Teaching
Climate Change

Natural Sciences Grades 7–9

Susan Brundrit

This is a teacher education text. Its purpose is to expand educators' knowledge of environmental topics to support the teaching thereof in the curriculum. Teachers and teacher educators should consult CAPS documents and textbooks for specific curriculum content, as these units are not a textbook, but rather a resource for teacher education.

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Orientation

Introduction

What is climate change?

Climate change refers to significant and lasting changes in long-term weather patterns in a specific region or across the whole Earth. It describes changes in overall weather patterns, including precipitation, temperatures, cloud cover, and so on. It can cause an increase or a decrease in the number of extreme weather conditions in an area, or result in a shift in an area's traditional weather patterns.

These changes are caused by both human activities and natural phenomena, which alter the chemical composition of the atmosphere through the build-up of greenhouse gases.

Why is climate change important?

Climate change has become an important topic all over the world – especially as we begin to feel the physical effects of these changes on our daily lives. Most people accept that climate change is happening, and that we need to deal with it in some way. Some of the effects of climate change may include more extreme weather events, increased floods and droughts, reduced agricultural yields, melting polar ice caps and extinction of plant and animal species. These changes may have further significant impacts on both the natural world and our human societies. Learners will need the geographical knowledge and skills that are fundamental to understanding climate processes AND climate change in order to respond effectively to these changes.

Climate change and its impacts are very broad, complex and highly debated. Although there is a large amount of scientific data available about climate change, there are also many beliefs, assumptions, and emotional reactions affecting the way that people think and speak about the changes that are happening. This means that learning about climate change is about MORE than learning the FACTS – it is also about questioning what people are saying, finding new perspectives and exploring how climate change affects our lives.

In these three Climate Change units, we will introduce you to a number of ways of teaching and learning about climate change.

How these units support teaching and learning about climate change

These units have been developed to support Senior phase Natural Science teachers in meeting the requirements for CAPS while teaching about climate change. The units here cover several aspects of core content knowledge taught in Grades 7-9. Each unit begins with a list of the relevant CAPS topics covered. This book has focussed mostly on the knowledge strands of Matter and Materials, Energy and Change and Planet Earth and Beyond.

For activities and information that have more of a focus on the Life and Living knowledge strand, refer to the Fundisa book *Teaching Biodiversity.*

As stated in the CAPS, the careful selection of content and the use of a variety of teaching approaches, should promote an understanding of:

- Science as a discipline that sustains enjoyment and curiosity about the world and natural phenomena;

- The need for using scientific knowledge responsibly in the interest of ourselves, of society and the environment; and
- The practical and ethical consequences of decisions based on Science.

In these three units, we support you as a teacher to:

- Strengthen your subject content knowledge of climate change;
- Enhance your teaching practice; and
- Support your assessment practice.

The different Senior Phase Natural Science Climate Change units in the Fundisa for Change programme integrate with each other to assist teachers to:

- Understand climate as a large energy-driven system; and
- Provoke critical thinking about the idea that people are part of the Earth System and can have positive and negative impacts on it.

Climate Change in the CAPS

The Senior Phase Natural Science Climate Change units

The three climate change units in this Fundisa for Change resource, have been developed to expand teachers' knowledge and expertise in ways that also support teaching the CAPS Natural Science curriculum for Grades 7-9. The sections do not necessarily follow the sequence of the CAPS. The most relevant connections to CAPS topics are indicated at the start of each unit with more details provided at the start of each activity.

The units are:

Unit 1: The Evolving Planet
Unit 2: Earth Systems and Climate Change
Unit 3: Energy and Carbon Dioxide

The Climate Change units and their relationship to teaching the CAPS

The CAPS includes much content knowledge that is necessary to the understanding of climate change. Often the link between the topic and its application to climate change is not made explicit. For example, the topics of density and the effect of temperature on density as described in the particle model of matter in Grade 8, Term 2 provide the crucial content knowledge behind understanding the thermohaline circulation of the ocean, which in turn influences climate. Many of the activities in the units below then, play the role of connecting the science content knowledge to the topic of climate change.

CAPS links to the Climate Change units

Teachers should consult the CAPS for specific curriculum content.

Unit 1: The evolving planet

The first Climate Change unit focuses on the past events in the Earth's history and the characteristics that make Earth able to sustain life.

The activities are:

1. Examining changes in global climate over time
2. A ball of ice?
3. Earth from Space
4. The special features of planet Earth

Unit 1 related topics within the CAPS, showing relevant grades and terms:

KEY CONCEPTS AND PROCESSES	GRADE	TERM
The Biosphere The concept of the biosphere Requirements for sustaining life	7	1
Relationship of the Sun to the Earth Solar energy and life on Earth	7	4
The Solar System Earth's position in the Solar System	8	4
The Earth as a system Spheres of the Earth **Lithosphere** The rock cycle	9	4

Unit 2: Earth systems and climate change

This Fundisa for Change unit focuses on the concept of the Earth as a system, exploring some of the different earth systems before focusing on the water cycle and the role of the ocean on climate.

The activities are:

1. Interconnectedness in global systems
2. Properties of the ocean
3. The ocean's circulatory system and climate
4. The polar albedo feedback loop

Unit 2 related topics within the CAPS, showing relevant grades and terms:

KEY CONCEPTS AND PROCESSES	GRADE	TERM
Properties of materials Physical properties of materials **Separating mixtures** Methods of physical separation	7	2
Heat transfer Convection Radiation	7	3
Particle model of matter Density and states of matter Density of different materials Expansion and contraction of materials	8	2
Visible light Absorption of light Reflection of light	8	3
The Earth as a System Spheres of the Earth Atmosphere	9	4

Unit 3: Energy and carbon dioxide

The final unit focuses on the sun as the source for all energy, the science of the greenhouse effect and the consequences of our use of fossil fuels.

The activities are:

1. The Greenhouse game
2. Consequences of increased levels of greenhouse gases in the atmosphere
3. Using solar energy to heat water
4. Energy use in your home

Unit 3 related topics within the CAPS, showing relevant grades and terms:

KEY CONCEPTS AND PROCESSES	GRADE	TERM
Sources of energy Renewable and non-renewable sources of energy **Heat transfer** Heating as a transfer of energy Conduction Convection Radiation **Insulation and energy saving** Using insulating materials	7	3
Relationship of the Sun to the Earth Stored solar energy	7	4
Interactions and interdependence within the environment Balance in an ecosystem	8	1
Visible light Radiation of light Reflection of light Refraction of light	8	3
Cost of electrical power The cost of power consumption	9	3
Atmosphere The greenhouse effect	9	4

Key concepts

A number of key ideas or concepts are especially important when teaching and learning about climate change. We have highlighted these here:

To help people to understand and discuss climate change, scientists and government representatives belonging to the IPCC (Intergovernmental Panel on Climate Change) have drawn up a set of agreed definitions relating to climate change. The following definitions have been adapted from the IPCC definitions. You can find the definitions that have been agreed upon by governments and scientists on the IPCC website: www.ipcc.ch

Climate:

We usually refer to climate as the average of daily weather over about 30-50 years (Richardson et al., 2011). This includes fluctuations in, amongst other variables, daily temperature, rainfall and air pressure. To observe a change in climate requires several years of data observation, e.g. changes in rainfall over the last 30 years.

Climate change:

Climate change refers to long-term changes in climate. Climate change usually also refers to significant changes in long-term weather patterns in a specific region or across the whole Earth.

Climate variability:

Climate variability refers to shorter-term changes in the climate compared with what is considered 'normal'. Various atmospheric factors can influence climate in the short term.

It is important to distinguish between climate change and climate variability. It is not accurate to consider weather events like a storm or hurricane as 'simply' part of climate change before we have examined the long-term weather data for a region to see if this event is 'normal' or if there is a notable, new emerging trend. Remember that while it is possible for storms to become more intense because of climate change, this is not always the case – so we cannot assume this before examining the data.

Climate variability (e.g. floods, El Niño events) could be compared to a coach on the climate change train. What happens to the train (climate change) will also influence the journey of the individual coaches (see IPPC SREX Report, 2011).

Scientists generally look at 30 years of data (e.g. changes in rainfall over the last 30 years) before accepting that a climatic event is due to climate change or not.

Climate adaptation:

The ability to adapt or change in response to changing climate.

Climate mitigation:

Efforts to reduce, limit and respond to the causes of greenhouse gases and other factors 'driving' climate change.

Greenhouse effect:

Gases in the atmosphere absorb, reflect and re-radiate energy in the climate system.

Enhanced greenhouse effect:

The greenhouse effect is a natural process that has operated over several thousands of years. Humans are adding to or 'enhancing' this process, so it is important to try to distinguish between the way in which humans contribute to the greenhouse effect compared to the Earth's natural processes.

Climate change drivers:

These are the factors that change the energy balance of the Earth system, causing climate change and climate variability. They include both human and natural effects on the climate, and are also known as 'forcing' factors (e.g. solar forcing).

Anthropogenic drivers of climate change:

Anthropogenic means 'caused by humans'; anthropogenic drivers are the human activities that are increasing climate change, e.g. land-use changes that influence the reflectivity (or albedo) of the Earth, and the addition of greenhouse gases into the atmosphere caused by the burning of fossil fuels.

Unit 1

The evolving planet

This Fundisa for Change unit focuses on the past events in the Earth's history and the characteristics that make Earth able to sustain life.

The key questions addressed by this unit are:

- What was the climate like in the past?
- How did the past climatic events influence life on Earth?
- What makes Earth able to sustain life?

Opportunites arise for discussing these questions as part of the CAPS topics listed in the table below.

KEY CONCEPTS AND PROCESSES	GRADE	TERM
The Biosphere The concept of the biosphere Requirements for sustaining life	7	1
Relationship of the Sun to the Earth Solar energy and life on Earth	7	4
The Solar System Earth's position in the Solar System	8	4
The Earth as a system Spheres of the Earth **Lithosphere** The rock cycle	9	4

Subject Content Knowledge

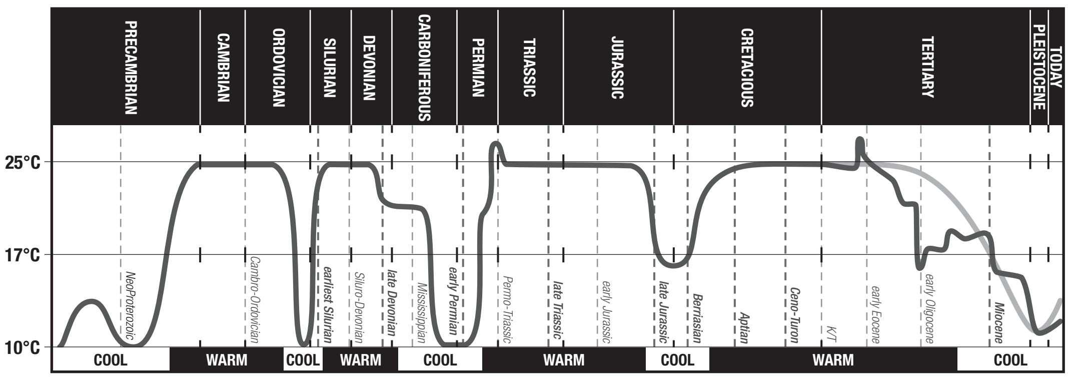
Introduction

Earth has had warming events before. In fact, if we look at the history of Earth we see that the planet has experienced many different climates in the past. We can also pick out five major extinction events in the Earth's history, some of which appear to be associated with climate changes whether they be cooling or warming events. What is evident though is that these 'events' took place over very long periods of time, sometimes millions of years. There was plenty of time for the life forms present on Earth to adapt and evolve in response to changing conditions. The serious concern over the current trend of global warming is that it is happening at a speed that will prevent many life forms being able to evolve and adapt.

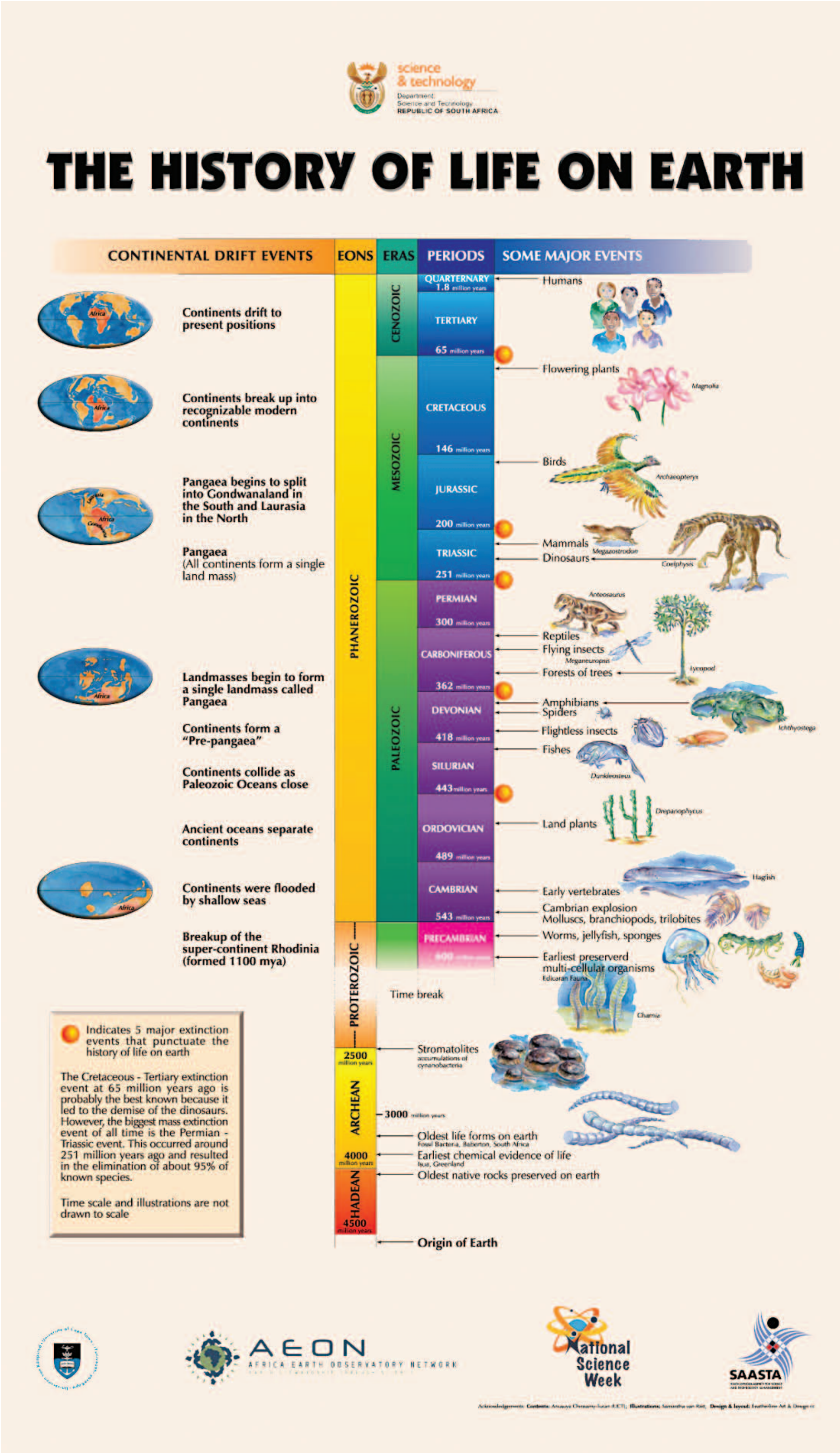
Paleoclimatology not only includes the collection of evidence of past climate conditions, but the investigation of the climate processes underlying these conditions. Climatic records made by humans only go back to 150 years. Scientists therefore have to depend on "proxy" sources or paleoclimatic records from glaciers, trees and sediments. Studying paleoclimatic trends has allowed us to develop models for explaining past events and to improve the ability of computer models to simulate future climate.

Before we can focus on current climate change as an issue, it is important for learners to gain some sense that the Earth as it is at this moment in time, is a special planet. The first acitivites in this unit reinforce this as they allow learners to see that the Earth has not always been the way it is now. The later activities explore what it is that makes Earth special – the features that make Earth habitable and that sustain life.

The first activities refer to the temperature timeline below and the poster from the Department of Science and Technology overleaf:



Source: Scotese, C.R., 2002, http://www.scotese.com (PALEOMAP website)


science & technology
Department: Science and Technology
REPUBLIC OF SOUTH AFRICA
THE HISTORY OF LIFE ON EARTH
CONTINENTAL DRIFT EVENTS
EONS
ERAS
PERIODS
SOME MAJOR EVENTS
Continents drift to present positions
Continents break up into recognizable modern continents
Pangaea begins to split into Gondwanaland in the South and Laurasia in the North
Pangaea (All continents form a single land mass)
Landmasses begin to form a single landmass called Pangaea
Continents form a "Pre-pangaea"
Continents collide as Paleozoic Oceans close
Ancient oceans separate continents
Continents were flooded by shallow seas
Breakup of the super-continent Rhodinia (formed 1100 mya)
PHANEROZOIC
PROTEROZOIC
ARCHEAN
HADEAN
CENOZOIC
MESOZOIC
PALEOZOIC
QUARTERNARY
1.8 million years
TERTIARY
65 million years
CRETACEOUS
146 million years
JURASSIC
200 million years
TRIASSIC
251 million years
PERMIAN
300 million years
CARBONIFEROUS
362 million years
DEVONIAN
418 million years
SILURIAN
443 million years
ORDOVICIAN
489 million years
CAMBRIAN
543 million years
PRECAMBRIAN
2500 million years
3000 million years
4000 million years
4500 million years
Humans
Flowering plants
Magnolia
Birds
Archaeopteryx
Mammals
Dinosaurs
Megazostrodon
Coelphysis
Anteosaurus
Reptiles
Flying insects
Meganeuropsis
Forests of trees
Lycopod
Amphibians
Spiders
Ichthyostega
Flightless insects
Fishes
Dunkleosteus
Land plants
Drepanophycus
Early vertebrates
Hagfish
Cambrian explosion
Molluscs, branchiopods, trilobites
Worms, jellyfish, sponges
Earliest preserverd multi-cellular organisms
Edicaran Fauna
Charnia
Time break
Stromatolites
accumulations of cyanobacteria
Oldest life forms on earth
Fossil Bacteria, Barberton, South Africa
Earliest chemical evidence of life
Isua, Greenland
Oldest native rocks preserved on earth
Origin of Earth
Indicates 5 major extinction events that punctuate the history of life on earth
The Cretaceous - Tertiary extinction event at 65 million years ago is probably the best known because it led to the demise of the dinosaurs. However, the biggest mass extinction event of all time is the Permian - Triassic event. This occurred around 251 million years ago and resulted in the elimination of about 95% of known species.
Time scale and illustrations are not drawn to scale
AEON
AFRICA EARTH OBSERVATORY NETWORK
National Science Week
SAASTA

Expanding knowledge

The following references and hyperlinks are all to interesting websites that present relevant information in an understandable way.

References

Philander, S. G. (2004). *Our Affair With El Niño*, Princeton University Press.

CCHEAP Resources (2008). Schools Development Unit and DEADP.

Hyperlinks

http://www.igbp.net/globalchange/ – IGBP (International Geosphere-Biosphere Programme) Global Change *Science for a sustainable planet* website contains an easy-to-read overview of Earth Systems science.

http://oceanworld.tamu.edu/resources/oceanography-book/oceansandclimate.htm – Our Ocean Planet: Oceanography in the 21st Century – An Open Source oceanography textbook written by Prof. Robert Stewart, Texas A&M University.

www.scotese.com/climate.htm – Paleomap project website, giving information on the history of Earth's climate including an animation showing the changes.

http://www.ncdc.noaa.gov/paleo/education.html – National Climatic Data Centre, National Oceanic and Atmospheric Administration website containing information about Paleoclimatology as well as many other links to other Paleoclimatology educational websites.

http://www.eoearth.org – The Encyclopedia of Earth website has a section on Climate Change. Select "Causes – Past History" for information on Earth's past climates.

http://www.globe.gov/ – The Global Learning and Observations to Benefit the Environment (GLOBE) programme is a worldwide hands-on, primary and secondary school-based science and education programme.

http://www.bbc.co.uk/nature/ancient_earth/Snowball_Earth – Discusses the Snowball Earth theory with a series of videos.

http://www.bbc.co.uk/science/earth/water_and_ice/ice_age – Explains the ice age cycle and includes video clips.

http://www.enchantedlearning.com/subjects/mammals/Iceagemammals.shtml – Provides some information about the mammals on Earth during the last Ice Age and before.

http://www.exitmundi.nl/Iceage.htm – Provides some alternative ideas around whether or not the Ice Age is about to start and what the causes might be.

http://www.wmich.edu/corekids/Climate-Change.htm – Western Michigan University's Core Kids MGRRE's K-12 Earth Science Outreach Programme.

Documentaries

Earth: The Power of the Planet (series), BBC.

How Earth Made Us (series), BBC.

Teaching Practice

In this section we explore various ways in which we can teach learners about The Evolving Planet. The activities are designed to model a number of the different methods and processes detailed in the Fundisa for Change *Methods and Processes to Support Change-Oriented Learning* booklet.

ACTIVITY 1

EXAMINING CHANGES IN GLOBAL CLIMATE OVER TIME

For more on this particular method, see the *Methods & Processes* book, p.14.

Method used: Information transfer and guided questioning

In this method we initially use structured questions to focus learner's attention on particular aspects of the information. Questions then change to become more interpretive in nature, allowing learners to make connections between new and existing knowledge.

Links to CAPS

This activity helps to develop the following knowledge and skills as described in the CAPS:

- Interpreting and sequencing data from the different eras and periods;
- Interpreting information;
- Raising questions;
- Hypothesising; and
- Graph reading and interpretation skills.

Core knowledge

Paleoclimatology is the study of the climate that existed before humans began collecting instrumental measurements of weather (for example, temperature from a thermometer, precipitation from a rain gauge, sea level pressure from a barometer, wind speed and direction from an anemometer). Instead of instrumental measurements of weather and climate, paleoclimatologists use natural environmental (or "proxy") records to infer past climate conditions. Paleoclimatology not only includes the collection of evidence of past climate conditions, but the investigation of the climate processes underlying these conditions.

Paleoclimatology: The study of past climate. The word is derived from the Greek root "paleo" which means "ancient," and the term "climate".

From the paleooclimate perspective, climate change is normal and part of the Earth's natural variability related to interactions among the atmosphere, ocean and land as well as changes in the amount of solar radiation reaching the Earth. The geologic record includes much evidence of large-scale climate changes.

The Earth is estimated to be over 5 billion years old. Over the past 40 million years, tectonic re-arrangement of the continents has led to changes in ocean circulation and to ice build-up. For example, 600 – 800 million years ago, it appears that ice sheets may have reached the equator, according to geological and paleomagnetic research, possibly resulting in what is referred to as "snowball Earth".

Some of the major factors resulting in climate change in the past, sometimes so severe as to result in mass extinctions, are:

- Volcanic eruptions which cause vast quantities of carbon dioxide to be emitted into the atmosphere, ash clouds blocking sunlight, potentially acid rain and large scale floods of basalt lava;
- Plate tectonics and continental drift;
- Sea level falls from the sinking of tectonic plates or sustained global cooling; and
- Asteroid impacts, the largest of which produced a crater of more than 100km wide.

Outline of activity

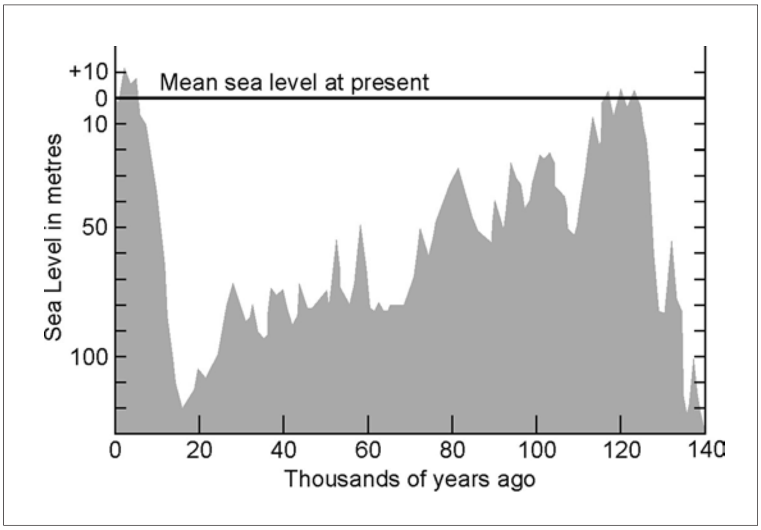
1. Refer learners to the poster entitled "The History of Life on Earth" (on page 14). The poster shows how global climate has changed over time.

   Learners should engage with the poster to answer the following questions:

   - When did the last ice-age take place?
   - What in your opinion could have caused the Earth's climate to change so dramatically?
   - Scan the poster for peaks of warm climatic periods over the past million years. Have any of the warmer periods exceeded the temperature recorded for today?

2. The figure below shows the sea level history recorded over the past 140 000 years.

   Sea-level history over past 140 000 years



   - Why did the sea level change?
   - Imagine you were living in Cape Town 140 000 years ago. Where would your house have to be situated to be on dry land?

Developing your teaching practice

Design an activity around the mass extinctions that have happened in the past. Include a part that involves learners translating information from one form to another, for example reading and writing about information presented on a graph or timeline, or drawing a diagram based on a written description. Include timelines and higher order thinking questions to get learners to think about climatic events in the past.

ACTIVITY 2

A BALL OF ICE?

In this activity, research on the past occurrences of ice ages leads to insight into what may be necessary to survive another ice age.

For more on this particular method, see the *Methods & Processes* book, p.35.

Method used: Deliberative method of scenario planning and investigation

This method involves a structured process of thinking about an unknown future based on the research conducted into a specific topic.

Links to CAPS

This activity helps to develop the following knowledge and skills as described in the CAPS:

- Researching information;
- Identifying problems and issues;
- Raising questions;
- Hypothesising; and
- Communicating.

Core knowledge

During the last 2.6 million years, ice ages or glacial ages, have occured a number of times. These are periods of extreme cooling of the Earth's climate where ice sheets and glaciers cover large areas of land. It is thought that at times in Earth's history, Earth was almost completely ice-bound with life surviving predominantly in the oceans. During one of these times, nicknamed "Snowball Earth", the average temperature of Earth fell from 15°C to -50°C. Between ice ages there are warmer interglacial periods – such as the time we are living in now where the only remnants of the last ice age are the ice caps and the Greenland ice sheet. The most recent ice age peaked about 21 000 years ago and ended about 11 500 years ago. The causes of ice ages are not completely understood. It is also not known whether the anthropogenic influences on the climate system will delay or encourage the onset of the next ice age.

Outline of activity

1. Learners read about the "Snowball Earth":

> **Snowball Earth Hypothesis**
>
> There is evidence that the Late Precambrian glaciation extended to the equatorial regions.
>
> Some scientists suggest the entire Earth (or at least the land areas) were covered in glacial ice, and melted only when volcanic eruptions raised the CO_2 content in the atmosphere, facilitating global warming.

The last ice age was 21 000 years ago. Find out more about Earth's ice ages.

- What animals were alive and how did they survive?
- What did the landforms on Earth look like?
- What would the climate have been like?
- How did humans survive?

Some useful websites:

http://www.bbc.co.uk/science/earth/water_and_ice/ice_age

http://www.enchantedlearning.com/subjects/mammals/Iceagemammals.shtml

http://www.exitmundi.nl/Iceage.htm

2. Learners do scenario planning in groups and brainstorm the following question:

   Imagine that we are heading into an ice age. What strategies would we need to implement in order to survive on this planet?

   Start by writing down a list of questions to which you would want to know the answers.

   Then see if you can find out the answers by researching on the Internet.

   Sometimes you may need to predict the answers to the questions yourselves, but always try to give reasons or arguments to back up your ideas.

Developing your teaching practice

Design a Grade 9 Term 4 activity around the ice ages that have happened in the past. Include the role of the rock cycle and volcanic activity in releasing Earth from the icy grip of "Snowball Earth".

ACTIVITY 3

EARTH FROM SPACE

This activity aims to identify the features of Earth that make it able to sustain life. By doing this activity learners gain a sense of the features that make Earth special. This activity is adapted from the CCHEAP Resources, 2008, Earth Systems Task Card 1: *Earth from space*.

A poster or picture showing the position of Earth in the solar system may help to contextualise Earth's place in space. Additional photos and images of Earth from space could be useful.

Method used: Interpretive

Learners interpret their observations. Learners access known content and re-interpret it in the light of the new question.

Links to CAPS

This activity helps to develop Specific Aim 2: 'Knowing the subject content and making connections' as well as the following cognitive and practical process skills as described in the CAPS:

- Observing;
- Sorting and classifying;
- Interpreting information; and
- Developing the language skill of writing.

More specifically, the skills developed in this activity are:

- Identifying features from a photograph;
- Writing a descriptive paragraph;
- Creative writing involving role play;

- Grouping information into categories; and
- Writing a list.

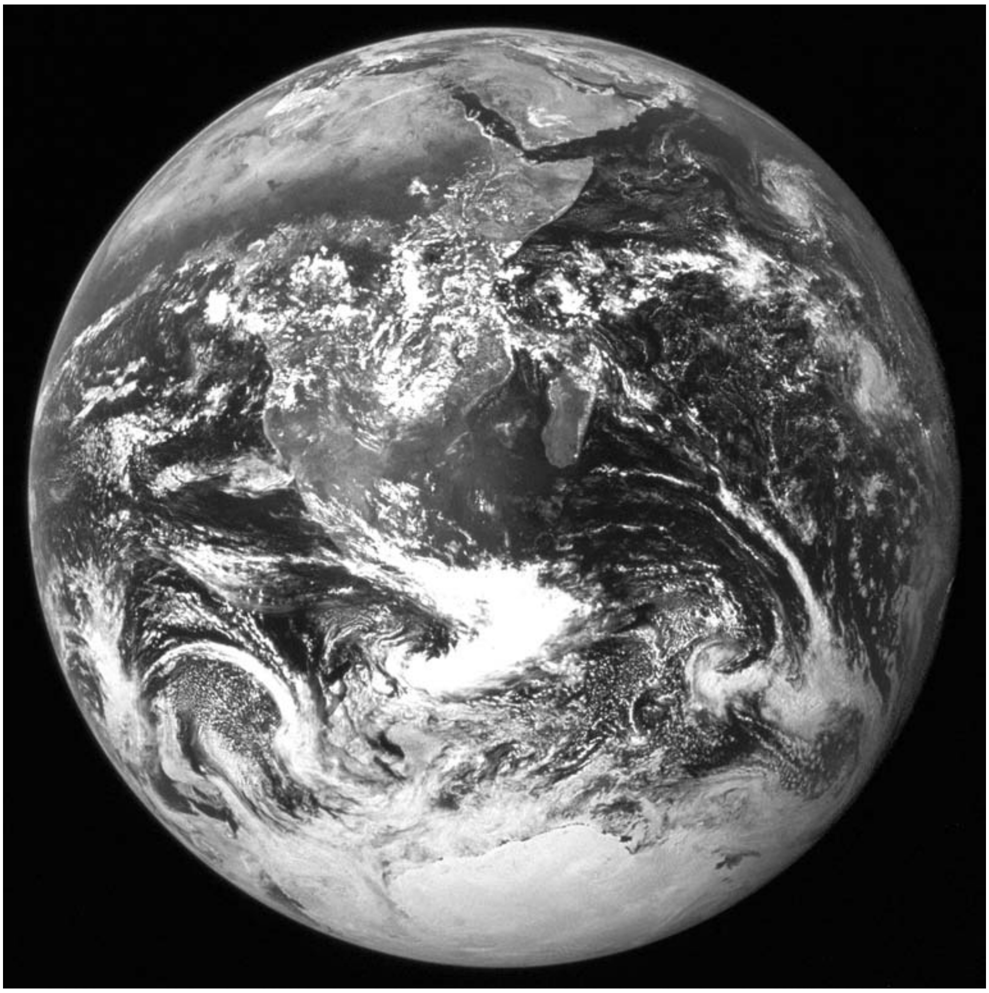
Core knowledge

Many of the features of Earth that can be observed from space would suggest a planet that could support life as we know it:

- Sunlight for energy
- Air (atmosphere) including clouds (and therefore rain)
- Water (hydrosphere) including oceans, lakes, rivers, etc. – this in turn suggests a temperature that allows water to be present in its liquid form – another prerequisite for life
- Soil (pedosphere) or land, some of which is green suggesting vegetation – the presence of which indicates that soil with nutrients are present and that there could be living things (biosphere) including plants, animals, people, etc.
- Snow or ice (cryosphere) – suggesting that some areas of the planet are colder than others
- Rocks (lithosphere)

Outline of activity

In groups, learners look at the picture below of Earth from space. They discuss the question: "What features of Earth can you see?"



Source: NASA photograph taken by astronaut on Apollo 17 mission.

Individually, learners now compete the three tasks below:

Imagine that you are aliens searching for a habitable planet. After passing two enormous planets with rings and many moons, you decide to investigate more closely the small blue dot in this particular solar system.

1. As you get into a closer orbit, you take the photograph above. Now write a short letter to your family on your home planet to describe what features you can see.
2. Your captain wants you to group the features you observed together into four groups. What are the four groups that you identify?
3. You think that this planet may be habitable. Write a list of conditions that appear to exist on Earth to support your idea that Earth may be habitable, to take to the captain.

Habitable: means 'has conditions that make it suitable to live in or on'.

Assessment

Learners' responses to these questions will vary. Some key words to look for in their writing are: oceans, water, land, mountains, clouds, soil, rocks, plants, desert (and maybe rain, animals, people).

When grouping the observed features, learners may come up with any combination of the following groups:

- Air (atmosphere) including rain and clouds;
- Water (hydrosphere) including oceans, lakes, rivers, etc.;
- Soil (pedosphere) or land;
- Living things (biosphere) including plants, animals, people, etc.;
- Snow or ice (cryosphere);
- Rocks (lithosphere); and
- Sunlight for energy.

At this point the emphasis changes slightly to how these features make Earth habitable and able to sustain life. Reasons given may include that Earth has:

- Water;
- An atmosphere with oxygen;
- Soil with nutrients;
- Carbon;
- Gravity;
- Sun that helps plants make food that we can eat; and
- Right temperature.

ACTIVITY 4

THE SPECIAL FEATURES OF PLANET EARTH

This activity aims to further develop an understanding of the characteristics of Earth that make it habitable. By doing this activity learners gain a sense of the complex interaction of systems that make Earth a special place. The ideas in this activity are developed from the work of George Philander in his 2004 book *Our Affair With El Niño*. The activity itself is adapted from the CCHEAP Resources, 2008, Earth Systems Task Card 2: *What makes planet Earth such a special place*.

Method used: Information transfer

Learners are required to engage with content and transform the content from written to diagrammatical.

Links to CAPS

This activity helps to develop Specific Aim 2: 'Knowing the subject content and making connections' as well as the following cognitive and practical process skills as described in the CAPS:

- Accessing and recalling information;
- Interpreting information; and
- Communicating.

More specifically, the skills developed in this activity are:

- Translate information from a description into a diagram;
- Drawing a labeled diagram to represent the movement of heat within the atmosphere; and
- Interpretation of a map.

Core knowledge

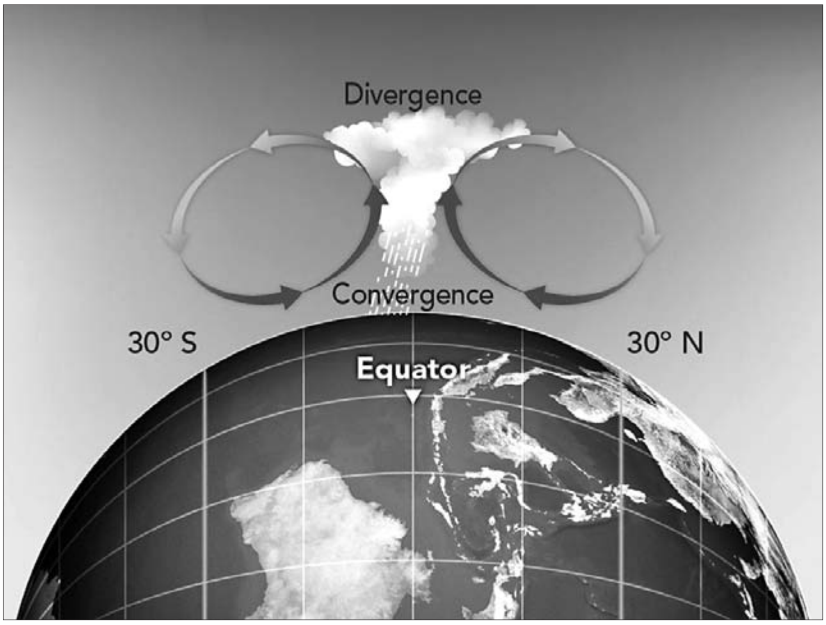
In his book, *Our Affair With El Niño*, George Philander discusses how one could construct a model of Earth's climate through investigating different scenarios.

Refer to the diagram detailing the different models in the activity below.

The first model asks the question, "What would Earth be like if it were a rock?" In other words, if Earth had no atmosphere? With no atmosphere, the land would reflect sunlight back into space. The average surface temperature of the Earth would decrease from 15°C to -18°C. Furthermore, the temperature variation would be greater, with the Earth cooling at night to as low as -160°C as any heat that may have been absorbed is radiated back into space – as it does on the moon.

The second model considers an earth with a static atmosphere and ocean. If the atmosphere and ocean were motionless, Earth would be extremely hot at the equator and the greenhouse effect would cause the atmosphere to become hotter and hotter.

The third model adds a moving atmosphere and ocean. The sun is the driving force behind atmospheric and oceanic circulation – the predominant source of energy for changes on the Earth's surface. As water evaporates from the ocean, the surface is cooled. Winds carry the water vapour up and away from the equator where heat is released as it condenses into water and rains. We now have a water cycle and climate.



Source: US Department of Energy (http://www.pnnl.gov/science/highlights/highlight.asp?id=1098)

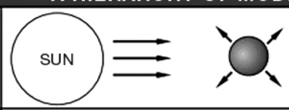
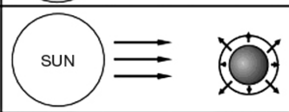
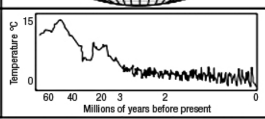
If we now add life to Earth, we also introduce the oxygen and carbon cycles.

The movement of the continents introduces climate change, ice ages and evolution.

We now start to get a glimpse of the climate system and the realisation that climate is not as simple as how much it usually rains or how sunny a place is, but is more a complex interaction between atmosphere, oceans, land masses, greenhouse gases, water, winds and currents. Change in any one of these affects all the others, often in ways we do not yet fully understand.

Outline of activity

1. With a partner, discuss the table below showing five different models of what Earth would be like under different conditions and what the results of those conditions would be.

	A HIERARCHY OF MODELS		
I	A bare rock		Too cold!! -18°C ALBEDO
II	I + static atmosphere & ocean		Too hot!! Greenhouse effect feedbacks
III	II + moving atmosphere & ocean		Water and climate
IV	III + life		Oxygen and carbon cycles
V	IV and drifting continents		Climate changes, ice ages and evolution

Source: CCHEAP Resources (2008), Schools Development Unit and DEADP, adapted from Philander, S. G. (2004). *Our Affair With El Niño*, Princeton University Press.

Albedo: the amount of radiation reflected by a surface.

a) Model I shows Earth as a bare rock. Why would Earth be so cold?

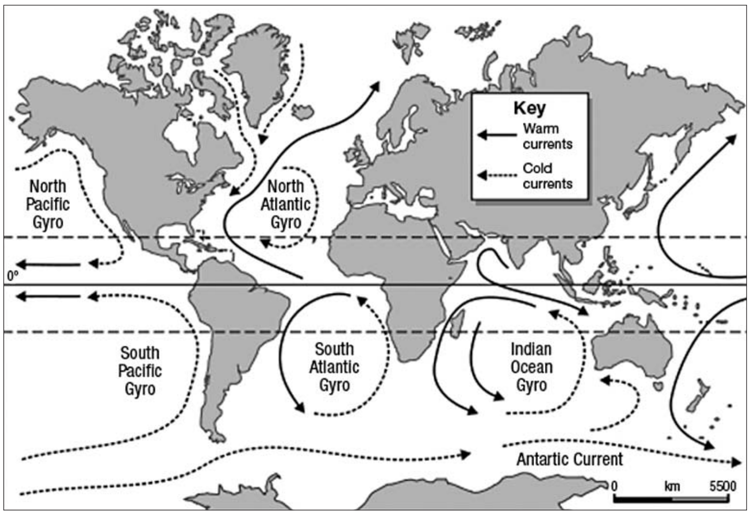
b) Model II shows Earth with an atmosphere and ocean that are still or static. Why would Earth have been too hot then?

2. Model III shows the atmosphere and oceans moving. Read the description below and then draw a labelled diagram to show the circular movement of air in the atmosphere.

> The spherical shape of the Earth means that the energy from the sun is not distributed evenly over Earth and some areas are hotter than others. In hotter areas, there is more evaporation, so the air has more water vapour in it. The hotter, moist air rises, forming clouds. As it rises, it draws colder air in from the surrounding areas, which in turn heats up and rises. A circular motion results, creating winds. Winds moving over the sea, blow the sea surface along creating surface ocean currents. In this way, the uneven distribution of temperature causes movement in the atmosphere and oceans that moves the heat from the sun around Earth more evenly.

Climate: the average weather taken over a long period of time for a given place or region.
Weather: the state of the atmosphere at a specific time and place.
Topography: the shape of the land.

3. The spinning of the Earth on its axis bends wind and surface ocean current directions across the surface of the Earth. The shape of the land also changes the direction of wind and ocean currents. The tilt of the Earth's axis from the vertical gives us our seasons. Together all these factors interact to produce different climates and weather, each combination of rainfall, temperature and topography resulting in different ecosystems. In turn, these diverse ecosystems have allowed for a diversity of life forms to evolve.



Source: CCHEAP Resources (2008), Schools Development Unit and DEADP

a) Write a paragraph to explain what you see happening in the picture of surface ocean currents above.

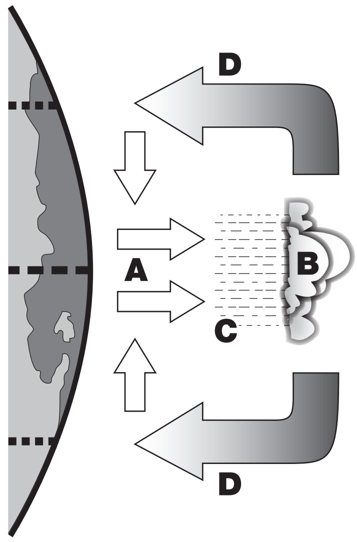
b) Make a list of all the factors that make Earth a habitable planet.

Assessment

1. a) In Model I, if Earth was a bare rock, it would reflect a lot of sunlight as it would have high albedo, making it cold.

b) In Model II, if Earth had a motionless atmosphere and ocean, it would be extremely hot at the equator and the greenhouse effect would cause the atmosphere to become hotter and hotter.

2. Learners draw a labelled diagram showing the circular movement of air in the atmosphere.



A. Temperatures at the equator are highest. Warm air rises containing evaporated moisture.
B. The air cools, condenses and forms clouds.
C. Heavy equatorial rainfall .
D. The cool, dry air then begins descending around 30°N and 30°S. The air warms up. Any moisture in the air is held as water vapour (invisible).

Assessment rubric for the labelled diagram

CRITERION	1 – NOT ACHIEVED	2 – PARTLY ACHIEVED	3 – ACHIEVED	4 – OUTSTANDING
Appearance of diagram	No diagram or diagram does not recognisably show air circulation	Some aspects of the diagram are missing or incomplete	Diagram has a title, labels, shows circular air movement	Diagram is neat and tidy, with a title, shows circular air movement
Information on diagram	Diagram is not labeled	Diagram has some aspects of the labeling or drawing incomplete	Diagram has correct labels and shows the correct directions that air is moving in.	Diagram is correctly and informatively labeled, with correct directions of air movement and clouds above the rising air

3. a) Cold water circles the Antarctic, then heads north, warming as it approaches the equator. Warm water flows along the equator, and then bends away to the north (if on the north side of the equator) or south (if on the south side) cooling as it moves close to the Antarctic. This results in a circular movement as the continents channel the currents.

b) Learners can extend their list from the previous activity. Their list may now look like the one below:

- Water;
- An atmosphere with oxygen;
- Soil with nutrients;
- Carbon;
- Gravity;

- The sun that provides the energy to drive systems and helps plants make food that we can eat;
- The movement of the atmosphere and oceans means more of Earth is the right temperature;
- The tilt of the Earth's axis means that heat is distributed unevenly and we have seasons;
- The spinning of the Earth on its axis also serves to distribute heat around the planet, making more of the Earth habitable.

Assessment Practice

In Grades 7-9, the CAPS formal assessment requirements for Natural Science are as follows:

FORMAL ASSESSMENTS	TERM 1	TERM 2	TERM 3	TERM 4	TOTAL % FOR THE YEAR
School-based assessments	Test 1 *Practical task / Investigation 1	Test 2 *Practical task / Investigation 2	Test 3 *Practical task / Investigation 3	*Practical task / Investigation 4 ***Project	40%
Exams		** Exam 1 on work from terms 1 & 2		** Exam 2 on work from terms 3 & 4	60%
Number of formal assessments	2	3	2	3	Total: 100%

In addition, a range of cognitive levels and abilities need to be carefully designed into formal assessments in the following way:

Cognitive levels for the assessment of content in Grades 7, 8 and 9

Setting tests and tasks for different cognitive levels	Knowing science	Understanding science	Applying scientific knowledge	Evaluating, analysing, synthesising scientific knowledge
Percentages indicating the proportion of low, middle and high order questions in tasks, tests and exams	**Low order questions** **40%**	**Middle order questions** **45%**		**High order questions** **45%**
Useful verbs to use when setting questions	State Name Label List Define Describe and others…	Explain Compare Rearrange Illustrate Give an example Calculate Make a generalisation and others…	Predict Apply Use knowledge to demonstrate Solve Implement Judge and others…	Select Differentiate Analyse Infer Suggest a reason Interpret Discuss Categorise and others

A third dimension to assessments, both formal and informal (formative), is the inclusion of the range of process skills listed below and detailed in Section 2.7 of the CAPS as well as exposure to the "Scientific Process".

Process skills

Accessing and recalling information	Predicting
Observing	Hypothesising
Comparing	Planning investigations
Measuring	Doing investigations
Sorting and classifying	Recording information
Identifying problems and issues	Interpreting information
Raising questions	Communicating

A fourth dimension is the use of assessments to create opportunity for development of language skills so that learners can communicate their thoughts and ideas.

The CAPS states that "content, concepts and skills across all the topics, including knowledge of investigations and some skills associated with practical work must be assessed in the written exams".

Tasks for the teacher

1. Changing cognitive levels

a) The CAPS Natural Science Grade 7 Term 1 suggests as an activity: "Describing conditions that sustain life". What cognitive level is this activity most likely to have?

b) Find an existing activity on this topic in a textbook. Analyse the cognitive levels of the questions. Re-write the exisiting or create new questions so that you have at least one question at each cognitive level. The 'useful verbs' listed in the table above should indeed prove useful.

c) The CAPS Natural Science Grade 8 Term 4 suggests as an activity: "Writing about why the conditions on Earth are ideal for life". What cognitive level is this activity most likely to have?

2. Identifying process skills

The CAPS Natural Science Grade 8 Term 4 suggests as an activity: "Interpreting a table of facts about the Solar System" and "comparing and writing about the conditions on other planets in our Solar System including their special features".

a) Create a worksheet with a memo/rubric that would incorporate these two activities and also include assessment of five of the process skills.

b) List the process skills that you have incorporated into your worksheet justifying each skill by referring to the question number in the worksheet.

Unit 2

Earth systems and climate change

This Fundisa for Change unit focuses on the concept of the Earth as a system, exploring some of the different earth systems before considering the effects of climate change on these global systems. The main focus is on the water cycle and the role of the ocean on climate.

The key questions addressed by this unit are:

- How are Earth's systems connected?
- What are the properties of the ocean?
- What makes the ocean move?
- What role does the ocean play in climate?
- What are climate change amplifiers?
- How does the polar albedo feedback loop work?

Relevant CAPS topics are listed in the table below.

KEY CONCEPTS AND PROCESSES	GRADE	TERM
Properties of materials Physical properties of materials **Separating mixtures** Methods of physical separation	7	2
Heat transfer Convection Radiation	7	3
Particle model of matter Density and states of matter Density of different materials Expansion and contraction of materials	8	2
Visible light Absorption of light Reflection of light	8	3
The Earth as a System Spheres of the Earth Atmosphere	9	4

Subject Content Knowledge

Introduction

In the first unit the aim was for learners to gain some sense that the Earth as it is at this moment in time, is a special planet. We now move on to a second important understanding – Earth is made up of a number of complex interrelated systems. Once these two key understandings are achieved, we can focus on climate change as an issue and learners can start to appreciate the enormity of the problem of anthropogenic climate change.

Summary of subject content knowledge

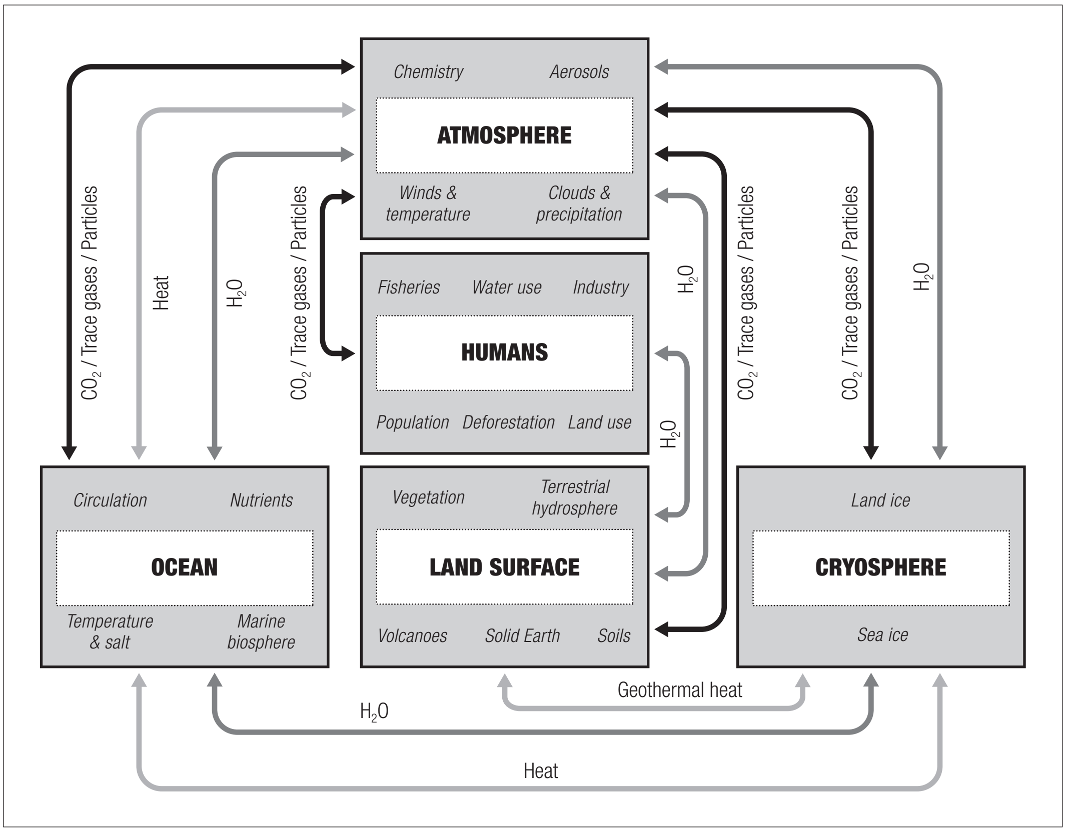
Earth system science

Earth system science can be defined as the study of the interactions between the atmosphere, hydrosphere, lithosphere, biosphere and heliosphere (the region in space influenced by the sun and solar winds). Traditionally, these spheres have been studied independently of each other. However, Earth systems science attempts to draw all the disciplines together and to study Earth as a whole.

In Grade 9, Earth's systems are referred to as spheres, but in earlier grades, learners may come across various aspects of Earth's systems in the form of cycles as shown in the table below.

The energy system powered by the sun	
EARTH SYSTEMS	
The water cycle	The movement of air in the Atmosphere
The carbon cycle	The rock cycle
The nitrogen cycle	The movement of the oceans

A cycle may involve movement across spheres forming a complex web of interactions as illustrated in the following diagram, which traces the movement of water, heat and carbon dioxide through the spheres:



Source: Adapted from Ohio State university, College of Education and Human ecology, Beyond Weather and the Water Cycle http://beyondweather.ehe.osu.edu/issue/understanding-earths-climate/climate-a-complex-interaction

The role of the ocean

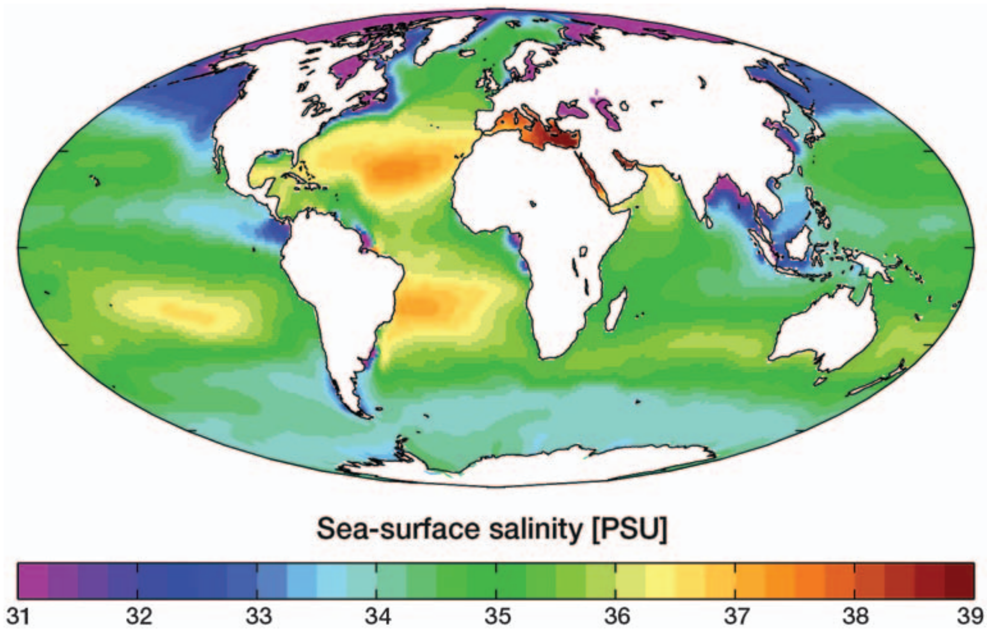
The ocean plays a central role in the redistribution of heat energy from the tropics to the polar regions. The key drivers of the movement of the ocean are winds, tides, the Earth's rotation and the relationships between the temperature, salinity and density of the ocean's water.

In the ocean, there is a complex interplay between the temperature, salinity and density of the ocean's water. Essentially, this interplay is governed by the following:

- Warm water will float on cold water.
- Warm water can dissolve more salt than cold water.
- Warm water has a higher evaporation rate than cold water.
- Salty water is more dense than fresh water, so fresh water floats on salty water.

As a result, the highest surface salinities occur in the middle of ocean basins, where the evaporation rate is high and the rainfall rate is low. Low salinity areas are often near sources of fresh water, such as major rivers and melting ice. Sea surface movement is greatly affected by winds.

The following map shows sea **surface** salinities:



Source: NASA

However, there is also a deep ocean current system called the thermohaline ocean circulation.

Thermohaline circulation of the ocean

Deep density-driven currents move like rivers along underwater valleys towards the deepest parts of the ocean. The cold, saline waters that drive the thermohaline circulation form near the poles. In the north, the topography of the sea floor channels the dense water southwards to join with the sinking waters of the Southern Ocean. Blocked by a shallow ocean floor to the west, the thermohaline circulation turns to the east and splits. One branch flows up the east coast of Africa into the Indian Ocean, while the other continues east along the south coast of Australia and then north into the Pacific basin.

Slowly the thermohaline circulation begins to mix with the less dense and warmer water on the surface as upwelling occurs. The flow of deep water into the Indian and Pacific basins is balanced by warm surface water flowing back out into the Indian Ocean. These surface currents then move westwards around South Africa into the South Atlantic and continue northward through the Atlantic. Once they reach the North Atlantic, the cycle begins again.

The thermohaline circulation plays an important role in redistributing heat from the tropics to the polar regions. As a result, it influences the rate of sea ice formation near the poles, which in turn affects other aspects of the climate system such as the albedo.

The fact that water makes this long trip in the depths of the ocean, far from the influence of surface water and contact with the atmosphere, means that there is a lag time between climate forcings and our planet's reactions to them. Heat and dissolved carbon dioxide, carried to the oceans depths by the thermohaline circulation, may remain "buried" for centuries, delaying and hiding the initial effects of global climate change.

Climate forcings refer to factors that force or drive the climate to change, such as energy from the Sun, volcanic eruptions, changes in the concentrations of gases in the atmosphere, seasonal changes etc.

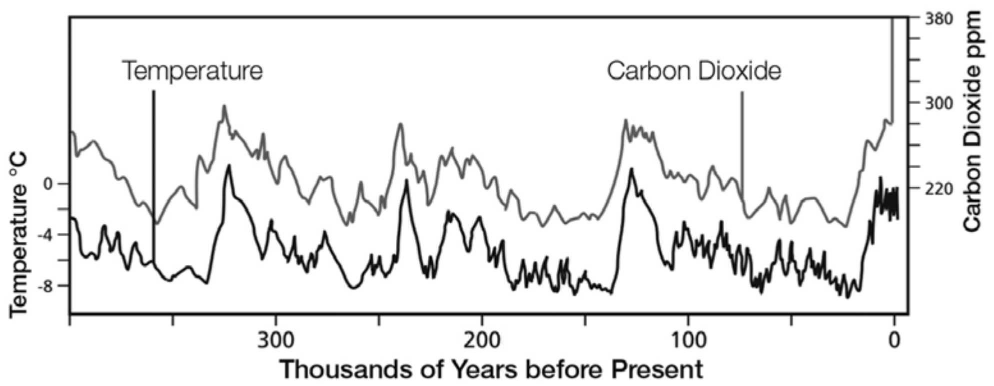
The 'age' of seawater is determined by how much time has elapsed since that sea water was in contact with the atmosphere. Characteristics such as the temperature and natural and anthropogenic gases of the atmosphere become imprinted on the surface sea water. The seawater is then downwelled in the polar regions. The question is: how many years does it take for that water to be on the surface again? It is thought that the thermohaline circulation may take many hundreds of years. Some deep and cold seawater in the Pacific has been there since the last ice age – at least 20 000 years.

Useful website: http://www.csir.co.za/nre/coasts_and_oceans/osc.html. The CSIR's Southern Ocean Carbon and Climate Observatory studies the patterns in the Southern Ocean in order to establish how it operates as a carbon sink or source.

Seawater's potential for taking up carbon dioxide from the atmosphere is greater when the water is cold. As upwelling water renews contact with the atmosphere, it can warm and lose carbon dioxide. In this way, the ocean can be a sink for heat and for carbon dioxide. At present, as much as half of the residual carbon from the burning of fossil fuels is taken up by the ocean. Deep water in the ocean is cold and carbon rich – storing the carbon away. Another important element in the ocean-carbon cycle is the seasonal bloom of phytoplankton which fixes the carbon dioxide and then sinks.

Climate change amplifiers

To make matters even more complicated, the Earth has a 41 000 year "wobble cycle" on its axis, changing the amount of energy received from the sun at the poles. Dramatic climate change results as we swing from periods of large quantities of ice cover over Earth (glacial maximums) to warmer periods of less ice coverage (inter-glacial periods). The diagram below shows the cycle of ice ages that has established itself over the past 400 000 years.



Source: CCHEAP Resources (2008), Schools Development Unit and DEADP, developed from Vostok Ice Core Data, NOAA National Climatic Data Center, 1998. http://www.ncdc.noaa.gov/paleo/icecore/antarctica/vostok/vostok_data.html (Open Access to Data)

But variations in the Sun's energy alone are not enough to cause these changes. The changes are somehow being "amplified" by other factors. We now consider the impact of albedo and the greenhouse gas content of the atmosphere on the climate as they interact to create the polar albedo feedback loop.

The polar albedo feedback loop

To understand how these amplifiers work, here is a description of the end of a glacial maximum when large ice sheets in the northern hemisphere melt rapidly:

A greater tilt of Earth's axis of rotation increases the sunlight received near the poles. The highly reflective sea ice surrounding Antarctica melts back and is replaced by dark blue ocean, which absorbs more of the Sun's energy and accelerates warming. This sea-ice retreat and warming of water lessen the ocean's ability to store carbon dioxide (CO_2). Over time, the rate at which surface waters mix with deeper waters changes and the growth of marine plants becomes less vigorous and the ocean will begin to release CO_2. After about 800-1000 years of warming, atmospheric CO_2 begins to rise.

This CO_2 rise leads to warming on a global scale, which accelerates the melt-back of large ice sheets in the northern hemisphere. The cycle continues as retreating ice sheets expose darker, more absorbent ice-free land, which captures more of the Sun's radiation: the result a rapid, runaway melting of the ice sheets.

The melting is so rapid that 10 000 years is enough to turn a cold, icy glacial climate into a warm, stable interglacial one such as ours today. The warmth normally lasts only about 5 000 years, however, before Earth's tilt starts to decrease, offering less sunlight at high altitudes and reducing summer melt-back of snow enough to allow the ice sheets to expand once again. The sheets grow until eventually a glacial maximum is reached and the cycle repeats.

Source: *Quest: Science for South Africa* magazine, vol 4, no. 2, 2008

Expanding knowledge

The following references and hyperlinks are all to interesting websites that present relevant information in an understandable way.

References

Quest: Science for South Africa magazine, (vol 4, no. 2, 2008), Climate: past changes and future uncertainties.

Fundamentals of Inquiry, Workshop II Process Skills, Institute for Inquiry, 2006.

Hyperlinks

http://www.nhm.ac.uk/education/online-resources/webquests/

http://www.pmel.noaa.gov Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration website includes science topics and education (including a Fact Sheet on Ocean acidification).

http://www.whoi.edu/home/oceanus_images/ries/calcification.html Through a slide show, this website explains the chemistry behind the theory that ocean acidification will interfere with the ability of marine animals to build shells.

http://www.globe.gov/documents/10157/334459/Earth_System_Poster_07_Activities.pdf The GLOBE Earth System Poster Learning Activities provide huge opportunity for understanding connections between Earth's systems using world data presented in pictures. There is a strong link here to data handling as the information lends itself to being represented graphically.

http://beyondweather.ehe.osu.edu/issue/understanding-earths-climate/climate-a-complex-interaction Ohio State university, College of Education and Human Ecology, *Beyond*

Weather and the Water Cycle online magazine for primary school teachers with lessons outlined on various themes.

http://www.windows2universe.org/teacher_resources/teach_Par5.html National Earth Science Teachers Association, Windows to the Universe website has lesson plans and classroom activites including Exploring Density with Salt and Fresh Water.

http://oceanservice.noaa.gov/education/literacy/ocean_literacy.pdf National Oceanic and Atmospheric Administration Ocean Service Education website has information for teachers including this pdf called Ocean Literacy and learner activities.

http://www.exploratorium.edu/ifi/workshops/fundamentals/ A series of workshops to introduce teachers to inquiry.

http://www.discoveringantarctica.org.uk/alevel_1_2.html Discovering Antarctica education website.

http://cleanet.org/resources/41833.html Climate Literacy and Energy Awareness Network has resources for the classroom including ‘Understanding Albedo’ experiment.

http://svs.gsfc.nasa.gov/vis/a010000/a011200/a011244/Arctic_sea_ice_max_2013_ipod_sm.mp4 This NASA video has current information regarding Arctic ice sheet information.

Teaching Practice

In this section we explore various ways in which we can teach learners about Earth systems and Climate Change. The activities are designed to model a number of the different methods and processes detailed in the *Fundisa for Change Methods and Processes to Support Change-Oriented Learning* resource.

ACTIVITY 5

INTERCONNECTEDNESS IN GLOBAL SYSTEMS

This activity aims to show interconnectedness by following the pathway of a drop of water. The activity is adapted from the GLOBE Earth System Science Activity GC2: Components of Earth System Working Together. The original activity is located at the website below:

http://www.globe.gov/documents/356823/356868/earth_la_connections_gc2.pdf

Method used: Information Transfer Method – Learning by participation to construct knowledge

This method involves the engagement of learners in a task where they translate information from one form to another, drawing on prior knowledge to construct the knowledge into new forms.

Links to CAPS

This activity helps to develop Specific Aim 2: 'Knowing the subject content and making connections' as well as the following cognitive and practical process skills as described in CAPS:

- Accessing and recalling information;
- Interpreting information – translation task; and
- Communicating.

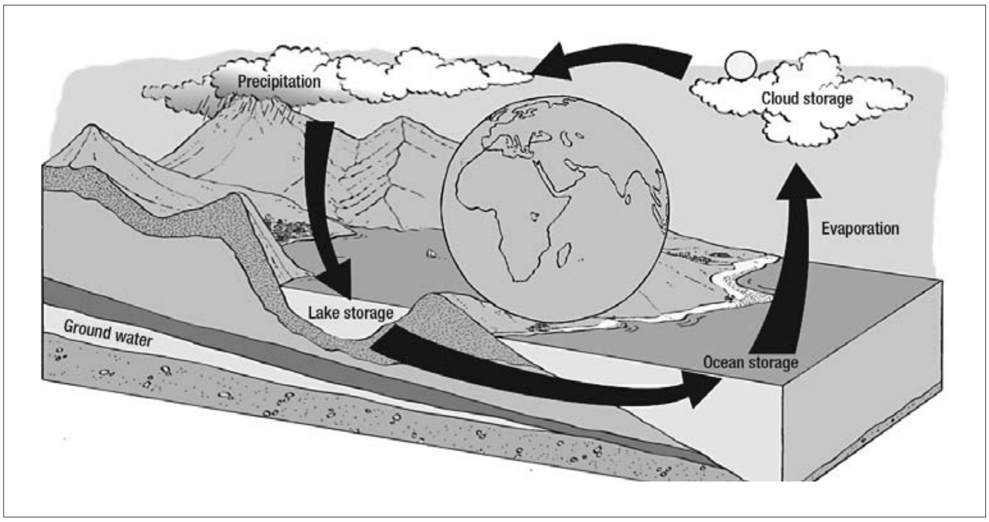
More specifically, the skills developed in this activity are:

- Recalling prior knowledge of the water cycle;
- Translating information from a description into an abstract diagram; and
- Identifying connections.

The CAPS topic that links directly to this activity is the Grade 9, Term 4 topic of The Earth as a System – Spheres of the Earth.

Core knowledge

The water cycle was last covered in Grade 4 Natural Science and Technology. A diagram such as the one below is useful for reminding learners about the water cycle.

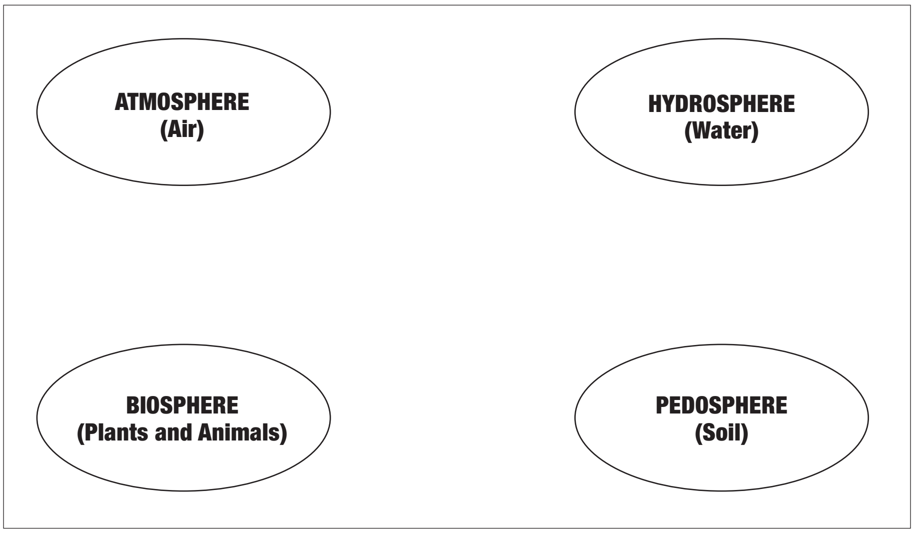


Source: CCHEAP Resources (2008), Schools Development Unit and DEADP

Outline of activity

Learners work in pairs or small groups for this activity.

1. Think about the pathway that water takes as it follows the water cycle. Describe, step-by-step, what happens to a drop of water. Include the various forms that water takes – solid, liquid and gas.
2. Copy the names of these four groups of Earth system components onto a piece of paper as shown below:

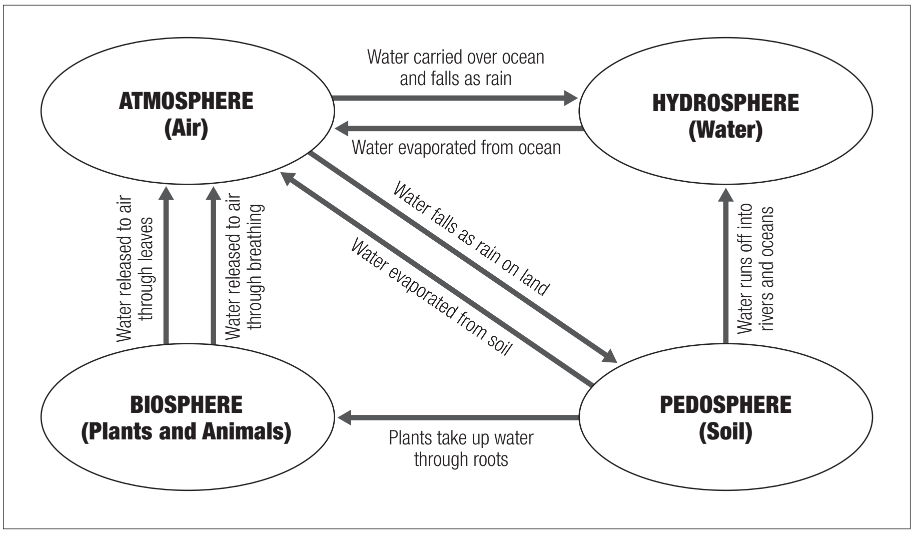


For each step in the water pathway where water moves from one Earth system to another, draw an arrow between the two features. Along the arrow, write a short description of how the water moved. Do this for all your water pathway steps that involved water moving from one component to the other. For example, if you have water evaporating from the ocean, you would draw an arrow from the Hydrosphere to the Atmosphere and could write “water evaporates from the ocean” along the arrow.

3. Discuss with your partner how humans use water. Now think about how you could show these human impacts on the water cycle in your diagram above. You may decide to add a new circle labelled “Human Impacts” or to add some extra arrows and descriptions.

Assessment

An example of a completed diagram is given below:



The human impacts that learners may add could be:

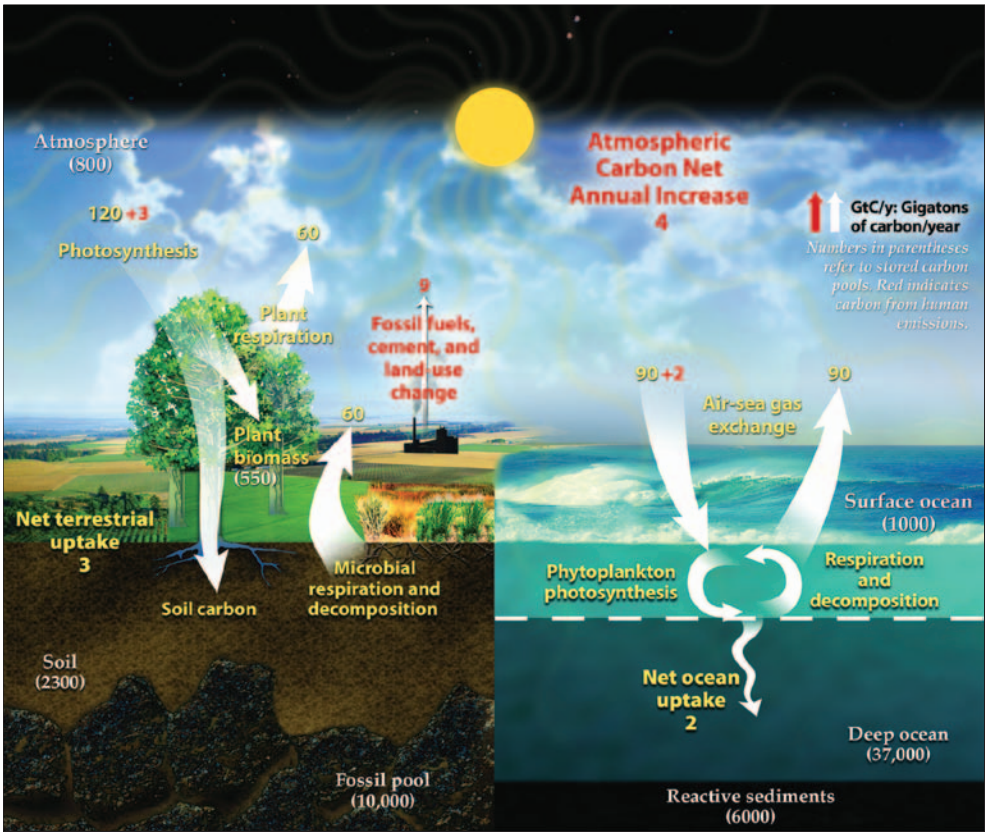
- Piping clean water from the hydrosphere;
- Returning polluted water back to the hydrosphere;
- Overuse of the resource; and
- Irrigation – taking water from the hydrosphere to the pedosphere.

The following rubric can be used to assess this activity:

	1	2	3	4
Description of water pathway through components	Describes very little of water pathway through components	Partially describes water pathway through components	Adequately and accurately describes water pathway through components	Fully and accurately describes water pathway through components with elaborate detail
Diagram of water pathway through components	Inadequately develops interconnections among components and demonstrates little expected science knowledge	Somewhat clearly represents a few interconnections among components and demonstrates some expected science knowledge	Completely and clearly represents most interconnections among components and demonstrates most expected science knowledge	Completely and clearly represents interconnections among components at the global scale and demonstrates all expected science knowledge
Human impacts	Does not show any human impacts	Partially attempts to show human impacts	Shows an adequate number of human impacts	Demonstrates interrelatedness of humans and environment in the human impacts that are shown

Developing your teaching practice

Various aspects of the carbon cycle are touched on as part of different topics during the Senior phase. Using a diagram of the carbon cycle such as the one below, follow the pathway of a carbon molecule through the Earth systems. Re-design the activity above to follow the path of a carbon molecule.



Source: http://en.wikipedia.org/wiki/Carbon_cycle

ACTIVITY 2

PROPERTIES OF THE OCEAN

This activity aims to find out how the thermohaline circulation of the ocean is driven through investigating density differences caused by temperature and salinity.

Method used: Information transfer

For more on these methods, see the *Methods & Processes* book, p.13,14 and 24.

This activity uses a cross-section of methods that may all form part of the Scientific Process of investigation:

- Demonstrations and experiments;
- Guided questioning; and
- Investigation.

Links to CAPS

This activity helps to develop “Specific Aim 1: ‘Doing Science’ Learners should be able to complete investigations, analyse problems and use practical processes and skills in evaluating solutions” as well as the following cognitive and practical process skills as described in CAPS:

- Predicting;
- Hypothesising;
- Observing;

- Comparing;
- Doing investigations;
- Recording information;
- Interpreting information; and
- Communicating.

The CAPS topics that link directly to this activity are the Grade 7, Term 2 topics of Properties of Materials and Separating Mixtures and the Grade 8, Term 2 topic of the Particle Model of Matter.

Core knowledge

Density is the mass per unit volume of a substance. To calculate density, we use the formula

$$density = \frac{mass}{volume}$$

The particle model of matter informs us that the density of a material will depend on the kinds of particles it is made up of and the size of the spaces between them. The density of water is affected by both temperature and salinity. When water temperature increases, water molecules vibrate faster and expand, thereby decreasing the density. Salt water has a higher density than fresh water. A less dense substance will always lie above a more dense substance.

Outline of activity

The activity below is an investigation into density differences caused by temperature and salinity.

Salinity is a measure of the proportion of dissolved salts in a solution.

You will need:

4 small, clear (baby food) jars of equal size
2 1-2 litre containers
2 colours of food colouring
permanent marker
plastic index card
measuring cup
hot and cold tap water
½ cup salt
stirring spoon

Experiment 1: To observe the effect of salt on the density of water

1. Pour 1 litre of water into each container. Add 3 drops of red food colouring to the one and 3 drops of blue food colouring to the other. Now add ½ cup of salt to the red water and stir until it dissolves.
2. Fill one jar with the red, salty water and label it “salt water”.
3. Fill another jar with the blue water and label it “fresh water”.
4. Fill the two remaining jars, one with red, salty water and one with blue fresh water to use as colour samples of each solution for comparison as the experiment proceeds.
5. Place a plastic or index card on top of the jar of salt water. Carefully turn it upside down and put it on top of the jar of fresh water (the card should now be between the openings of the two jars). Have someone carefully remove the card while you hold the jars.

6. Write down what you observe happening. Here are some things to look for:
   a) Do you see any evidence of mixing?
   b) How does the colour of each jar change?
   c) Is the colour uniform throughout each jar?
   d) How much time did the changes take?
7. Repeat the experiment using the second set of jars. This time, turn the fresh water jar upside down over the salt water jar. Remove the card and observe the results.
8. Confirm your results by repeating the experiment.

Questions:

a) Is salt water heavier or lighter (more dense or less dense) than fresh water? Support your answer using the results of your experiment.

b) How does the density of water change as its salinity increases?

c) Write a paragraph to explain how your results relate to the mixing of fresh water flowing from a river when it meets the ocean.

Experiment 2: To observe the effect of temperature on the density of water

In this experiment you follow the same procedure as above except that you fill one jar with hot water and red food colouring and the other with cold water and blue food colouring. Make sure that the hot water is not hot enough to burn you.

Questions

a) Is cold water more or less dense than hot water? Support your answer using the results of your experiment.

b) How does the density of water change as temperature increases?

c) Write a paragraph to explain how your results relate to the mixing of ocean water when currents carrying water at different temperatures meet.

Assessment

Experiment 1: Answers to the questions:

a) Salt water is heavier (more dense) than fresh water. Learners should have observed that the salt water will sink to the lower jar.

b) As salinity increases, so does the density of water.

c) Fresh water flowing from a river will tend to lie on top of the sea water where it meets the ocean, causing a decrease in the sea surface salinity. Wave action and tides will cause some mixing.

Experiment 2: Answers to the questions:

a) Cold water is more dense than hot water. Learners should have observed that the cold water will sink to the lower jar.

b) As temperature increases, so does the density of water.

c) When ocean currents of different temperatures meet, the colder water will tend to move under the warmer water.

Developing your teaching practice

1. In the Natural Science CAPS Grade 7 Term 2, the following investigation is suggested:

   Investigating what happens when water heats up and boils *[heat water and take the temperature reading every 3 minutes until the temperature reading becomes constant for three readings]*. Record time intervals and temperature readings in a table, and draw a line graph *[Note: you can do the same with other liquids such as orange juice, apple juice, cola.]*

   Design this investigation using salt water as another liquid for comparison.

   This investigation can also be designed to measure the thermal expansion of water by using a conical flask with two-hole cork for the thermometer and a thin, glass tube. See: http://www.windows2universe.org/teacher_resources/ocean_temperatures.html National Earth Science Teachers Association, Windows to the Universe website for videos, lesson plans and classroom activities including Changing Planet: Rising Ocean Temperatures – Rising Sea Levels. Sea level rise is an important consequence of rising ocean temperatures.

2. A greater volume of salt can be dissolved in hot water compared to cold water. Devise an experiment to test this. Work through the checklist of process skills at the beginning of the CAPS document and try to include questions on as many of the skills as possible.

ACTIVITY 3

THE OCEAN'S CIRCULATORY SYSTEM AND CLIMATE

This activity investigates the impact of the ocean's movement on climate.

Method used: Active learning

This activity involves dialogue and applying knowledge to new situations.

Links to CAPS

This activity helps to develop Specific Aim 2: 'Knowing the subject content and making connections' as well as the following cognitive and practical process skills as described in CAPS:

- Interpreting information; and
- Communicating.

More specifically, the skills developed in this activity are:

- Identifying features from maps;
- Interpreting information from maps;
- Synthesising information;
- Describing the thermohaline circulation of the ocean; and
- Describing the effect of currents on climate.

Core knowledge

The thermohaline circulation of the world's oceans or the ocean's conveyor belt, strives to distribute heat and salt evenly throughout the ocean – at the surface and at greater depths

– playing a crucial role in distributing heat from the tropics to the poles. Driving this system are winds, tides, the Earth's rotation and the relationships between the temperature, salinity and density of the ocean's water.

The ocean absorbs most of the sun's radiation reaching Earth, moderating global weather and climate. Heat exchange between the ocean and atmosphere drives the water cycle.

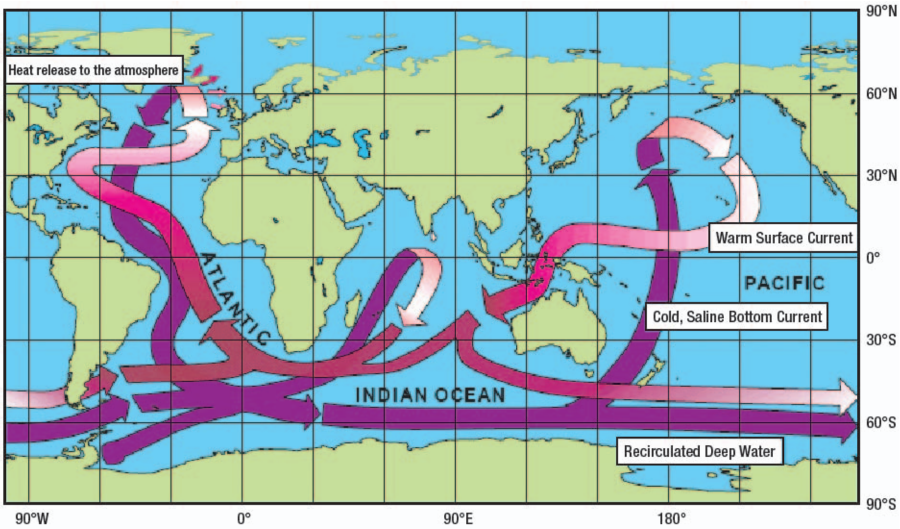
Generally speaking, the warmer the ocean, the less heat energy is required for water to evaporate. The water vapour condenses to form clouds, providing the energy to power weather systems. Water evaporating over warm seas can power hurricanes and cyclones and heavy precipitation will follow.

Outline of activity

Learners are to work in pairs.

Thermohaline circulation refers to the global ocean circulation driven by the joint effects of temperature and salinity on the density of sea water.

1. Referring to the diagram, can you explain to your partner how the thermohaline circulation of the oceans works.



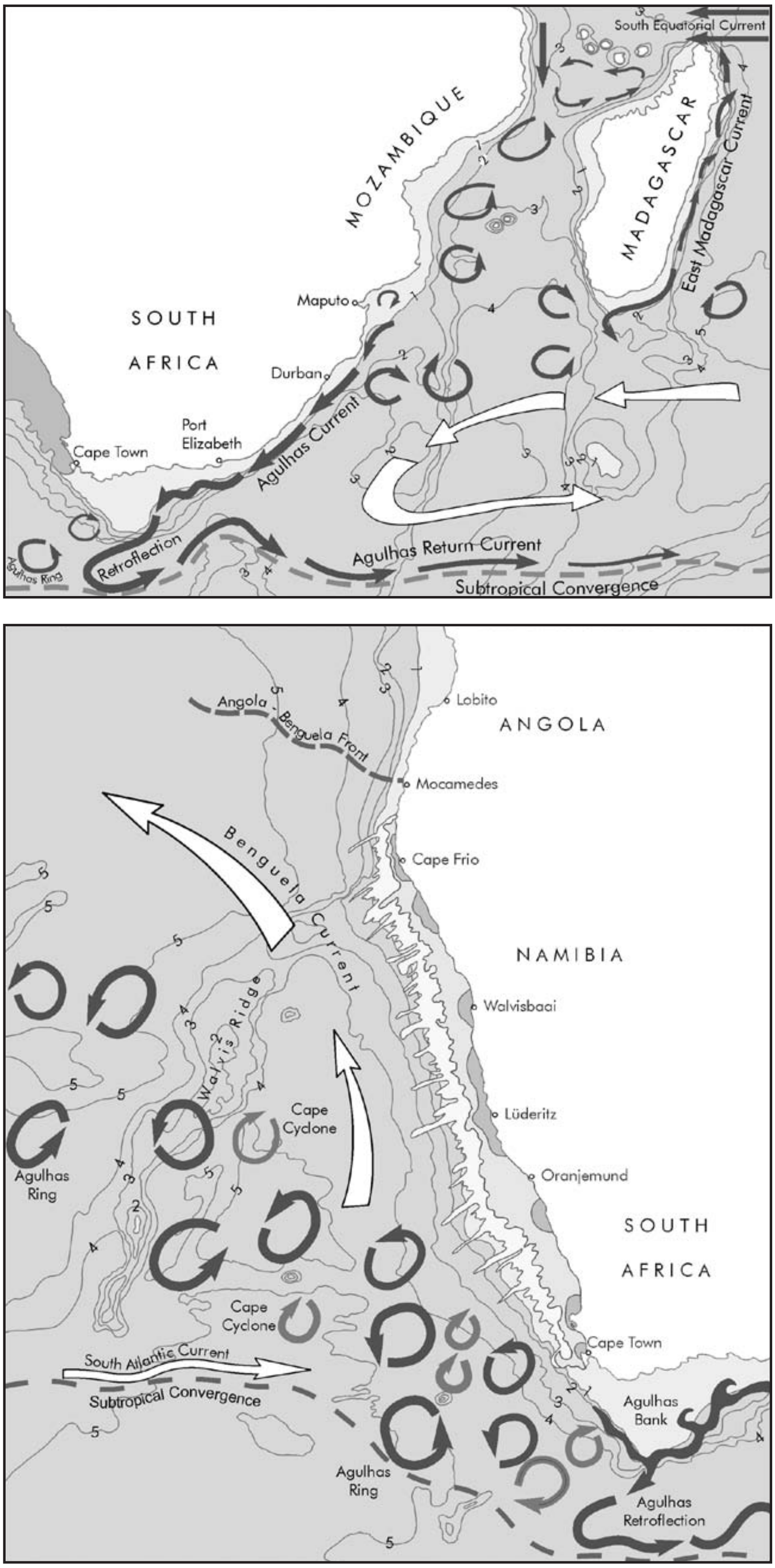
Source: Windows to the Universe® (http://www.windows2universe.org/earth/Water/thermohaline_ocean_circulation.html) 2010, National Earth Science Teachers Association. Credit: Image courtesy CLIVAR (after W. Broecker, modified by E. Maier-Reimer)

2. Examine the two pictures in the opposite page showing ocean currents along the coast of South Africa.

   a) What effect do you think the warm Agulhas Current has on the climate of the south and east coast of South Africa?

   b) What effect do you think the cold Benguela Current has on the climate of the west coast of South Africa?

   c) What currents are along the coast nearest to where you live? How do these currents influence the climate in your area?



Source: Ansorge I.J. & Lutjeharms J.R.E. (2008) *Currents, continents and convergences. The cetacean environment off Southern Africa.* Cambridge University Press.

Developing your teaching practice

There appear to be indications that the thermohaline circulation in the ocean is slowing. It is thought that in the past, large amounts of fresh water from melting glaciers may have caused a drop in salinity and prevented water from sinking, thereby turning off the thermohaline pump.

These articles are included in Appendix 1 and Appendix 2 respectively.

1. Read the information at http://www.windows2universe.org/earth/Water/thermohaline_ocean_circulation.html titled "The Younger Dryas - A Warning from the Past?" or read the article: http://www.time.com/time/magazine/article/0,9171,1137645-1,00.html "Is Europe Due For a Big Chill?" from the December 12, 2005 issue of TIME magazine.
2. Write a paragraph on what the implications might be for the climate if the ocean's 'conveyor belt' were to stop.
3. Write a short paragraph that your learners would be able to read, followed by three questions to get learners thinking about the implications of an ocean that is not moving.

ACTIVITY 4

THE POLAR ALBEDO FEEDBACK LOOP

Albedo refers to the proportion of light reflected by a surface.

This activity aims to explain the polar albedo feedback loop through investigating absorption capabilities of different substances.

For more on these methods, see the *Methods & Processes* book, p.13,14 and 24.

Method used: Information transfer

- Demonstrations and experiments;
- Guided questioning; and
- Investigation.

This activity uses a cross-section of methods that may all form part of the Scientific Process of investigation.

Links to CAPS

This activity helps to develop "Specific Aim 1: 'Doing Science' Learners should be able to complete investigations, analyse problems and use practical processes and skills in evaluating solutions" as well as the following cognitive and practical process skills as described in CAPS:

- Predicting;
- Hypothesising;
- Observing;
- Comparing;
- Doing investigations;
- Recording information;
- Representing information - draw a line graph to show the results;
- Interpreting information; and
- Communicating.

The CAPS topics that link directly to this activity are the Grade 7, Term 3 topic of Heat Transfer – Radiation and the Grade 8, Term 3 topic Visible Light – Absorption and reflection of light.

Core knowledge

Shiny surfaces (such as silver) are good reflectors of radiant heat and dark surfaces (such as black) absorb heat energy.

Outline of activity

The first part of this activity is an experiment on the reflective and absorptive properties of different surfaces. The second part of the activity applies this knowledge to develop an understanding of the polar albedo feedback loop.

1. Investigating the reflective and absorptive properties of different surfaces.

   Materials needed:

   Different coloured card including black and white
   Aluminium foil
   Lamp or direct sunlight
   Thermometers (2)

   Method:

   Learners make envelopes of different coloured cardboard, including black and white, and aluminium foil.

   Place the bulb end of each thermometer into the envelope.

   Place the thermometers under a lamp so that they receive equal amounts of light. The lamp should be pointed straight down.

   Record the temperature every 2 minutes.

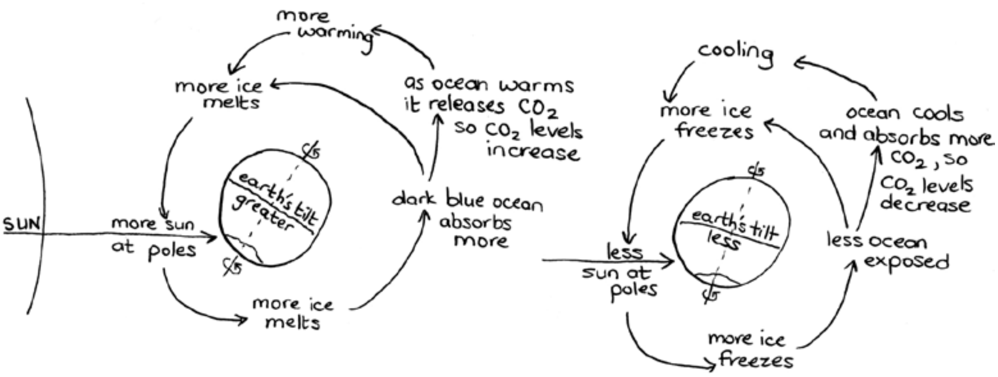
   Draw a broken line graph of the temperatures for each colour card or foil.

2. Read the summary description of the polar albedo feedback loop at the beginning of the unit. Underline the key phrases in the text. Watch this NASA video regarding Arctic ice sheet information: http://svs.gsfc.nasa.gov/vis/a010000/a011200/a011244/Arctic_sea_ice_max_2013_ipod_sm.mp4.

   Now draw a diagram to illustrate how the polar albedo feedback loop works.

Assessment

Learners' diagrams will vary. Two possible diagrams are shown below:



This is included as Appendix 3.

Developing your teaching practice

Read through the Indicators of Development of Process Skills handout in the Process Skills Workshop from the Institute of Inquiry at the website below:

http://www.exploratorium.edu/ifi/workshops/fundamentals/

Identify the level of the skills in the investigation in the activity. Now make changes to the working of the questions in the activity, to shift the level of the skills to a higher level.

Assessment Practice

Tasks for the teacher

1. Changing the level of learner control in investigations

Most investigations in textbooks are highly structured where learners are really learning to follow a procedure in order to get to a particular conclusion. If that is the aim, then the structured investigation is an effective way of achieving it. However, we often need to also provide learners with opportunities to demonstrate their ability to engage in the scientific process or aspects thereof. Learners need opportunities to demonstrate the process skills of Raising questions, Predicting, Hypothesising, Planning, Recording etc.

The topic Separating mixtures, Methods of Physical Separation in Grade 7, Term 3, includes:

- Evaporation (retrieving salt from sea water); and
- Distillation (retrieving pure water from sea water). Distillation always involves boiling and condensation (change from gas to a liquid)

Extend the investigations you have developed already as part of Activity 2, to include an investigation into which evaporates quicker – fresh water or salt water. If your goal for this investigation was to get learners involved in problem-solving and to demonstrate their application of knowledge, how could you structure the investigation for these goals to be realised?

2. Changing the level of the process skills

The Institute for Inquiry identifies the following as indicators of development for the process skill of observation:

Do the students:

1. *Succeed in identifying obvious differences and similarities between objects and materials?*
2. *Make use of several senses in exploring objects or materials?*
3. *Identify differences of detail among objects or materials?*
4. *Identify points of similarity among objects where differences are more obvious than similarities?*
5. *Use their senses appropriately and extend the range of sight using a hand lens or microscope as necessary?*
6. *Distinguish from many observations those that are relevant to the problem at hand?*

Refer to the *Spot On Natural Science, Gr 7 Learner Book*, p.61, Practical Activity 2.1: “Investigate what happens when water heats up and boils”. (If this text is unavailable, refer to another Natural Science textbook, as most should have some investigation in this section on properties of materials).

Identify the level of the observation skill that is required in the investigation.

What changes could you make to the wording of the questions in the investigation to shift the observation skill to a higher level?

Unit 3

Energy and carbon dioxide

This Fundisa for Change unit focuses on the sun as the source for all energy, the science of the greenhouse effect and the consequences of our use of fossil fuels.

The key questions addressed by this unit are:

- How does the greenhouse effect work?
- What happens to the energy from the sun?
- How can we capture the energy from the sun?
- What is the anthropogenic effect of carbon dioxide emission?
- What alternative energy sources are there available?
- How can we learn to live more sustainably and reduce our impact?

Opportunites arise for discussing these questions as part of the CAPS topics listed in the table below.

KEY CONCEPTS AND PROCESSES	GRADE	TERM
Sources of energy Renewable and non-renewable sources of energy **Heat transfer** Heating as a transfer of energy Conduction Convection Radiation **Insulation and energy saving** Using insulating materials	7	3
Relationship of the Sun to the Earth Stored solar energy	7	4
Interactions and interdependence within the environment Balance in an ecosystem	8	1
Visible light Radiation of light Reflection of light Refraction of light	8	3
Cost of electrical power The cost of power consumption	9	3
Atmosphere The greenhouse effect	9	4

Subject Content Knowledge

Introduction

This unit starts off by developing an understanding of the natural greenhouse effect. The unit then examines some of the causes and effects of increasing concentrations of greenhouse gases and the possibly mitigating results of changing patterns of energy use. The last activity in the unit affords learners the opportunity to examine their own energy use and to think about ways in which their consumption might be reduced.

Summary of subject content knowledge

The greenhouse effect

The greenhouse effect occurs naturally and plays an important role in moderating the planet's temperature. Energy from the sun enters the atmosphere and is absorbed by the surface of the Earth, warming it. Some of the energy is reflected off the Earth's surface (especially at the poles and other snow or ice covered areas) and some is radiated back from the surface as heat, a percentage of which is trapped by gases in the atmosphere. Heat-trapping gases are known as greenhouse gases and include carbon dioxide, methane, nitrous oxide and importantly, water vapour. They act as heat absorbers keeping the Earth warm and without which Earth would be about 35°C colder.

Unfortunately, many human activities (such as energy use, transportations and deforestation), release stored carbon dioxide and other greenhouse gases into the atmosphere. The effect of these 'extra' gases is to absorb and retain more heat, keeping Earth a little warmer than it would otherwise have been. A world average temperature rise of even 1°C has huge implications for Earth's systems and therefore for life on the planet. The human (anthropogenic) causes of increased carbon dioxide levels and the resultant changing climate are huge causes for concern. Our individual decision-making capacity has the potential to play an important role in whether we manage to reach mitigation goals or not. We need learners to understand the science behind climate, what is driving current climate change and why it is unusual. We also need learners to understand the impact that climate change may have on their lives and how the decisions that they make could become part of a solution or at least could help alleviate the problem.

Renewable and non-renewable sources of energy

The debate around the various sources of energy continues. There are some useful websites listed in the next section that cover this topic. In this unit the focus is on solar water heating systems.

Expanding knowledge

The following references and hyperlinks are all to interesting websites that present relevant information in an understandable way.

References

Harlen, Wynne. ASEESA International Conference, Rand Afrikaans University, Johannesburg, South Africa, September 2004. The role of assessment in raising the standards of all. http://www.aseesa-edu.co.za/Proceed04/Harlem1.htm

Smart Living Handbook, City of Cape Town, 2007

Hyperlinks

http://www.ucar.edu/learn/1_3_1.htm and http://www2.ucar.edu The University Corporation for Atmospheric Research has detailed information (career information as well) and lessons on various atmosphere-related topics including the greenhouse effect.

http://www.epa.gov/climatestudents/ The United States Environmental Protection Agency http://www.pbs.org/strangedays/ National Geographic, Strange Days on Planet Earth website for well-presented issues with video material.

http://greenteacher.com/the-carbon-dioxide-game/ Green Teacher, Education for Planet Earth is an online magazine for teachers including lots of resources including the Greenhouse Game and Action cards.

http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/sternreview_index.htm The executive summary of the Stern review is well worth the time and effort to read.

http://www.nhm.ac.uk/education/online-resources/webquests/ Natural History Museum, London has a webquest on Investigating Climate Change.

http://www.green-planet-solar-energy.com The Green Planet Solar Energy website Solar Power Facts has lots of information on a variety of topics related to solar energy.

http://www.eia.gov/kids/energy.cfm?page=1 U.S. Energy Information Administration, Energy kids website covers: What is energy?; Energy sources; Using and saving energy; History of energy; Games and activities; For teachers.

http://www.altenergy.org Alternative energy solutions for the 21st century website explores various forms of energy.

http://www.iol.co.za/scitech/science/environment/first-sa-solar-farm-starts-feeding-grid-1.1606082#.Upeb4hZpu8U Independent online Scitech article about SA's first solar farm feeding into the national grid.

Documentaries

Six Degrees Could Change the World. National Geographic.

Teaching Practice

In this section we explore various ways in which we can teach learners about Energy and Carbon Dioxide. The activities are designed to model a number of the different methods and processes detailed in the *Fundisa for Change Methods and Processes to Support Change-Oriented Learning* resource.

ACTIVITY 1

THE GREENHOUSE GAME

Method used: Experiential method of role play

In this activity, learners model the greenhouse effect by taking on the roles of light and heat waves and carbon dioxide molecules.

For more on this particular method, see the *Methods & Processes* book, p.20.

Links to CAPS

This activity helps to develop Specific aim 2: 'Knowing the subject content and making connections' as well as the following knowledge and skills as described in the CAPS:

- Observing;
- Comparing;
- Predicting;
- Hypothesising; and
- Communicating.

More specifically, the skills developed in this activity are:

- Translation of an experience into a diagram; and
- Understanding how human activities affect the concentration of greenhouse gases in the atmosphere.

The CAPS topics that link directly to this activity are the:

- Grade 7 Term 3 topic of Heat transfer – Radiation;
- Grade 8, Term 3 topic of Visible light – Radiation, reflection and refraction of light; and
- Grade 9, Term 4 topic of The Atmosphere – The Greenhouse Effect.

Core knowledge

The greenhouse effect is a very important, naturally occurring, function of Earth's atmosphere. It is a 'blanket' effect that keeps the Earth at a relatively warm temperature in which life can flourish. When energy from the sun enters the atmosphere, some of the energy is reflected off the Earth's surface (especially at the poles and other snow or ice covered areas). However, some energy warms the surface of the Earth and is radiated back as heat and trapped by gases in the atmosphere.

How does light energy turn into heat? Sunlight itself is not hot, but as soon as the electromagnetic radiation that is sunlight, strikes a surface, the photons or particles of light interact with the surface, 'exciting' the surface molecules by causing them to vibrate and generating heat.

Outline of activity

This activity is designed to help learners understand how the greenhouse effect works. The activity starts off with a game that provides a good visual and experiential model of the greenhouse effect. The game is then extended to include a way of showing the impact and consequences of human activities on the natural greenhouse effect. You will need an open area to play the game.

Materials:

Chalk/rope

Basin

Red cards with HEAT written on – one card for each player

Yellow cards with LIGHT written on – one card for each player

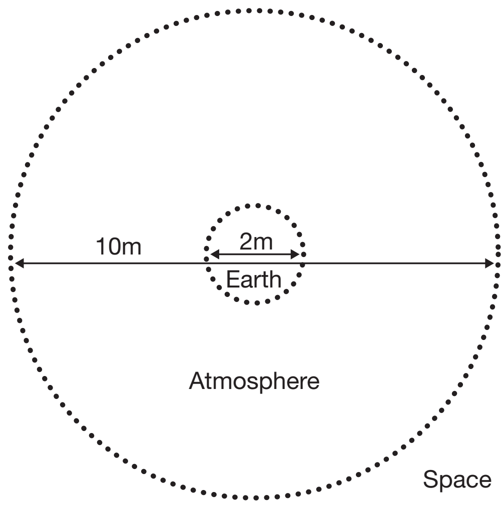
A small bag with the words "What do humans do?" written on it, containing the Action cards - representing human actions that affect CO_2 levels in the atmosphere.

8 Action cards – see cards at the end of this activity

Newsprint for learners to draw on

Method:

- Two circles, one inside the other, are drawn on the ground with chalk or marked out with rope, to represent Earth and the atmosphere, as shown in the diagram.



- A basin with the red cards labelled HEAT, is put in the centre of the Earth circle.

ROUND 1:

1. Choose two learners to be CO_2 molecules, and place them anywhere in Earth's "atmosphere". Once the student "molecules" are within the atmosphere circle, they cannot move their feet.
2. The game starts with the rest of the learners standing in Space (around the outside of the atmosphere circle), holding a yellow LIGHT card, to represent light energy (sunbeams) from the sun.
3. On the teacher's command, the LIGHT cardholders must try to exchange their cards for red ones and escape back into space without being touched by the 'CO_2 molecules'.
4. LIGHT cardholders may move freely to the centre of the Earth to exchange their card for a HEAT card.

5. If HEAT cardholders are touched by ‘CO_2 molecules’, they need to stand still in the atmosphere, representing that their heat is trapped.

At the end of Round 1, ask these QUESTIONS:

- How many HEAT people were trapped? Why?
- How may this affect the temperature of the planet? Remind students that a certain amount of CO_2 is necessary to keep the planet consistently warm enough to support life.

During the first round, most of the heat energy will have escaped the atmosphere because CO_2 levels are low. Before continuing the game, clear all the trapped sunbeams out of the atmosphere (have them put their red cards back in the bucket) but keep the two CO_2 molecule students in the outer circle.

ROUND 2:

Increase the number of CO_2 molecules in the atmosphere by reading from an action card in the “What do humans do?” bag.

For this round, include only cards that add CO_2 to the atmosphere. After a student reads the card, increase the number of CO_2 molecules in the game (dictated by card) and play again.

As before, the CO_2 molecules stand in place in the atmosphere while the sunbeams rush in.

Repeat the QUESTIONS.

ROUND 3 etc.:

Put all of the action cards in the bag. CO_2 levels will now rise and fall depending on which card is drawn.

Discuss what happens each time, by asking the QUESTIONS.

The game should demonstrate that when you increase the amount of CO_2, more heat is held. This is shown by the touched ‘sunbeams’ holding HEAT cards standing in the atmosphere. The result is that Earth warms up. The action cards demonstrate how even small-scale actions affect the amount of greenhouse gas that we emit into the atmosphere.

It is important to clarify that the greenhouse game is a simplified simulation and that such actions as using energy efficient technology or alternative forms of transportation do not actually remove carbon dioxide from the atmosphere. Rather, they contribute less than do their more commonly used counterparts. Eliminating actions that normally add greenhouse gases also stems the increase but does not reduce existing gases. Some actions, such as planting trees, can indeed reduce carbon dioxide emissions.)

Points for Discussion

Review how heat energy from the sun is held in Earth’s atmosphere.

Discuss how human actions, particularly burning fossil fuels, can amplify the greenhouse effect by putting more CO_2 into the atmosphere. The game can be an entry into a variety of other explorations such as researching alternative energy sources, discussing sustainable lifestyles, and examining the different choices humans can make in relation to the environment.

The greenhouse game as a model

Discuss with learners, the ways in which the greenhouse game realistically models the atmosphere and the the ways in which it doesn’t.

Examples of differences would be:

- In reality, the atmosphere is not as large in comparison to the Earth as we are making it in the game. In fact, if the Earth were an apple, the atmosphere would be like the skin. In the game we enlarge the atmosphere so that we can see what is happening.
- There are other greenhouse gases as well that are not taken into consideration in the greenhouse game although essentially they operate in much the same way as carbon dioxide. Water vapour absorbs even more longwave radiation than carbon dioxide. As carbon dioxide traps heat and warms the planet, more water is evaporated and the additional water vapour helps to warm the planet as well. It is possible to extend the game to include clouds. Remember that clouds can reflect incoming radiation back outwards as well as absorb it or reflect outgoing radiation back towards Earth.

Similarities would be:

- High energy light waves travel as short-wave radiation in straight lines from the Sun, passing through the atmosphere until they hit clouds or Earth. After they hit Earth, the Earth warms up and re-emits the energy in the form of long-wave radiation.
- Carbon dioxide absorbs the long-wave radiation and re-emits it back within the atmosphere, thereby reducing the amount of heat that escapes to space, and warming the planet.
- Thus in the game, the 'carbon dioxide molecules' can only trap the LIGHT card-holders once they have exchanged their cards for HEAT cards.

Greenhouse Game Sample Action Cards – these can be added to!

Action Cards	
Humans drive cars Every litre of petrol puts 2.35 kg of CO_2 into the atmosphere. *(Add two CO_2 molecules)* 	**Humans drive more cars** In 1908 Ford built the Model T car. Between 1908 and 1928, 15 million were sold. Today, an estimated 500 million cars are in use worldwide. *(Add two CO_2 molecules)* 
Humans cut down trees Trees remove CO_2 from the atmosphere during photosynthesis. Fewer trees means more CO_2. *(Add four CO_2 molecules)* 	**Humans burn trash** Burning waste puts CO_2 into the atmosphere along with other pollutants. *(Add two CO_2 molecules)* 
Humans ride bikes Riding a bike is the most energy efficient form of transportation, and it's fun! *(Remove two CO_2 molecules)* 	**Humans plant trees** Trees remove CO_2 from the atmosphere during the process of photosynthesis. More trees means less atmospheric CO_2. *(Remove four CO_2 molecules)* 
Humans create energy efficient technology *(Remove four CO_2 molecules)* 	**Humans recycle** Recycling saves energy, reducing our use of fossil fuels. *(Remove two CO_2 molecules)* 

Source: http://greenteacher.com/the-carbon-dioxide-game/ Green Teacher, Education for Planet Earth

Task

Ask students to draw a diagram illustrating the greenhouse effect. Illustrate or list actions that influence carbon dioxide emissions into the atmosphere both positively and negatively.

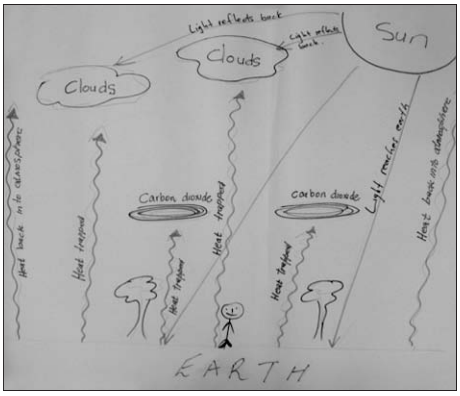
Assessment

Rubric for diagram of greenhouse effect

CRITERION	1 – NOT ACHIEVED	2 – NEEDS IMPROVEMENT	3 - ACHIEVED	4 - EXCELLENT
Information in diagram	Diagram is incorrect or absent.	Learner identifies one or no actions that influence carbon dioxide emissions.	Diagram generally reflects the process of greenhouse gases holding heat and warming the atmosphere. Learner identifies at least two actions that contribute to increasing and reducing greenhouse gases.	Diagram reflects in detail how greenhouse gases hold heat and warm the atmosphere. Learner identifies three or more actions that affect greenhouse gas emissions and those actions reflect both increases and reductions.

Developing your teaching practice

A group of teachers played this game, in a version where some people were clouds and some were CO_2 molecules. Below are two examples of their diagrams of the greenhouse effect.



Use the rubric and discuss how you would evaluate the diagram. Make adjustments to the wording of the task as well as the rubric criteria if necessary.

ACTIVITY 2

CONSEQUENCES OF INCREASED LEVELS OF GREENHOUSE GASES IN THE ATMOSPHERE

Method used: Investigative – research

The activity is designed to stimulate thinking and discussion around the consequences of increasing the amount of greenhouse gases in the atmosphere. Learners then investigate one of the consequences of increased greenhouse gases in more detail.

Links to CAPS

This activity helps to develop Specific aim 3: 'Understanding the uses of Science' as well as the following knowledge and skills as described in the CAPS:

- Accessing and recalling information;
- Interpreting information; and
- Communicating.

More specifically, the skills developed in this activity are:

- Translation of information in a diagram into a report.
- Understanding how increased concentration of greenhouse gases in the atmosphere are expected to impact on the habitability of the planet.

The CAPS topic that links directly to this activity is the Grade 8, Term 1 topic of Interactions and interdependence within the environment – Balance in an ecosystem.

Core knowledge

Measuring the warming potential of greenhouse gases

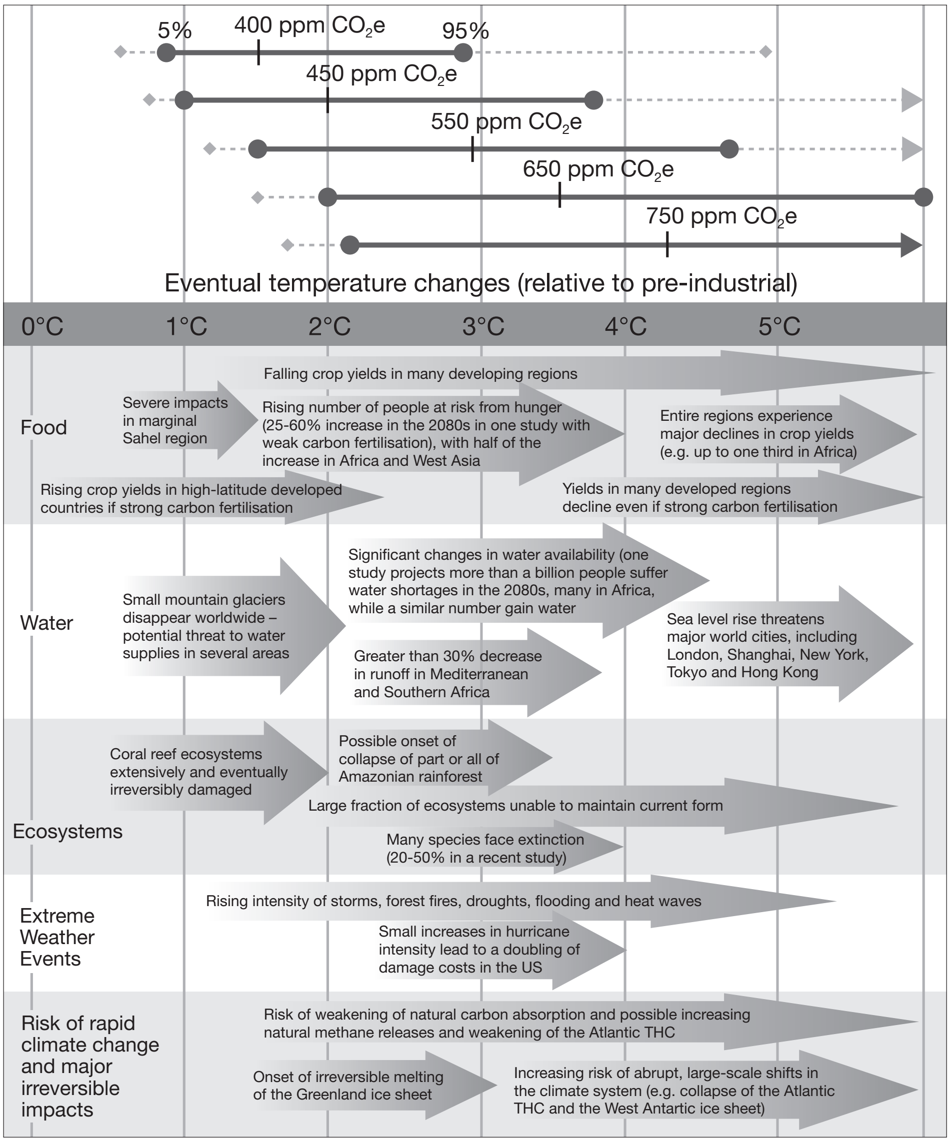
Equivalent carbon dioxide (CO_2e) is the concentration of carbon dioxide that would cause the same level of atmospheric warming as a given type and concentration of greenhouse gas. This means that the warming effects of all greenhouse gases is compared to that of carbon dioxide and can be measured as if it were carbon dioxide. For example, CO_2 is given a global warming potential (GWP) of 1. Methane has a GWP of 21. We say that 10 tons of methane has a GWP equal to 21 tons of CO_2e.

Outline of activity

The average global temperature continues to increase. It has increased by just less than 1°C over the last 100 years. It is now understood that this increase is due mainly to increased levels of greenhouse gases in the atmosphere.

What will be the consequences of increased levels of greenhouse gases?

1. Identify the human activities that contribute to a rise in temperature as a result of an increasing concentration of greenhouse gases.
2. Look at the diagram below. What are some of the suggested impacts of an increase in temperature?



Source: Stern Review, Executive summary page 5, http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/sternreview_index.htm

3. Choose one of the impacts and research what this impact might be in the area in which you live. Present your findings to the class in the form of either a powerpoint presentation or a poster. Include ways in which people may need to adapt to changes as well as ways in which the changes might be mitigated.
4. Write a report on how you think climate change is going to affect YOU.

Mitigate means to make less severe.

Developing your teaching practice

Develop a rubric for the powerpoint presentation or poster in the activity above.

ACTIVITY 3

USING SOLAR ENERGY TO HEAT WATER

Method used: Information transfer

The activity involves reading text for meaning and understanding a diagram. The information must then be translated by learners into another form.

Links to CAPS

This activity helps to develop Specific aim 3: 'Understanding the uses of Science' as well as the following knowledge and skills as described in the CAPS:

- Accessing and recalling information;
- Observing; and
- Communicating.

More specifically, the skills developed in this activity are:

- Developing language skills; and
- Translation of an diagram into a description.

The CAPS topics that link directly to this activity are the Grade 7 Term 3 topics of:

- Heat transfer – Heating as a transfer of energy, Conduction, Convection and Radiation; and
- Insulation and energy saving – Using insulating materials.

Core knowledge

A solar panel or solar collector in a solar water heating system is different to a solar panel with photovoltaic cells. In the solar water heating system, the sun's energy is used to heat water. In the solar photovoltaic panel, the sun's energy is used to generate electricity. The fact that we tend to refer to both the solar collector of a water heating system and the panel of photovoltaic cells as "solar panels" can lead to confusion.

There are now many different types of solar water heating systems on the market. These can be classified roughly as follows:

Types of solar water heating system

Active – Requires electric power to activate pumps and/or controls.

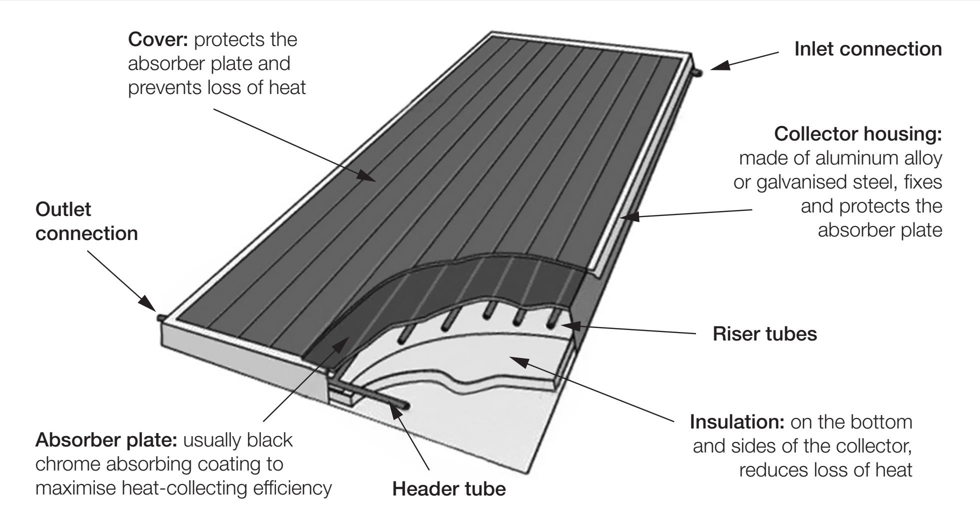
Passive – Relies on convection, not electric power, to circulate the heated water.

Direct – Heats the water directly in the collector.

Indirect – Heats a heat transfer fluid in the collector and transfers heat to the water in a heat exchanger tank.

The heat collector panel may also be of two different types: Flat plate or evacuated tubes. As the flat plate is probably the most common in South Africa, this is the type that is focussed on in the activity.

Diagram of a flat plate solar collector



Source: http://inlightsolar.en.alibaba.com/product/219109937-218874130/Solar_Water_Heater_Parts_Flat_Roof_solar_collector.html

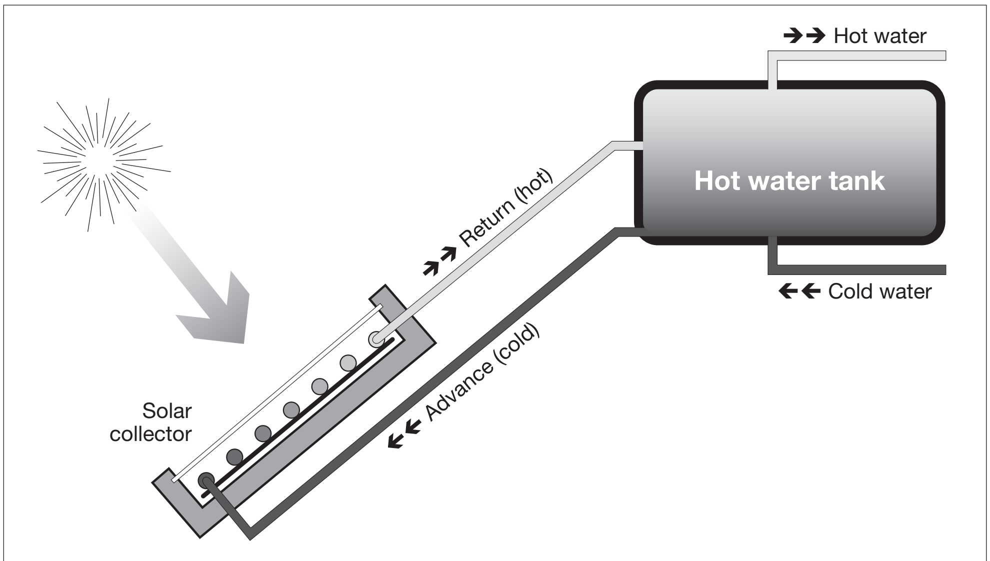
Outline of activity

In South Africa we have an abundance of sunshine that we can use to heat up water!

Read the text below and look at the diagram.

> There are different types of solar water heating systems. The type most commonly used in South Africa is a passive thermosiphon solar water heating system. The hot-water storage tank is above the solar collector in this system. Hot water rises from the top of the solar collector back into the hot-water tank while the cold, denser water sinks down into the bottom of the solar collector to be heated up. This is called the thermosiphon effect. It is also called a passive system because no electricity or pump is needed to make the water circulate. Solar collectors may be flat plate or evacuated tube collectors. The flat plate collector uses copper tubes for the water to flow through. The copper tubes lie on a black absorber plate inside an insulated box covered with a glass panel.

Diagram showing a passive thermosiphon solar water heating system



Source: http://www.solarsense.co.za/solar-water-heating-explained.php

Explain to a partner how this solar water heating system works using the words radiation, conduction and convection.

Write a description of this solar water heating system followed by an explanation of how this solar water heating system works, again using the words radiation, conduction and convection.

Discussion

What other alternative energy sources are available?

Developing your teaching practice

Set up the investigation below to focus on developing the process skills of observing, comparing, measuring and recording.

Grade 7, Term 3 CAPS suggested investigation:

> Investigating different insulating materials (such as styrofoam, newspaper, plastic, glass) by how well they keep hot objects hot (such as a cup of tea) or prevent cold objects (such as ice) from heating up. Measure temperature loss or gain and record results. Sequence the insulators from very good to poor.

ACTIVITY 4

ENERGY USE IN YOUR HOME

For more on this particular method, see the *Methods & Processes* book, p.24.

Method used: Investigative method – fieldwork and research

The activity takes learners through the steps of conducting an audit of their energy usage.

Links to CAPS

This activity helps to develop Specific aim 3: 'Understanding the uses of Science' as well as the following knowledge and skills as described in the CAPS:

- Measuring;
- Recording information;
- Identifying problems and issues; and
- Communicating.

More specifically, the skills developed in this activity are:

- Calculating electricity consumption via an audit;
- Collecting and processing data;
- Calculating carbon emissions;
- Language skill: writing a report; and
- Making informed decisions.

The CAPS topic that links directly to this activity is the Grade 9 Term 3 topic of Cost of electrical power – The cost of power consumption.

Core knowledge

The quantity of electrical power used is measured in kilowatt hours (kWh).

Outline of activity

This activity was based on the activity ‘Find out where you can save energy and money on your home’ from the *Smart Living Handbook*, City of Cape Town, 2007, pp. 45-49. The activity takes learners through the steps of conducting an audit of their energy usage.

You will need to supply learners with the information sheet titled “Typical Home Appliance Electricity Consumption” from the City of Cape Town’s Smart Living Handbook shown below.

Typical Home Appliance Electricity Consumption

Appliance	Power use (watts)	Ave hrs/ day in use	Appliance	Power use (watts)	Ave hrs/day in use
Lighting			**Refrigeration**		
Incandescent bulb (40 W)	40	5	Freezer (chest)	105	4
Incandescent bulb (60 W)	60	5	Fridge with freezer	158	5
Incandescent bulb (100 W)	100	5	Fridge – no freezer	250	5
CFL (12 W)	12	5	**Home maintenance**		
CFL (18 W)	18	5	Dishwasher	2 500	0,9
CFL (20 W)	20	5	Vacuum cleaner	1 000	0,5
Security (120 W)	120	0,3	**Laundry**		
Cooking			Iron	980	0,4
Coffee machine	670	0,5	Iron (steam)	1 235	0,8
Electric stove	3 000	2	Washing machine	3 000	0,75/load
Frying pan	1 250	0,4	Tumble dryer	3 300	0,5/load
Hotplate – large	2 400	0,3	**Music, entertainment, home office equipment and other**		
Hotplate – small	1 275	0,2	Burglar alarm	10	24
Kettle	1 900	0,3	Cell phone charger	9	2
Microwave oven	1 230	0,8	Compact disc player	9	0,4
Toaster	1 010	0,3	Computer	134	1,5
Snackwich	1 200	0,3	Cordless phone	2	15
Food processor	166	0,2	Fax machine	45	13,6
Geyser			Hair drier	647	0,1
Geyser (electric)	2600	4,4	Radio	12	3
Geyser (solar with electric backup)	2600	1,7	M-Net decoder	28	12,1

Source: *Smart Living Handbook*, City of Cape Town, 2011, p.67

When learners have completed this activity, give them the following information to compare their carbon emissions with typical annual CO_2 emissions from Cape Town homes:

HOUSEHOLD TYPE	KG CO_2 / MONTH
Average low-income non-electrified home in Cape Town	146
Average low-income electrified home in Cape Town	193
Average mid-income home in Cape Town	737
*These figures do not include emissions from our use of transport	

Source: *Smart Living Handbook*, p.49, City of Cape Town, 2007

The costs of the different forms of energy such as paraffin, gas, batteries, wood, etc. will need to be updated.

Energy can be a big cost. It is important to know how you are using energy, as only then can you start to try to cut down on your energy use.

Step 1: Copy the format of the table below and complete your table below to audit your electricity use. Your teacher will provide you with a table showing "Typical Home Appliance Electricity Consumption" to help you calculate your electricity use.

HOUSEHOLD ELECTRIC APPLIANCE AUDIT SHEET					
Appliance	Power use (watt)	Hours per day in use	Number of appliances	Average kWh per day (watt x hours ÷ 1000)	Average kWh per month
e.g. light bulb	60 w	4	7	60 x 4 x 7 = 1680 ÷ 1000 = 1,68	1,68 x 30 = 5,04
etc.					
				Electricity consumption total	

Step 2: Copy and complete the table below to audit all your energy sources such as paraffin, gas, batteries, electricity and wood. Use the second column to record what you use the particular type of energy for, such as cooking, lighting, heating, music, fridge, iron etc. Refer to your electricity bill to estimate your electricity consumption.

Fuel type	Service	Amount per month (litres, kilos, number)	Cost per unit (Rands per litre, kg or number	Fuel cost per month
e.g. paraffin	cooking	3 litres	R9,30 per l	R27,90
etc.				
Total cost				

Step 3: Identify your carbon emissions. Complete the table below to calculate your household's annual carbon emissions.

Total electricity ....kWh	X 1,08 kg CO_2 per kWh	= ....kg CO_2 / month	..............kg CO_2 / yr
Total LP gas ....kg	X 3,09 kg CO_2 per kg	= ....kg CO_2 / month	..............kg CO_2 / yr
Total paraffin ....litres	X 2,58 kg CO_2 per litre	= ....kg CO_2 / month	..............kg CO_2 / yr
Total energy-related household emissions from your home per year		= ....kg CO_2 / month	..............kg CO_2 / yr

Source: Adapted from p.45, *Smart Living Handbook*, City of Cape Town, 2007

Step 4: Present your findings in the form of a report. Identify where you could be saving energy. What actions could you take to reduce your energy consumption? By how much could you reduce your carbon emissions?

Assessment

Rubric for assessment of the report in Step 4:

CRITERION	1	2	3	4
Calculates energy use	No calculations	Incomplete or incorrect calculations	Correctly calculates energy use	
Identifies where energy saving could be made and suggests actions	Doesn't comment on energy saving or suggest any actions	Identifies some areas where energy saving could be made and makes some suggestions	Adequately identifies where energy saving could be made and suggests relevant actions	Makes a detailed analysis of where energy saving could be made and suggests comprehensive and appropriate actions
Comments on carbon emissions	Makes no comment on carbon emissions	Incorrectly attempts to work out carbon emissions reduction	Correctly calculates carbon emissions reduction	Correctly calculates carbon emissions reductions for various proposed energy-reducing actions

Developing your teaching practice

Plan the activities for a series of five lessons using the suggested activities in the CAPS Grade 9, Term 3 topic 'The cost of power consumption' and building up the skills that will be required for learners to successfully be able to complete the energy audit in the activity above.

Assessment Practice

Tasks for the teacher

1. Marking questions of different cognitive levels

Consider the two assessment items below:

- List the greenhouse gases in the atmosphere.
- Why do we need greenhouse gases in the atmosphere?

Discuss the cognitive levels associated with each question. Also discuss which of these items it is easier to mark and to make a memo for.

Look at the questions and answers below:

Assessment questions to ask after the greenhouse game

1. Why do we need greenhouse gases in the atmosphere?
2. How does an increase in carbon dioxide affect the temperature of the planet?
3. What human actions increase the amount of carbon dioxide in the atmosphere?
4. What human actions could slow down the rate of increase in carbon dioxide in the atmosphere?
5. What human actions can decrease the amount of carbon dioxide in the atmosphere?

Answers

1. We need carbon dioxide in the atmosphere to moderate the Earth's temperature to within a habitable range.
2. When you increase the amount of CO_2, more heat is held, as shown by the caught sunbeams holding HEAT cards standing in the atmosphere, and Earth warms up.
3. Human actions that increase the amount of carbon dioxide in the atmosphere include burning of fossil fuels, deforestation, etc,
4. Human actions that could considerably slow down the rate of increase in carbon dioxide in the atmosphere are energy saving solutions, recycling, using energy efficient technology, using alternative forms of transportation.
5. Human actions that can decrease the amount of carbon dioxide in the atmosphere are afforestation and carbon sequestration (burying).

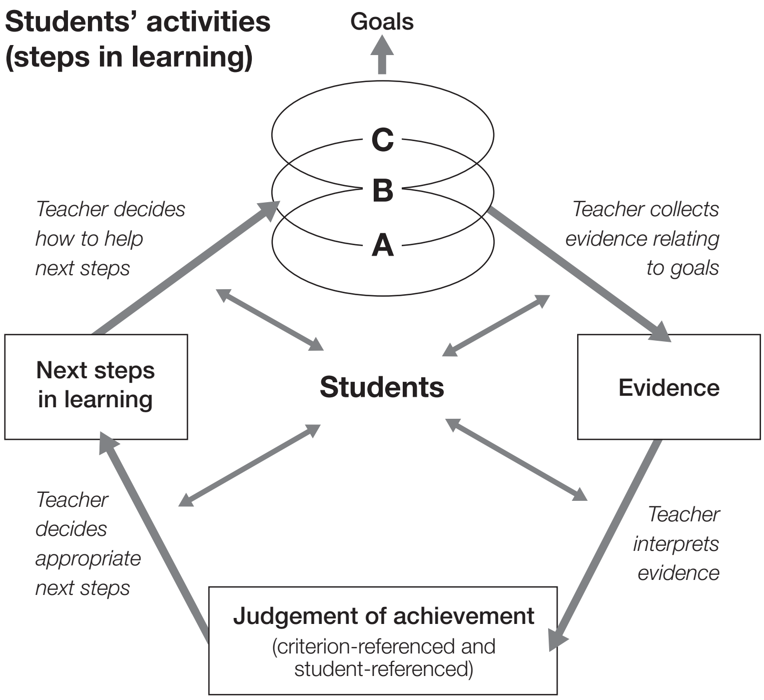
Identify the cognitive levels of the questions. Discuss how you would allocate marks to these questions.

Set a 20 mark test with a memo, on the greenhouse effect, using the 40:45:15 ratio of low order questions : middle order questions : high order questions as recommended in the CAPS.

2. Interpreting evidence of the development of ideas from learners writing and drawings and the role of feedback in enabling learners to further develop their ideas

The diagram below shows the formative assessment cycle. This cycle illustrates how formative assessment can be crucial in raising standards in the classroom. Key to this are the teachers' interpretation of 'evidence' and the feedback that the teacher gives the learner.

Formative assessment cycle



After learners have completed an activity where different materials are discussed in term of their insulation properties, the Grade 7, Term 3 CAPS topic on using insulating materials has as a suggested activity that learners should "design, make and test a system ("hot box/ wonder box/solar box cooker") which uses insulating materials to keep food hot for longer or to keep ice cold."

Learners are asked to first provide a plan for their cooker design that takes the form of a labelled diagram and notes explaining how they predict it will work.

Identify what the goals for the learners would/could be for this design part of the task. Identify the science content goals, process skills and attitudes that may be involved.

What 'evidence' will you as the teacher look for in the design the learner provides and how will you interpret this evidence. In other words, think to yourself: "I will look for … because this will indicate to me that the learner …

Discuss the kinds of comments that learners would find the most useful in terms of helping them to move to the next step.

Appendices

Appendix 1

The Younger Dryas – A warning from the past?

About 12 000 years ago, as the Earth was beginning to warm near the end of the Wisconsin glacial, a tremendous cold spell gripped the high latitude regions of the Northern Hemisphere. For roughly 1 300 years at least some northern regions returned to peak ice age conditions. The onset of this return to frigid conditions was relatively sudden; the transition apparently occurred within a century or less. This sudden return to extremely cold conditions is known as the Younger Dryas, after the vast quantities of pollen from tundra flower species, *Dryas octopetala*, found in sediment cores associated with that time period. There was also an older, less dramatic cooling event known as the Older Dryas.

Scientists are not sure exactly how widespread the Younger Dryas was; whether it was an event of global or more regional scale. They are not entirely certain about the cause or causes of the Younger Dryas, either. However, many scientists believe a partial or total shutdown of the thermohaline circulation may have been involved; and that we would be wise to heed this as a warning of one potential fate that may befall us as a result of global climate change.

As the vast North American ice sheets began to melt towards the end of the Wisconsin glacial, a huge lake formed from the meltwater in what is now central Canada. Some scientists believe that the Younger Dryas was triggered when a huge flood of water from Lake Agassiz burst forth, suddenly dumping a large supply of fresh water into the North Atlantic. According to this theory, the influx of fresh water shut down the normal cycle of the thermohaline circulation, effectively turning off that current system in a very short time. As we've mentioned, the thermohaline circulation brings warm, tropical waters northward towards the Arctic and sends cold, polar waters southward. A disruption of this flow would dramatically alter regional, and possibly even global, patterns of heat transfer. The theory claims that this shutdown temporarily plunged at least some parts of the Northern Hemisphere back into peak "ice age" conditions. Eventually, the flow from Lake Agassiz subsided, and the thermohaline circulation re-established itself.

A deluge of fresh water from glacial Lake Agassiz, flowing into the North Atlantic via the Great Lakes and the St. Lawrence Seaway, may have triggered the Younger Dryas event.

Some scientists believe a repeat performance of this event, more or less, could happen in the future. Continued rapid melting of Arctic sea ice, combined with extensive melting of the Greenland ice sheet, would inject a lot of fresh water into the North Atlantic. This is a path which continued global warming might lead us down. Could such an infusion be large enough and rapid enough to shut down, or at least disrupt, the thermohaline circulation? Nobody knows for sure. Most scientists believe this is a “low probability, but high consequence” scenario. Some think that the Younger Dryas event should serve as a cautionary tale; that not all climate change is gradual, and that a series of unlikely events can sometimes be strung together to produce catastrophic changes.

Source: http://www.windows2universe.org/earth/Water/thermohaline_ocean_circulation.html

Appendix 2

Is Europe due for a Big Chill?

By shutting down ocean currents, global warming could actually cool things off

By Michael D. Lemonick, 5 December 2005

Even in the dead of winter, long stretches of subzero temperatures are pretty rare in London. It may come as a surprise, therefore, to learn that the capital of Britain lies nearly 400 miles farther north than Montreal – or that Paris is farther from the equator than Fargo, N.D. The relatively balmy climate of much of Western Europe suggests that many countries in that region should lie well south of where they actually are, and that's all thanks to the Gulf Stream, a gigantic river of tropical water that flows up and across the Atlantic, warming the waters that lap figuratively against Europe's western shores. Turn it off, and the region's temperatures could plunge disastrously.

That was precisely the spectre raised last week when scientists from Britain's National Oceanography Center reported in Nature that a component of the oceanic current system that drives the Gulf Stream has slowed by 30% since 1992. The likely, paradoxical cause? Global warming. While climate experts around the world caution that the data are too preliminary to be definitive, "the result," writes University of Hamburg climatologist Detlef Quadfasel in a commentary on the study that also appears in Nature, "is alarming."

It's also not entirely unexpected. Back in the 1980s, Wallace Broecker, a geophysicist at Columbia University's Lamont-Doherty Earth Observatory, was trying to understand why temperatures in Greenland had plunged dramatically several times over the past 70 000 years. His theory: fresh water, perhaps from melting glaciers, might have diluted the ocean's salinity, making it harder for cooling water to sink and return southward to pick up more heat. That could shut off the entire "conveyor belt" of water that keeps Europe temperate. It's hard to determine precisely what would have caused such a big thaw 70 000 years back, but we do know that today global warming is causing more meltwater to stream into the North Atlantic from glaciers and older sea ice, which is lower in salt. Could the conveyor belt stop again?

Climate experts are not sure – and some have serious reservations about the new paper – mostly because the observed change is happening too fast. Computer models predict that it should take at least 100 years to weaken the ocean conveyor belt. What's more, nobody was even measuring those currents before 1957. Says Broecker: "We don't know how much the flow bounces around normally."

Clearly, pieces are still missing from the equation, so even the scientists who wrote the study counsel against panic. Rather than be worried, says co-author Stuart Cunningham, "people should be more interested and concerned. The ocean seems to have changed in a large enough way to be detectable." It's something, in other words, to keep an eye on.

[The following text appears in a complex diagram – see PDF or hardcopy of magazine.]

GLOBAL WARMING – Increased rainfall as well as the melting of sea ice, glaciers and the Greenland ice sheet could add enormous amounts of freshwater to the Atlantic currents, reducing their salinity enough to slow the sinking of cooler water and shut down the heat conveyor.

THE GULF STREAM – As the currents move warm surface water from the equator to the north, the water releases its heat into the atmosphere and cools. That heat loss makes the water saltier and very dense. By the time it reaches north of Iceland and east of Labrador, it becomes dense enough to sink.

SINKING WATER – In wintertime the cold, salty, dense water that originates in the Gulf Stream plunges down into the deep ocean, beginning the return of the conveyor belt. The deep current slowly flows back across the equator and into the Pacific, Indian and Southern oceans.

MID-ATLANTIC CIRCULATION – The addition of fresh, less salty water in the northern hemisphere essentially locks the flow of new warm water from the Tropics. That water heads east and south instead of pursuing the northward part of its normal route.

>> Warm surface current >> 50% larger southward-moving mid-ocean recirculation of warm surface water

Deep cold current << 50% decrease in the southward transport of Lower North Atlantic Deep Water

ARRAY OF 22 MOORINGS HOW THE MEASUREMENTS WERE TAKEN – In spring 2004, scientists deployed 22 moorings across a strip of the Atlantic about 25 north. Each mooring was equipped with numerous instruments that gathered all types of information, from temperature and salinity to current speed and direction.

• Large buoyancy sphere • Current meter • Every two days a sensor crawls up and down 14,436 ft. of wire as it measures conductivity, temperature and depth • Current meter • Buoyancy spheres • Acoustic release • Anchor made of railway wheels

POOR CIRCULATION – Recent findings suggest that the Atlantic Ocean currents that warm Northern Europe are weakening as a result of global warming and may ultimately mean frigid weather for Europe.

The slowing of the Gulf Stream conveyor belt could mean that less warm water would reach the northeastern Atlantic.

Sources: Nature*; Professor Harry Bryden, University of Southampton; NASA; USGS.*

Indicators of Development of Process Skills

Using indicators of development of process skills

One way to identify process skills is by the actions that using each of the process skills involves. For example, if children are sorting leaves into groups based on how smooth or fuzzy they are, they are "identifying obvious differences between objects," an observation skill. These "operational" definitions of process skills are important for recognizing the skills in students' actions.

This list of questions for process skills helps you focus your observation on significant aspects of student behavior and to interpret your observations of these behaviors. The questions in this list can be used to interpret the full range of student behavior that can be found in their speech, artifacts, writing, and drawings. Observations from all these sources can be used to decide which of the questions in the lists below can be answered by "yes."

Finding where the positive answers to the questions turn into negative ones—or more realistically, where it becomes difficult to say yes or no—locates the students' development within the map. Furthermore, and importantly, this process indicates the next step, which is to consolidate the skills and ideas around the area where "yes" turns into "no." This pointer to where progress is to be made helps you determine what your teaching should focus on next.

Observing

Do the students:

1. Succeed in identifying obvious differences and similarities between objects and materials?
2. Make use of several senses in exploring objects or materials?
3. Identify differences of detail among objects or materials?
4. Identify points of similarity among objects where differences are more obvious than similarities?
5. Use their senses appropriately and extend the range of sight using a hand lens or microscope as necessary?
6. Distinguish from many observations those that are relevant to the problem in hand?

Indicators of Development of Process Skills

Questioning

Do the students:

1. Readily ask a variety of questions that include investigable and noninvestigable ones?
2. Participate effectively in discussing how their questions can be answered?
3. Recognize the difference between an investigable question and one that cannot be answered by investigation?
4. Suggest how answers to questions of various kinds can be found?
5. Generally, in science, ask questions that are potentially investigable?
6. Help in turning their own questions into a form that can be tested?

Hypothesizing

Do the students:

1. Attempt to give an explanation that is consistent with evidence, even if only in terms of the presence of certain features or circumstances?
2. Attempt to explain things in terms of a relevant idea from previous experience even if they go no further than naming it?
3. Suggest a mechanism for how something is brought about, even if it would be difficult to check?
4. Show awareness that there may be more than one explanation that fits the evidence?
5. Give explanations that suggest how an observed effect or situation is brought about and that could be checked?
6. Show awareness that all explanations are tentative and never proved beyond doubt?

Predicting

Do the students:

1. Attempt to make a prediction relating to a problem even if it is based on preconceived ideas?
2. Make some use of evidence from experience in making a prediction?
3. Make reasonable predictions based on a possible explanation (hypothesis) without necessarily being able to make the justification explicit?
4. Explain how a prediction that is made relates to a pattern in observations?
5. Use patterns in information or observations to make justified interpolations or extrapolations?
6. Justify a prediction in terms of a pattern in the evidence or an idea that might explain it?

Indicators of Development of Process Skills

Planning and Investigating

Do the students:

1. Start with a useful general approach even if details are lacking or need further thought?
2. Identify the variable that has to be changed and the things that should be kept the same for a fair test?
3. Identify what to look for or what to measure to obtain a result in an investigation?
4. Succeed in planning a fair test using a given framework of questions?
5. Compare their actual procedures after the event with what was planned?
6. Spontaneously structure their plans so that independent, dependent, and controlled variables are identified and steps taken to ensure that the results obtained are as accurate as they can reasonably be?

Interpreting

Do the students:

1. Discuss what they find in relation to their initial questions?
2. Compare their findings with their earlier predictions?
3. Notice associations between changes in one variable and another?
4. Identify patterns or trends in their observations or measurements?
5. Draw conclusions that summarize and are consistent with all the evidence that has been collected?
6. Recognize that any conclusions are tentative and may have to be changed in the light of new evidence?

Communicating

Do the students:

1. Talk freely about their activities and the ideas they have, with or without making a written record?
2. Listen to others' ideas and look at their results?
3. Use drawings, writing, models, and paintings to present their ideas and findings?
4. Use tables, graphs, and charts when these are suggested to record and organize results?
5. Regularly and spontaneously use reference books to check or supplement their investigations?
6. Choose a form for recording or presenting results that is both considered and justified in relation to the type of information and the audience?

Adapted from Wynne Harlen, *Teaching, Learning, and Assessing Science, 5–12*, 3rd ed., (London: Paul Chapman Publishing Ltd. 2000), pages 147–150.

Source: http://www.exploratorium.edu/ifi/workshops/fundamentals/

fundisa for change

A partnership programme for environmental learning and teacher education