware of Climate Change, it is not given the level of concern it needs when compared to other environmental issues. This gap indicates that Climate Change should be considered as a top priority in environmental education curricula. Regarding the findings, the results show a gap. Many pre-service teachers show an inadequate understanding of basic ideas like the greenhouse effect process and its worldwide consequences.

Furthermore, it seems that the strong emphasis on individual experiences limits an improved understanding of Climate Change. Experiences can help in learning, but they should not take away from the broader deeper effects of Climate Change. Teachers need to be able to combine their own experiences with facts from science and current events to provide an in-depth perspective.

Furthermore, there is a lack of understanding among pre-service teachers regarding the causal relationships between Climate Change and specific environmental occurrences, such as floods. This knowledge gap limits their ability to explain to their students how Climate Change is related to other natural phenomena and the range of climate-related problems there are.

Additionally, discussions around Climate Change often exclude actionable solutions or mitigation strategies. The lack of inclusion is critical as it prevents future teachers from gaining the information and skills needed for encouraging students to take action. An active informed approach to Climate Change Education requires including talks about possible solutions, political efforts, and individual actions into the curriculum.

It is very important to help future teachers understand the science behind Climate Change better, stress how important Climate Change is compared to other environmental problems,

make sure they understand how one event can cause another, and include mitigatation and adapation strategies that can be used in the lessons and in real situations. By addressing these gaps, we can better prepare future teachers to teach about and address one of the biggest issues of our time.

A more enhanced teaching on Climate Change should be included into pre-service teachers' curricula. This includes important scientific concepts such as the carbon cycle and greenhouse effect and how it works, as well as the most current information and evidence of the continuous effects of Climate Change. Practical exercises, such as studying case studies of climate impacts around the world, can help deepen preservice teachers' understanding and make the subject more relatable.

Furthermore, the topic of Climate Change should be in all modules and given more time to engage future teachers into further detail. Helping future teachers develop critical thinking skills is also important. Preservice teachers must learn how to assess information sources, understand the processes and evaluate news and stories on this topic. Modules may decrease the impact of political biases and promote a more fact-based knowledge of climate issues by creating a setting where preservice teachers may engage in discussions. This can be done by use of activities like role-playing, structured debates, and talks that stress the use of evidence.

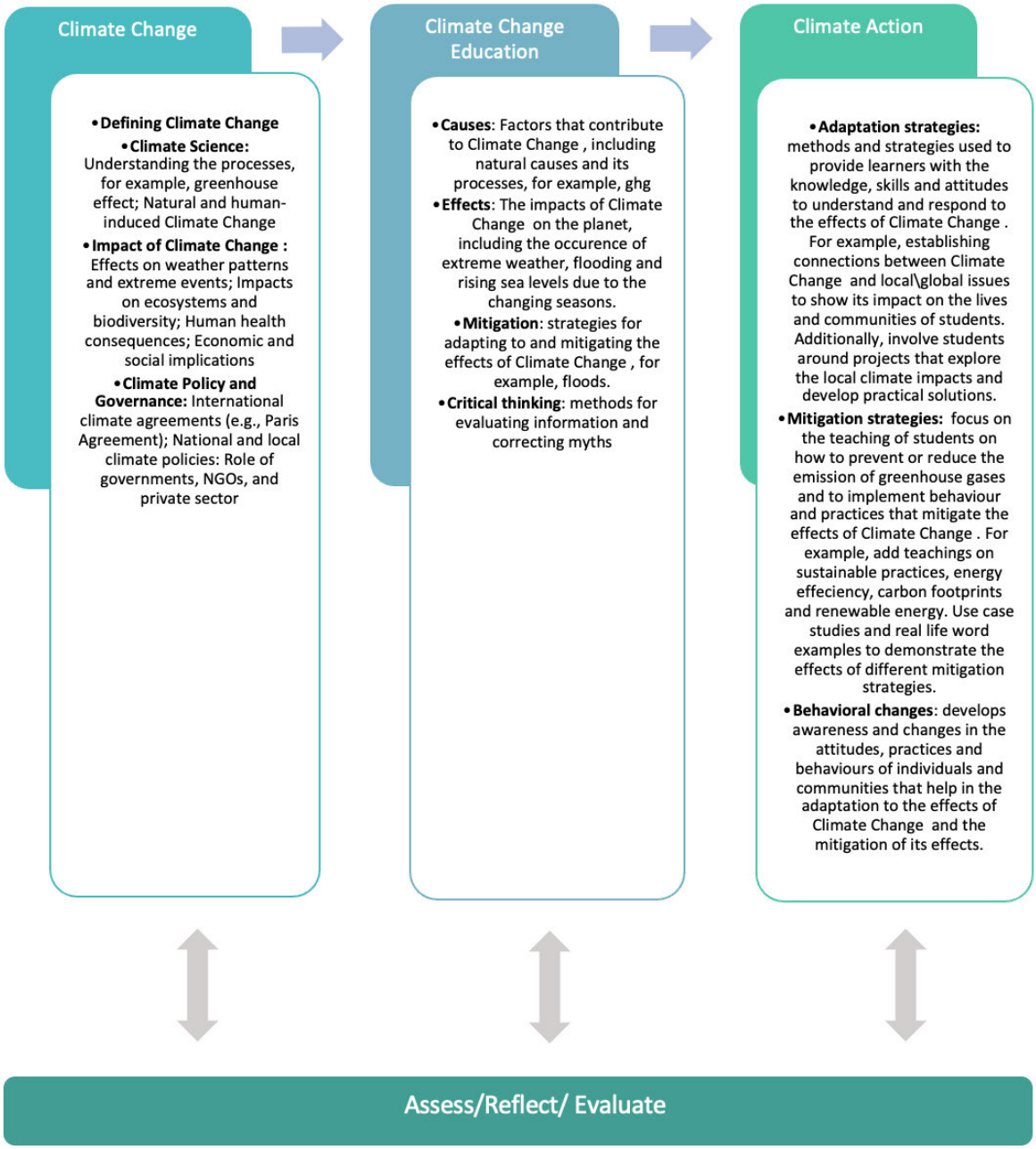
To conclude, the two most important approaches for getting preservice teachers ready to teach about Climate Change involve including detailed Climate Change Education and to develop critical thinking abilities to be able to be more aware of mitigation and adaptation techniques.

In this study, the analysis was guided by the conceptual framework outlined in Figure 2.1 of Chapter 2, which provided the foundation for understanding the data. This framework, in conjunction with the Climate Change framework discussed in Chapter 3, was instrumental in systematically examining the data. The conceptual framework, illustrated in Figure 2.1, served as a lens through which the findings were interpreted, leading to the development of an enhanced conceptual model. This model, which integrates insights from the literature review, the findings, and the conclusions of this study, resulted in the design of a content-pedagogical, action-oriented model for Climate Change Education (CCE), as depicted in Figure 5.2. This proposed model aims to advance CCE by bridging content knowledge and pedagogical strategies. It is adaptable and can be implemented across various educational levels, including

schools, communities, higher education, and tertiary institutions. Continuous assessing, reflecting, and evaluating Climate Change, Climate Change Education, and action (Figure 5.2) are important for understanding the depth and impacts of Climate Change, developing and improving policies and educational content, as well as ensuring effective and responsible climate action. These processes help identify vulnerabilities, enhance public awareness, measure the effectiveness of strategies, allocate resources efficiently, and develop continuous improvement and advancement. Furthermore, they support informed decision-making, international collaboration, and a shift to sustainable practices, which is crucial for building resilience and improving a sustainable future.

Figure 5.2

A Content-Pedagogical Action Orientated Model



5.6 Future research

Considering the study's emphasis on the understandings and practices of climate change among pre-service science teachers, future research could involve doing an in-depth case study with five pre-service science teachers. This methodology includes the selection of five participants enrolled as a pre-service teacher. The research would involve conducting semi-structured interviews, observing their classroom activities, and analyzing reflective journals.

The objective of this study would be to investigate the participants' personal and professional beliefs regarding climate change and examine how these beliefs impact their teaching methods. In addition, a framework of action research could be utilized, in which pre-service teachers actively participate in the creation of educational resources pertaining to climate change. This process entails a continuous loop of planning, executing, observing, and reflecting. It enables teachers to develop and apply creative teaching materials while assessing their effectiveness and making any needed changes. Moreover, investigating the effects of curriculum design affected by students on teaching methods and student achievements can provide important information. The above research can expand this area of focus and provide alternative viewpoints to further enhance the understanding and practice of climate change among pre-service science teachers.

5.7 Limitations

The study's small sample size and withdrawals limited the data. As this is a small case study, this research is not applicable to all educational institutions or all PSTs due to the sample size and the socioeconomic environment. However, the findings can be applied to schools and PSTs in similar situations and to enhance future teaching and learning of climatic change.

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ANNEXURES

Annexure A: Questionnaire

1a. Please look at the following list of environmental issues and **tick** the **three** issues that **you experience** the most. *Please tick only **three** issues from the list:*

- ☐ Pollution
- ☐ Flooding
- ☐ Poor waste management (e.g., overuse of landfills)
- ☐ Traffic/ congestion
- ☐ Climate Change
- ☐ Overpopulation (of the earth by humans)

1b. Why did you choose the above three?

Choice 1_____

_____

_____

Choice 2_____

_____

_____

Choice 3_____

_____

_____

2. Have you experienced any drastic environmental conditions in the past ten years
Yes/ no/ don't know
(Including your home, garden, or vehicle)?
Explain what was experienced.

_____
_____
_____
_____
_____
_____.

3a. Do you feel the pattern of weather is generally changing?

- ☐ Yes
- ☐ No
- ☐ Don't know

3b. If yes, why do you think this might be?

_____

_____

_____.

4a. Have you heard of 'Climate Change'?

- ☐ Yes
- ☐ No
- ☐ Don't know

4b. What do you know about it? _____

_____

_____

_____

_____

5. Where did you hear about Climate Change ?

- ☐ University
- ☐ Television
- ☐ Radio
- ☐ Internet

- ☐ YouTube
- ☐ WhatsApp
- ☐ Other _____.

6a. How much would you trust Climate Change information if you heard it from the following?

Family or friend: *A lot/ A little/ Not very much/ Not at all*

Television/ Radio/ Newspaper: *A lot/ A little/ Not very much/ Not at all*

Internet: *A lot/ A little/ Not very much/ Not at all*

Educational institute professionals: *A lot/ A little/ Not very much/ Not at all*

6b. Explain your choices

_____

_____

_____.

7a. How significant is the problem of Climate Change to you?

- ☐ Very important
- ☐ Quite important
- ☐ Not important

7b. Why?

_____

_____

_____

_____.

8. What do you think causes Climate Change ? Explain

_____

_____.

9. What impacts, if any, do you think Climate Change may have in the next five years? Explain

_____

_____.

10a. Do you think Climate Change is something that is affecting or is going to affect you personally?

- Yes
- No
- Don't know

10b. If yes, in what way(s) is it affecting you, or is it going to affect you?

11a. Do you think anything can be done to tackle Climate Change ?

- Yes
- No
- Don't know

11b. Why did you choose the above?

12a. Who do you think should have the main responsibility for tackling Climate Change ?

Please tick one box only:

- ☐ International organisations (e.g., the UN)
- ☐ The national government
- ☐ Local government
- ☐ Business and industry environmental organisations/lobby groups (e.g., Worldwide Fund for Nature)
- ☐ Individuals
- ☐ Other (please write in: _____)

12b. Explain your choice/s

_____

_____

_____

_____

13a. Have you ever taken, or do you regularly take, any action out of concern for Climate Change ?

- ☐ Yes
- ☐ No
- ☐ Don't know

13b. If yes, what did you do/are you doing? _____

_____

_____.

Annexure B: Informed Consent Document

Dear Participant

My name is Caitlin Govender (*216007603*). I am a master's candidate studying at the University of KwaZulu-Natal, Edgewood Campus. The title of my research is: Pre-Service Teachers' Understandings and Practices of Climate Change Education. I am interested in interviewing you so as to share your experiences and observations on the subject matter.

Please note that:

- The information that you provide will be used for scholarly research only.
- Your participation is entirely voluntary. You have a choice to participate, not to participate, or stop participating in the research. You will not be penalised for taking such an action.
- Your views in this interview will be presented anonymously. Neither your name nor identity will be disclosed in any form in the study.
- The interview will take about (*how long?*).
- The record, as well as other items associated with the interview, will be held in a password-protected file accessible only to myself and my supervisors. After a period of five years, in line with the rules of the university, it will be disposed of by shredding and burning.
- If you agree to participate, please sign the declaration attached to this statement (a separate sheet will be provided for signatures).

I can be contacted at:
Email: 216007603@stu.ukzn.ac.za
Cell: 0626933660
My supervisor is Professor N Govender who is located at the School of Education, Edgewood Campus, Durban of the University of KwaZulu-Natal.
Contact details:
email govendern37@ukzn.ac.za Phone number: 0743733259
My co-supervisor Dr. A James who is located at the School of Education, Edgewood Campus, Durban of the University of KwaZulu-Natal Contact details:
email jamesa1@ukzn.ac.za Phone number: 0735114558

The Humanities and Social Sciences Research Ethics Committee contact details are as follows: Ms. Phumelele Ximba, University of KwaZulu-Natal, Research Office, Email: ximbap@ukzn.ac.za,Phone number +27312603587.

Thank you for your contribution to this research.

DECLARATION

I…… *(full names of participant*) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participate in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire. I understand the intention of the research. I hereby agree to participate.

I consent / do not consent to have this interview recorded (if applicable)

…… …….

SIGNATURE OF PARTICIPANT DATE