Earth & Environmental Science 2025 v1.0

General senior syllabus

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Queensland Government

Queensland Curriculum & Assessment Authority

For all Queensland schools

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Queensland syllabuses for senior subjects

In Queensland, a syllabus for a senior subject is an official 'map' of a senior school subject. A syllabus's function is to support schools in delivering the Queensland Certificate of Education (QCE) system through high-quality and high-equity curriculum and assessment.

Syllabuses are based on design principles developed from independent international research about how excellence and equity are promoted in the documents teachers use to develop and enliven the curriculum.

Syllabuses for senior subjects build on student learning in the Prep to Year 10 Australian Curriculum and include General, General (Extension), Senior External Examination (SEE), Applied, Applied (Essential) and Short Course syllabuses.

More information about syllabuses for senior subjects is available at www.qcaa.qld.edu.au/senior/senior-subjects and in the 'Queensland curriculum' section of the *QCE and QCIA policy and procedures handbook*.

Teaching, learning and assessment resources will support the implementation of a syllabus for a senior subject. More information about professional resources for senior syllabuses is available on the QCAA website and via the QCAA Portal.

Course overview

Rationale

At the core of all scientific endeavour is the inquiry into the nature of the universe. Science uses a systematic way of thinking, involving creative and critical reasoning, in order to acquire better and more reliable knowledge. Scientists recognise that knowledge is not fixed, but is fallible and open to challenge. As such, scientific endeavour is never conducted in isolation, but builds on and challenges an existing body of knowledge in the pursuit of more reliable knowledge. This collaborative process, whereby new knowledge is gained, is essential to the cooperative advancement of science, technology, health and society in the 21st century.

Tertiary study in any field will be aided by the transferable skills developed in this senior Science subject. It is expected that an appreciation of, and respect for, evidence-based conclusions and the processes required to gather, scrutinise and use evidence will be carried forward into all aspects of life beyond the classroom.

The purpose of senior Science subjects in Queensland is to introduce students to a scientific discipline. Students will be required to learn and apply aspects of the knowledge and skills of the discipline (thinking, experimentation, problem-solving and research skills), understand how it works and how it may impact society.

Upon completion of the course, students will have an appreciation for a body of scientific knowledge and the process that is undertaken to acquire this knowledge. They will be able to distinguish between claims and evidence, opinion and fact, and conjecture and conclusions.

In each of the senior Science subjects, students will develop:

- a deep understanding of a core body of discipline knowledge
- aspects of the skills used by scientists to develop new knowledge, as well as the opportunity to refine these skills through practical activities
- the ability to coordinate their understandings of the knowledge and skills associated with the discipline to refine experiments, verify known scientific relationships, explain phenomena with justification and evaluate claims by finding evidence to support or refute the claims.

Earth & Environmental Science provides opportunities for students to engage with the dynamic interactions in and between four systems: geosphere, hydrosphere, atmosphere and biosphere. In Unit 1, students examine the evidence underpinning theories of the development of Earth systems, their interactions and their components. In Unit 2, students investigate how Earth processes involve interactions of Earth systems and are interrelated through transfers and transformations of energy. In Unit 3, students examine renewable and non-renewable resources, the implications of extracting, using and consuming these resources, and associated management approaches. In Unit 4, students consider how Earth processes and human activity can contribute to Earth hazards, and the ways in which these hazards can be predicted, managed and mitigated to reduce their impact on earth environments.

Earth & Environmental Science aims to develop students':

- interest in Earth and environmental science and their appreciation of how this multidisciplinary knowledge can be used to understand contemporary issues
- understanding of Earth as a dynamic planet consisting of four interacting systems: the geosphere, atmosphere, hydrosphere and biosphere
- appreciation of the complex interactions, involving multiple parallel processes, that continually change Earth systems over a range of timescales
- understanding that Earth and environmental science knowledge has developed over time; is used in a variety of contexts; and influences, and is influenced by, social, economic, cultural and ethical considerations
- ability to conduct a variety of field, research and laboratory investigations involving collection and analysis of qualitative and quantitative data, and interpretation of evidence
- ability to critically evaluate Earth and environmental science concepts, interpretations, claims and conclusions with reference to evidence
- ability to communicate understanding, findings, arguments and conclusions related to Earth and its environments, using appropriate representations, modes and genres.

Syllabus objectives

The syllabus objectives outline what students have the opportunity to learn.

1. **Describe ideas and findings.**

   Students use scientific representations and language in appropriate genres to give a detailed account of scientific phenomena, concepts, theories, models and systems.

2. **Apply understanding.**

   Students use scientific concepts, theories, models and systems within their limitations. They use algebraic, visual and graphical representations of scientific relationships and data to determine unknown scientific quantities or features. They explain phenomena, concepts, theories, models, systems and modifications to methodologies.

3. **Analyse data.**

   Students consider scientific information from primary and secondary sources to identify trends, patterns, relationships, limitations and uncertainty. In qualitative data, they identify the essential elements, features or components. In quantitative data, they use mathematical processes and algorithms. They identify data to support ideas, conclusions or decisions.

4. **Interpret evidence.**

   Students use their understanding of scientific concepts, theories, models and systems and their limitations to draw conclusions and develop scientific arguments. They compare, deduce, extrapolate, infer, justify and make predictions based on their analysis of data.

5. **Evaluate conclusions, claims and processes.**

   Students critically reflect on the available evidence and make judgments about its application to research questions. They extrapolate findings to support or refute claims. They use the quality of the evidence to evaluate the validity and reliability of inquiry processes and suggest improvements and extensions for further investigation.

6. **Investigate phenomena.**

   Students develop rationales and research questions for experiments and investigations. They modify methodologies to collect primary data and select secondary sources. They manage risks, environmental and ethical issues and acknowledge sources of information.

Designing a course of study in Earth & Environmental Science

Syllabuses are designed for teachers to make professional decisions to tailor curriculum and assessment design and delivery to suit their school context and the goals, aspirations and abilities of their students within the parameters of Queensland's senior phase of learning.

The syllabus is used by teachers to develop curriculum for their school context. The term *course of study* describes the unique curriculum and assessment that students engage with in each school context. A course of study is the product of a series of decisions made by a school to select, organise and contextualise subject matter, integrate complementary and important learning, and create assessment tasks in accordance with syllabus specifications.

It is encouraged that, where possible, a course of study is designed such that teaching, learning and assessment activities are integrated and enlivened in an authentic setting.

Course structure

Earth & Environmental Science is a General senior syllabus. It contains four QCAA-developed units from which schools develop their course of study.

Each unit has been developed with a notional time of 55 hours of teaching and learning, including assessment.

Students should complete Unit 1 and Unit 2 before beginning Units 3 and 4. Units 3 and 4 are studied as a pair.

More information about the requirements for administering senior syllabuses is available in the 'Queensland curriculum' section of the *QCE and QCIA policy and procedures handbook*.

Curriculum

Senior syllabuses set out only what is essential while being flexible so teachers can make curriculum decisions to suit their students, school context, resources and expertise.

Within the requirements set out in this syllabus and the *QCE and QCIA policy and procedures handbook*, schools have autonomy to decide:

- how and when subject matter is delivered
- how, when and why learning experiences are developed, and the context in which learning occurs
- how opportunities are provided in the course of study for explicit and integrated teaching and learning of complementary skills.

These decisions allow teachers to develop a course of study that is rich, engaging and relevant for their students.

Assessment

Senior syllabuses set out only what is essential while being flexible so teachers can make assessment decisions to suit their students, school context, resources and expertise.

General senior syllabuses contain assessment specifications and conditions for the assessment instruments that must be implemented with Units 3 and 4. These specifications and conditions ensure comparability, equity and validity in assessment.

Within the requirements set out in this syllabus and the *QCE and QCIA policy and procedures handbook*, schools have autonomy to decide:

- specific assessment task details
- assessment contexts to suit available resources
- how the assessment task will be integrated with teaching and learning activities
- how authentic the task will be.

In Unit 1 and Unit 2, schools:

- develop at least two but no more than four assessments
- complete at least one assessment for each unit
- ensure that each unit objective is assessed at least once.

In Units 3 and 4, schools develop three assessments using the assessment specifications and conditions provided in the syllabus.

More information about assessment in senior syllabuses is available in 'The assessment system' section of the *QCE and QCIA policy and procedures handbook*.

Subject matter

Each unit contains a unit description, unit objectives and subject matter. Subject matter is the body of information, mental procedures and psychomotor procedures (see Marzano & Kendall 2007, 2008) that are necessary for students' learning and engagement with the subject. Subject matter itself is not the specification of learning experiences but provides the basis for the design of student learning experiences.

Subject matter has a direct relationship with the unit objectives and provides statements of learning that have been constructed in a similar way to objectives.

Aboriginal perspectives and Torres Strait Islander perspectives

The QCAA is committed to reconciliation. As part of its commitment, the QCAA affirms that:

- Aboriginal peoples and Torres Strait Islander peoples are the first Australians, and have the oldest living cultures in human history
- Aboriginal peoples and Torres Strait Islander peoples have strong cultural traditions and speak diverse languages and dialects, other than Standard Australian English
- teaching and learning in Queensland schools should provide opportunities for students to deepen their knowledge of Australia by engaging with the perspectives of Aboriginal peoples and Torres Strait Islander peoples
- positive outcomes for Aboriginal students and Torres Strait Islander students are supported by successfully embedding Aboriginal perspectives and Torres Strait Islander perspectives across planning, teaching and assessing student achievement.

Guidelines about Aboriginal perspectives and Torres Strait Islander perspectives and resources for teaching are available at www.qcaa.qld.edu.au/k-12-policies/aboriginal-torres-strait-islander-perspectives.

Where appropriate, Aboriginal perspectives and Torres Strait Islander perspectives have been embedded in the subject matter.

Complementary skills

Opportunities for the development of complementary skills have been embedded throughout subject matter. These skills, which overlap and interact with syllabus subject matter, are derived from current education, industry and community expectations and encompass the knowledge, skills, capabilities, behaviours and dispositions that will help students live and work successfully in the 21st century.

These complementary skills are:

- literacy — the knowledge, skills, behaviours and dispositions about language and texts essential for understanding and conveying English language content
- numeracy — the knowledge, skills, behaviours and dispositions that students need to use mathematics in a wide range of situations, to recognise and understand the role of mathematics in the world, and to develop the dispositions and capacities to use mathematical knowledge and skills purposefully
- 21st century skills — the attributes and skills students need to prepare them for higher education, work, and engagement in a complex and rapidly changing world. These skills include critical thinking, creative thinking, communication, collaboration and teamwork, personal and social skills, and digital literacy. The explanations of associated skills are available at www.qcaa.qld.edu.au/senior/senior-subjects/general-subjects/21st-century-skills.

It is expected that aspects of literacy, numeracy and 21st century skills will be developed by engaging in the learning outlined in this syllabus. Teachers may choose to create additional explicit and intentional opportunities for the development of these skills as they design the course of study.

Additional subject-specific information

Additional subject-specific information has been included to support and inform the development of a course of study.

Science understanding

The science understanding subject matter in each unit develops students' understanding of the key concepts, models and theories that underpin the subject, and of the strengths and limitations of different models and theories for explaining and predicting complex phenomena. It uses cognitions from Objectives 1–4.

The science understanding subject matter from Units 3 and 4 will be assessed by the external assessment.

Science as a human endeavour (SHE)

Each Queensland senior science subject requires students to learn and apply aspects of the knowledge and skill of the discipline. However, it is recognised that students should also develop an appreciation for the *nature* and *development* of science, and its *use* and *influence* on society.

While this appreciation is not directly assessed, the syllabus provides guidance as to where it may be developed. Importantly, this guidance draws students' attention to the way in which science operates, both in relation to the development of understanding and explanations about the world and to its influence on society.

Students should become familiar with the following SHE concepts:

- Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility.
- Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines.
- Advances in science understanding in one field can influence other areas of science, technology and engineering.
- The use and acceptance of scientific knowledge is influenced by social, economic, cultural and ethical contexts.
- The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences.
- Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions.
- Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability.
- ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of datasets with which scientists work.
- Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power.
- Scientific knowledge can be used to inform the monitoring, assessment and evaluation of risk.
- Science can be limited in its ability to provide definitive answers to public debate; there may be insufficient reliable data available, or interpretation of the data may be open to question.
- International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia–Pacific region.

To support the development of these concepts, this syllabus identifies SHE subject matter in each unit. This highlights opportunities for teachers to contextualise the associated science understanding and science inquiry subject matter and provides stimulus for the development of claims and research questions for investigation.

Additional opportunities include:

- practicals provide opportunities for students to witness the *nature* of science
- the student experiment provides opportunity for students to experience how the *development* of new science knowledge is built upon existing knowledge
- the research investigation provides opportunity for students to appreciate the *use* and *influence* of scientific evidence to make decisions or to contribute to public debate about a claim.

Science inquiry

Defining *inquiry* in science education

In order to support the school's task of aligning their chosen pedagogical framework with the curriculum and assessment expectations outlined in this syllabus, some guidance has been provided in the form of clarification of the use of the term *inquiry* and the articulation of a framework to describe the process of inquiry. The purpose of this guidance is to prevent misunderstandings and problematic conflations and their subsequent negative impact on student learning. As Abrams, Southerland and Silva (2008, p. xv) stated in their book, *Inquiry in the Classroom: Realities and opportunities*:

> Inquiry in the classroom can be conceived as a complex set of ideas, beliefs, skills, and/or pedagogies. It is evident that attempting to select a singular definition of inquiry may be an insurmountable and fruitless task. Any single definition of inquiry in the classroom would necessarily reflect the thinking of a particular school of thought, at a particular moment in time, or a particular goal, and such a singular definition may serve to limit legitimate and necessary components of science learning. **However, operating without a firm understanding of the various forms of inquiry leaves science educators often 'talking past' one another, and often results in very muddled attempts in the classroom** [emphasis added].

Uses of the term *inquiry*

Common phrases involving the term *inquiry* have been listed below:

- science inquiry
- science inquiry skills
- the inquiry process
- inquiry-based learning.

This syllabus refers to the first three uses listed above. The first, *science inquiry*, defines the practical work of a scientist (Harlen 2013). The second, *science inquiry skills*, refers to the skills required to do the work of a scientist (Harlen 2013). The third, *the inquiry process*, is a framework that can be used to describe the process of asking a question and then answering it.

The final phrase, *inquiry-based learning*, refers to a variety of teaching and learning strategies an educator may choose to use within their school's pedagogical framework. Although a school may choose to adopt an inquiry-based pedagogy, this syllabus is *not* intended to endorse or recommend an inquiry-based learning approach.

Framework to describe the inquiry process

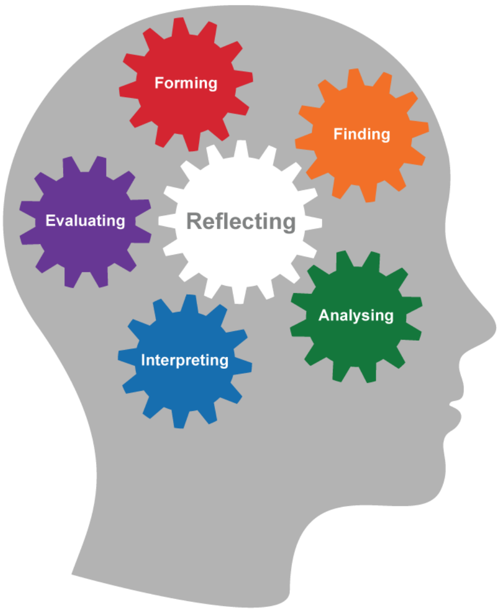
In order to support student engagement in activities involving inquiry, it is useful to establish a common language or framework to distinguish between stages of the process.

The stages involved in any inquiry are:

- forming and describing the inquiry activity
- finding valid and reliable evidence for the inquiry activity
- analysing the evidence collected
- interpreting the evidence selected
- evaluating the conclusions, processes or claims.

This framework uses reflection as the connection between, and driver of, all the stages. The progression through the inquiry process requires reflection on the decisions made and any new information that has emerged during the process to inform the next stage. Each stage of the inquiry process is worthy of reflection, the result of which may be the revision of previous stages (Marzano & Kendall 2007).

Figure 1: Stages of inquiry process



Science inquiry and science inquiry skills

Science inquiry involves identifying and posing questions and working to answer them. It is concerned with evaluating claims, investigating ideas, solving problems, reasoning, drawing valid conclusions and developing evidence-based arguments. It can easily be summarised as the 'work of a scientist' (Hackling 2005).

Within this syllabus, it is expected that students will engage in *aspects* of the work of a scientist by engaging in scientific inquiry (Tytler 2007). This expectation can be seen, for example, by the inclusion of practicals and investigations in the subject matter, and in the internal assessments for Units 3 and 4.

Science inquiry skills are the skills required to do the work of a scientist. They include writing research questions, planning, conducting, recording information, and reflecting on investigations; processing, analysing and interpreting evidence; evaluating conclusions, processes and claims; and communicating findings (ACARA 2015).

It is expected that students are explicitly taught science inquiry skills (Krajcik et al 2000), a number of which are outlined throughout the syllabus. Some science inquiry skills will be used to complete the listed practicals and investigations. The selection, application and coordination of science inquiry skills will be required in the student experiment and research investigation.

It is the prerogative of the educator to determine how listed practicals and investigations are used as opportunities to:

- develop, rehearse and refine science inquiry skills
- engage students in scaffolded or open-ended science inquiry tasks
- formatively assess science inquiry skills.

Science inquiry skills

Throughout the course of study, students will:

- identify, research and construct questions for investigation
- propose hypotheses and/or predict possible outcomes
- design investigations, including the procedure/s to be followed, the materials required, and the type and amount of primary and/or secondary data required to obtain valid and reliable evidence, e.g.
  - distinguish between different types of investigations: descriptive, comparative, correlational, experimental, secondary data investigations
  - consider replicates, sample size, number of data points and quality of sources
  - identify the types of errors and extraneous or confounding variables that are likely to influence results and implement strategies to minimise systematic and random error
- identify and implement strategies to manage risks, ethics and environmental impact, e.g.
  - ethical guidelines
  - cultural guidelines, protocols for working with the knowledges of First Nations peoples
  - material safety data sheets
  - workplace health and safety guidelines
  - appropriate disposal methods
  - standard operating procedures
  - acknowledgment of sources and referencing

- use appropriate equipment, techniques, procedures and sources to systematically and safely collect primary and secondary data, e.g.
  - ecosystem surveying techniques: quadrats, transects
  - laboratory and field techniques: measurement, equipment calibration, species identification
  - models and simulations
  - ICTs, scientific texts, databases, online sources
- use scientific language and representations to systematically record information, observations, data and measurement error, e.g.
  - symbols, units and prefixes
  - scale and magnification
  - indicators of measurement uncertainty
  - tables, graphs and diagrams
  - charts and maps
  - logbooks
- translate information between graphical, numerical and/or algebraic forms, e.g.
  - units and measurement conversions
  - ratios and percentages
  - symbols and notation
  - charts and maps
- use mathematical techniques to summarise data in a way that allows for identification of relevant trends, patterns, relationships, limitations and uncertainty, e.g.
  - comparative investigations: mean, standard deviation, standard error, Student's t-test
  - correlational investigations: regression analysis, Pearson's correlation coefficient
- select and construct appropriate representations to present data and communicate findings, e.g.
  - summary tables
  - column graphs (with error bars)
  - scatterplots (with trendline and R^2)
  - profile diagrams
  - scientific drawings
  - charts and maps
  - indexes and summary statistics
- analyse data to identify trends, patterns and relationships; recognising error, uncertainty and limitations of evidence
- select, synthesise and use evidence to construct scientific arguments and draw conclusions
- extrapolate findings to determine unknown values, predict outcomes and evaluate claims

- use data and reasoning to discuss and evaluate the validity and reliability of evidence, e.g.
  - discuss ways in which measurement error, instrumental uncertainty, the nature of the procedure, sample size or other factors influence uncertainty and limitations in the data
  - evaluate information sources and compare ideas, information and opinions presented within and between texts, considering aspects such as acceptance, bias, status, appropriateness and reasonableness
  - compare findings to theoretical models or expected values
- suggest improvements and extensions to minimise uncertainty, address limitations and improve the overall quality of evidence
- communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes
- acknowledge sources of information and use standard scientific referencing conventions.

Science inquiry subject matter uses cognitions from across all objectives, and is primarily assessed through the internal assessments for Units 3 and 4. To support the development of these science inquiry skills, this syllabus identifies suggested practicals and investigations for each unit. These highlight opportunities for students to directly experience the associated Science understanding subject matter and provide stimulus for student experiments and research investigations.

It is expected that approximately five hours of fieldwork will be required to develop the associated science inquiry skills. Fieldwork can allow students to engage in science inquiry by offering authentic real-world learning. It offers students an opportunity to gather primary data to analyse and respond to questions they pose.

Safety and ethics

Workplace health and safety

Earth & Environmental Science is designed to expose students to the practical components of science through practical experiences in the laboratory and the field. These experiences expose students to a variety of hazards, from biological and poisonous substances to injury from equipment. Besides a teacher's duty of care that derives from the *Education (General Provisions) Act 2006*, there are other legislative and regulatory requirements, for example the *Work Health and Safety Act 2011*, that will influence the nature and extent of practical work.

All practical work must be organised with student safety in mind. The *Department of Education and Training (DET) Policy and Procedure Register* (https://ppr.qed.qld.gov.au) provides guidance about current science safety protocols.

It is the responsibility of all schools to ensure that their practices meet current legislation requirements. References to relevant legislation and regulations are supported by the Reference list located on the Earth & Environmental Science subject page of the QCAA website.

Care and use of animals for scientific purposes

Governing principles

The QCAA recognises that school personnel involved in the care and use of animals for scientific purposes have legal obligations under the *Animal Care and Protection Act 2001* (the Act). Queensland schools intending to use animals for scientific purposes must apply for and receive animal ethics approval from the Queensland Schools Animals Ethics Committee (QSAEC) prior to conducting these activities. The purpose of the Act is to promote the responsible care and use of animals, provide standards for the care and use of animals, protect animals from unjustifiable, unnecessary or unreasonable pain, and ensure that the use of animals for scientific purposes is accountable, open and responsible.

The Act also requires mandatory compliance with the *Australian Code of Practice for the Care and Use of Animals for Scientific Purposes 2013 (8th edition)*, available from the National Health and Medical Research Council's publications website.

It should also be recognised that school personnel and students are not carrying out essential, groundbreaking research. Therefore, standards in schools should be more stringent than those used in universities and research and development organisations.

Separate to the Act and ethical approval, best practice includes referring to the *3Rs* principle of animal welfare:

- **replacement** — any investigations involving animals should initially consider replacing the animals with cells, plants or computer simulations
- **refinement** — refinement of the investigation should aim to alleviate any harm or distress to the animals used
- **reduction** — reduce the number of animals used.

Respect for animals must underpin all decisions and actions involving the care and use of animals. The responsibilities associated with this obligation apply throughout the animal's lifetime, including acquisition, transport, breeding, housing, husbandry and the use of animals in a project. Experiments that require the endpoint as the death of any animal (e.g. lethal dose LD_{50}) are unacceptable.

Animal dissections

There is no requirement for students to witness or carry out a dissection of any animal, invertebrate or vertebrate in this course. If animal dissections are chosen by the teacher as an important educational experience, the *3Rs* principle of animal welfare should be applied (i.e. replacement, refinement and reduction — see above for more information). Teachers should always discuss the purpose of the dissection and allow any student, without requirement for explanation, to opt out if they wish. Teachers should be respectful of the variety of reasons students may have for choosing not to participate.

Strategies for retaining and recalling information for assessment

The following practices[1] can support preparation for senior assessment in Earth & Environmental Science.

The spacing effect

The spacing effect draws on research about forgetting and learning curves. By recalling and revisiting information at intervals, rather than at the end of a study cycle, students remember a greater percentage of the information with a higher level of accuracy. Exposing students to information and materials numerous times over multiple spaced intervals solidifies long-term memory, positively affecting retention and recall.

Teachers should plan teaching and learning sequences that allow time to revisit previously taught information and skills at several intervals. These repeated learning opportunities also provide opportunities for teachers to provide formative feedback to students.

The retrieval effect

The retrieval effect helps students to practise remembering through quick, regular, low-stakes questioning or quizzes that exercise their memories and develop their ability to engage in the deliberate act of recalling information. This has been shown to be more effective at developing long-term memories than activities that require students to search through notes or other resources.

Students may see an inability to remember as an obstacle, but they should be encouraged to understand that this is an opportunity for learning to take place. By trying to recall information, students exercise or strengthen their memory and may also identify gaps in their learning. The more difficult the retrieval practice, the better it can be for long-term learning.

Interleaving

Interleaving involves interspersing the concepts, categories, skills or types of questions that students focus on in class or revision. This is in contrast to blocking, in which these elements are grouped together in a block of time. For example, for concepts A, B and C:

- Blocking A A A A A B B B B B C C C C C
- Interleaving A B C B C A B A C A C B C A B

Studies have found that interleaving in instruction or revision produces better long-term recall of subject matter. Interleaving also ensures that spacing occurs, as instances of practice are spread out over time.

Additionally, because exposure to one concept is interleaved with exposure to another, students have more opportunities to distinguish between related concepts. This highlighting of differences may explain why studies have found that interleaving enhances inductive learning, where participants use exemplars to develop an understanding of broader concepts or categories. Spacing without interleaving does not appear to benefit this type of learning.

Interleaving can seem counterintuitive — even in studies where interleaving enhanced learning, participants often felt that they had learnt more with blocked study. Despite this, their performance in testing indicated greater learning through the interleaving approach.

[1] Based on Agarwal, Roediger, McDaniel & McDermott (2020); Birnbaum, Kornell, Ligon Bjork & Bjork (2013); Carpenter & Agarwal (2020); Chen, Paas & Sweller (2021); Ebbinghaus (1885); Rohrer (2012); Taylor & Rohrer (2010).

Reporting

General information about determining and reporting results for senior syllabuses is provided in the 'Determining and reporting results' section of the *QCE and QCIA policy and procedures handbook*.

Reporting standards

Reporting standards are summary statements that describe typical performance at each of the five levels (A–E).

A
The student accurately describes a variety of concepts, theories, models and systems, and their limitations. They give clear and detailed accounts of a variety of concepts, theories, models and systems by making relationships, reasons or causes evident. The student communicates effectively by using scientific representations and language accurately and concisely within appropriate genres. They efficiently collect, collate and process relevant evidence. The student accurately applies their understanding of scientific concepts, theories, models and systems within their limitations to explain a variety of phenomena, and predict outcomes, behaviours and implications. They accurately use representations of scientific relationships and data to determine a variety of unknown scientific quantities and perceptively recognise the limitations of models and theories when discussing results. The student analyses systematically and effectively by identifying the essential elements, features or components of qualitative data. They use relevant mathematical processes to appropriately identify trends, patterns, relationships, limitations and uncertainty in quantitative data. They interpret evidence insightfully by using their knowledge and understanding to draw justified conclusions based on their thorough analysis of evidence and established criteria. The student critically evaluates conclusions, claims and processes by insightfully scrutinising evidence, extrapolating credible findings, and discussing the reliability and validity of experiments. They investigate phenomena by carrying out effective experiments and research investigations.
B
The student accurately describes concepts, theories, models and systems, and their limitations. They give clear and detailed accounts of concepts, theories, models and systems by making relationships, reasons or causes evident. The student communicates accurately by using scientific representations and language within appropriate genres to present information. They collect, collate and process relevant evidence. The student accurately applies their understanding of scientific concepts, theories, models and systems within their limitations to explain phenomena and predict outcomes, behaviours and implications. They accurately use representations of scientific relationships and data to determine unknown scientific quantities, and accurately recognise the limitations of models and theories when discussing results. The student analyses effectively by identifying the essential elements, features or components of qualitative data. They use mathematical processes to appropriately identify trends, patterns, relationships, limitations and uncertainty in quantitative data. They interpret evidence by using their knowledge and understanding to draw reasonable conclusions based on their accurate analysis of evidence and established criteria. The student evaluate processes, claims and conclusions by scrutinising evidence, applying relevant findings and discussing the reliability and validity of experiments. They investigate phenomena by carrying out effective experiments and research investigations.

C
The student describes concepts, theories, models and systems, and their limitations. They give detailed accounts of concepts, theories, models and systems by making relationships, reasons or causes evident. The student communicates using scientific representations and language within appropriate genres to present information. They collect, collate and process evidence. The student applies their understanding of scientific concepts, theories, models and systems within their limitations to explain phenomena and predict outcomes, behaviours and implications. They use representations of scientific relationships and data to determine unknown scientific quantities and recognise the limitations of models and theories when discussing results. The student analyses by identifying the essential elements, features or components of qualitative data. They use mathematical processes to identify trends, patterns, relationships, limitations and uncertainty in quantitative data. They interpret evidence by using their knowledge and understanding to draw conclusions based on their analysis of evidence and established criteria. The student evaluates processes, claims and conclusions by describing the quality of evidence, applying findings, and describing the reliability and validity of experiments. They investigate phenomena by carrying out experiments and research investigations.
D
The student describes and gives accounts of aspects of concepts, theories, models and systems. The student uses scientific representations or language to present information. They use rudimentary representations of scientific relationships or data to determine unknown scientific quantities or variables. The student analyses by identifying the elements, features or components of qualitative data. They use parts of mathematical processes to identify trends, patterns, relationships, limitations or uncertainty in quantitative data. They interpret evidence by drawing conclusions based on evidence or established criteria. The student considers the quality of evidence and conclusions and discusses processes, claims or conclusions. They carry out aspects of experiments and research investigations.
E
The student describes scenarios and communicates by referring to representations of information. They discuss physical phenomena and evidence. They follow established methodologies in research situations. They discuss evidence. The student carries out elements of experiments and research investigations.

Determining and reporting results

Unit 1 and Unit 2

Schools make judgments on individual assessment instruments using a method determined by the school. They may use the reporting standards or develop an instrument-specific marking guide (ISMG). Marks are not required for determining a unit result for reporting to the QCAA.

The unit assessment program comprises the assessment instrument/s designed by the school to allow the students to demonstrate the unit objectives. The unit judgment of A–E is made using reporting standards.

Schools report student results for Unit 1 and Unit 2 to the QCAA as satisfactory (S) or unsatisfactory (U). Where appropriate, schools may also report a not rated (NR).

Units 3 and 4

Schools mark each of the three internal assessment instruments implemented in Units 3 and 4 using ISMGs.

Schools report a provisional mark by criterion to the QCAA for each internal assessment.

Once confirmed by the QCAA, these results will be combined with the result of the external assessment developed and marked by the QCAA.

The QCAA uses these results to determine each student’s subject result as a mark out of 100 and as an A–E.

Units

Unit 1: Introduction to Earth systems

In Unit 1, students explore the ways Earth and environmental science describes and explains Earth processes and phenomena that occur in different Earth systems and how they are interrelated. An understanding of Earth processes is essential to appreciate the significance of Earth's four systems: geosphere, atmosphere, hydrosphere and biosphere. Students investigate phenomena associated with Earth systems and processes. They examine relevant concepts, models, principles and theories to analyse common past and present Earth features, processes and phenomena.

Contexts that could be investigated include local, regional or global Earth features, processes and phenomena. Through the investigation of these contexts, students can explore ways to predict future changes to the geosphere, atmosphere, hydrosphere and biosphere; provide advice about ways to mitigate the effect of human-induced change; explore ways in which science knowledge interacts with social, economic, cultural and ethical factors; and describe and explain complex models of Earth's interior.

Participation in a range of experiments and investigations will allow students to progressively develop their suite of science inquiry skills while gaining an enhanced appreciation of different Earth features and processes, phenomena, systems and their interactions. Collaborative experimental work will also help students to develop communication, interaction, and self-management skills. Throughout the unit, students develop skills in investigating phenomena, analysing and interpreting primary and secondary data, and making decisions that describe and explain Earth systems.

Unit objectives

1. Describe ideas and findings about Earth systems and models and the development of the geosphere, atmosphere, hydrosphere and biosphere.
2. Apply understanding of Earth systems and models and the development of the geosphere, atmosphere, hydrosphere and biosphere.
3. Analyse data about Earth systems and models and the development of the geosphere, atmosphere, hydrosphere and biosphere.
4. Interpret evidence about Earth systems and models and the development of the geosphere, atmosphere, hydrosphere and biosphere.
5. Evaluate processes, claims and conclusions about Earth systems and models and the development of the geosphere, atmosphere, hydrosphere and biosphere.
6. Investigate phenomena associated with Earth systems and models and the development of the geosphere, atmosphere, hydrosphere and biosphere.

Subject matter

Topic 1: Earth systems and models (4 hours)

Science understanding

Natural systems

- Describe the features of a system, including
  - open systems
  - closed systems
  - isolated systems.
- Compare open, closed and isolated systems in terms of the flow of energy and matter.
- Describe each of the four spheres of Earth: geosphere, atmosphere, hydrosphere and biosphere.
- Explain the purposes of models of Earth processes using an example that conceptualises a specific Earth and environmental process, e.g. subduction.
- Contrast models of Earth processes with the actual Earth processes and identify limitations of the models.
- Explain the nature of scientific theories and models.

Science as a human endeavour (SHE)

- Understand the main elements of a natural system (i.e. ecosystem) in the local or regional area and identify inputs and outputs of that system.

Topic 2: Development of the geosphere (24 hours)

Science understanding

Uniformitarianism

- Apply the principle of uniformitarianism to infer past events and processes using present-day observations.

Stratigraphy and fossil records

- Explain how the principles of stratigraphy are used to determine the relative age of structures and sequence the fossil record, including
  - superposition
  - cross-cutting relationships
  - inclusions
  - horizontality and fossil record
  - correlation.
- Explain how geological processes may involve
  - slow transitions, including subduction and erosion
  - fast transitions, including volcanic eruptions and earthquakes.

- Determine age relationships, including conformable and unconformable geological boundaries.
- Determine correlations and make decisions about index fossils and the process of correlation.
- Explain the role of index fossils and stratigraphic evidence in the construction of the fossil record and geological timescale.
- Analyse stratigraphic evidence and justify decisions using the principles of stratigraphy.

Radioactive dating

- Explain how precise dates can be assigned to points on the relative geological timescale using data derived from the decay of radioisotopes in rocks and minerals.
- Interpret graphical representations of half-life to show how radioisotopes can be used to date rocks and minerals.

Interior structure of Earth

- Describe Earth's internal differentiation into a layered structure: a solid metallic inner core, a liquid metallic outer core and a silicate mantle and crust.
- Explain how the study of seismic waves (e.g. P-wave and S-wave shadow zones and discontinuities in seismic wave velocities) and meteorites provides evidence for Earth's interior structure.
- Interpret data relating to Earth's interior structure, including seismic waves.

Rocks and minerals

- Describe the chemical composition of a variety of minerals present in rocks, including felsic and mafic minerals.
- Explain how rocks are composed of characteristic assemblages of mineral crystals or grains that are formed through specific processes
  - igneous — plutonic and volcanic
  - sedimentary — clastic, chemical and organic
  - metamorphic — contact, regional and dynamic.
- Classify examples of sedimentary, igneous and metamorphic rocks.
- Identify the limitations of tools used to classify rock samples.

Soil formation and classification

- Explain how soil formation requires interaction between atmospheric, geologic, hydrologic and biotic processes, including weathering and erosion.
- Explain the processes of physical (mechanical) and chemical weathering of rock.
- Compare the composition of soil in terms of rock and mineral particles, organic material, water, gases and living organisms.
- Classify different soil types using percentage composition of sand, silt and clay, e.g. soil ternary diagram.

- Explain the correlation between soil type and native vegetation, i.e. many soils maps of Australia are based on this correlation.
- Analyse properties of soil samples (including organic content, pH, moisture content, soil texture and structure) to
  - classify soil type
  - describe soil quality.

Science as a human endeavour (SHE)

- Understand that scientific knowledge can enable scientists to offer valid explanations and make reliable predictions about the formation and relative ages of geological structures and fossils.
- Understand that the principle of uniformitarianism suggests that change is constant and uniform.
- Appreciate how advances in science understanding in physics (e.g. radioisotopes/half-life) and the development of supercomputing can influence geological understanding.
- Appreciate that the development of complex models and/or theories about the interior structure of Earth often require a wide range of evidence from multiple scientific international organisations.
- Understand that the current agreed age of Earth is around 4.54 billion years. This age has been calculated from radiometric dating of meteorites and is consistent with various younger ages obtained from Earth and Moon rocks.
- Recognise the connection between physical and chemical characteristics of different local or regional soil types is linked to sustainable farming practices, urban development or environmental impacts.

Science inquiry

- Interpret stratigraphic sequences from secondary data to and infer relative age relationships of fossils and/or sediments.
- Use relevant standard measures (e.g. grain size, shape and sorting charts, felsic vs. mafic composition, and an acid test for carbonate) to collect and organise data about rock samples.
- Interpret data to make connections between indicator plant species and land use with specific soil types, e.g. field-based or satellite imagery data.
- Classify soils using an appropriate classification system (e.g. The Australian Soil Classification system) and identify limitations made about soil classification.
- Classify common rocks and make reasoned decisions using keys, tables or flow charts.
- Investigate soil properties of local soil samples to classify and describe quality, including organic content, pH, moisture content, soil texture and structure.

Topic 3: Development of the atmosphere and hydrosphere (6 hours)

Science understanding

Hydrosphere

- Explain how water's unique properties (including its boiling point, density in solid and liquid phase, surface tension, ability to act as a solvent, and its abundance on the surface of Earth) make it an important component of Earth system processes (including precipitation, ice sheet formation, evapotranspiration and solution of salts).
- Discuss evidence for theories on the origins of water on Earth, including volcanic outgassing and the impact of icy bodies from space.

Atmosphere

- Explain the layered structure of the modern atmosphere as characterised by changes in temperature and movement of air masses in the troposphere, stratosphere, mesosphere and thermosphere.
- Explain the location and role of the ozone layer in the atmosphere.
- Discuss the evidence for theories of how the atmosphere was formed, including
  - volcanic outgassing during cooling and differentiation of Earth
  - significant modification of its composition by the actions of photosynthesising organisms.

Science as a human endeavour (SHE)

- Understand that scientific knowledge can enable scientists to offer valid explanations and make reliable predictions about the properties and role of the hydrosphere and the evolution and structure of the atmosphere.
- Appreciate that the development of complex models and theories about the atmosphere often requires a wide range of evidence from multiple disciplines, including geology, biology and meteorology.
- Appreciate the contribution of Global Atmosphere Watch in seeking to identify and understand changes in the atmosphere in order to predict future change and provide advice about ways to mitigate the effect of human-induced atmospheric change.
- Understand that scientists theorise that planets with surface water will occur within a 'Goldilocks zone' of distance from their sun, where surface temperatures are not too hot and not too cold, based on models of Earth.

Science inquiry

- Investigate the properties of water in relation to important Earth system processes.
- Use standard apparatus and techniques to collect, organise and interpret data about meteorological conditions.
- Investigate historical records of the ozone layer to show changes in the thickness of the layer at different locations.

Topic 4: Development of the biosphere (11 hours)

Science understanding

Origin of the biosphere

- Discuss evidence for theories about the origin and development of the biosphere, including
  - fossil and geological evidence that indicates that life first appeared on Earth approximately four billion years ago, including stromatolites and zircon crystals from Western Australia containing graphite
  - laboratory experimentation that has informed theories that life emerged under anoxic atmospheric conditions in an aqueous mixture of inorganic compounds, either in a shallow water setting as a result of lightning strike or in an ocean floor setting due to hydrothermal activity.

Characteristics of the biosphere

- Explain how biotic and abiotic characteristics of the spheres, such as organisms, temperature, surface water, substrate and available light, will vary with location.
- Explain how the unique nature of individual communities in the biosphere is dependent on the characteristics of the location.
- Explain how communities are dynamic in nature and processes will allow communities to change as the characteristics of the spheres change.

Biosphere past to present

- Explain processes and limitations of evidence of the biosphere's past by explaining
  - the formation of body and trace fossils in strata and how the processes of formation lead to preservation of different levels of detail in the fossils
  - how past environments and communities can be inferred from sedimentary rocks and enclosed fossils, including limitations of this record.
- Interpret evidence of the biosphere's past by analysing sedimentary sequences with differing characteristics and inferring the original depositional environment.
- Interpret evidence from the fossil record for the diversification and proliferation of living organisms over time.
- Interpret fossil evidence to support theories of mass extinctions and ecosystem change, including the Permian or Cretaceous mass extinction events.

Science as a human endeavour (SHE)

- Understand that the fossil record links to the existence of different organisms and changes in the biosphere over time.
- Appreciate the contributions of Stanley Miller and Harold Urey, who indicated that by introducing a spark to an aqueous mixture of compounds that were likely to have been present on early Earth, organic molecules could form.
- Understand that current data on global species loss indicates that a ‘sixth extinction’ of greater severity than previous events may be imminent.
- Appreciate that fossil record and sedimentary rock evidence, in addition to the oral histories and art sites of Aboriginal peoples and Torres Strait Islander peoples, suggest that Australia’s environments have changed in significant ways since it separated from Antarctica approximately 45 million years ago.

Science inquiry

- Investigate the characteristics of community by using a transect study, i.e. quadrats. If possible, use a field study with an obvious plant succession, but simulations can be used.
- Model the process of the formation of different depositional environments.

Unit 2: Earth processes — energy transfers and transformations

In Unit 2, students explore the ways Earth and environmental science is used to describe and explain energy transfer and transformation in Earth systems. An understanding of the movement of energy between systems is essential to appreciate the importance of energy to control processes below and above Earth's surface. Students conduct experiments and investigate different modes of energy transfer within systems, and use models to predict the characteristics of systemic ocean currents, different sources of energy, and how greenhouse gases reflect or scatter infrared radiation leading to the greenhouse effect. They examine synoptic charts, satellite images and climatic data to analyse primary data to make predictions about weather patterns.

Contexts that could be investigated include weather prediction, energy for human consumption and transfer and transformation of energy in oceans. Through the investigation of these contexts, students may explore the importance of accurate weather predictions to the public and private sector to provide severe weather warnings and to inform decision-making in aviation and marine industries, as well as agriculture and forestry. They also explore the importance of environmentally friendly energy sources and the significance of photosynthesis for primary production in marine environments.

Participation in a range of experiments and investigations will allow students to progressively develop their suite of science inquiry skills while gaining an enhanced appreciation of energy transfer and transformation in Earth systems. Collaborative experimental work also helps students to develop communication, interaction, character and management skills. Throughout the unit, students develop skills in collecting, analysing and interpreting primary and secondary data on Earth processes and applying secondary data to explore ways to predict future changes to the different Earth systems and provide advice about ways to mitigate the effect of human-induced change.

Unit objectives

1. Describe ideas and findings about energy for Earth, atmospheric, hydrologic and biogeochemical processes.
2. Apply understanding of energy for Earth, atmospheric, hydrologic and biogeochemical processes.
3. Analyse data about energy for Earth, atmospheric, hydrologic and biogeochemical processes.
4. Interpret evidence about energy for Earth, atmospheric, hydrologic and biogeochemical processes.
5. Evaluate processes, claims and conclusions about energy for Earth, atmospheric, hydrologic and biogeochemical processes.
6. Investigate phenomena associated with energy for Earth, atmospheric, hydrologic and biogeochemical processes.

Subject matter

Topic 1: Energy for Earth processes (11 hours)

Science understanding

Energy

- Apply the first law of thermodynamics to Earth systems.
- Analyse modes of energy transfer, including convection, conduction and radiation.
- Identify energy transformations and storage in Earth systems, including evaporation, movement of tectonic plates, photosynthesis and the ocean as a heat sink.
- Interpret data on energy transfer, including convection, conduction and radiation.

Energy and the water cycle

- Explain the relationship between thermal and light energy from the Sun and phase changes of water as it relates to the water cycle.
- Identify the transfer, transformation and storage of energy in the water cycle.

Energy and Earth's core

- Describe how the decay of radioisotopes is the source of heat in Earth's core.
- Explain how energy is transferred from the core to the crust.
- Explain how transformations of kinetic, gravitational and thermal energy generate movement of tectonic plates, including mantle convection, plume formation and slab pull.

Science as a human endeavour (SHE)

- Investigate the first proposed theory of continental drift in 1912 and the publication of an expanded theory in 1915.
- Understand that geothermal heat from Earth's interior provides a low carbon emission energy source.

Science inquiry

- Investigate modes of energy transfer, including convection, conduction and radiation.
- Investigate the movement of convection currents by creating a model, e.g. heating the side of a beaker of oil and measuring movement with tea leaves.
- Examine how transformations of kinetic, gravitational and thermal energy generate movement of tectonic plates, including mantle convection, plume formation and slab pull.

Topic 2: Energy for atmospheric and hydrologic processes (20 hours)

Science understanding

Solar energy

- Describe solar energy as electromagnetic radiation, including ultraviolet radiation.
- Analyse how the transfer of solar energy to Earth's surface is influenced by
  - atmospheric absorption, including ozone
  - reflection by aerosols and back-scattering
  - physical characteristics of Earth's surface, including albedo.

Thermal radiation and the greenhouse effect

- State that absorbed solar radiation is emitted as infrared radiation.
- Explain how emitted infrared radiation is mostly absorbed by greenhouse gases, which re-radiate in all directions, including back towards Earth's surface.
- Explain how this process leads to the greenhouse effect.
- Compare the major greenhouse gases and their sources, including carbon dioxide, methane and water vapour.
- Interpret data relevant to the greenhouse effect.
- Interpret data about the effect of greenhouse conditions on temperature.

Atmospheric circulation

- Explain how heating and cooling cause differences in atmospheric pressure.
- Explain how the movement of air masses due to heating and cooling, and Earth's rotation and revolution, cause systematic atmospheric circulation, including
  - geostrophic wind
  - the Walker Circulation.
- Apply knowledge of air pressure to explain
  - patterns of systematic atmospheric circulation
  - the transfer of thermal energy around Earth's surface via systematic atmospheric circulation.
- Interpret the features of synoptic charts and satellite images, including high and low pressure and isobars.

Ocean currents

- Identify the following key features of the ocean conveyor (also known as the thermohaline circulation)
  - sinking of dense water in the North Atlantic and regions around Antarctica
  - spreading of dense water in the deep ocean
  - broad upwelling of deep water
  - near surface currents, such as the Gulf Stream.
- Explain how global oceans act as heat sinks.

- Explain how the density of seawater depends on temperature and salinity.
- Interpret evidence demonstrating systematic ocean currents are due to
  - differences in density
  - the rotation of Earth
  - the action of the wind.

Weather and climate

- Describe weather as an interaction between the atmosphere and hydrosphere.
- Describe the effect of the following Australian climate influences on rainfall conditions
  - El Niño and La Niña
  - Madden-Julian Oscillation
  - Indian Ocean Dipole
  - Southern Annular Mode.
- Compare the conditions that cause El Niño and La Niña, including the Southern Oscillation Index (SOI), and their associated effects at local and global levels.
- Interpret data to make reasoned decisions about El Niño and La Niña patterns.

Science as a human endeavour (SHE)

- Understand that scientific knowledge of solar energy can be used to develop and evaluate economic, social and environmental actions for sustainability, e.g. solar panels and carbon-neutral-built environments.
- Explore how advances in science knowledge in solar energy and Earth's systems can influence other areas of science, technology and engineering, such as in the development of more efficient and sustainable building design.
- Understand that scientific knowledge can enable scientists to offer valid explanations and make reliable predictions about the possible causes and effects of climate change.
- Understand that the use of scientific knowledge of thermal radiation and the greenhouse effect has beneficial and/or unintended consequences, e.g. the use and eventual banning of CFCs.
- Appreciate that the development of the global ocean conveyor model requires a wide range of evidence from multiple individuals and across scientific disciplines.
- Appreciate that meteorology relies on clear communication and international conventions and that accurate weather forecasting is vital to the public and private sectors, e.g. to provide severe weather warnings and to inform decision-making in aviation and marine industries, as well as agriculture and forestry.
- Explore how knowledge and data about weather patterns can enable scientists to offer valid explanations and make reliable predictions in relation to El Niño and La Niña.

Science inquiry

- Investigate the effect of greenhouse conditions on temperature, using a model.
- Compare or contrast Earth's atmosphere with sister planets Venus and Mars to appreciate the impact of greenhouse gases from secondary data.
- Interpret data, including ocean temperature, air pressure, rainfall and SOI to identify El Niño and La Niña patterns.

Topic 3: Energy for biogeochemical processes (14 hours)

Science understanding

Net primary production

- Describe a balanced chemical equation to represent photosynthesis.
- Explain how the process of photosynthesis is the principal mechanism for the transformation of energy from the Sun into energy forms that are useful for living things.
- State that net primary production is the rate at which new biomass is generated, mainly through photosynthesis.
- Interpret data regarding energy transfer and transformations within ecosystems, e.g. food chains, webs and pyramids.

Ecosystem carrying capacity

- Describe the concept of carrying capacity in relation to ecosystems.
- Infer how energy and matter directly affect the number of organisms that can be supported in an ecosystem.
- Identify the differences in carrying capacity between ecosystems using algebraic, visual and/or graphical representations.

Biogeochemical cycling

- Explain the cycling of nitrogen and phosphorus between Earth systems.
- Interpret data (e.g. measured concentrations of nitrogen and phosphorus in different water samples) to make reasoned judgments about the quality of water and health of the system it came from.

Carbon cycle

- Explain the cycling of carbon between Earth systems.
- Identify examples of energy storage, transfer and transformation in the carbon cycle.
- Compare different geological elements of carbon storage including hydrocarbons, coal and kerogens.
- Compare energy storage timescales between living things and geological elements, including sinks and residency periods.

Science as a human endeavour (SHE)

- Appreciate that the use of scientific knowledge in relation to the carbon cycle, particularly to reduce fossil fuel emissions, is influenced by social, economic and ethical considerations.
- Understand that biological soil crusts play an important role in soil fertility and protect the soil surface from erosion and evaporation.
- Appreciate that artificial ecosystems have been developed to aid research in ecosystem function.
- Understand that phytoplankton populations appear to be rising in a number of locations across the globe as they absorb more carbon dioxide from the atmosphere.

Science inquiry

- Investigate photosynthesis by testing the effect of a limiting factor (e.g. temperature, CO_2 concentration, light intensity) on the process.
- Compare carrying capacities in different ecosystems (e.g. a desert and tropical rainforest) by graphing secondary data.
- Investigate the levels of nitrogen and phosphorous in samples of local water.
- Investigate the precipitation of carbonate minerals in solution.

Unit 3: Living on Earth — extracting, using and managing Earth resources

In Unit 3, students explore the ways Earth and environmental science is used to describe and explain differences between renewable and non-renewable Earth resources and how their extraction, use, consumption and disposal affect Earth systems. An understanding of Earth resources is essential to appreciate the need for sustainable sources to maintain quality of everyday life, balanced with the need to limit the effect that extraction and use will have on different Earth systems. Students conduct experiments and investigations about Earth resources. They examine case studies to analyse secondary data and make decisions about the viability of using renewable and non-renewable Earth resources using an 'ecological footprint'.

Contexts that could be investigated in this unit include technologies of extraction, non-renewable and renewable Earth resources at a regional and global level, and overfishing of marine resources. Through investigating these contexts, students may explore how the rate of extraction and other environmental factors affect the quality and availability of renewable and non-renewable resources, including water, energy resources and biota, and the importance of monitoring and modelling to manage these resources at local, regional and global scales.

Participation in a range of experiments and investigations will allow students to progressively develop their suite of science inquiry skills while gaining an enhanced appreciation of renewable and non-renewable Earth resources. Collaborative experimental work also helps students to develop communication, interaction, character and management skills. Throughout the unit, students develop skills in collecting, analysing and interpreting primary and secondary data on Earth resources and applying secondary data to explore ways to describe and explain decisions relating to environmental and social implications of extracting, using and managing Earth resources.

Unit objectives

1. Describe ideas and findings about the use of renewable and non-renewable resources.
2. Apply understanding of the use of renewable and non-renewable resources.
3. Analyse data about the use of renewable and non-renewable resources.
4. Interpret evidence about the use of renewable and non-renewable resources.
5. Evaluate processes, claims and conclusions about the use of renewable and non-renewable resources.
6. Investigate phenomena associated with the use of renewable and non-renewable resources.

Subject matter

Topic 1: Use of non-renewable Earth resources (22 hours)

Science understanding

The following subject matter can be assessed in the external assessment.

Formation and location of non-renewable mineral and energy resources

- Explain the differences between metallic, non-metallic and energy resources.
- Describe non-renewable resources as those that are typically replenished at timescales of centuries to millennia, including
  - metallic resources (gold and iron ore)
  - non-metallic (mineral sands)
  - fossil fuels (coal, coal seam gas, crude oil and natural gas).
- Interpret information relating to
  - metallic formation including banded iron formations and hydrothermal and alluvial gold formations
  - non-metallic formation (mineral sands) including alluvial and placer deposits
  - fossil fuel formation (coal seams and stratigraphic traps).

Exploration of mineral and energy resources

- Explain how mineral and energy resources are discovered using a variety of techniques to identify the location, spatial extent of the deposit and quality of the resource, including
  - literature and historic records
  - remote sensing techniques, including satellite and aerial imaging, hyperspectral imaging, and geophysical datasets for magnetic and gravitational
  - direct sampling geochemical techniques, including soil, rock sampling, auguring, drilling and core sampling.
- Interpret geophysical and geochemical data to predict the presence of a resource, e.g.
  - remote sensing (magnetic imaging to detect iron ore)
  - density (bore hole logging).

Extraction, separation and processing of mineral and energy resources

- Explain how a feasibility study is conducted to determine whether the resource can be extracted effectively and profitably, which includes analysis of the
  - size and value (market value and associated economic factors) of the resource
  - suitable extraction methods
  - refining processes of the commodity
  - environmental impacts
  - rehabilitation plan
  - other key parameters such as availability of
    - support facilities and infrastructure
    - site access
    - social impacts (land rights, employment, health).
- Analyse how the type, volume and location of mineral and energy resources influences the methods of extraction, including
  - for coal, gold and iron ore
    - open-cut mining
    - underground mining (stoping, room and pillar — also known as bord and pillar)
  - for mineral sands
    - dredging
    - open-cut mining
  - for coal seam gas, oil and natural gas
    - onshore and offshore drilling
    - fracking.
- Determine the appropriate method of extraction (e.g. sluicing, froth flotation, gravitational separation, smelting) by analysing the physical and chemical properties of
  - metallic resources — gold and iron ore
  - non-metallic resources — mineral sands.
- Explain how the method of extraction, processing and separation is determined by the physical and chemical properties of these metallic and non-metallic resources.

Environmental monitoring and management

- Describe how resource extraction can affect the atmosphere, hydrosphere and biosphere.
- Explain how common environmental factors are monitored to minimise environmental impacts on
  - air quality, e.g. ozone, SO_2, CO, visibility, fine particles PM10
  - water quality, e.g. pH, dissolved oxygen, turbidity, BOD
  - soil quality, e.g. pH, erosion, changes in soil structure
  - distribution and abundance of organisms, e.g. line transects, Lincoln index
  - noise pollution, e.g. sound level meters, sleep patterns.

- Interpret data from environmental monitoring, including distribution and abundance surveys, air quality, water quality.
- Interpret data relating to the effectiveness of environmental monitoring strategies.
- Interpret data about the effectiveness of turbidity management strategies, using settling ponds.

Science as a human endeavour (SHE)

The following subject matter may be assessed in the internal assessments.

- Appreciate the role of licensing and permissions in resource exploration.
- Appreciate that ICT and other technologies for exploration of mineral and energy resources have dramatically increased the size, accuracy and geographic and temporal scope of datasets with which scientists work.
- Appreciate that people can use scientific knowledge about exploration for coal seam gas (CSG) to inform the assessment and evaluation of economic risk.
- Understand that scientific knowledge about environmental monitoring and management is linked to a social, economic or cultural context in which it is considered.
- Understand that people can use quantitative data collected from environmental monitoring to assess and evaluate the risk to the environment.
- Appreciate that modern technologies have had a significant impact on improving the efficiency and effectiveness of locating and extracting resources, including by aerial and satellite imagery to map resource location, use of software packages to model resource distribution, and validation of the model using technologies such as seismic surveys.
- Appreciate that community concern over CSG industry development also reflects the limited information available on the long-term effects of CSG industries.
- Consider carbon pricing can provide funds for investment in cleaner energy and aims to act as an incentive for businesses to reduce their pollution.
- Appreciate the purpose of Environmental Impact Assessments (EIAs) as well as how to nominate trigger values and formulate actions based on those trigger values.

Science inquiry

The following subject matter may be assessed in the internal assessments.

- Use experiments to model separation or processing techniques, e.g. crushing, smelting, froth flotation, gravitational separation.
- Investigate the effect of slope revegetation on the volume of water run-off and amount of topsoil lost through erosion.
- Investigate distribution and abundance from surveys using quadrats or transects, e.g. a survey of weed species in a local area to determine human impact.
- Investigate a factor that affects evaporation rates of water (e.g. surface area, volume, temperature, turbidity, salinity) in a lake/dam situation.
- Model different turbidity management strategies using settling ponds.
- Investigate geophysical and geochemical exploration datasets to predict the presence of a resource.

Topic 2: Use of renewable Earth resources (23 hours)

Science understanding

The following subject matter can be assessed in the external assessment.

Renewable resources

- Describe renewable resources as those that are typically replenished at timescales of years to decades, including
  - harvestable resources, including water, biota
  - energy resources, including solar, wind and hydroelectric.
- Explain how sustainable use of a resource is dependent on abundance and its replenishment rate scales for
  - biota, including marine species and forestry
  - surface water and groundwater
  - hydroelectric.
- Discuss how cost-effective use of solar, wind and hydroelectric energy are constrained by the efficiency of available technologies to collect, transfer and store energy by
  - identifying methods for harvesting, transformation and storage
  - comparing the efficiency of energy capture, transfer and storage
  - drawing conclusions about their relative potential as an energy source.
- Interpret data related to sustainability using one of the following
  - biota, including marine species and forestry
  - surface water and groundwater
  - hydroelectric.
- Interpret data about the efficiency of renewable energy sources, such as solar, wind or hydroelectricity, to make decisions about their viability for a particular application, e.g. domestic, industrial or agricultural energy source.

Ecosystems

- Explain how ecosystems provide a range of
  - renewable resources, including provisioning of food and water
  - regulating services, including carbon sequestration
  - supporting services, including soil formation, nutrient and water cycling, air and water purification
  - cultural services, including aesthetics and the connection between social, ecological understanding and sustainability.
- Interpret evidence relating to the impact of human activities on ecosystems, including
  - introduction of pests
  - species removal
  - habitat destruction.
- Compare case studies of positive and negative human influences on ecosystem viability at local, regional and global scales.

Availability of fresh water

- Compare local and regional issues that affect availability and quality of fresh water, e.g. using evidence about the quality and availability of fresh water in the Murray–Darling River Basin.
- Explain how the availability of fresh water is influenced by
  - human activities, e.g. provisioning of dams, urbanisation, over-extraction and pollution
  - natural processes, e.g. salinity, siltation, drought and algal blooms.
- Determine solutions to situations that lead to siltation, drought, and eutrophication (algal blooms).
- Determine (using appropriate representations, e.g. flow charts, concept maps or diagrams) how the availability and quality of fresh water is influenced by
  - human activities, including provisioning of dams, urbanisation, over extraction and pollution
  - natural processes, including salinity, siltation, drought and algal blooms.

Sustainable harvesting of biota

- Explain the concept of an ecological footprint.
- Discuss how over-harvesting biota reduces populations (including native fisheries) below the threshold of population viability.
- Determine how the size of a population is affected by four processes: birth rate (B), death rate (D), immigration (I) and emigration (E).
- Calculate the population growth rate using R = (B + I) – (D + E) and identify that there will be zero population growth (R = 0) when a population reaches its carrying capacity due to the limitation of resources.
- Calculate the estimated size of a population using the Lincoln index ($N = \frac{M \times n}{m}$).
- Interpret fish population data and identify the reliability of this data to inform fisheries management decision-making on quota and total allowable catch.
- Draw a conclusion about the maximum sustainable yield of relevant aquatic or terrestrial Australian biota using secondary data.
- Determine how the demand for ecological resources must be balanced against the costs of their production, harvesting, transportation and processing, as well as associated wastes.
- Discuss the viability of using resources relative to maintaining a sustainable ecological footprint.

Science as a human endeavour (SHE)

The following subject matter may be assessed in the internal assessments.

- Understand that scientific knowledge about renewable resources can be used to develop and evaluate projected economic, social and environmental effects and to design action for sustainability.
- Appreciate the creative ways of recycling through art movements in the Torres Strait Islands.
- Understand the benefits of Aboriginal ranger programs around Queensland.
- Explore the positive effect of renewable energy (e.g. wind farming, hydropower and solar energy) on Aboriginal communities.

- Consider the pros and cons of commercial production of bush tucker.
- Appreciate the local knowledge of community for sustainable hunting, protection and recordkeeping for animals, fish and birds.
- Appreciate how Aboriginal peoples' and Torres Strait Islander peoples' connection to country supports a sustainable environment.
- Appreciate the intricate way that culture and a community's country (land, environment) is part of their identity, e.g. highlight links between land management tasks and how the oral tradition of storytelling enables survival of a community.
- Consider the scope for sustainable farming using the Kununurra seasonal calendar.
- Understand the negative impact of human activities on ecosystems, e.g. the effect that the clearing of native eucalypt forests has on koala populations and the actions taken by governments and conservation groups to reduce this impact.
- Appreciate how scientific knowledge about sustainable harvesting of aquaculture species in native fisheries can be used to develop and evaluate projected economic, social and environmental effects and to design action for the sustainability of species and the relevant fishing industries.
- Appreciate how scientific knowledge about an ecological footprint can be used to develop and evaluate projected economic, social and environmental effects and to design action for sustainability.
- Understand that the use of fishing quotas to prevent overfishing has been shown to be successful, but calculation of these quotas needs to take into account the population dynamics of the species, ecosystem dynamics and the effects of changes in the biotic and abiotic conditions of that ecosystem.
- Appreciate how the economic value for ecosystem services can be determined from an analysis of the economic benefits that derive from ecosystems and biodiversity, and a comparison made between the costs of failing to protect these resources with the costs of conserving them.
- Understand that global actions to maintain biodiversity of agricultural species include the International Treaty on Plant Genetic Resources for Food and Agriculture, which provides a framework for national, regional and international efforts to conserve genetic resources.
- Explain how population size and nomadic culture of Aboriginal peoples and Torres Strait Islander peoples allowed sustainable harvesting of Australian biota.

Science inquiry

The following subject matter may be assessed in the internal assessments.

- Investigate the sustainability of biota (including marine species and forestry), surface water and groundwater or hydroelectric.
- Investigate a variable that affects the efficiency of a renewable energy source, such as solar, wind or hydroelectric.
- Investigate the ecological footprint of different countries.
- Investigate local water samples using standard water quality testing and compare to data from other waterways, or historical data of the same waterway.
- Apply the Lincoln index in a modelled capture-recapture scenario.

Unit 4: The changing Earth — the cause and impact of Earth hazards

In Unit 4, students explore the ways Earth and environmental science is used to describe and explain the cause and effect of naturally occurring Earth hazards and the ways they are affected by Earth systems. An understanding of the causes of naturally occurring hazards is essential to appreciate their impacts and the development of management and mitigation strategies. Students design and conduct experiments and investigations to collect primary and secondary data about Earth hazards and associated processes and techniques. They examine ways in which human activities can contribute to the frequency, magnitude and intensity of Earth hazards. This unit focuses on the timescales at which the effects of natural and human-induced change are apparent, and ways in which scientific data is used to provide strategic direction for the mitigation of Earth hazards and environmental management decisions.

Contexts that could be investigated in this unit include human activities and technology in agriculture and climate change. Through the investigation of these contexts, students may explore decisions about actions to mitigate hazards that will depend on the perception of risk by individuals, communities, governments and international agencies, and reflect their social, economic and ethical values.

Participation in a range of experiments and investigations will allow students to progressively develop their suite of science inquiry skills while gaining an enhanced appreciation of the cause and effect of naturally occurring Earth hazards. Collaborative experimental work also helps students to develop communication, interaction, and self-management skills.

Throughout the unit, students develop skills in collecting, analysing and interpreting primary and secondary data on Earth hazards and applying secondary data to explore ways to predict future changes to the different Earth systems and provide advice about ways to mitigate the effect of human-induced change.

Unit objectives

1. Describe ideas and findings about the cause and impact of Earth hazards and global climate change.
2. Apply understanding of the cause and impact of Earth hazards and global climate change.
3. Analyse data about the cause and impact of Earth hazards and global climate change.
4. Interpret evidence about the cause and impact of Earth hazards and global climate change.
5. Evaluate processes, claims and conclusions about the cause and impact of Earth hazards and global climate change.
6. Investigate phenomena associated with the cause and impact of Earth hazards and global climate change.

Subject matter

Topic 1: The cause and impact of Earth hazards (22 hours)

Science understanding

The following subject matter can be assessed in the external assessment.

Earth hazards and plate tectonic processes

- Identify boundary types using geological maps of Earth and models of processes that have contributed to their formation.
- Explain how features of earth processes at plate boundaries, including divergent, convergent and transform boundaries and their impact on the atmosphere, geosphere and biosphere.
- Explain how earthquakes, volcanoes and tsunamis are the result of
  - plate tectonics
  - interactions between Earth's systems.
- Predict how hazardous outcomes of earthquakes, volcanoes and tsunamis can affect life, health, property and the environment (biosphere).
- Analyse evidence relating to how the occurrence of earthquakes, volcanoes and tsunamis influences other Earth processes in the atmosphere, hydrosphere and lithosphere, including the effect of ash clouds on global weather patterns.
- Interpret evidence and draw conclusions about the effect that mitigation strategies, such as building design, location and early warning systems, can have on the consequences of earthquakes, tsunamis and volcanic activity.
- Interpret data on recent and/or historic volcanic activity to describe the relationship between volcanic eruptions and the effect of ash clouds on global temperature patterns.

Predicting Earth hazards

- Interpret data, including earthquake location and frequency data, and ground motion monitoring to map potentially hazardous zones for earthquakes, volcanic eruptions and tsunamis.
- Interpret data to predict the location and probability of repeat occurrences of hazardous Earth events, including volcanic eruptions, earthquakes and tsunamis.
- Interpret data from maps and historical records of hazardous zones to predict possible future volcanic activity, earthquakes and tsunamis.

Effects of cyclones, flood events and droughts

- Describe the phenomena of tropical cyclones, floods and droughts.
- Describe and apply the Australian naming and classification systems of cyclones.
- Explain the likely location of major weather hazards, including cyclones, flood events and droughts, using topographic maps, meteorological data and knowledge of Australian climate influences.

- Predict the effects of cyclones, flood events and droughts on Earth processes and interactions, including
  - habitat destruction
  - vegetation distribution patterns
  - erosion
  - river system structures
  - ecosystem regeneration.

Natural hazards

- Explain how human activities, including land clearing and urbanisation, can positively and negatively contribute to the frequency, magnitude and intensity of local and regional incidents of
  - droughts
  - floods
  - bushfires
  - landslides.
- Infer how biomass and substrate influence droughts, floods and bushfires.
- Infer how organisms (including humans) and ecosystems, are affected by the location, magnitude and intensity of droughts, floods and bushfires.
- Interpret evidence about the influence of run-off coefficient of different substrates on the run-off rate in a modelled flood event.

Science as a human endeavour (SHE)

The following subject matter may be assessed in the internal assessments.

- Understand that scientific knowledge can be used to evaluate projected environmental impacts of earthquakes, volcanic eruptions and tsunamis and to develop strategies to limit environmental, social and economic consequences on a community or specific geographical location.
- Appreciate that people can use scientific knowledge to identify the location of potentially hazardous zones for earthquakes, volcanic eruptions and tsunamis to inform the monitoring, assessment and evaluation of risk to a specific geographic location.
- Understand that scientific knowledge can be used to evaluate projected economic, social and environmental impacts of major weather systems, including cyclones, flood events and droughts, and design strategies for limiting the consequences of these major weather events.
- Appreciate that people can use scientific knowledge of major weather systems, including cyclones, flood events and droughts, to inform the monitoring, assessment and evaluation of risk of these weather events on a specific community or geographical location.
- Understand that scientific knowledge can be used to evaluate projected environmental impacts of natural hazardous events, such as droughts, floods, bushfires or landslides due to human activity, and design strategies and an action plan for sustainable human interaction with the natural environment.

- Appreciate that people can use scientific knowledge of natural hazards, including bushfires, flood events and droughts, to inform the monitoring, assessment and evaluation of risk of these hazards to a specific community or geographical location.
- Appreciate that earthquake prediction is still considered by many as an immature science, as it is not able to predict from first principles the location, date or magnitude of an earthquake.
- Explore the role of government in creating stricter restrictions on urban development in high-risk areas given the significant costs of managing mitigation of and recovery from severe weather events.
- Explore mitigation activities, including planting trees and planting deep-rooted crops or salt-adapted species, can reduce loss of agricultural land and remnant native vegetation.

Science inquiry

The following subject matter may be assessed in the internal assessments.

- Investigate volcanic activity data to describe the relationship between volcanic eruptions and the effect of ash clouds on global temperature patterns.
- Investigate evidence from maps and historical records of hazardous zones to predict possible future volcanic activity, earthquakes and tsunamis.
- Investigate the design and location of buildings to mitigate against hazards, such as earthquakes and tsunamis.
- Determine suitable strategies in a proposed action plan for sustainable development in defined hazardous areas of major weather systems, including cyclones, flood events and droughts.
- Investigate historical data and case studies about major weather systems to infer their impacts on Earth processes and interactions. This could include the effects of
  - cyclones on habitat destruction in rainforest and reef communities
  - flood events on erosion and river structure
  - drought on vegetation distribution.
- Investigate examples of natural hazards (i.e. droughts, floods and bushfires) to identify the link between location and magnitude and the impact of the event.
- Investigate the influence of run-off coefficient of different substrates on the run-off rate in a modelled flood event.

Topic 2: The cause and impact of global climate change (23 hours)

Science understanding

The following subject matter can be assessed in the external assessment.

Contributions to climate changes

- Explain the concept of radiative forcing (RF).
- Explain how natural processes contribute to global climate changes, including
  - oceanic circulation
  - orbitally induced solar radiation fluctuations
  - the plate tectonic super-cycle.
- Apply the concept of radiative forcing to draw conclusions about the potential climate response to Milankovitch cycles and different processes, including
  - variation in the shape of Earth's orbit (eccentricity)
  - the angle of tilt of Earth's axis in relation to Earth's orbital plane (obliquity)
  - the direction Earth's axis of rotation is pointed (precession).

The effect of human activities on atmosphere and climatic conditions

- Compare different greenhouse gases using equivalent carbon dioxide.
- Explain the influences of human and natural processes on the generation of gases into the atmosphere.
- Compare the effects of natural processes and human activities on the composition of the atmosphere and climatic conditions, including an enhanced greenhouse effect, at a variety of time scales.
- Analyse the contribution of human activities, including land clearing and fossil fuel consumption on the composition of the atmosphere.
- Analyse secondary data to determine how changes in atmospheric gases and particulate materials contribute to changes in climatic conditions.
- Interpret data about the impact of changes in atmospheric carbon dioxide concentration over time on global temperatures.

Impacts of climate change

- Explain how climate change affects the biosphere, atmosphere, geosphere and hydrosphere.
- Interpret evidence that demonstrates how climate changes has affected different regions and species differently over time.
- Interpret data relating to the influence of climate change on
  - species distribution patterns
  - crop productivity changes
  - sea level changes
  - rainfall patterns
  - surface temperature changes
  - extent of ice sheets.

Paleoclimates

- Explain how isotopic and elemental ratios provide information about paleoclimates, including
  - isotopic ratios
    - $\delta^{18}O$ for temperature
    - $\delta^{14}C$ for ocean water age
  - elemental ratios
    - Mg/Ca for sea surface and benthic temperatures
    - $^{230}Th/^{234}U$ for determining speleothem and coral age.
- Interpret geological, prehistorical and historical records that provide evidence for climate change, including
  - fossils
  - pollen grains
  - ice core data
  - isotopic ratios
  - elemental ratios.

Climate models

- Distinguish between the terms *climate* and *weather*; and *weather forecast* and *climate projection*.
- Explain how climate-ocean general circulation models (AOGCMs) describe the behaviour and interactions of the oceans and atmosphere.
- Explain how the following phenomena influence Australian climate
  - El Niño and La Niña
  - Madden-Julian Oscillation
  - Indian Ocean Dipole
  - Southern Annular Mode.
- Explain the importance of predictions based on these phenomena for making government decisions.
- Analyse the output of AOGCMs to infer responses to changes contributing components, including atmospheric composition and global ice cover.
- Draw conclusions about climate outlooks for relevant parts of Australia using data including climate indices such as the Southern Oscillation index and the Indian Ocean Dipole index.

Science as a human endeavour (SHE)

The following subject matter may be assessed in the internal assessments.

- Appreciate that acceptance of scientific knowledge related to the causes of global climate change can be influenced by the social, economic and cultural context in which it is considered.
- Appreciate that people can use scientific knowledge about global climate change to inform the evaluation of risk (e.g. rising sea levels) to a specific community or geographic location.
- Understand that people can use historical records, including oral histories and art sites of Aboriginal peoples and Torres Strait Islander peoples, to provide evidence that climate change has affected different regions and species differently over time.
- Appreciate that people can use scientific geological, prehistorical and historical knowledge to inform the monitoring, assessment and evaluation of risk of climate change over time.
- Appreciate that people can use scientific knowledge obtained from models and theories to inform the monitoring, assessment and evaluation of risk in response to changes in climate patterns.
- Consider how climate change models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power.
- Understand that analysis of gas concentrations in the atmosphere and ice cores indicates that greenhouse gas levels have increased as a result of emissions from human activities over the 20th and 21st centuries.
- Appreciate that changes in surface and ocean temperature will lead to changes in the distribution of some species of plants and animals, with flow-on effects for ecosystems.
- Explore how decisions about actions to mitigate the effects of climate change depend on the perception of risk by individuals, communities, governments and international agencies and reflect their social, economic and ethical values.

Science inquiry

The following subject matter may be assessed in the internal assessments.

- Investigate the environmental impact of changes in climate over time on
  - species distribution
  - crop productivity
  - sea level
  - rainfall patterns
  - surface temperature
  - extent of ice sheets.
- Investigate the effect of changes in atmospheric carbon dioxide concentration over time on global temperatures.
- Investigate acidification of oceans by CO_2 using dry ice in an alkaline solution as a model.
- Investigate changing atmospheric conditions over time, using ice core data simulation models as a source of CO_2 data.
- Investigate patterns of El Niño and La Niña to predict future cycles and environmental implications from secondary data.

Assessment

Internal assessment 1: Data test (10%)

Students respond to items using qualitative data and/or quantitative data derived from practicals, activities or case studies from Unit 3.

Assessment objectives

2. Apply understanding of use of renewable or non-renewable resources to given algebraic, visual or graphical representations of scientific relationships and data to determine unknown scientific quantities or features.
3. Analyse data about use of renewable or non-renewable resources to identify trends, patterns, relationships, limitations or uncertainty in datasets.
4. Interpret evidence about use of renewable or non-renewable resources to draw conclusions based on analysis of datasets.

Specifications

The teacher provides an examination that may ask students to respond using:

- single words
- sentences (up to 150 words per question)
- calculations.

Question specifications

The examination must be aligned to the specifications provided in the table below.

Focus of question	Mark allocation (± 2%)	Objective	In these questions, students:
Unknown scientific quantities or features of datasets	~ 30%	2	calculate using algorithms, determine, identify, use
Trends, patterns, relationships, limitations or uncertainty in datasets	~ 30%	3	categorise, classify, compare, contrast, identify, organise, sequence
Conclusions based on analysis of datasets	~ 40%	4	deduce, determine, draw (a conclusion), extrapolate, infer, interpolate, justify, predict

Stimulus specifications

The teacher provides unseen stimulus that:

- uses qualitative data and/or quantitative data from the listed practicals, activities or case studies from Unit 3
- contains between two and four datasets.

Conditions

- Time allowed
  - Perusal time: 5 minutes
  - Working time: 60 minutes
- This is an individual supervised task.
- Students are permitted a QCAA-approved graphics or scientific calculator.

Mark allocation

Criterion	Assessment objectives	Marks
Data test	2, 3, 4	10
	Total marks:	10

Instrument-specific marking guide

Data test	Cut-off	Marks
The student response has the following characteristics:		
• consistent demonstration, across a range of scenarios, of – selection and correct application of scientific concepts, theories, models and systems to predict outcomes, behaviours and implications – correct calculation of quantities through the use of algebraic, visual and graphical representations of scientific relationships and data – correct and appropriate use of analytical techniques to correctly identify trends, patterns, relationships, limitations and uncertainty – correct interpretation of evidence to draw valid conclusions	> 90%	10
	> 80%	9
• consistent demonstration of – selection and correct application of scientific concepts, theories, models and systems to predict outcomes, behaviours and implications – correct calculation of quantities through the use of algebraic, visual and graphical representations of scientific relationships and data – correct use of analytical techniques to correctly identify trends, patterns, relationships, limitations and uncertainty – correct interpretation of evidence to draw valid conclusions	> 70%	8
	> 60%	7
• adequate demonstration of – selection and correct application of scientific concepts, theories, models and systems to predict outcomes, behaviours and implications – correct calculation of quantities through the use of algebraic, visual and graphical representations of scientific relationships and data – correct use of analytical techniques to correctly identify trends, patterns, relationships, limitations and uncertainty – correct interpretation of evidence to draw valid conclusions	> 50%	6
	> 40%	5
• demonstration of elements of – selection and correct application of scientific concepts, theories, models and systems to predict outcomes, behaviours and implications – correct calculation of quantities through the use of algebraic, visual or graphical representations of scientific relationships or data – correct use of analytical techniques to correctly identify trends, patterns, relationships, limitations or uncertainty – correct interpretation of evidence to draw valid conclusions	> 30%	4
	> 20%	3
• demonstration of elements of – application of scientific concepts, theories, models or systems to predict outcomes, behaviours or implications – calculation of quantities through the use of algebraic or graphical representations of scientific relationships and data – use of analytical techniques to identify trends, patterns, relationships, limitations or uncertainty – interpretation of evidence to draw conclusions.	> 10%	2
	> 1%	1
The student response does not match any of the descriptors above.	≤ 1%	0

Internal assessment 2: Student experiment (20%)

Students modify (i.e. refine, extend or redirect) an experiment relevant to Unit 3 subject matter to address their own related hypothesis or question. This assessment provides opportunities to assess science inquiry skills.

Assessment objectives

1. Describe ideas and experimental findings about the use of renewable or non-renewable resources.
2. Apply understanding of the use of renewable or non-renewable resources to modify experimental methodologies and process data.
3. Analyse experimental data about the use of renewable or non-renewable resources.
4. Interpret experimental evidence about the use of renewable or non-renewable resources.
5. Evaluate experimental processes and conclusions about the use of renewable or non-renewable resources.
6. Investigate phenomena associated with the use of renewable or non-renewable resources.

Specifications

This task requires students to:

- identify an experiment to modify
- develop a research question to be investigated
- research relevant background scientific information to inform the modification of the research question and methodology
- conduct a risk assessment and account for risks in the methodology
- conduct the experiment
- collect relevant qualitative data and/or quantitative data to address the research question
- process and present the data appropriately
- analyse the evidence to identify trends, patterns or relationships
- analyse the evidence to identify uncertainty and limitations
- interpret the evidence to draw conclusion/s to the research question
- evaluate the reliability and validity of the experimental process
- suggest possible improvements and/or extensions to the experiment
- communicate findings in an appropriate scientific genre, e.g. report, poster presentation, journal article, conference presentation.

Scientific inquiry is a non-linear, iterative process. Students will not necessarily complete these steps in the stated order; some steps may be repeated or revisited.

It is recommended that this task is designed so that students can develop a response in approximately 10 hours of class time.

Conditions

- Students can develop their responses in class time and their own time.
- This is an individual task.
- The following aspects of the task may be completed as a group
  - identifying an experiment
  - developing a research question
  - conducting a risk assessment
  - conducting the experiment
  - collecting data.
- Students use a practical or simulation performed in class as the basis for their methodology and research question.

Response requirements

One of the following:

- Multimodal (at least two modes delivered at the same time): up to 11 minutes
- Written: up to 2000 words

Mark allocation

Criterion	Assessment objectives	Marks
Forming	1, 2, 6	5
Finding	6	5
Analysing	2, 3	5
Interpreting and Evaluating	4, 5	5
	Total marks:	20

Instrument-specific marking guide

Forming	Marks
The student response has the following characteristics:	
• a considered rationale for the experiment • justified modifications to the methodology • a specific and relevant research question • appropriate use of genre and referencing conventions • fluent and concise use of scientific language and representations	4–5
• a reasonable rationale for the experiment • feasible modifications to the methodology • a relevant research question • use of basic genre and referencing conventions • competent use of scientific language and representations	2–3
• a vague or irrelevant rationale for the experiment • inappropriate modifications to the methodology • an inappropriate research question • inadequate use of genre and referencing conventions • simplistic use of language and representations.	1
The student response does not match any of the descriptors above.	0

Finding	Marks
The student response has the following characteristics:	
• a methodology that enables the collection of sufficient, relevant data • considered management of risks/ethical issues/environmental issues • collection of sufficient and relevant raw data	4–5
• a methodology that enables the collection of relevant data • management of risks/ethical issues/environmental issues • collection of relevant raw data	2–3
• a methodology that causes the collection of insufficient and irrelevant data • inadequate management of risks/ethical issues/environmental issues • collection of insufficient and irrelevant raw data.	1
The student response does not match any of the descriptors above.	0

Analysing	Marks
The student response has the following characteristics:	
• correct and relevant processing of data • thorough identification of relevant trends/patterns/relationships • thorough and appropriate identification of the uncertainty and limitations of evidence	4–5
• basic processing of data • identification of obvious trends/patterns/relationships • basic identification of uncertainty/limitations of evidence	2–3
• incorrect or irrelevant processing of data • identification of incorrect or irrelevant trends/patterns/relationships • incorrect or insufficient identification of uncertainty/limitations of evidence.	1
The student response does not match any of the descriptors above.	0

Interpreting and Evaluating	Marks
The student response has the following characteristics:	
• justified conclusion/s linked to the research question • justified discussion of the reliability and validity of the experimental process • suggested improvements and extensions to the experiment that are logically derived from the analysis of evidence	4–5
• reasonable conclusion/s relevant to the research question • reasonable description of the reliability and validity of the experimental process • suggested improvements and/or extensions to the experiment that are related to the analysis of evidence	2–3
• inappropriate or irrelevant conclusion/s • cursory or simplistic statements about the reliability and validity of the experimental process • ineffective or irrelevant suggestions.	1
The student response does not match any of the descriptors above.	0

Internal assessment 3: Research investigation (20%)

Students gather evidence related to a research question to evaluate a claim relevant to Unit 4 subject matter. This assessment provides opportunities to assess science inquiry skills and science as a human endeavour (SHE) subject matter.

Assessment objectives

1. Describe ideas and findings about the cause and impact of Earth hazards or global climate change.
2. Apply understanding of the cause and impact of Earth hazards or global climate change to develop research questions.
3. Analyse research data about the cause and impact of Earth hazards or global climate change.
4. Interpret research evidence about the cause and impact of Earth hazards or global climate change.
5. Evaluate research processes, claims and conclusions about the cause and impact of Earth hazards or global climate change.
6. Investigate phenomena associated with the cause and impact of Earth hazards or global climate change through research.

Specifications

This task requires students to:

- select a claim to be evaluated, from a list provided by the teacher
- identify the relevant scientific concepts associated with the claim
- conduct research to gather evidence from scientifically credible sources to evaluate the claim
- pose a research question that addresses an aspect of the claim
- identify relevant evidence to answer the research question
- identify the trends, patterns or relationships in the evidence
- analyse the evidence to identify limitations
- interpret the evidence to construct scientific arguments
- interpret the evidence to form a conclusion to the research question
- discuss the quality of the evidence
- evaluate the claim by applying the findings of the research to the claim
- suggest improvements and/or extensions to the investigation
- communicate findings in an appropriate scientific genre, e.g. report, journal article, essay, conference presentation.

Scientific inquiry is a non-linear, iterative process. Students will not necessarily complete these steps in the stated order; some steps may be repeated or revisited.

Evidence must be obtained by researching scientifically credible sources, such as:

- books and podcasts by well-credentialed scientists
- ‘popular’ science websites or magazines
- websites of governments, universities, independent research bodies or science and technology manufacturers
- scientific journals.

It is recommended that this task is designed so that students can develop a response in approximately 10 hours of class time.

Conditions

- Students can develop their responses in class time and their own time.
- This is an individual task.
- The following aspects of the task may be completed as a group
  - selecting a claim
  - identifying the relevant scientific concepts associated with the claim
  - conducting research.

Response requirements

One of the following:

- Multimodal (at least two modes delivered at the same time): up to 11 minutes
- Written: up to 2000 words

Mark allocation

Criterion	Assessment objectives	Marks
Forming and Finding	1, 2, 6	5
Analysing	3	5
Interpreting	4, 5	5
Evaluating	5, 1	5
	Total marks:	20

Instrument-specific marking guide

Forming and Finding	Marks
The student response has the following characteristics:	
• a considered rationale identifying clear development of the research question from the claim • a specific and relevant research question • selection of sufficient and relevant sources • acknowledgment of sources of information through appropriate use of referencing conventions • fluent and concise use of scientific language/representations	4–5
• a reasonable rationale that links the research question and the claim • a relevant research question • selection of relevant sources • use of basic referencing conventions • competent use of scientific language/representations	2–3
• a vague or irrelevant rationale for the investigation • an inappropriate research question • selection of insufficient or irrelevant sources • inadequate acknowledgment of sources • incorrect use of language/representations.	1
The student response does not match any of the descriptors above.	0

Analysing	Marks
The student response has the following characteristics:	
• the identification of sufficient and relevant evidence • thorough identification of relevant trends/patterns/relationships in evidence • thorough and appropriate identification of limitations of evidence	4–5
• the identification of relevant evidence • identification of obvious trends/patterns/relationships in evidence • basic identification of limitations of evidence	2–3
• the identification of insufficient and irrelevant evidence • identification of incorrect or irrelevant trends/patterns/relationships in evidence • incorrect or insufficient identification of limitations of evidence.	1
The student response does not match any of the descriptors above.	0

Interpreting	Marks
The student response has the following characteristics:	
• justified scientific argument/s • justified conclusion linked to the research question • justified discussion of the quality of evidence	4–5
• reasonable scientific argument/s • reasonable conclusion relevant to the research question • reasonable description of the quality of evidence	2–3
• inappropriate or irrelevant argument/s • inappropriate or irrelevant conclusion • cursory or simplistic statements about the quality of evidence.	1
The student response does not match any of the descriptors above.	0

Evaluating	Marks
The student response has the following characteristics:	
• extrapolation of credible findings of the research to the claim • suggested improvements and extensions to the investigation that are considered and relevant to the claim • appropriate use of genre conventions	4–5
• application of relevant findings of the research to the claim • suggested improvements and/or extensions to the investigation that are relevant to the claim • use of basic genre conventions	2–3
• application of insufficient or inappropriate findings of the research to the claim • ineffective or irrelevant suggestions • inadequate use of genre conventions.	1
The student response does not match any of the descriptors above.	0

External assessment: Examination — combination response (50%)

External assessment is developed and marked by the QCAA. The external assessment in Earth & Environmental Science is common to all schools and administered under the same conditions, at the same time, on the same day.

Assessment objectives

1. Describe ideas and findings about use of renewable and non-renewable resources and the cause and impact of Earth hazards and global climate change.
2. Apply understanding of use of renewable and non-renewable resources and the cause and impact of Earth hazards and global climate change.
3. Analyse data about use of renewable and non-renewable resources and the cause and impact of Earth hazards and global climate change to identify trends, patterns, relationships, limitations or uncertainty.
4. Interpret evidence about use of renewable and non-renewable resources and the cause and impact of Earth hazards and global climate change to draw conclusions based on analysis.

Specifications

This examination:

- includes two papers. Each paper consists of a number of different types of questions relating to Units 3 and 4
- may ask students to respond using
  - multiple choice
  - single words
  - sentences or paragraphs
- may ask students to
  - calculate using algorithms
  - interpret unseen stimulus, including graphs, tables or diagrams.

Conditions

Paper 1

- Time allowed
  - Perusal time: 5 minutes
  - Working time: 90 minutes
- Students may use a QCAA-approved graphics or scientific calculator.

Paper 2

- Time allowed
  - Perusal time: 5 minutes
  - Working time: 90 minutes
- Students may use a QCAA-approved graphics or scientific calculator.

Glossary

The syllabus glossary is available at www.qcaa.qld.edu.au/downloads/senior-qce/common/snr_glossary_cognitive_verbs.pdf.

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Version history

Version	Date of change	Information
1.0	January 2024	Released for familiarisation and planning (with implementation starting in 2025)