Science

Earth and Environmental Science

Rationale and aims

Rationale

The senior secondary Earth and Environmental Science curriculum encompasses the three interrelated areas of science inquiry skills (incorporating skills and understanding of science as a way of knowing and doing), science as a human endeavour (incorporating knowledge and understanding of the personal, social, environmental, cultural and historical significance and relevance of science), and science understanding (incorporating knowledge and understanding of the biological, physical, and earth and space sciences).

Building on students' science knowledge and skills acquired up to Year 10, the senior secondary Earth and Environmental Science curriculum provides opportunities for students to explore the contextual framework for understanding Earth's origins and history, the variety of its natural physical environments and hazards, and the origin of its minerals and energy resources. Students examine the developments in, and current applications of, current understandings in earth and environmental science and evaluate the future impact of past and current human actions.

Earth and environmental science is a diverse field of inquiry and knowledge. As a multidisciplinary science, it draws on the laws and principles of biology, chemistry and physics to explain interactions between physical and human systems and processes. Society is dependent on the work of scientists such as geologists, meteorologists, land conservation engineers and oceanographers to solve problems related to responsible resource management.

By studying the senior secondary Earth and Environmental Science curriculum, students appreciate both the changing and expanding body of contemporary knowledge in earth and environmental science, and the study of earth and environmental science as an independent and collaborative human endeavour.

Aims

The aim of the senior secondary Earth and Environmental Science curriculum is to provide students with a solid foundation in science knowledge, understanding, skills and values on which further learning and adult life can be built.

Students should be able to:

- draw on their curiosity and willingness to speculate about and explore the world to expand their interest in earth and environmental science
- plan and undertake practical and other research investigations involving collection, collation and analysis of qualitative and quantitative data, interpretation of experimental outcomes, and the use of models and simulations to visualise, explore and explain events
- engage in communication of and about earth and environmental science, value evidence and scepticism, and critically evaluate the scientific claims made by others
- solve problems, and make informed, responsible and ethical decisions when considering local and global issues and applications of earth and environmental science concepts, techniques and technologies in daily life
- appreciate earth and environmental science as both an independent and a collaborative human endeavour
- develop in-depth knowledge, understanding, skills and scientific values relating to earth and environmental science
- appreciate the changing and expanding body of contemporary knowledge in earth and environmental science.

Organisation

Content structure

The senior secondary Earth and Environmental Science curriculum is organised around three interrelated strands: *Science inquiry skills*, *Science* *as a human endeavour* and *Science understanding.*

Science inquiry skills

Scientific inquiry involves posing questions; formulating testable hypotheses; planning, conducting and critiquing investigations; collecting, analysing and interpreting evidence; and communicating findings. This strand is concerned with investigating ideas, evaluating claims, solving problems, drawing valid conclusions and developing evidence-based arguments. It also recognises that scientific explanations change as new or different evidence becomes available.

Science as a human endeavour

Science influences society through posing and responding to social and ethical issues, and scientific research is influenced by societal challenges or social priorities. This strand highlights the need for informed, evidence-based decision-making about current and future applications of science. It acknowledges that, in making decisions about science and its practices, moral, ethical and social implications must be taken into account. This strand also acknowledges that science has been advanced through, and is open to, the contributions of many different people from different cultures at different times in history. It identifies the historical aspects of science as well as contemporary scientific issues and activities, and that science offers rewarding career paths.

Science understanding

An understanding of science is evident when a person selects and integrates appropriate science knowledge in ways that explain and predict phenomena, and applies that knowledge to new situations and events. Science knowledge refers to facts, concepts, principles, laws, theories and models that have been established and continue to be challenged and refined by scientists over time. Science knowledge represents the building blocks of science understanding, but it is the dynamic nature of science understanding that will benefit citizens in an ever-changing world.

Links to K–10

The senior secondary Earth and Environmental Science curriculum builds on the science knowledge and skills developed by students in science up to the end of Year 10, and extends their learning in the K–10 biological, physical and earth sciences. The three organisational strands in Science K-–10, *Science understanding*, *Science as a human endeavour* and *Science inquiry skills* are continued into the senior secondary Earth and Environmental Science curriculum. As with the Years K–10 science course, it is expected that teachers are able to show connections across these three strands in the exploration of ideas, concepts and principles. The inquiry approach to science fostered throughout Years K–10 is strengthened in the senior secondary years, with students formulating hypotheses generated from their own questions, and investigating and reporting on these. They also undertake an extended experimental investigation to explore an aspect of earth and environmental science in depth.

Pathways

The senior secondary Earth and Environmental Science curriculum provides pathways for students wishing to pursue further studies or those wishing to enter the workforce. While students may choose to specialise in earth and environmental science, synergies between the four senior science courses provide opportunities for students to pursue multidisciplinary areas of science in addition to studying specific concepts through different discipline lenses. Concurrent study of *Earth and Environmental Science* and *Biology* enables students to evaluate evidence for varying scientific viewpoints and theories, and enhance their decision-making capacity related to issues of local concern, for example monitoring environmental change, species extinction and evolution. Concurrent study of *Earth and Environmental Science* and *Chemistry* provides opportunities for students to understand the principles and concepts which underpin the management of environmental problems and issues, for example factors which affect the rate of change of chemical reactions occurring in the environment, energy considerations in the use of natural resources and in the generation of alternative energy solutions, and the application of technologies used in pollution monitoring and control. The concurrent study of *Earth and Environmental Science* and *Physics* provides opportunities for students to engage in creative problem-solving relating to issues in society, for example enhancing efficiencies of energy conversions, developing novel ways of conserving energy in local and global applications, and using the spectroscopic analysis of light emitted by distant stars to predict the nature of matter in the universe.

In addition to providing pathways for further study or employment, the senior secondary Earth and Environmental Science curriculum provides opportunities for all students to develop an understanding of earth and environmental science concepts and principles which will enable them to become more informed citizens who can make evidence-based decisions about the science-related issues which arise in their lives.

Unit structure

Content of the senior secondary Earth and Environmental Science curriculum is outlined below.

Unit 1: Origins and interactions

In this unit, students will use an inquiry approach to investigate and develop their understanding of Earth's origins, and the interactions between Earth's environments and processes.

This will include: Earth's origin and internal structure; tools, technologies and techniques used in field studies to investigate ancient and present-day environments; the age of Earth and the geological time scale; interactions between the atmosphere and the hydrosphere; and Earth's environments and processes.

Students will reflect on how knowledge in earth and environmental science in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Unit 2: The dynamic Earth

In this unit, students will use an inquiry approach to investigate and develop their understanding of the changing nature of Earth's surface.

This will include the study of: continental drift and plate tectonics; consequences of plate motions; natural hazards and plate tectonics; and relationships between mineral and energy resources, and plate tectonics.

Students will reflect on how knowledge in earth and environmental science in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Unit 3: Life through time

In this unit, students will use an inquiry approach to investigate and develop their understanding of changes in life forms through time.

This will include the study of: the role of the fossil record in the establishment of Darwin's theory of evolution by natural selection; major events in the origin and evolution of life; mass extinctions and radiations; and evolutionary events which changed global environmental conditions.

Students will reflect on how knowledge in earth and environmental science in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Unit 4: Managing environmental change

In this unit, students will use an inquiry approach to investigate and develop their understanding of the management of changes in the environment.

This will include the study of: human-induced change in environmental and climatic conditions; interaction of natural systems to change environmental conditions and global climate; reduction and mitigation of the negative environmental consequences of human activities; and maintenance of ecological and habitat diversity.

Students will reflect on how knowledge in earth and environmental science in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

General capabilities

The Australian Curriculum, Assessment and Reporting Authority (ACARA) has identified 10 general capabilities that will be specifically covered in the curriculum. In the senior secondary Earth and Environmental Science curriculum, eight of these are considered inherent to science and so are explicitly included in the content descriptions and achievement standards. These are literacy, numeracy, information and communication technologies (ICT), thinking skills, creativity, teamwork, ethical behaviour and self-management. Each of these is embedded in the content descriptions of the *Science inquiry skills* strand and many are also incorporated into the *Science as a human endeavour* strand.

Literacy is an important capability in earth and environmental science. Students will be taught how to use and interpret the scientific language associated with earth and environmental science, including specific terminology and correct representation of visual texts. They will be required to communicate their knowledge within and beyond the earth and environmental science community, selecting and using formats appropriate to a purpose and audience, including written texts, multimodal representations and oral presentations. They will access, critically read, and extract information related to earth and environmental science from a variety of sources, and acknowledge these sources appropriately.

Numeracy knowledge and skills are used and developed within the earth and environmental science course, often through the measurement and analysis of results from investigations and field work. Both qualitative and quantitative data will be collected and represented in appropriate formats. Students will be required to analyse numerical and graphical data in a range of situations which could include, for example, investigation of geological and environmental change over time, requiring an understanding of time scales used in this area of science, and analysis of data from field studies. Students will evaluate the reliability of measurements in first- and second-hand data. They will be required to use skills of statistical analysis when using data from both their own experiments and secondary sources.

Information and communication technologies (ICT) are relevant to teaching and learning in a large part of the senior secondary Earth and Environmental Science curriculum. This will include the use of the internet to research concepts and applications as well as the use of digital learning objects such as animations and simulations to enhance students' understanding and engagement in earth and environmental science. The use of the internet and local networks will facilitate a collaborative approach among students that models methods of modern science. In practical investigations, ICT will aid students in tasks such as data collection in field studies and the use of spreadsheets in the analysis of data. This enables students to use and analyse results efficiently, allowing for the development of valid conclusions, and also allows access to other potential areas for investigation. Simulations and modelling using digital technologies provide students with opportunities to experience situations which cannot be investigated through practical experiments in the classroom, especially relating to geological and climate change. ICT offers opportunities to provide a range of media for communicating and sharing students' ideas and understandings both within and beyond the classroom.

Thinking skills are integral to the development of understanding in earth and environmental science, including the ability to pose questions, make predictions, speculate, solve problems through investigation, make evidence-based decisions, analyse and evaluate evidence from their own and others' work and summarise information. Students will be encouraged to plan and conduct practical investigations and field studies, as well as to select appropriate information from secondary sources and to evaluate the sources of information used to formulate conclusions. Students will also develop skills to evaluate claims based on the earth and environmental sciences, for example in the media and advertising.

Creativity enables the development of ideas that are new to the individual. Students will develop skills that enable them to formulate creative questions, speculate, think in new ways about observations of the world around them and suggest solutions to earth and environmental science-based problems. In this course some of the students' understandings of the world around them will be taken to a deeper level, involving the development and amendment of existing understandings. Students will be encouraged to be flexible and open-minded as their own understandings of the earth and environment change and develop. Creative approaches to problem-solving may also be applied when students are required to perform experiments using new methodologies or limited resources. For example, they may be required to develop ways in which they can simulate the decay of a radioactive substance or represent measurements of half-life comparisons of a range of radioactive materials.

Self-management is intrinsic to the ability to effectively carry out experiments and investigations. Specific self-management skills will be developed as students are encouraged to plan effectively for individual, collaborative, online and fieldwork activities, and when they reflect on their own practices and learning. In this course the degree of guidance given to students will be reduced when compared with that experienced in earlier stages of schooling, requiring that students work as independent learners.

Teamwork is an important aspect of science at a number of levels, both personal and organisational. At times students will be required to work together, sharing ideas and discussing and debating their work in order to develop and consolidate their knowledge. They will study examples of scientists working in teams, both harmoniously and discordantly, to develop ideas or undertake research in a specific branch of earth and environmental science. The focus in this course will be on developing harmonious, collaborative methods of student inquiry in their own learning and for future work applications.

Ethical behaviour is considered in relation to both experimental science and the acquisition and use of scientific information, including when working independently, in teams or in an online environment. In carrying out investigations students are encouraged to gather evidence honestly and ethically, considering the implications of the investigation, especially in the areas of safety and environmental impact. Students will also develop skills to evaluate claims based on science. This will enable them to make more valid judgments about social and personal issues that involve earth and environmental science. There will also be opportunities for students to discuss the ethical implications of applications of earth and environmental science in areas such as land use and management, climate change and the use of natural resources such as water and minerals.

Cross-curriculum dimensions

The cross-curriculum dimension of sustainability is addressed in the content descriptions of the senior secondary Earth and Environmental Science curriculum. Knowledge and understanding of the natural environment is incorporated within the content descriptions for the *Science understanding* strand. It includes the function of the ozone layer; the water, carbon and nitrogen cycles; human activities such as deforestation and pollution; addition and removal of carbon dioxide, oxides of sulfur and chlorofluorocarbons to and from the atmosphere; sustainable water management; and human-induced changes in conditions that affect habitats and ecosystems. Sustainability as a social and environmental issue is incorporated in the *Science as a human endeavour* strand in areas such as mitigating the effects of increasing human consumption; responsible use of rocks and minerals; management of water resources; preservation of biodiversity; climate modelling; and predicting outcomes of human interactions with the Earth's systems. Important skills associated with sustainability including analysing data related to resource use and ozone depletion, and evaluating claims and arguing a proposed stance are incorporated within the *Science inquiry skills* strand.

Curriculum content that relates to Indigenous history and culture is represented in the content descriptions of the senior secondary Earth and Environmental Science curriculum. The Science as a human endeavour strand explicitly includes the effects over time of practices of Indigenous peoples on biodiversity and sustainability of populations and ecosystems. The relationship between the land and Indigenous peoples over time is implicit in the *Science understanding* strand through the study of human-induced changes in environmental conditions, including strategies for maintaining ecological and habitat diversity.

The cross-curriculum perspective of Asia provides engaging and rich contexts for science learning.

Unit 1 - Origins and interactions

In this unit, students will use an inquiry approach to investigate and develop their understanding of Earth's origins, and the interactions between Earth's environments and processes. This will include: Earth's origin and internal structure; tools, technologies and techniques used in field studies to investigate ancient and present-day environments; the age of Earth and the geological time scale; interactions between the atmosphere and the hydrosphere; and Earth's environments and processes. Students will reflect on how knowledge in earth and environmental science in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Science understanding

Earth's origin and internal structure, including:

• the formation of the solar system and Earth due to the gravitational collapse of an enormous cloud of gas and dust (planetesimal accretion theory)

• evidence used to establish structural layering within Earth, and the identification of the core, mantle and crust

• composition of characteristic materials of the core, mantle and crust

• the mineral composition of rocks

• processes in the formation of sedimentary, igneous and metamorphic rocks

• origin of Earth's initial heat and the maintenance of the planet's internal temperature by radioactive decay.

Tools, technologies and techniques used in field studies to investigate ancient and present-day environments, including:

• use of geological and topographic maps, inclinators, landsat satellite images and petrographic techniques

• classification keys for identification of the geological features and rock types of the local environment

• analysis of the soils for organic content, pH, moisture content, presence of salts

• chemical analysis of stream water.

Age of Earth and the geological time scale, including:

• relative and absolute dating techniques

- the use of isotopic evidence to establish the age of Earth
- divisions of the geological time scale.

Interactions between the atmosphere and the hydrosphere, including:

- chemical composition of the atmosphere and oceans
- the probable origin of the atmosphere and oceans due to volcanic outgassing of the planet
- the interactions between the rotation of Earth and solar heating that produce atmospheric and oceanic circulations as well as Earth’s climate zones
- the role of water, carbon and nitrogen cycles in maintaining life on Earth
- carbon dioxide and the natural greenhouse effect
- major contributing gases to the enhanced greenhouse effect and at least one of the associated local, state, national or international protocols
- origin and function of the ozone layer.

Earth’s environments and processes, including:

- the variety and global distribution of Earth’s land-based, freshwater and marine environments
- the role of both water and atmospheric gases in the formation of soil during rock weathering
- erosion and sediment transport by wind, water and gravity
- interactions between the hydrosphere, atmosphere and Earth’s crustal rocks to create physical environments that support marine and terrestrial ecosystems.

Science as a human endeavour

The nature and practice of earth and environmental science, including:

- the dynamic nature of the body of knowledge related to earth and environmental science which is subject to change as new knowledge and technologies are developed and as the validity and reliability of underlying models, data and conclusions improves
- the interdisciplinary nature of the knowledge within the many fields of study within earth and environmental science (for example, the structure and composition of Earth, the origin of the universe, changing nature of biogeochemical cycles) which depends on an understanding of aspects of chemistry, physics and mathematics
- the interaction between scientists from the many branches of science which has led to scientific progress in the study and monitoring of the interactions between Earth’s atmosphere, hydrosphere and geosphere
- the change in the nature of earth and environmental science which has given rise to emerging fields of study relying on interdisciplinary perspectives (for example, meteorology, oceanography).

Contemporary research and applications of earth and environmental science, including:

• the controls and dynamics of biogeochemical cycling

• processes and phenomena which influence our daily lives (for example, the El Nino and La Nina effects and their influence on local weather patterns, the significance of the ozone layer and strategies for minimising damage to it)

• areas currently being researched in earth and environmental sciences (for example, the GLOBEC project investigating ocean ecosystems and key species and the effect of climate and other factors (including humans) on marine life, the IMBER/SOLAS project researching oceanic carbon, the CERN project researching the origin of the universe)

• investigating areas of current earth and environmental science research (for example, variations in the quantity of carbon dioxide and methane in the atmosphere)

• development of environmental monitoring technologies (for example, to enable more reliable weather forecasting by the Bureau of Meteorology)

• increases in our understanding of earth and environmental sciences that have resulted from technological developments (for example, development of technology for quantitative investigation and monitoring of the atmosphere and hydrosphere).

The development of ideas in earth and environmental science, including:

• research that has led to our current knowledge of the origin and structure of Earth, its atmosphere, hydrosphere and geosphere

• the human stories related to the application of scientific values and endeavour in developing new knowledge in earth and environmental science

• the interdisciplinary nature of the development of the modern geological time scale with the discovery and application of radioactivity

• technological developments (for example, the growth of information and communication applications) that have contributed to improved scientific understanding of Earth and its environment.

Science inquiry skills

Design and perform investigations and experiments related to the earth's origins and biogeochemical interactions, addressing relevant aspects of safety, methodology and ethics, and including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations and experiments include:

• measuring the density of a selection of earth materials representative of core, mantle and crust

• collecting and analysing data from fieldwork and experiments to demonstrate interactions in and between Earth's spheres

• investigating the characteristics of the climate, soils, rocks and/or landscapes of a particular present-day or ancient environment

• investigating the nature and characteristics of solar energy

• investigating crystal formation and relating it to the formation of igneous rocks

• examining a variety of igneous, sedimentary and metamorphic rocks to determine the percentage of components

• identifying several igneous, sedimentary and metamorphic rocks using a key

• modelling the formation of sedimentary rocks (for example, sandstone, conglomerate)

- undertaking a field study of an area identifying and mapping the geological features and rock types
- analysing the soil in a field study for organic content, pH, moisture content, presence of salts
- performing a chemical analysis of stream water in a field study area
- identifying the personal dangers posed by some geological features and mining activities, when undertaking field activities (for example, sampling)
- observing alpha and beta particle tracks with a cloud chamber
- investigating absorption of alpha, beta and gamma rays by a variety of materials
- simulating the decay of a radioactive isotope and measuring its half-life
- investigating the production of carbon dioxide by the fermentation of sugar by yeast
- modelling the role of ocean currents in redistributing heat in the oceans
- performing experiments to compare physical and chemical weathering (for example, abrasion, dissolution)
- investigating and analysing the effect of stream velocity on size of particles that can be transported and deposited
- investigating the shape of river channels.

Develop skills in performing investigations and experiments, including:

- using observations of Earth and its environment to generate questions and guide the construction of hypotheses that inform the design of investigations
- selecting and safely using appropriate scientific equipment for a specific task (for example, data loggers, environmental probes, video cameras, hand lenses, binocular microscopes, measuring devices)
- using geological and topographic maps, inclinators, landsat satellite images, petrographic techniques and ICT
- collecting and recording first- and second-hand data using appropriate formats and ICT (for example, labelled scale scientific drawings, geological cross-sections)
- locating and selecting relevant and reliable second-hand data
- analysing quantitative data using mathematical and/or graphical methods, including plotting of data and lines of best fit
- formulating explanations and conclusions based on experimental evidence
- evaluating methods employed in investigations and suggesting specific changes to improve the reliability, validity or accuracy of results of their own experimental investigations or of any investigations described in secondary sources.

Engage in critical, creative, innovative and reflective thinking, including:

- applying knowledge of earth and environmental science to solve problems and to understand and predict biogeochemical cycles in Earth's spheres

• evaluating the validity of varying scientific results and scientific arguments

• proposing new questions for investigation and innovative solutions to problems related to earth and environmental science

• generating ideas, plans, processes and/or products, including using ICT where appropriate, to solve problems or to challenge current practice and thinking

• reflecting on individual learning progress and processes with consideration to preferred learning styles and previous misconceptions

• testing ideas, identifying the strengths and weaknesses of ideas, and recognising better ideas

• applying techniques for the generation of innovative ideas and alternative applications of technology (for example, 'thinking outside the square', suspending disbelief).

Analyse and evaluate information relating to earth and environmental science, including:

• researching and synthesising information from a range of sources

• using and interpreting models and simulations to aid understanding of earth and environmental science concepts (for example, the origin of the universe, the hole in the ozone layer)

• evaluating the scientific accuracy of claims in advertising and the media

• using evidence as the primary criterion for decisions about the validity of suggested ideas and arguments.

Communicate ideas and findings, including:

• creating and presenting structured reports of experimental and investigative work, using ICT where appropriate

• sharing and exchanging information, including through ICT, in collaborative endeavours, observing social protocols, ethical use of information and security of information

• discussing results and findings with others in order to develop understanding

• using correct scientific language when describing methods, conclusions and explanations

• using correct representations, including use of appropriately labelled scientific drawings with scale measurements and explanatory captions

• explaining concepts and debating issues relating to earth and environmental science.

Unit 2 - The dynamic Earth

In this unit, students will use an inquiry approach to investigate and develop their understanding of the changing nature of Earth’s surface. This will include the study of: continental drift and plate tectonics; consequences of plate motions; natural hazards and plate tectonics; and relationships between mineral and energy resources and plate tectonics. Students will reflect on how knowledge in earth and environmental science in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Science understanding

Continental drift and plate tectonics, including:

• Alfred Wegener's proposal of continental drift in the early twentieth century and the arguments used to reject the concept

• evidence which was used to establish the existence of moving tectonic plates

• comparison of models for plate motion

• the plate tectonic supercycle.

Consequences of plate motions, including:

• mountain building and seafloor formation

• changing distribution of the continents and geographic configuration of the oceans over geological time

• plate tectonic events that influenced the geological evolution of the Australian continent

• isolation of Australia from the other continents about 80 million years ago and its influence on the course of evolution of Australia's unique flora and fauna.

Natural hazards and plate tectonics, including:

• characteristics of the natural hazards (earthquakes, tsunamis and vulcanism) associated with plate tectonics

• probable locations of future large earthquakes and volcanic eruptions predicted by the theory of plate tectonics

• strategies to reduce the loss of life and damage to buildings and infrastructure resulting from natural disasters.

Relationship between mineral and energy resources, and plate tectonics, including

• mineral deposits (for example, gold, copper, lead, zinc) commonly found at present-day or ancient plate tectonic boundaries

• common tectonic settings in which coal and oil deposits develop.

Science as a human endeavour

The nature and practice of earth and environmental science, including:

• the dynamic nature of the body of knowledge related to earth and environmental science which is subject to change as new knowledge and technologies are developed and as the validity and reliability of underlying models, data and conclusions improves

• the role of earth and environmental scientists in the study of the environment and the responsible use and management of Australian energy resources

• the management of the environment, exploration and exploitation of mineral and energy resources, and construction and engineering

• earth and environmental science methods that are being used in early warning systems for disaster prevention as a result of explosive volcanic eruptions, earthquakes, meteor collisions and tsunamis

• the interdisciplinary nature of contemporary applications of earth and environmental science in the development of technologies for monitoring the earth in an effort to minimise loss of life from earthquakes, volcanic eruptions and tsunamis

• the application of new technologies to earth and environmental science (for example, the technologies used in resource exploration, mining and processing).

Contemporary research and applications of earth and environmental science, including:

• choices that are made regarding the exploration and exploitation of mineral resources

• applications which can affect the sustainability of the environment where increasing human consumption places severe stress on the biogeochemical processes that renew some resources and deplete those resources which cannot be renewed (for example, the acidification of oceans; the uses of rocks and minerals as building materials such as gravel and sand and as components of many commercial products such as kaolin in paper, tablets and ceramics)

• understanding and respecting Indigenous cultural perspectives regarding the extraction and use of minerals from our Earth

• use of modelling to simulate and predict Earth plate movements

• technological advances that have led to new and innovative methods for natural disaster monitoring and the exploration and extraction of mineral resources.

The development of ideas in earth and environmental science, including:

• the impact of evidence on changing ideas in earth and environmental science (for example, evidence collected from mapping and sampling the oceanic floor and its impact on the development of plate tectonic theory)

• research that has led to our current knowledge of the occurrence of mineral deposits at plate boundaries, both ancient and modern

• the human stories related to the application of scientific values and endeavour in developing new knowledge in earth and environmental science

• use of technological developments to map mineral resources and monitor movements on plate boundaries.

Science inquiry skills

Design and perform investigations and experiments related to the dynamic nature of the earth, addressing relevant aspects of safety, methodology and ethics, and including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations and experiments include:

• analysing data on the monitoring of earthquakes, volcanoes and other natural phenomena

• testing for the presence of ore minerals or metals

• investigating the effects of pollutants from extraction processes, their methods of control and waste management (for example, cyanide from gold extraction, sodium hydroxide associated with alumina extraction from bauxite)

• investigating the properties of fossil fuels, including combustion.

Develop skills in performing investigations and experiments, including:

• using earth and environmental science concepts to guide the formation of hypotheses which may be tested in fieldwork, investigations and experiments

• identifying the personal dangers posed by some geological features and mining activities when undertaking field studies (for example, sampling)

• using mathematical and graphical methods to analyse quantitative data related to contemporary issues of environmental sustainability (for example, data from students' fieldwork, investigations and experiments; data from secondary sources)

• locating and selecting relevant and reliable second-hand data

• evaluating methods employed in investigations and suggesting specific changes to improve the reliability and validity of results

• formulating explanations based on first-hand data

• working ethically when undertaking investigations and collaborative research with others.

Engage in critical, creative, innovative and reflective thinking, including:

• evaluating the validity of their own and other scientific arguments

• debating ethical and social issues related to earth and environmental science (for example, deforestation, air and water pollution)

• applying knowledge to propose new questions for investigation and to suggest innovative solutions to problems related to earth and environmental science

• generating ideas, plans, processes and/or products, including using ICT where appropriate, to solve problems or to challenge current practice and thinking

• reflecting on the learning process and any previous misconceptions that have been addressed

• testing ideas, identifying the strengths and weaknesses of ideas, and recognising better ideas

• reflecting on changes in their attitudes or behaviours as a result of the learning process.

Analyse and synthesise information relating to earth and environmental science, including:

• evaluating claims in advertising and the media (for example, the impact of the forestry industry on local ecosystems)

• researching and synthesising information from a range of sources

• discussing alternative approaches to water management and sustainable use of natural resources with consideration of the appropriate data and evidence required to support claims.

Communicate ideas and findings, including:

• creating and presenting structured reports of experimental and investigative work

• creating and presenting information in a range of communication formats (for example, seminars, ICT-rich presentations)

• sharing and exchanging information, including through ICT, in collaborative endeavours, observing social protocols, ethical use of information and security of information

• discussing ethical considerations, results and findings of investigations with others in order to develop and clarify understanding

• explaining concepts and debating issues related to human activities causing direct and indirect environmental change

• using correct scientific language when describing hypotheses, proposals, procedures, results, conclusions and explanations.

Unit 3 - Life through time

In this unit, students will use an inquiry approach to investigate and develop their understanding of changes in life forms through time. This will include the study of: the role of the fossil record in the establishment of Darwin's theory of evolution by natural selection; major events in the origin and evolution of life; mass extinctions and radiations; and evolutionary events which changed global environmental conditions. Students will reflect on how knowledge in earth and environmental science in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Science understanding

The role of the fossil record in the establishment of Darwin's theory of evolution by natural selection, including:

• fossils and Cuvier's concept of extinction

• evidence for faunal succession and identification of the geological periods of the Phanerozoic (Cambrian to Quaternary) based on characteristic groups of fossils

• recognition of sequences of change in the anatomy of fossil organisms and the appearance of progressively more modern animals through geological time

• Darwin's use of the fossil record to support his theory of evolution by natural selection.

Major events in the origin and evolution of life, including:

• geochemical evidence for the appearance of living organisms 3.8 billion years ago

• evidence for major events in the evolution of life (for example, the oldest known cellular organisms, first eukaryotes, first marine plants and animals, first terrestrial plants and animals)

• evolutionary drivers for the apparently explosive appearance of animals at the beginning of the Cambrian period.

Mass extinctions and radiations, including:

• the defining characteristics of mass extinctions and radiations

• use of geological evidence to identify the likely causes of mass extinctions

• the Permo–Triassic and Cretaceous–Tertiary mass extinctions

• appearance of the early mammals

• radiation of the modern mammalian groups in the aftermath of the Cretaceous–Tertiary extinction event.

Evolutionary events which changed global environmental conditions, including:

• changes in global climate, atmospheric composition, weathering processes and ocean chemistry due to the proliferation of marine cyanobacteria in the late Archean and early Proterozoic

• changes in global climate and atmospheric composition due to the radiation of land plants during the Devonian and Carboniferous.

Science as a human endeavour

The nature and practice of earth and environmental science, including:

• the dynamic nature of the body of knowledge related to earth and environmental science which is subject to change as new knowledge and technologies are developed and as the validity and reliability of underlying models, data and conclusions improves

• the range of careers in the fields of earth and environmental science

• the interaction between scientists from different branches of the earth and environmental sciences that has led to scientific progress in geohistorical analysis of biotic systems and the study and monitoring of the associated environmental processes

• modern earth and environmental science methods that have led to advances in a variety of areas of science (for example, palaeoecology, palaeoclimatology).

Contemporary research and applications of earth and environmental science, including:

• investigating of areas currently being researched in earth and environmental sciences

• technological advances that have led to new and innovative methods for determining evolutionary patterns

• oceanographic research that has led to the discovery of black smokers at mid-ocean ridges and the unique ecosystems existing there.

The development of ideas in earth and environmental science, including:

• the historical development of earth and environmental science concepts related to the geologic evolution of the Australian continent

• research that has led to our current knowledge of the origin and evolution of life and the ecological impact of climate variability

• the historical development of earth and environmental science concepts related to the origin and evolution of life on earth

• the human stories related to the application of scientific values and endeavour in developing new knowledge in earth and environmental science

• the learning journey followed by significant researchers and their work to change understanding of evolutionary processes and events

• the application of new technologies to earth and environmental science (for example, the identification and dating of fossils).

Science inquiry skills

Design and perform investigations and experiments related to evolutionary events and change through time, addressing relevant aspects of safety, methodology and ethics, and including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations and experiments include:

• investigating the structure of single-celled organisms (for example, *Amoeba*, *Paramecium*)

• exploring and predicting the response of single-celled organisms to different environmental conditions (for example, various concentration gradients of glucose or salt, pH, temperature)

• researching the diversity of living things occurring together in a well-known fossil site (for example, Riversleigh, Canowindra Fish Beds, Ediacara, Burgess Shale).

Develop skills in performing investigations and experiments, including:

• using earth and environmental science concepts and models to develop testable hypotheses

• analysing quantitative data using graphical and statistical methods (for example, data from field investigations, data from investigations described in secondary sources)

• evaluating primary and secondary data in terms of the methods used to collect the data

• formulating evidence-based explanations and relating these to theoretical concepts

• comparing the validity of alternative explanations based on experimental results when considering the outcomes of their investigations or when exploring contemporary issues or applications of earth and environmental science

• working ethically both as a collaborative team member and as an independent self-managing learner.

Engage in critical, creative, innovative and reflective thinking, including:

• contributing evidence-based opinions and information to discussions about issues involving earth and environmental science (for example, climate change, carbon sequestration, mining versus conservation)

• debating ethical and social issues related to earth and environmental science (for example, strategies that can be used to mitigate and/or prevent the environmental consequences of human activities such as monitoring geohazards)

• justifying ideas for future investigation (for example, climate modelling, oceanic acidification, sustainable water management and agricultural systems)

• generating ideas, plans, processes and/or products, including using ICT where appropriate, to solve problems or to challenge current practice and thinking.

Analyse and synthesise information relating to earth and environmental science, including:

• analysing the accuracy of arguments presented by various stakeholders about issues of environmental significance (for example, the maintenance of ecological and habitat diversity)

• researching and synthesising information from a range of sources, and commenting on the validity of the information sources in terms of its origin and provision of supporting data

• formulating evidence-based explanations and relating these to scientific concepts (for example, climate change modelling).

Communicate ideas and findings, including:

• using correct scientific language when describing methods, conclusions and explanations

• sharing and exchanging information, including through ICT, in collaborative endeavours, observing social protocols, ethical use of information and security of information

• creating and presenting structured reports of investigative work and making a public presentation of findings

• using and interpreting models and simulations to aid understanding and communication of earth and environmental concepts (for example, devising computer animations or simulations to demonstrate natural selection)

• using models and simulations to explain and communicate global earth and environmental science concepts (for example, human-induced changes in climatic or environmental conditions that can lead to changes in habitats and ecosystems).

Unit 4 - Managing environmental change

In this unit, students will use an inquiry approach to investigate and develop their understanding of the management of changes in the environment. This will include the study of: human-induced change in environmental and climatic conditions; interaction of natural systems to change environmental conditions and global climate; reduction and mitigation of the negative environmental consequences of human activities; and maintenance of ecological and habitat diversity. Students will reflect on how knowledge in earth and environmental science in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations, experiments and field work to develop and apply their inquiry skills, and will complete an extended experimental investigation.

Science understanding

Human-induced change in environmental and climatic conditions, including:

• local and regional environmental change due to human activities (for example, land clearing, deforestation, mining and water extraction from rivers and aquifers)

• impacts of introduced plant and animal species on the Australian environment

• global environmental and climatic effects of human activities (for example, use of chlorofluorocarbons, the release of carbon dioxide and oxides of sulfur into the atmosphere due to the combustion of fossil fuels).

Interactions of natural systems to change environmental conditions and global climate, including:

• the climate change record throughout Earth’s history

• natural rates of climate change

• role of Earth’s orbital oscillations (Milankovic cycles) in controlling global climate, environmental conditions and sea level during the Quaternary

• long-term influences of interacting biological and geological processes on natural environments and global climate.

Reduction and mitigation of the negative environmental consequences of human activities, including:

• the Montreal Protocol and control of ozone-depleting gases

• strategies and methods for reducing reliance on fossil fuels

• characteristics of sustainable water management and agricultural systems

• environmentally sustainable extraction and processing of natural resources.

Maintenance of ecological and habitat diversity, including:

• environmental monitoring and assessment methods

• strategies and methods used to control or eradicate introduced pest species

• strategies for maintaining ecological and habitat diversity

• role of Australia's national parks and marine reserves in preserving habitats, ecosystems and biodiversity.

Science as a human endeavour

The nature and practice of earth and environmental science, including:

• the dynamic nature of the body of knowledge related to earth and environmental science which is subject to change as new knowledge and technologies are developed and as the validity and reliability of underlying models, data and conclusions improves

• earth and environmental science methods that are being used in mitigating the environmental consequences of human activities

• the application of new technologies to environmental monitoring, including the variability, extent and consequences of habitat alteration

• the importance of sharing knowledge and skills between collaborating scientists working in a range of disciplines when considering data to support arguments about biodiversity and sustainability of ecosystems.

Contemporary research and applications of earth and environmental science, including:

• processes that influence our daily lives (for example, alternative management practices that do not require the use of pesticides in agriculture)

• research that can be applied to improving the management of national water resources and the natural environment (for example, the Murray-Darling system, environmental flows in the Snowy River and biodiversity in the Coorong, revegetation strategies, coral bleaching in the Great Barrier Reef)

• applications that can affect the sustainability of the environment (for example, stormwater management, licensing bore water users, minimising soil salinity resulting from land clearing and irrigation)

• increases in our understanding that have led to technological developments (for example, the development of desalination plants for recycling sea water)

• different groups in society (for example, industrial, agricultural and environmental agencies that are involved in debates relating to the use of resources such as water and fuels, and the ethical, economic and political implications of these debates)

• the ethics of decisions related to the disposal of radioactive waste in stable cratonic areas of the Australian continent

• investigation of areas currently being researched in earth and environmental sciences (for example, climate modelling, ecological dynamics of environmental change, preservation of biodiversity and habitat enhancement, the global impact on the atmosphere of rainforest deforestation and burning fossil fuels)

• forecasting outcomes of human interactions with Earth’s systems to enhance the prospects for mitigating the adverse impacts on Earth

• issues that may arise when applying relevant scientific understanding to plans concerning contemporary sustainability issues when there are conflicts with economic, social or cultural concerns of the people involved (for example, energy production and use; water management; land use for agriculture, logging or exploitation of living and mineral resources).

The development of ideas in earth and environmental science, including:

• the learning journey followed by significant researchers and their work to change understanding of climatic and environmental change

• the human stories related to the application of scientific values and endeavour in developing new knowledge in earth and environmental science

• consideration of differing viewpoints resulting in historical, ethical and social debates (for example, the implications of climate change)

• the application of new technologies to earth and environmental science (for example, the technologies used in emissions control).

Science inquiry skills

Design and perform investigations and experiments related to managing environmental change, addressing relevant aspects of safety, methodology and ethics, and including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations and experiments include:

• measuring and analysing the presence of an air pollutant in a selected environment

• analysing human-induced atmospheric change and options for remediation (for example, urban pollution, enhanced greenhouse effect)

• using air quality monitoring data to determine the pollution levels in a local area

• examining changing concentration of atmospheric carbon dioxide over the last 100 years using data from scientific literature and Antarctic core samples

• investigating the influence of water-related SEPPs (state environment protection policies) in determining water quality monitoring programs

• using titrimetric analysis to show the level of chloride ions in water samples

• using colorimetric analysis to determine the amount of phosphate ions in water samples

• undertaking a field study of a local ecosystem using sampling techniques to measure or estimate species numbers, density and distribution patterns

• monitoring abiotic components of the environment (for example, temperature, air pressure, humidity, wind speed, light intensity, pH, nutrient and salinity levels)

• observing and recording natural short-term cyclical environmental changes in ecosystems

• investigating the effects of environmental change (for example, temperature, pH, salinity) by comparing growth rates of plants/animals in response to the change

• undertaking a field study to identify and record the presence of Indigenous and non-Indigenous flora and fauna.

Develop skills in designing and performing investigations and experiments, including:

• interpreting data to show that water use from agriculture, manufacturing, mining and urbanisation affects surrounding water sources

• evaluating primary and secondary data in terms of the methods used to collect the data

• selecting and using appropriate scientific equipment, technologies and techniques for specific observational and measurement tasks in fieldwork and experiments (for example, tools used to monitor environmental conditions such as remote sensing technology)

• formulating evidence-based explanations and relating these to scientific concepts

• working ethically both as a collaborative team member and as an independent self-managing learner.

Engage in critical, creative, innovative and reflective thinking, including:

• developing arguments showing consideration of ethical, social and economic aspects of an environmental management strategy (for example, rehabilitation of ecosystems after mining, forestry or agriculture)

• contributing evidence-based opinions and information to discussions about contemporary aspects and issues in earth and environmental science

• justifying ideas for future earth and environmental science investigations

• generating ideas, plans, processes and/or products, including using ICT where appropriate, to solve problems or to challenge current practice and thinking

• investigating and discussing ethical and social issues regarding the mining industry (for example, native title, heritage, human health impacts)

• making decisions relating to contentious environmental issues considering scientific evidence as well as social, ethical, economic and political views and values.

Analyse and synthesise information relating to earth and environmental science, including:

• researching and synthesising information from a range of sources

• commenting on the validity of the information sources in terms of their origin and provision of supporting data

• comparing the validity of alternative explanations based on experimental results.

Communicate ideas and findings, including:

• using correct scientific language when describing methods, conclusions and explanations

• sharing and exchanging information, including through ICT, in collaborative endeavours, observing social protocols, ethical use of information and security of information

- creating and presenting structured reports of investigative work and making a public presentation of findings
- using models, flow charts or digital simulations to explain and communicate earth and environmental science concepts (for example, the ecological dynamics of environmental change)
- justifying arguments on controversial topics related to options for reducing the enhanced greenhouse effect (for example, National Greenhouse Strategy, Kyoto Protocol).