

## Study Designs Detailed Analysis

### 1. Australian and Global Politics

#### 1.1. Analysis of Rationale Aims and Structure

CC appear in the Introduction within the first section entitled 'Scope of Study'. CC is introduced through the humanistic end of the CC perspectives continuum (see Table 1), as follows: 'Global policy... considers global ethical issues including human rights, people movement, development and arms control and explores the nature and effectiveness of global responses to crises such as climate change, armed conflict, terrorism and economic instability' [58] (p.6). The perspective taken is human action oriented, emphasizing the three fundamental humanistic aspects of socio-economic, policy and governance, and ethics.

#### 1.2. CC within the Four Units

Units 1-3 do not address CC in any way. Unit 4 consists of two Areas of Study. In Area of Study 2, there is an invitation to select two out of four global crises and investigate their causes. The four options for selection include: climate change, armed conflict, terrorism, and economic instability. The topic of CC is introduced as follows:

Climate change presents policy makers with significant difficulties, some of which stem from responses requiring global cooperation by states at an unprecedented level. Students consider whether national interests prevail over global climate challenges, and how other economic priorities and political factors play a role [58] (p.36).

The study design addresses CC as a crisis, primarily human crisis. CC conceptualisation reflects: *complexity and multiple systems interactions* and *inherently involves human action*. The complexity is expressed by the competing interests, at the national, global and the economy. Human action is expressed as the requirement for global cooperation of responses.

Under Outcome 2, the Key Knowledge specified in relation to CC includes: 'the causes; the responses from relevant global actors and their effectiveness; challenges to achieving effective resolutions; key aspects of the crisis of climate change including: resource exploitation, national interests, methods of adapting to and reducing climate change' [58] (p.36). In addition to the two above characteristics, Outcome 2 also reflects *cross-disciplinary approaches*, as it relates to both underlying science and human responses, and involves action by global actors.

#### 1.3. Content Knowledge

In the Advice for Teachers, under Examples of Learning Activities, the content knowledge is varied and spans over seven out of eight CC content themes (see Table 1).

The first activity: 'Discuss the causes of climate change using edited clips from the film *Inconvenient Truth*' [79], addresses both the drivers of CC and observed changes in CC, which appear in the film.

The second activity: 'produce a flow chart or an annotated timeline of the key events and developments in the emergence of the climate change crisis' [79], could relate to two aspects of CC: to a timeline of evidence accumulation, or/and to a timeline of political responses.

The third activity addresses effects of CC and relates both to observed changes in CC and future CC.

The fourth activity: 'define key terms in the context of the crisis of climate change: crisis diplomacy, international cooperation, globalisation and unilateralism' [79] addresses policy and governance as well as the socio-economic aspects of globalisation.

The fifth and sixth activities address policy and governance in more details, including identifying the role of UNFCCC and tracing its activities over time, and identifying competing interests.

The seventh activity: 'discuss key aspects of the crisis of climate change, including resource exploitation, national interests, and methods of adapting to and reducing climate change' [79] addresses risks and impacts, adaptation and mitigation in an interconnected way.

The eighth activity: 'research and share in a class blog articles and journal analysis of climate change and include up-to-date reports', adds another dimension, beyond content knowledge. It relates to UNESCO's [47] notion of understanding of and attentiveness, referring to the ongoing reinforcement of tentativeness to the realities of climate change, the understanding of root causes and the invisible crippling nature of climate change [47] (p. 5).

The final activity: 'write an essay on the topic: 'the climate change crisis is shaped by its causes' (*ibid*), provides students with an opportunity to connect the various themes of knowledge by relating the causes to the economic-social-cultural and other human-related systems.

#### 1.4. Essential Content Left as 'Holes' in Knowledge

Overall, the study design Australian and Global Politics addresses most of the fundamental questions and essential content knowledge related to CC. The following specific contents outlines in Table 1, were left out in the various categories:

*Observed changes in climate.* The question: What are the instruments and means for measuring the climate in different time scales? - is not addressed.

*Future CC.* The questions: How are future projections produced? What are scenarios? What are the sources of uncertainties in CC projections? – are not addressed.

*Risks and impacts.* The question: What characterises risks and impacts distribution? – is not addressed

*Ethics.* The questions: What is the role of ethics in combating CC? What are some of the relevant ethical dilemmas? – are not addressed.

Overall, the study design addresses most of the contents related to CC including many scientific aspects. Our main critique is that the topic is provided as an elective option. Students may be completing Australian and Global Politics without ever studying CC.

#### 1.5. Cross-curriculum integration

The study design covers most themes across the science – humanity perspectives continuum. It operates in a silo, autonomous from other curriculum subjects. There is no mentioning of cross-curriculum integration or collaboration. There are also no provisions for students whose teachers did not choose the CC elective, to complement their CC education.

### 2. Environmental Science

#### 2.1. Analysis of Rationale Aims and Structure

Under Scope of the Study, CC appears as an outcome of human actions, to which humans are responding. This section states:

Students investigate the extent to which humans modify their environments and the consequences of these changes in local and global contexts with a focus on pollution, biodiversity, energy use and climate change; they explore the conceptual, behavioural, ethical and technological responses to these changes [59] (p. 6).

According to the scope, climate change is a consequence; an output. Humans' responses to the output are multidimensional, involving behaviour, ethics, and technology. This perspective expresses *cross-disciplinary approaches* and *inherently involves human action*, CC characteristics.

#### 2.2. CC within the Four Units

CC is absent from Units 1-3. It is addressed in Unit 4 under Area of Study 2. Unit 1 focuses on the interconnections between the atmosphere, biosphere, hydrosphere and lithosphere, with no mentioning of CC. Unit 2 focuses on pollutants. Area of Study 2 focuses on pollutants' management. CC is not mentioned. However, there is reference to excessive carbon in the atmosphere, as follows:

Contamination of the atmosphere that disturbs the natural composition and chemistry of the air may be caused by particulate matter such as dust or excessive gases such as carbon dioxide that cannot be effectively removed through natural cycles, including the carbon and nitrogen cycles [59] (p. 19).

In this Area of Study, CC is not addressed as a wholesome phenomenon, but rather one aspect, the accumulation of carbon dioxide in the atmosphere, is pulled out of the CC context and addressed in the context of air pollution. This is followed by a simplistic question for students to answer: 'Should technologies that produce carbon dioxide be banned?' [59] (p. 19). It is puzzling to see such a naïve question appearing in a VCE document. It seems self-explanatory that this closed type of question has no simple 'yes' or 'no' answer. If we choose to answer 'yes' and ban carbon dioxide producing technologies, it would mean that communities around the world which rely on wood-burning stoves, would be banned from cooking. At the other end - the 'no' answer, we find that the question's phrasing does not invite any in-depth conversation as to the complexity of what 'no' means.

Unit 3 is entitled 'How can biodiversity and development be sustained?' The unit focuses on biodiversity services, threats and management. CC is not mentioned.

The term CC appears for the first time in Unit 4, entitled 'How can the impacts of human energy use be reduced?' The description of the scope of the unit includes the following statement: 'They distinguish between natural and enhanced greenhouse effects and discuss their impacts on living things and the environment, including climate change' [59] (p. 29). According to this sentence, CC is conceptualised as an outcome of the enhanced greenhouse effect. This is a highly reductionist view of CC, as well as scientifically incorrect. The sentence portrays the enhanced greenhouse effect as a cause, and CC as an outcome. In fact, the enhanced greenhouse effect is considered part of CC processes [80]. The causes are fossil fuel burning, and land use changes, driven by economic and population growth (see Table 1).

Area of Study 2 in Unit 4, has the peculiar title 'Is climate predictable?' (Evidently, the answer is both 'yes' and 'no'). It describes the scope of learning as follows:

In this area of study students investigate the **astronomical, solar**, and Earth systems and human-based factors that have altered important relationships between the energy, water and nutrient cycles, resulting in the enhanced greenhouse effect and **climate change**. They compare natural and enhanced greenhouse effects and their significance for sustaining ecological integrity [59] (p. 30).

The phrasing of the sentence suggests that astronomical and solar systems are responsible for CC. This is an error, in contradiction with scientific facts [13] (p. 4).

Outcome 2 of Area of Study 2 states:

On completion of this unit the student should be able to explain the causes and effects of changes to Earth's climate, compare methods of measuring and monitoring atmospheric changes, and explain the impacts of atmospheric changes on living things and the environment [59] (p. 31).

From a conceptualization perspective, the above outcome addresses the CC characteristic: *complexity and multiple systems interactions*. The outcome identifies relationships between different systems and disciplines.

Key Knowledge for this Area of Study include: 'measures used to assess the rate of climate change: global average annual temperatures, regional and global sea level rise, and global snow and ice coverage' [59] (p. 31). Here too, CC appears as an effect or an outcome that is being measured. The authors do not distinguish between measuring changes in climate, and CC as broader phenomena.

### 2.3. Content Knowledge

Regardless of the fact that the term CC is rarely mentioned and when it is mentioned, its causes are inaccurately described, it is surprising to find that many CC science facts contents are covered under the alternative term *enhanced greenhouse effect*. Students study about the structure and composition of the atmosphere; astronomical cycles and natural variability of climate; energy and greenhouse gases; carbon sequestration; GHG ability to absorb infra-red radiation; the impact of human activities on changes in atmospheric gas concentrations; instruments and methods for measuring past and present changes in atmosphere; measures to assess the rate of climate change; the impacts of greenhouse effect on humans and ecosystems; reporting and confidence of climate predictions; and, projected impacts of the greenhouse effect.

In the Advice for Teachers, the term CC appears more often. However, the term is absent when addressing aspects related to mitigation and adaptation. The activity is as follows:

Compare and contrast atmospheric carbon dioxide mitigation (seeks to reduce amount of carbon in atmosphere) versus adaptation (seeks to help reduce the effects of carbon in atmosphere) strategies for a selected geographic location; provide a justified response as to which approach is most important for the selected geographic location [81]

We find it peculiar that mitigation and adaptation are defined in relation to carbon dioxide disregarding other GHG and the broader CC context. Overall, the study designs presents substantial amount of contents related primarily to the *science-facts* end of the perspectives-continuum.

#### 2.4. Essential Content Left as 'Holes' in Knowledge

The Environmental Science study design addresses mainly scientific aspects of CC. The humanistic aspects, are addressed to lesser degree.

*Observed changes in climate.* This theme is addressed in both the study design and the learning activities.

*Drivers of CC.* The learning activities address the role of energy production from fossil fuels in creating the *enhanced greenhouse effect*. However, the information seems sporadic and there is no clear discussion about the drivers of CC phenomena.

*Future CC.* Future projections are addressed awkwardly as follows: 'projected consequences and uncertainties of the enhanced greenhouse effect on the four major Earth systems (atmosphere, biosphere, hydrosphere, lithosphere), and on the health of living things and on the environment, at a selected location' [59] (p. 31). The sentence is awkward for a few reasons: First, the choice to organise impacts of CC in accordance to Earth's spheres. Second, once this choice was made, why add 'health of living things'? Isn't this included in the biosphere? Why add 'environment'? Isn't this equal to all four spheres? And thirdly, why focus on a selected location?

The learning activities provide more specific opportunities to study future projections by studying the impact of CC on biodiversity.

IPCC scenarios are not addressed. However, students are requested to create their own scenarios.

In regard to the sources of uncertainty, they are narrowly focused on statistical measurements, disregarding CC's three causes of uncertainty discussed above. This is stated as follows: 'They learn to differentiate between relationships that are correlative and those that are cause-and-effect, and make judgments about accuracy, validity and reliability of evidence' [59] (p. 29).

*Risks and impacts.* The impacts are not addressed specifically in relation to CC, but rather 'the natural greenhouse effect and the enhanced greenhouse effect' [59] (p. 31), appear together in relation to impacts.

*Adaptation and mitigation.* This aspect appears only in the Learning Activities in relation to a local context.

*Socio-economic.* The theme is not addressed.

*Policy and governance.* The theme is not addressed.

*Ethics.* The scope of Study states ‘they explore the conceptual, behavioural, ethical and technological responses to these changes’ [59] (p. 6). However behavioural ethical and technological responses are not addressed in relation to CC or the alternative term *enhanced greenhouse effect*.

In summary, two major holes are identified. The first, is the curriculum’s avoidance from addressing CC directly, and the inclination to address CC themes concealed under the term the *enhanced greenhouse effect*. As an under-stated problem, the major humanistic issues related to CC are played down. Socio-economic, policy and governance and ethics are not addressed at all. Risks and impacts are limited to mainly physical and biological systems. Adaptation and mitigation are addressed in a narrow way, relating to carbon dioxide at a local region.

## 2.5. Cross-Curriculum Integration

There is no mentioning of either cross-curriculum integration, collaboration, or supplementary pathways for concluding students’ CC education.

## 3. Physics

### 3.1. Analysis of Rationale Aims and Structure

The Rationale states ‘Physicists also work in cross-disciplinary areas such as bushfire research, climate science, forensic science, geology, materials science, neuroscience and sports science’ [60] (p. 7). In this sentence, CC is clearly conceptualized as a cross-disciplinary area.

### 3.2. CC within the Four Units

CC is addressed in Unit 1, entitled ‘What ideas explain the physical world?’ It is not addressed in Units 2-4. Under Area of Study 1, appears the following description:

Students examine the environmental impacts of Earth’s thermal systems and human activities with reference to the effects on surface materials, the emission of **greenhouse gases** and the contribution to the **enhanced greenhouse effect**. They analyse the strengths and limitations of the collection and interpretation of thermal data in order to consider debates related to climate science [60] (p. 14).

CC conceptualization in the above quote includes: *Complexity and multiple systems interactions, cross-disciplinary approaches, and future oriented and uncertainty*. Complexity and multiple systems interactions, and cross-disciplinary approaches are expressed by the interactions between thermal systems and human activities. Uncertainty is expressed by the reference to limitations in the collection and interpretation of data. The future orientation aspect of this characteristic is not apparent.

This rich conceptualization of CC is reiterated in Outcome 1, stating:

On completion of this unit the student should be able to apply thermodynamic principles to analyse, interpret and explain changes in thermal energy in selected contexts, and describe the environmental impact of human activities with reference to thermal effects and **climate science** concepts [60] (p. 14).

An additional reference to uncertainties appears in Area of Study 1 under Key Knowledge, Thermodynamics and Climate Science, as follows: ‘explain how concepts of reliability, validity and uncertainty relate to the collection, interpretation and communication of data related to thermodynamics and climate science’. While the quote addresses CC uncertainties, the three types of CC uncertainties related to future projections, are not explicitly addressed by this quote.

### 3.3. Content Knowledge

The Physics study design thoroughly addresses the scientific themes of CC. These are expressed in Area of Study 1 under the Key Knowledge in Thermodynamics and Climate Science, as follows:

Describe electromagnetic radiation emitted from the Sun as mainly ultraviolet, visible and infrared; explain the roles of conduction, convection and radiation in moving heat around in Earth's mantle (tectonic movement) and atmosphere (weather); model the greenhouse effect as the flow and retention of thermal energy from the Sun, Earth's surface and Earth's atmosphere; explain how greenhouse gases in the atmosphere (including methane, water and carbon dioxide) absorb and re-emit infrared radiation; analyse changes in the thermal energy of the surface of Earth and of Earth's atmosphere; analyse the evidence for the influence of human activity in creating an enhanced greenhouse effect, including affecting surface materials and the balance of gases in the atmosphere [60] (p. 15).

The unit continues and expands beyond thermodynamics to examine various aspects related to the environmental impacts of human activities in relation to the enhanced greenhouse effect. Students conduct various calculations such as: proportion of national energy use due to heating and cooling of homes; or, use of thermal imaging and infrared thermography in locating heating losses in buildings and/or system malfunctions [60] (p. 15).

In the Teaching and Learning Activities, students' preconceptions are addressed as follows: 'Determine pre-conceptions held in the class by using a context related to warming of Earth, for example the NASA global climate change site; capture interest using engaging images, simulations and current information for exploration' [82].

Measurements and future projections of CC are addressed in the following activity:

Use an interactive simulation to investigate the greenhouse effect; select and compare levels of greenhouse gases during the Ice Age, in the 1800s, in the 1900s, today and in the future to see how Earth's temperature, sunlight and infrared photons change with changing concentrations of greenhouse gases [82].

Human activity is addressed only as a driver of CC, as expressed in the following learning activity: 'Generate data to investigate the relationship between human activity and the enhanced greenhouse effect over time...' [82].

### 3.4. Essential Content Left as 'Holes' in Knowledge

*Observed changes in climate.* The question: 'What is climate change?' is addressed indirectly through the study of the enhanced greenhouse effect. This approach allows only partial addressing of the question, since it leaves out substantial knowledge, such as the underlying drivers of CC, the economic and population growth drivers, focusing on secondary effects such as fuel combustion. The instruments and means of measurements, as well as the observed facts are addressed extensively.

*Drivers of CC.* As discussed above, the study design does not provide opportunities for in-depth discussion of the drivers. By limiting the causes to 'human activities' (as compared with 'behaviour') only, there is no room for discussing socio-economic systems. The focus then remains on a superficial level of fossil fuel burning and land use changes.

*Future CC.* Future trajectories are limited to measurements of GHG, earth's temperature, sunlight and infrared photons. Students do not study how future projections are produced; what are scenarios; the three types of CC uncertainties; and broader issues related to future projections, such as Intensification of heat waves, and extreme precipitation.

*Risks and impacts.* Not addressed.

*Adaptation and mitigation.* Not addressed.

*Socio-economic.* Not addressed.

*Policy and governance.* Not addressed.

*Ethics.* Not addressed.

In summary, CC within the Physics VCE study design is focused on the scientific content knowledge related to the creation and maintenance of the enhanced greenhouse effect. Only three out of eight content knowledge themes are addressed. The three themes are within the *science-facts* end of the spectrum. Even within these categories, CC education is limited and incomplete.

### 3.5. Cross-Curriculum Integration

There is no mentioning of either cross-curriculum integration, collaboration, or supplementary pathways for concluding students' CC education.

## 4. Economics

### 4.1. Analysis of Rationale Aims and Structure

CC is not mentioned.

### 4.2. CC within the Four Units

Units 1, 3, and 4 do not address CC. It is addressed in Unit 2 entitled 'Contemporary economic issues', under Area of Study 1, entitled 'Economic growth, long-term economic prosperity and environmental sustainability'. The overview of the area of study addresses issues related to CC, without mentioning the term. The term CC appears under Key Knowledge for Outcome 1, as follows: 'Economic and environmental costs of economic growth such as climate change, depletion of natural resources and deterioration of common access resource' [61] (p.14). This statement suggests that CC is conceptualized as an outcome of economic growth. In addition, CC is conceptualized as characterized by *cross-disciplinary approaches*. This characteristic is expressed by connecting economic growth with depletion of natural resources. While this Key knowledge correctly identifies economic growth as a driver of CC, it fails to capture the full scope of CC. According to the above statement, CC is conceptualized as mere outcome, an end-state parallel to other outcomes such as depletion of natural resources.

This perception of CC as an outcome is further demonstrated in the Examples for Learning Activities.

Undertake an investigation, ... into a current economic issue facing the Australian economy; illustrates the potential trade-off between the pursuit of economic growth and environmental sustainability; use a range of resources ...to prepare for a 'hypothetical'/summit/ forum to be conducted around the issue; issues might include: tackling **climate change**; managing Victoria's water resources; how to achieve strong and sustainable economic growth; Australia introducing the use of nuclear power plants to source electricity; tackling traffic congestion in urban centres such as Melbourne; investing in more road infrastructure in Melbourne rather than more rail infrastructure [74] ( p. 17)

The activity portrays a linear simplistic relations between economic growth and CC, where CC is a direct linear outcome. The study designs fails to make connections between the various other outcomes listed, and CC. Thus failing to conceptualize CC as a driver, process and outcome, all at once.

Another learning activity suggests that students 'prepare a report for the Environment minister recommending a range of policy actions to tackle the issue of climate change' [74] (p. 17). The activity expresses the *inherently involves human action* characteristic of the *nature of CC*. However, as the unit does not address teaching CC aspects, it is not clear what information can students draw upon to develop an informed report.

### 4.3. Content Knowledge

There is no evidence for the presence of CC themes. The term CC appears sporadically with no explanations regarding its meaning. The only piece of information that is provided in relation to CC is that it is driven by economic growth. However, the learning activities are based on an assumption that students know what CC is. They require students to develop policy recommendations and suggest ways to 'tackle' CC.

### 4.4. Essential Content Left as 'Holes' in Knowledge

*Observed changes in climate.* The theme is not addressed.

*Drivers of CC.* Economic growth appears as driving CC. The other major driver of population growth is not mentioned.

*Future CC.* The theme is not addressed. CC is presented as a stable end-product.

*Risks and impacts.* The theme is not addressed.

Adaptation and mitigation. Mitigation is addressed from a policy perspective, focusing on Australia's economic policy. The unit does not address adaptation, nor the role of mitigation and adaptation.

*Socio-economic.* Not addressed

*Policy and governance.* The study design touches on this aspect by requesting students to develop their own Australian policy-mechanisms. The role of policy, and the international, regional and national organizations, agreements and mechanisms established for dealing with CC are not addressed.

*Ethics.* The theme is not addressed.

In summary, CC is very poorly addressed in this study design. Only three out of the eight CC themes are present in a very limited way. Not one of the themes is addressed in full.

#### 4.5. Cross-Curriculum Integration

There is no mentioning of either cross-curriculum integration, collaboration, or supplementary pathways for concluding students' CC education. Prior knowledge is not discussed. There is an implicit unsubstantiated assumption that students have prior knowledge regarding CC.

### 5. *Agricultural and Horticultural Studies*

#### 5.1. Analysis of Rationale Aims and Structure

CC is not mentioned.

#### 5.2. CC within the Four Units

Units 1-3 do not address CC in any way. In Unit 4, entitled 'Sustainable Management', CC is conceptualised primarily as a management problem. It appears as follows:

Students consider the effects of **climate change** and how business responds to these effects. They develop an understanding of the importance of identification, rectification and prevention of environmental degradation for the sustainability of agribusinesses. Students consider strategies for economic, social and environmentally sustainable resource management within agriculture and horticulture [62] (p.27).

The statement focuses on resource management. This emphasize on CC management also suggest that CC is conceptualized as *inherently involve human action*. Three aspects of CC are highlighted. The aspect of adaptation (represented by 'responds to'); mitigation (represented by 'rectification and prevention'), and multi-system management (represented by 'strategies for economic, social and environmentally sustainable resource management').

The CC management perspective is reiterated in Outcome 1 of Area of Study 1, which states that 'on completion of this unit the student should be able to explain and evaluate sustainable resource management practices within agriculture and/or horticulture, and analyse adaptations in response to climate change' [62] (p. 27).

The Key Knowledge for this outcome reflects conceptualization of the *complexity and multiple systems interactions* characteristic of CC. This aspect is presented as follows: 'effects of agricultural and horticultural processes and operations on climate change; and, climate change and its likely impacts on agricultural and/or horticultural production' [62] (p. 28). The complexity is expressed by the two-way relationship between agriculture and CC.

#### 5.3. Content Knowledge

In the Advice for Teachers, under Examples of Learning Activities, three learning activities are suggested. Two of the activities examine CC impact and adaptation in relation to agriculture and horticulture. The third activity focuses on calculating carbon emissions by a particular agricultural business.

In regard to the impacts of CC on agriculture and horticulture, the learning-activity suggests to 'use the Internet to examine climate change impacts and greenhouse gas emissions issues in agriculture and/or horticulture' [62] (p. 57). In regard to calculating carbon emissions, it states as follows: 'Use the website Greenhouse in Agriculture [www.greenhouse.unimelb.edu.au/](http://www.greenhouse.unimelb.edu.au/) to calculate and evaluate the carbon emissions for a particular agricultural or horticultural business' [62] (p. 57). This activity does not teach the observed changes in the climate. Instead, it focuses on calculating carbon emissions in a disconnected way.

#### 5.4. Essential Content Left as 'Holes' in Knowledge

The scarcity of content knowledge related to CC suggests that the following 'holes' remain unaddressed in students' understanding and comprehension of CC:

*Observed changes.* The theme is not addressed.

*Drivers of CC.* Only agriculture business's causes are addresses, leaving the underlying main causes of economic and population growth out of the discussion.

*Future projections.* This theme is not addressed.

*Risks and impacts.* These are discussed in the context of agriculture business only. Thus leaving the broad risks and impacts of CC, and risk distribution characteristics, unaddressed.

*Adaptation and mitigation.* The study design focuses on agricultural adaptation and mitigation. Broader adaptation and mitigation issues beyond agriculture are not discussed, thus leaving most of the answers to the fundamental questions, unanswered. These questions include: What are the roles of mitigation and adaptation? What are the means of mitigation? What are the means of adaptation?

*Socio-economic.* The theme is not addressed.

*Policy and governance.* The theme is not addressed.

*Ethics.* The theme is not addressed.

In summary, CC is very poorly addressed in this study design. Only three out of the eight CC themes are present in a very limited way. Not one of the themes is addressed in full.

#### 5.5. Cross-Curriculum Integration

There is no mentioning of either cross-curriculum integration, collaboration, or supplementary pathways for concluding students' CC education. Prior knowledge is not discussed. There seems to be an assumption that students already know quite a lot about CC, as the unit focuses only on providing that 'extra bit' related to the role of agriculture in CC. No information is provided as to how the additional missing knowledge may be acquired.

### 6. Geography

#### 6.1. Analysis of Rationale Aims and Structure

CC is mentioned under Cross Study Specifications, as follows: 'Scale is also involved when seeking explanations or outcomes at different levels. Local events can have global outcomes, for example the effects of local actions such as local carbon dioxide production on global climate' [63] (p. 10). The statement expresses conceptualization of CC from *complexity and multiple systems interaction* perspective, as it connects systems across scales.

#### 6.2. CC within the Four Units

CC is addressed in Units 1 and 3. It is not specifically addressed in Units 2 and 4. Unit 1 is entitled 'Hazards and disasters'. The scope is described as follows:

Technological hazards are human induced and exacerbated hazards including oil spills, air pollution, radiation leaks, flooding primarily caused by land clearances, epidemics caused by poor living conditions and hazards caused by current **climate change** such as rising sea levels or increased intensification of weather events [63] ( p. 14).

Climate change is conceptualized as human induced problem, which causes hazards such as sea rise. From this perspective CC is both an outcome and a cause. This representation of CC expresses the two characteristics of *complexity and multiple systems interactions*, and *cross-disciplinary approaches*.

Unit 3 entitled 'Changing the land', adds an additional dimension to CC perception, which is CC as a process. This appears as follows:

Natural land cover has been altered by **many processes** such as geomorphological events, plant succession and **climate change**. People have modified land cover to produce a range of land uses to satisfy needs such as housing, resource provision, communication, recreation and so on. Students investigate three major processes that are changing land cover in many regions of the world: deforestation, desertification, and melting glaciers and ice sheets [63] (p. 20).

In the above quote CC is perceived as a process and to some extent as a cause that leads to changes in land cover. No further information is provided in regard to *nature of CC*.

### 6.3. Content Knowledge

The term CC appears only twice throughout the study design, without any explanation. However some aspects of CC are addressed in disregard to the phenomena as whole. These include: What is climate and how is it different than weather? [63] (p. 14); Human impacts on creating hazards [63] (p. 15); adaptation and mitigation [63] (p. 16); observed changes [63] (pp. 20 - 21); students examine global responses to land cover changes [63] (p. 21); and, population growth [63] (p. 24). These aspects are taught in various contexts. No connections are made between the various fragments of CC information.

### 6.4. Essential Content Left as 'Holes' in Knowledge

*Observed changes in climate.* This theme is taught in a fragmented way with much information missing. There is no answer to the question: What is climate change? Instruments and means of measuring CC in different time scales are not addressed. Observed facts are partially addressed.

*Drivers of CC.* The theme is not addressed.

*Future CC.* The theme is not addressed.

*Risks and impacts.* Only limited risks are discussed in the context of hazards and disasters. These are disconnected from the broader context of CC. The characteristics of risk and impact distribution are not addressed.

*Adaptation and mitigation.* This aspect is partially addressed in the context of hazards and disasters. These are disconnected from the broader context of CC.

*Socio-economic.* The theme is not addressed in the context of CC.

*Policy and governance.* The theme is not addressed.

*Ethics.* The theme is not addressed.

In summary, the VCE Geography study design mentions CC, but does not teach it. Some CC themes which are addressed, appear disconnected from the broader CC phenomena.

### 6.5. Cross-Curriculum Integration

There is no mentioning of either cross-curriculum integration, collaboration, or supplementary pathways for concluding students' CC education. Prior knowledge is not discussed. There seems to be an assumption that when CC appears in the text, it is understood by students without need for explanation.

## 7. System Engineering

### 7.1. Analysis of Rationale Aims and Structure

The Aims outline a few CC associated challenges, ranging from energy issues to health and education. The focus is on technology and its ability to transform other systems. It states that 'the study enables student to: ...develop an understanding of how technologies have transformed people's lives and can be used to solve challenges associated with climate change, efficient energy generation and use, security, health, education and transport' [64] (p. 5).

CC in the quote above seems to be conceptualized as a problem that requires technological fix. Within this context, two of the four CC characteristics are apparent: The *complexity and multiple systems interactions*, and *cross-disciplinary approaches*. These characteristics are expressed through the connections made between technology and other areas such as health and education, in relation to CC challenges.

### 7.2. CC within the Four Units

Climate change is not addressed in Units 1-2. In Unit 3 it appears under Area of Study 2, entitled 'Clean energy technologies'. The term CC does not appear specifically. Carbon dioxide is mentioned in the context of energy technologies, as follows:

Students consider the technological systems developed to capture and store renewable energy and technological developments to improve the credentials of non-renewables. These developments include gains in efficiency through the transformation of non-renewables to other types of energy such as electricity, reduction of **carbon dioxide** emissions with non-renewable fuel technologies and hybrid technologies [64] (p. 25).

The above quote once again expresses a perception of CC as an issue requiring technological fix, rather than a fundamental problem of humanity.

### 7.3. Content Knowledge

The unit focuses on energy technology and addresses impacts on socio-economic and environmental issues, as follows: 'They consider the relevance of designing systems that are beneficial to the economy, environment and society. Demand for energy to produce electricity, heating and propulsion has sharply increased in recent years. However, current use of non-renewable energy cannot be sustained' [64] (p. 25). Students study about alternative forms of energy production and use, and 'technological developments to reduce carbon emissions' [64] (p. 25).

### 7.4. Essential Content Left as 'Holes' in Knowledge

Regardless of the mentioning of CC within the Aims, the topic itself is not addressed. Out of the eight themes of CC knowledge, only mitigation is addressed to a very limited extent. Students learn about technological means to reduce carbon emissions. All other themes are not addressed, including: observed changes in climate, drivers of CC, future CC, risks and impacts, adaptation and most aspects of mitigation, socio-economic, policy and governance, and ethics.

### 7.5. Cross-Curriculum Integration

There is no mentioning of either cross-curriculum integration, collaboration, or supplementary pathways for concluding students' CC education.

## 8. Chemistry

### 8.1. Analysis of Rationale Aims and Structure

CC is not mentioned.

### 8.2. CC within the Four Units

Units 1, 2 and 4 do not address CC in any way. Unit 3 is entitled 'How can chemical processes be designed to optimise efficiency?' Under Area of Study 1, the term *greenhouses gases* appears twice under Key Knowledge, as follows:

calculations related to the combustion of fuels including use of mass-mass, mass-volume and volume-volume stoichiometry in calculations of enthalpy to determine heat energy released, reactant and product amounts and net volume of **greenhouse gases** at a given temperature and pressure;

the comparison of the use of fuel cells and combustion of fuels to supply energy with reference to their energy efficiencies (qualitative), safety, fuel supply (including the storage of hydrogen), production of **greenhouse gases** and applications [65] (p. 26).

In the Chemistry study design CC is conceptualised as a mere technological problem related to efficiency. There is no evidence for conceptualising CC as the major global humanity challenge of our time.

The Advice to Teachers adds a humanistic perspective that may be associated with the ethics and/or the socio-economic content knowledge themes. It suggests to 'create a blog to evaluate public arguments for the use of biofuels as a replacement for fossil fuels, for example consider arguments for the future of biofuels from articles at Eniday or Howstuffworks or the Washington Post' [83]. This activity suggests a *cross-disciplinary conceptualization* of CC, though limited to consideration of types of energy sources.

### 8.3. Content Knowledge

The study design addresses technological aspects that may be related to mitigation. The Advice to Teachers suggests two learning activities in line with the technological conceptualization of CC. The first is 'compare the advantages and disadvantages of the use of fossil fuels and biofuels as energy sources' [83]. The second activity, mentioned above relates to evaluating public opinion regarding fuels. Though the second activity offers a somewhat wider perspective of CC, it is still limited to comparing biofuels to fossil fuels, disregarding the broader CC context.

### 8.4. Essential Content Left as 'Holes' in Knowledge

The VCE in chemistry does not address most CC content knowledge themes. These include: Observed changes in climate; drivers of CC; future CC; risks and impacts; adaptation; socio-economic; policy and governance; and, ethics. In adaptation and mitigation, only mitigation is addressed in a very technical way, focusing on comparing two types of energy sources, in a way that is devoid of the broader CC context. The essential questions: What are the roles of mitigation and adaptation? What are the means of mitigation? And, what are the means of adaptation? – These remain mostly unaddressed.

It seems appropriate to conclude that in the VCE Chemistry study design, CC remains as a 'hole' in knowledge almost in its entirety. The technical calculation of GHG emissions under different energy production methods, is insufficient to qualify this study design as teaching CC.

### 8.5. Cross-Curriculum Integration

There is no mentioning of either cross-curriculum integration, collaboration, or supplementary pathways for concluding students' CC education.

## 9. Outdoor and Environmental Studies

### 9.1. Analysis of Rationale Aims and Structure

CC is not mentioned.

### 9.2. CC within the Four Units

Unit 1 does not address CC. Climate changes is addressed in Units 2, 3 and 4. Unit 2, is entitled 'Discovering Outdoor Environments'. Under Area of Study 1, Key knowledge states: 'scientific understandings of specific outdoor environments, including: ...effects of natural changes to environments on people and places such as day to night, seasons, tides, flood, drought, migration, succession, and climate change' [66] (p. 12). According to the statement, CC is conceptualized as a natural change, acting as a cause.

The same misconception by which CC is a natural change appears once again in the Learning Activities as follows:

select an outdoor environment you have visited and create a **table identifying natural changes** that occur in that environment; for example, the difference between seasons, day and night, high and low tide or as a result of **climate change**; describe how these changes affect that specific environment and how they impact on the way people use that environment ([84]).

Similar to the above, in this learning activity CC is conceptualised as a cause of natural changes.

In Unit 3, Area of Study 2, is entitled 'Relationships with Australian environments since 1990' The Key knowledge states: 'social and political debates about climate change, water management, and renewable energy and the impacts of these debates on societal relationships with outdoor environments' [66] (p. 16). This statement presents CC as a political debatable issue within the Australian society and government.

CC is portrayed once again as debatable in the following Learning Activity: 'Produce a discussion paper that summarises the arguments that both support and reject the case that humans have created climate change; discuss how differing opinions on the issue of climate change influence contemporary relationships with outdoor environments' [84]. To our view it is unacceptable to debate the question of whether humans cause climate change in a VCE study design. This question has been firmly resolved by the scientific community and it is beyond debate. Portraying CC as debatable (in regard to anthropogenic causes) is similar to requesting students to debate and provide evidence that support or reject the Theory of Evolution, by which species evolve through natural selection.

This same inappropriate idea is reiterated for the third time in the following activity: 'debate an environmental issue, such as climate change, water management or renewable energy' [84].

The study design provides expansion beyond the Australian political context. It appears in the Advice for Teachers Learning Activities, as follows: 'signing of the Kyoto protocol and Paris Agreement; the proposals for carbon tax and emissions trading schemes' [84].

Unit 4 is entitled 'Sustainable outdoor relationships'. In Area of Study 1, a Key Knowledge states: 'the potential impact on society and outdoor environments of land degradation, introduced species, climate change, urbanisation and other significant threats' [66] (p. 19). CC in this statement is presented once again as a cause with effects on society and the environment. It appears as equivalent and in line with other causes such as introduced species and land degradation. We find this presentation of CC as reductionist and to extent, inaccurate, as these are not parallel effects.

There is no evidence in the study design for conceptualization of CC in accordance to any of the four *nature of CC* characteristics.

### 9.3. Content Knowledge

In some parts of the study design CC seems to me misunderstood and perceived as a naturally occurring phenomena. The only CC contents that are explicitly taught are the Kyoto Protocol and Paris Agreement. These seem to be out of context, falling under the Policy and Governance theme.

### 9.4. Essential Content Left as 'Holes' in Knowledge

Overall, seven out of the eight content knowledge themes are not present in the study design. Policy and governance appear to a very limited extent, focusing on the two international agreements only, the Kyoto protocol and the Paris Agreement.

### 9.5. Cross-Curriculum Integration

There is no mentioning of either cross-curriculum integration, collaboration, or supplementary pathways for concluding students' CC education. While CC is mentioned in the study design, prior knowledge is not discussed, and there is no information as to where and when students may acquire the missing knowledge.

## 10. Food Studies

### 10.1. Analysis of Rationale Aims and Structure

CC is not mentioned.

### 10.2. CC within the Four Units

Units 1-3 do not address CC in any way. Unit 4 is composed of two Areas of Study. In Area of Study 1, entitled 'Environment and ethics', CC is presented as an outcome state forming environmental risk. The Key Perspective states: 'the environmental sustainability of primary food production in Australia, including use of fertilisers, pesticides and water, choice of crops and animals for farming, and risks associated with biosecurity, climate change and loss of biodiversity' [67] (p. 19). Climate change in this statement is conceptualised as a risk, characterised by *complexity and multiple systems interactions* and *future oriented and uncertainty*. The perception of CC as an environmental risk is further enhanced in the Learning Activity associated with this Area of Study. In this activity students are invited to participate in a class discussion related to biodiversity. The following information is presented as a prompt for conversation:

Fewer than 20 animal and plant species now provide most of the world's food and just three crop plants, wheat, rice and maize (corn), supply more than half of the world's food energy. Agricultural systems with low genetic variation are more susceptible to pests and diseases and are also less able to adapt to environmental challenges, such as **climate change** and water scarcity. As biodiversity declines, the food supply becomes more vulnerable and unsustainable ...' [85 in 67].

Similar to the above statements, CC is understood in this activity as an outcome state of environmental challenge, or a risk.

### 10.3. Content Knowledge

The study design and the associated learning activities do not provide any content knowledge related to CC, apart from mentioning the term.

### 10.4. Essential Content Left as 'Holes' in Knowledge

The eight themes constituting CC are not addressed.

### 10.5. Cross-Curriculum Integration

There is no mentioning of either cross-curriculum integration, collaboration, or supplementary pathways for concluding students' CC education. Prior knowledge is not discussed, and therefore it is not clear what sources may facilitate students' understanding of the term CC when introduced in Unit 4.