Earth & Environmental Science 2019 v1.4

General Senior Syllabus

This syllabus is for implementation with Year 11 students in 2019.

Queensland Government
Queensland Curriculum & Assessment Authority
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Contents

1 Course overview

1.1 Introduction

1.1.1 Rationale

At the core of all science 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 understanding 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 the 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 the Earth and its environments, using appropriate representations, modes and genres.

Assumed knowledge, prior learning or experience

The Australian Curriculum: Science P–10 is assumed knowledge for this syllabus.

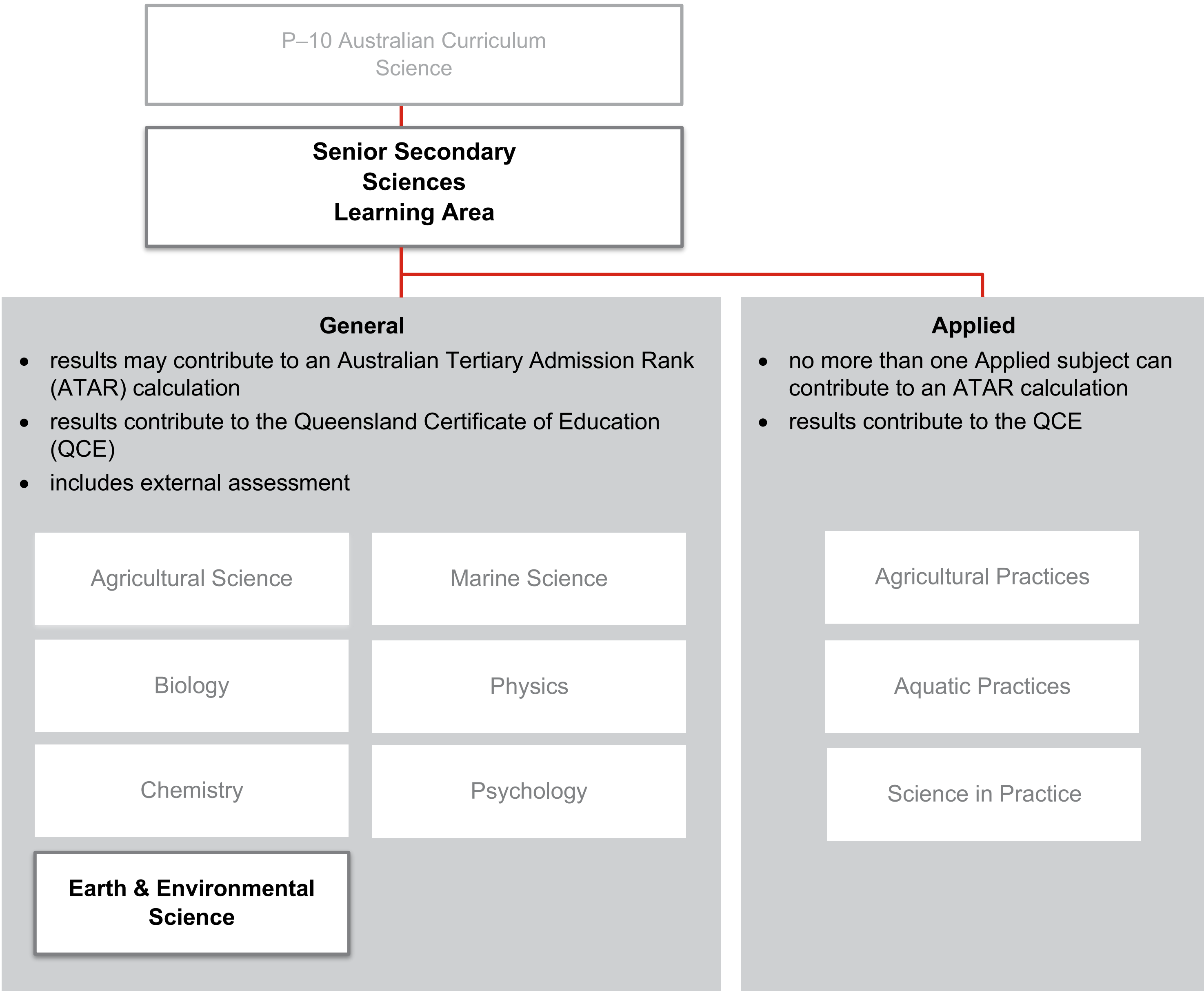
Pathways

Earth & Environmental Science is a General subject suited to students who are interested in pathways beyond school that lead to tertiary studies, vocational education or work. A course of study in Earth & Environmental Science can establish a basis for further education and employment in the fields of geoscience, soil science, agriculture, marine science, environmental rehabilitation, urban planning, ecology, natural resource management, wildlife, environmental chemistry, conservation and ecotourism.

1.1.2 Learning area structure

All learning areas build on the P–10 Australian Curriculum.

Figure 1: Learning area structure



1.1.3 Course structure

Earth & Environmental Science is a course of study consisting of four units. Subject matter, learning experiences and assessment increase in complexity from Units 1 and 2 to Units 3 and 4 as students develop greater independence as learners.

Units 1 and 2 provide foundational learning, which allows students to experience all syllabus objectives and begin engaging with the course subject matter. Students should complete Units 1 and 2 before beginning Units 3 and 4.

Units 3 and 4 consolidate student learning. Only the results from Units 3 and 4 will contribute to ATAR calculations.

Figure 2 outlines the structure of this course of study.

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

Figure 2: Course structure

Earth & Environmental Science

Unit 1
Introduction to Earth systems

- Topic 1: Earth systems and models
- Topic 2: Development of the geosphere
- Topic 3: Development of the atmosphere and hydrosphere
- Topic 4: Development of the biosphere

Assessment
Formative internal assessment/s

Unit 2
Earth processes — energy transfers and transformations

- Topic 1: Energy for Earth processes
- Topic 2: Energy for atmospheric and hydrologic processes
- Topic 3: Energy for biogeochemical processes

Assessment
Formative internal assessment/s

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

- Topic 1: Use of non-renewable Earth resources
- Topic 2: Use of renewable Earth resources

Assessment
Summative internal assessment 1: Data test (10%)
Summative internal assessment 2: Student experiment (20%)

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

- Topic 1: The cause and impact of Earth hazards
- Topic 2: The cause and impact of global climate change

Assessment
Summative internal assessment 3: Research investigation (20%)

Students should have opportunities in Units 1 and 2 to experience and respond to the types of assessment they will encounter in Units 3 and 4.

For reporting purposes, schools should develop at least *one* assessment per unit, with a maximum of *four* assessments across Units 1 and 2.

Summative external assessment: Examination (50%)

1.2 Teaching and learning

1.2.1 Syllabus objectives

The syllabus objectives outline what students have the opportunity to learn. Assessment provides evidence of how well students have achieved the objectives.

Syllabus objectives inform unit objectives, which are contextualised for the subject matter and requirements of the unit. Unit objectives, in turn, inform the assessment objectives, which are further contextualised for the requirements of the assessment instruments. The number of each objective remains constant at all levels, i.e. Syllabus objective 1 relates to Unit objective 1 and to Assessment objective 1 in each assessment instrument.

Syllabus objectives are described in terms of actions that operate on the subject matter. Students are required to use a range of cognitive processes in order to demonstrate and meet the syllabus objectives. These cognitive processes are described in the explanatory paragraph following each objective in terms of four levels: retrieval, comprehension, analytical processes (analysis), and knowledge utilisation, with each process building on the previous processes (see Marzano & Kendall 2007, 2008). That is, comprehension requires retrieval, and knowledge utilisation requires retrieval, comprehension and analytical processes (analysis).

By the conclusion of the course of study, students will:

Syllabus objective	Unit 1	Unit 2	Unit 3	Unit 4
1. describe and explain scientific concepts, theories, models and systems and their limitations	●	●	●	●
2. apply understanding of scientific concepts, theories, models and systems within their limitations	●	●	●	●
3. analyse evidence	●	●	●	●
4. interpret evidence	●	●	●	●
5. investigate phenomena	●	●	●	●
6. evaluate processes, claims and conclusions	●	●	●	●
7. communicate understandings, findings, arguments and conclusions	●	●	●	●

1. describe and explain scientific concepts, theories, models and systems and their limitations

When students describe and explain scientific concepts, theories, models and systems and their limitations, they give a detailed account of a concept, theory, model or system by making relationships, reasons or causes evident. They reflect on relevant social, economic, ethical and cultural factors.

2. apply understanding of scientific concepts, theories, models and systems within their limitations

When students apply their understanding of scientific concepts, theories, models and systems within their limitations, they explain local, regional and global phenomena and determine outcomes, behaviours and implications. They use algebraic, visual and graphical representations of scientific relationships and data to determine unknown scientific quantities or variables. They recognise the limitations of models and theories when discussing results.

3. **analyse evidence**

   When students analyse evidence, they recognise the variety of forms of evidence, and distinguish between quantitative, qualitative, primary and secondary evidence. When students analyse evidence in the form of qualitative data, they identify the essential elements, features or components of the data. When students analyse evidence in the form of quantitative data, they use mathematical processes to identify trends, patterns, relationships, limitations and uncertainty in the data.

4. **interpret evidence**

   When students interpret evidence, they use their knowledge and understanding of scientific concepts, theories, models and systems and their limitations to draw conclusions based on their analysis of qualitative and quantitative evidence and established criteria.

5. **investigate phenomena**

   When students investigate phenomena, they plan and carry out experimental and/or research activities in order to obtain evidence for the purpose of reaching a conclusion. They collect, collate and process evidence. Students ensure that relevant ethical, environmental and safety considerations have been incorporated into their practice.

6. **evaluate processes, claims and conclusions**

   When students evaluate processes, claims and conclusions, they critically reflect on the available evidence and make judgments about its application to a research question, and its use to inform further investigation. When students evaluate processes, they use the quality of evidence to evaluate the validity and reliability of the method used, the appropriateness of assumptions made and possible refinements required. When students evaluate claims, they identify the evidence that would be required to support or refute the claim. They scrutinise evidence for bias, conjecture, alternatives or inaccuracies. When students evaluate conclusions, they consider the credibility of the supporting evidence.

7. **communicate understandings, findings, arguments and conclusions**

   When students communicate, they use scientific representations and language within appropriate genres to present information. They use technology to share knowledge by exchanging information and creating information products.

1.2.2 Underpinning factors

There are three skill sets that underpin senior syllabuses and are essential for defining the distinctive nature of subjects:

- literacy — the set of knowledge and skills about language and texts essential for understanding and conveying Earth & Environmental Science 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 skill sets, which overlap and interact, are derived from current education, industry and community expectations. They encompass the knowledge, skills, capabilities, behaviours and dispositions that will help students live and work successfully in the 21st century.

Together these three skill sets shape the development of senior subject syllabuses. Although coverage of each skill set may vary from syllabus to syllabus, students should be provided with opportunities to learn through and about these skills over the course of study. Each skill set contains identifiable knowledge and skills that can be directly assessed.

Literacy in Earth & Environmental Science

The skills of literacy in science (distinct from 'scientific literacy') are essential for successful scientific inquiry (Douglas et al. 2006, Saul 2004, Yore et al. 2003). In any scientific inquiry activity, literacy skills support students by enabling them to grapple with ideas, conduct research, discuss their thoughts, enhance conceptual understanding and solve problems (Krajcik & Southerland 2010).

The literacy skills important to this subject are those related to the comprehension and composition of texts that provide information, describe and explain events and phenomena, report on experiments, present and analyse data, and offer opinions or claims (ACARA 2015a). Earth & Environmental Science students comprehend and compose multimedia texts, such as reports, charts, graphs, diagrams, pictures, maps, animations, models and other visual media. They understand and apply language structures that are used to link information and ideas, give descriptions and explanations, formulate research questions and construct evidence-based arguments capable of expressing an informed position (ACARA 2015a).

Students learn these skills by having opportunity to engage with:

- rich and varied science and media texts
- class activities that use literacy as a tool for learning
- strategies for reading scientific texts (Moore 2009).

The learning opportunities described above can be integrated with stimulus questions, Science as a Human Endeavour subject matter and mandatory practicals. Students could be asked to:

- explain links between new ideas and prior knowledge and experiences
- engage in learning experiences directed by a question that is meaningful to their lives
- connect multiple representations of a concept, e.g. written texts, formulas, graphs or diagrams of the same concept
- use scientific ideas to compose evidence-based conclusions in the mandatory practicals
- engage with the discourses of science, such as those found in scientific literature and media texts (Krajcik & Southerland 2010).

These strategies will promote students' ability to read, write and communicate about science so that they can engage with science-related issues throughout their lives.

These aspects of literacy knowledge and skills are embedded in the syllabus objectives, unit objectives and subject matter, and instrument-specific marking guides (ISMGs) for Earth & Environmental Science.

Numeracy in Earth & Environmental Science

The skills of numeracy in Earth & Environmental Science are essential for successful scientific inquiry. In any scientific inquiry activity, numeracy skills support students by enabling them to make and record observations; order, represent and analyse data; and interpret trends and relationships (ACARA 2015b).

The numeracy skills important to this subject are those related to the interpretation of complex spatial and graphical representations, and the appreciation of the ways in which scientific concepts, theories, systems and models are structured, communicated, interact or change across spatial and temporal scales (ACARA 2015b). Students will use knowledge and skills in areas such as:

- graphing
- ratio and proportion
- converting from one unit to another
- scientific notation
- an understanding of place in number (significant figures)
- estimation and calculation in order to analyse data
- determining the reliability of data
- interpreting and manipulating mathematical relationships in order to calculate and predict values (ACARA 2009, 2015b).

Students will learn these skills as they:

- measure and record data during the mandatory practicals
- use or interpret meaning from formulas
- interpret graphical information presented in science and media texts
- undertake class activities that use numeracy as a tool for learning
- use mathematics or equations as justification or evidence for conclusions
- interpret and represent information in a variety of forms.

These opportunities will promote students' ability to develop and use numeracy skills in Earth & Environmental Science.

These aspects of numeracy knowledge and skills are embedded in the syllabus objectives, unit objectives and subject matter, and ISMGs for Earth & Environmental Science.

21st century skills

The 21st century skills identified in the following table reflect a common agreement, both in Australia and internationally, on the skills and attributes students need to prepare them for higher education, work and engagement in a complex and rapidly changing world.

21st century skills	Associated skills	21st century skills	Associated skills
critical thinking	• analytical thinking • problem-solving • decision-making • reasoning • reflecting and evaluating • intellectual flexibility	creative thinking	• innovation • initiative and enterprise • curiosity and imagination • creativity • generating and applying new ideas • identifying alternatives • seeing or making new links
communication	• effective oral and written communication • using language, symbols and texts • communicating ideas effectively with diverse audiences	collaboration and teamwork	• relating to others (interacting with others) • recognising and using diverse perspectives • participating and contributing • community connections
personal and social skills	• adaptability/flexibility • management (self, career, time, planning and organising) • character (resilience, mindfulness, open- and fair-mindedness, self-awareness) • leadership • citizenship • cultural awareness • ethical (and moral) understanding	Information & communication technologies (ICT) skills	• operations and concepts • accessing and analysing information • being productive users of technology • digital citizenship (being safe, positive and responsible online)

Earth & Environmental Science helps develop the following 21st century skills:

- critical thinking
- creative thinking
- communication
- collaboration and teamwork
- personal and social skills
- information & communication technologies (ICT) skills.

These elements of 21st century skills are embedded in the syllabus objectives, unit objectives and subject matter, and ISMGs for Earth & Environmental Science.

1.2.3 Aboriginal perspectives and Torres Strait Islander perspectives

The QCAA is committed to reconciliation in Australia. 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.

1.2.4 Pedagogical and conceptual frameworks

Defining *inquiry* in science education

This syllabus provides guidance to support schools in aligning a chosen pedagogical framework with the curriculum and assessment expectations outlined in this syllabus. This guidance clarifies the use of the term *inquiry* and articulates 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**.

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.

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 science inquiry (Tytler 2007). This expectation can be seen, for example, in the inclusion of the student experiment and research investigation, and mandatory practicals.

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 taught science inquiry skills (Krajcik et al 2000). The syllabus outlines a number of these skills in the subject matter. Some science inquiry skills will be used to complete the mandatory and suggested practicals. The selection, application and coordination of science inquiry skills will be required in the student experiment and research investigation.

Teachers decide how the science inquiry skills are to be developed. For example, teachers will determine how mandatory practicals 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.

Framework to describe the inquiry process

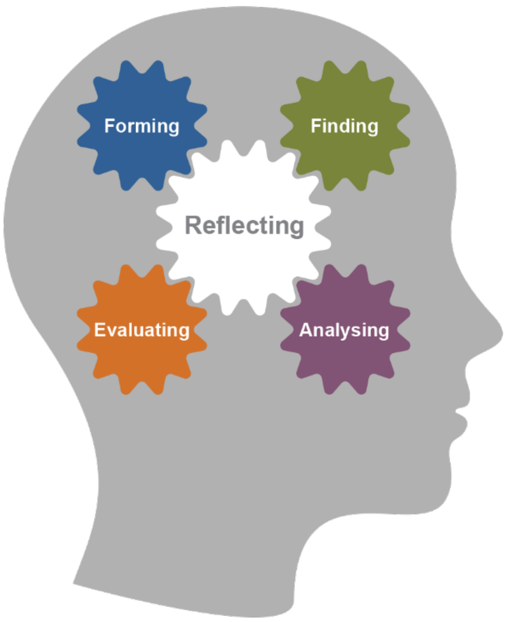
In order to support student engagement in activities involving inquiry, it is useful to establish a common language or framework to distinguish between stages of the process.

The stages involved in any inquiry are:

- forming and describing the inquiry activity
- finding valid and reliable evidence for the inquiry activity
- analysing and 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 3: Stages of inquiry process



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* 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). 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. 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 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 'Guidelines and publications' section of the National Health and Medical Research Council 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 — as detailed in 'Governing principles' above. 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.

1.2.5 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 Earth & Environmental Science. It is particular to each unit in the course of study and provides the basis for student learning experiences.

Subject matter has a direct relationship to the unit objectives, but is of a finer granularity and is more specific. These statements of learning are constructed in a similar way to objectives. Each statement:

- describes an action (or combination of actions) — what the student is expected to do
- describes the element — expressed as information, mental procedures and/or psychomotor procedures
- is contextualised for the topic or circumstance particular to the unit.

Organisation of subject matter

The subject matter is organised as topics within each unit.

The subject matter indicates the required knowledge and skills that students must acquire. Students should experience the mandatory practicals. It is expected that approximately five hours will be required to complete the mandatory practicals that involve fieldwork.

The subject matter from Units 3 and 4 will be assessed by the external examination.

Science as a Human Endeavour

Each Queensland senior science subject requires students to learn and apply aspects of the knowledge and skills of the discipline. 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 will not be assessed, the syllabus provides guidance about 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 Science as a Human Endeavour (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 guidance in each topic. This highlights opportunities for teachers to contextualise the associated subject matter and provides stimulus for the development of claims and research questions for investigation.

Additional opportunities include:

- mandatory and suggested practicals that provide opportunities for students to witness the *nature* of science
- a student experiment that provides opportunities for students to experience how the *development* of new science knowledge is built upon existing knowledge

- a research investigation that provides an opportunity for students to appreciate the *use* and *influence* of scientific evidence to make decisions or to contribute to public debate about a claim.

Finally, the SHE statements at the end of each topic may be used to support the development and interrogation of claims, and be useful as a starting point for the research investigation.

Guidance

The guidance included with each topic is designed to clarify the scope of the subject matter and identify opportunities to integrate science inquiry skills and SHE strands into the subject matter. A number of tags are used to highlight aspects of the guidance:

- **Notional time:** the depth of subject matter coverage is indicated by the amount of time needed to cover this subject matter in the sequence presented in the syllabus.
- **SHE:** identifies an opportunity to integrate an aspect of the Science as a Human Endeavour strand and may also be used as a starting point for a research investigation.
- **Suggested practical:** identifies an opportunity for inquiry skills to be developed and may be used as a starting point for a student experiment.
- **Syllabus links:** identifies links between syllabus units.

1.3 Assessment — general information

Assessments are formative in Units 1 and 2, and summative in Units 3 and 4.

Assessment	Unit 1	Unit 2	Unit 3	Unit 4
Formative assessments	●	●		
Summative internal assessment 1			●	
Summative internal assessment 2			●	
Summative internal assessment 3				●
Summative external assessment			●	●

1.3.1 Formative assessments — Units 1 and 2

Formative assessments provide feedback to both students and teachers about each student's progress in the course of study.

Schools develop internal assessments for each senior subject, based on the learning described in Units 1 and 2 of the subject syllabus. Each unit objective must be assessed at least once.

For reporting purposes, schools should devise at least *two* but no more than *four* assessments for Units 1 and 2 of this subject. At least *one* assessment must be completed for *each* unit.

The sequencing, scope and scale of assessments for Units 1 and 2 are matters for each school to decide and should reflect the local context.

Teachers are encouraged to use the A–E descriptors in the reporting standards (Section 1.4) to provide formative feedback to students and to report on progress.

1.3.2 Summative assessments — Units 3 and 4

Students will complete a total of *four* summative assessments — three internal and one external — that count towards their final mark in each subject.

Schools develop *three* internal assessments for each senior subject, based on the learning described in Units 3 and 4 of the syllabus.

The three summative internal assessments will be endorsed and the results confirmed by the QCAA. These results will be combined with a single external assessment developed and marked by the QCAA. The external assessment results for Earth & Environmental Science will contribute 50% towards a student's result.

Summative internal assessment — instrument-specific marking guides

This syllabus provides ISMGs for the three summative internal assessments in Units 3 and 4.

The ISMGs describe the characteristics evident in student responses and align with the identified assessment objectives. Assessment objectives are drawn from the unit objectives and are contextualised for the requirements of the assessment instrument.

Criteria

Each ISMG groups assessment objectives into criteria. An assessment objective may appear in multiple criteria, or in a single criterion of an assessment.

Making judgments

Assessment evidence of student performance in each criterion is matched to a performance-level descriptor, which describes the typical characteristics of student work.

Where a student response has characeristics from more than one performance level, a best-fit approach is used. Where a performance level has a two-mark range, it must be decided if the best fit is the higher or lower mark of the range.

Authentication

Schools and teachers must have strategies in place for ensuring that work submitted for internal summative assessment is the student's own. Authentication strategies outlined in QCAA guidelines, which include guidance for drafting, scaffolding and teacher feedback, must be adhered to.

Summative external assessment

The summative external assessment adds valuable evidence of achievement to a student's profile. External assessment is:

- common to all schools
- administered under the same conditions at the same time and on the same day
- developed and marked by the QCAA according to a commonly applied marking scheme.

The external assessment contributes 50% to the student's result in Earth & Environmental Science. It is not privileged over the school-based assessment.

1.4 Reporting standards

Reporting standards are summary statements that succinctly describe typical performance at each of the five levels (A–E). They reflect the cognitive taxonomy and objectives of the course of study.

The primary purpose of reporting standards is for twice-yearly reporting on student progress. These descriptors can also be used to help teachers provide formative feedback to students and to align ISMGs.

Reporting standards

A
The student accurately describes and explains 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 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 evidence 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 investigates phenomena by carrying out effective experiments and research investigations. They efficiently collect, collate and process relevant evidence. They critically evaluate processes, claims and conclusions by insightfully scrutinising evidence, extrapolating credible findings, and discussing the reliability and validity of experiments. The student communicates effectively by using scientific representations and language accurately and concisely within appropriate genres.
B
The student accurately describes and explains 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 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 evidence by effectively 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 investigates phenomena by carrying out effective experiments and research investigations. They collect, collate and process relevant evidence. They evaluate processes, claims and conclusions by scrutinising evidence, applying relevant findings and discussing the reliability and validity of experiments. The student communicates accurately by using scientific representations and language within appropriate genres to present information.

C
The student describes and explains 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 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 evidence 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 investigates phenomena by carrying out experiments and research investigations. They collect, collate and process evidence. They evaluate processes, claims and conclusions by describing the quality of evidence, applying findings, and describing the reliability and validity of experiments. The student communicates using scientific representations and language within appropriate genres to present information.

D
The student describes and gives accounts of aspects of concepts, theories, models and systems. They use rudimentary representations of scientific relationships or data to determine unknown scientific quantities or variables. The student analyses evidence 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 carries out aspects of experiments and research investigations. They discuss processes, claims or conclusions. They consider the quality of evidence and conclusions. The student uses scientific representations or language to present information.

E
The student describes scenarios and refers 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. The student communicates information.

2 Unit 1: Introduction to Earth systems

2.1 Unit description

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 the 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.

2.2 Unit objectives

Unit objectives are drawn from the syllabus objectives and are contextualised for the subject matter and requirements of the unit. Each unit objective must be assessed at least once.

Students will:

1. describe and explain 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 evidence 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. investigate phenomena associated with Earth systems and models and the development of the geosphere, atmosphere, hydrosphere and biosphere
6. evaluate processes, claims and conclusions about Earth systems and models and the development of the geosphere, atmosphere, hydrosphere and biosphere
7. communicate understandings, findings, arguments and conclusions about Earth systems and models and the development of the geosphere, atmosphere, hydrosphere and biosphere.

2.3 Topic 1: Earth systems and models

In this topic, students will:

Subject matter	Guidance

Natural systems
• define and describe a system, including:
  – open systems
  – closed systems
  – isolated systems
• describe the difference between open, closed and isolated systems in terms of the flow of energy and matter
• describe each of the four systems: geosphere, atmosphere, hydrosphere and biosphere
• describe the purposes of models using an example that conceptualises a specific Earth and environmental process (e.g. subduction)
• explain the nature of scientific theories and models.
	• **Notional time:** 4 hours
	• In the study of Earth and environmental science, theories and models are used to represent Earth processes. Students should understand the difference between models of Earth processes and the actual Earth processes, including the limitations of models.
	• Students should identify the four systems using the terms used in this syllabus.
	• **SHE:** Students could discuss the main elements of a natural system (i.e. ecosystem) in their local or regional area and recognise inputs and outputs of that system.

2.4 Topic 2: Development of the geosphere

In this topic, students will:

Subject matter	Guidance
Uniformitarianism • explain and apply the principle of uniformitarianism to infer past events and processes using present-day observations.	• **Notional time:** 1 hour • The principle of uniformitarianism could be linked to other fields of science to understand past events and predict future events. • The principle of actualism could be included in the general explanation. • Refer to the glossary for a definition of *uniformitarianism*.

Subject matter	Guidance
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 • describe how geological processes may involve: – slow transitions, including subduction and erosion – fast transitions, including volcanic eruptions and earthquakes • deduce age relationships, including conformable and unconformable geological boundaries, and evaluate decisions made using the principles of stratigraphy • deduce correlations and evaluate decisions about index fossils and the process of correlation • summarise the role of fossils (including index fossils) and stratigraphic evidence in the construction of the fossil record and geological timescale.	• **Notional time:** 4 hours • **SHE:** Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions about the formation and relative ages of geological structures and fossils. • **Suggested practical:** Use secondary data to interpret stratigraphic sequences and infer relative age relationships of fossils and/or sediments.
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; this establishes an absolute timescale and places the age of the Earth at 4.5 billion years • interpret graphical representation of half-life to show how radioisotopes can be used to date rocks and minerals.	• **Notional time:** 1 hour • Use of radioactive decay formulas are not required. • Students should understand that the fewer radioisotopes in a sample, the older the age of the sample. • **SHE:** Advances in science understanding in physics (e.g. radioisotopes/ half-life) can influence geological understanding.
Interior structure of the Earth • describe the Earth's internal differentiation into a layered structure: a solid metallic inner core, a liquid metallic outer core and a silicate mantle and crust • evaluate how the study of seismic waves (P-wave and S-wave shadow zones and discontinuities in seismic wave velocities) and meteorites provides evidence for the Earth's interior structure.	• **Notional time:** 3 hours • Students could create a visual representation to show the interior structure of the Earth. • **SHE:** Development of complex models and/or theories about the interior structure of the Earth often require a wide range of evidence from multiple scientific international organisations.

Subject matter	Guidance

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
• explain the rock cycle
• classify common rocks using keys, tables or flow charts
• evaluate and make reasoned decisions using keys, tables or flow charts to identify rocks.
• **Mandatory practical:** Identify examples of sedimentary, igneous and metamorphic rocks from the local or regional environment using key-based classification.
	• **Notional time:** 7 hours
	• The terms used to describe rock formation in the subject matter are preferred.
	• When students use keys, tables or flow charts to identify rocks, they should evaluate the usefulness and the adequacy of the classification tool and the limitations of the tool.
	• Fieldwork should be used to develop scientific skills, collect data and to develop student understanding of rock formation processes and classification.
	• **Suggested practical:** 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.

Subject matter	Guidance
Soil formation and classification • explain how soil formation requires interaction between atmospheric, geologic, hydrologic and biotic processes, including weathering and erosion • describe the processes of physical (mechanical) and chemical weathering of rock • describe and 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 (i.e. soil ternary diagram) • explain the correlation between soil type and native vegetation (i.e. this correlation is what many soils maps of Australia are based on) • collect and organise data to classify soils and evaluate decisions and limitations made about soil classification. • **Mandatory practical:** Use local soil samples to measure soil properties to classify and assess quality, including organic content, pH, moisture content, soil texture and structure.	• **Notional time:** 8 hours • Students should be using *The Australian Soil Classification* system for identification of soils. • Students are not required to recall the names of different soil types. • Field and/or laboratory work should be used to develop scientific skills, collect data and develop student understanding of soil properties, soil classification and land use. • If fieldwork cannot be done, samples of soil can be obtained directly from local nursery supplies, brought in from outside sources or made up by sourcing and mixing the basic ingredients. • Students could draw, classify or contrast soil profiles in two different locations during fieldwork or from online sources. • A discussion about the correlation between soil type and natural vegetation could look at the relationship to rocks underneath and how this can be used to determine exploration for minerals. • **SHE:** Link knowledge of physical and chemical characteristics of different local or regional soil types to sustainable farming practices, urban development or environmental impacts. • **Suggested practical:** Interpret data to make connections between indicator plant species and land use with specific soil types (e.g. field-based or satellite imagery data).
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination but could be used in the development of claims and research questions for a research investigation.	• **Changing views on the age of the Earth:** The current agreed age of the 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. • **Modern processes as analogues for ancient processes:** The principle of uniformitarianism suggests that change is constant and uniform. • **Understanding the interior of Earth:** The development of supercomputing has enabled the design of complex models of the Earth's interior.

2.5 Topic 3: Development of the atmosphere and hydrosphere

In this topic, students will:

Subject matter	Guidance
Hydrosphere • describe how water naturally occurs in three phases (i.e. solid, liquid, gas) on Earth • 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 • describe and evaluate evidence for theories on the origins of water on Earth, including volcanic outgassing and the impact of icy bodies from space.	• **Notional time:** 3 hours • Students could use visual representations of the distribution of Earth's water throughout Earth's spheres. • **SHE:** Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions about the properties and role of the hydrosphere. • **Suggested practical:** Collect, organise and interpret data about the properties of water in relation to important Earth system processes.

Atmosphere
• describe 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
• describe and evaluate 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.
	• **Notional time:** 3 hours
	• Students should be able to describe general changes in temperature and movement of air masses through each layer of the atmosphere.
	• Further investigation of the ozone layer could look at historical records that show changes in the thickness of the layer at different locations.
	• **SHE:** Development of complex models and theories about the atmosphere often requires a wide range of evidence from multiple disciplines, including geology, biology and meteorology.
	• **SHE:** Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions about the evolution and structure of the atmosphere.
	• **Suggested practical:** Use standard apparatus and techniques to collect, organise and interpret data about meteorological conditions.

Subject matter	Guidance
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination but could be used in the development of claims and research questions for a research investigation.	• **Monitoring Earth's atmosphere:** Global Atmosphere Watch seeks 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. • **Water and the search for life on other planets:** Based on models of Earth, 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.

2.6 Topic 4: Development of the biosphere

In this topic, students will:

Subject matter	Guidance
Origin of the biosphere • describe and evaluate 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.	• **Notional time:** 2 hours • Students do not need to recall the geological timescale; however, it could be used as a tool to assist in understanding the development of life on Earth. • Students do not need to know the earliest examples of fossil records, but this evidence could further demonstrate the type of organisms that first appeared on Earth. • The Miller–Urey experiment could be discussed as an example of laboratory experimentation that has informed theories of life.
Characteristics of the biosphere • describe 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 • discuss how communities are dynamic in nature and processes will allow communities to change as the characteristics of the spheres change.	• **Notional time:** 3 hours • Theories of evolution do not need to be covered. Limited treatment of natural selection could be included. • **Suggested practical:** Collect and analyse data about the characteristics of a community by using a transect study (i.e. quadrats). If possible, a field study with an obvious plant succession would be ideal, but simulations can be used.

Subject matter	Guidance
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 – analysing sedimentary sequences with differing characteristics and inferring the original depositional environment – discussing how past environments and communities can be inferred from sedimentary rocks and enclosed fossils, including limitations of this record • evaluate evidence from the fossil record for the diversification and proliferation of living organisms over time • analyse and evaluate fossil evidence to support theories of mass extinctions and ecosystem change, including the Permian or Cretaceous mass extinction events.	• **Notional time:** 6 hours • Other evidence of the biosphere's history, such as pollen, could be addressed. • **Suggested practical:** Model the process of the formation of different depositional environments. • **SHE:** Link the fossil record to the existence of different organisms and changes in the biosphere over time.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination but could be used in the development of claims and research questions for a research investigation.	• **Evidence for the origin of life:** Stanley Miller and Harold Urey indicated that by introducing a spark to an aqueous mixture of compounds likely to have been present on early Earth, organic molecules could form. • **Evidence for a 'sixth extinction':** Current data on global species loss indicates that a 'sixth extinction' of greater severity than previous events may be imminent. • **Evidence for changes to the Australian environment over time:** The 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.

2.7 Assessment guidance

In constructing assessment instruments for Unit 1, schools should ensure that the objectives cover, or are chosen from, the unit objectives. If one assessment instrument is developed for a unit, it must assess all the unit objectives; if more than one assessment instrument is developed, the unit objectives must be covered across those instruments.

It is suggested that student performance on Unit 1 is assessed using techniques modelled on the techniques used in Unit 3:

- a student experiment
- an examination that includes some items modelled on the data test.

3 Unit 2: Earth processes — energy transfers and transformations

3.1 Unit description

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 the 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.

3.2 Unit objectives

Unit objectives are drawn from the syllabus objectives and are contextualised for the subject matter and requirements of the unit. Each unit objective must be assessed at least once.

Students will:

1. describe and explain energy for Earth, atmospheric, hydrologic and biogeochemical processes
2. apply understanding of energy for Earth, atmospheric, hydrologic and biogeochemical processes
3. analyse evidence about energy for Earth, atmospheric, hydrologic and biogeochemical processes
4. interpret evidence about energy for Earth, atmospheric, hydrologic and biogeochemical processes
5. investigate phenomena associated with energy for Earth, atmospheric, hydrologic and biogeochemical processes
6. evaluate processes, claims and conclusions about energy for Earth, atmospheric, hydrologic and biogeochemical processes
7. communicate understandings, findings, arguments and conclusions about energy for Earth, atmospheric, hydrologic and biogeochemical processes.

3.3 Topic 1: Energy for Earth processes

In this topic, students will:

Subject matter	Guidance
Energy • describe different types of energy, including nuclear, kinetic, gravitational, thermal and light • describe and apply the first law of thermodynamics to Earth systems • explain and investigate 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 • analyse primary data on energy transfer, including convection, conduction and radiation.	• **Notional time:** 4 hours • Energy transformations and storage in Earth systems (i.e. evaporation, movement of tectonic plates, photosynthesis, the ocean as a heat sink) should only be introduced at this stage and will be developed throughout this unit. • Primary data from the suggested practical can be used to analyse energy transfer, including convection, conduction and radiation. • **Suggested practical:** Through a laboratory experiment, investigate modes of energy transfer, including convection, conduction and radiation.
Energy and the water cycle • describe the water cycle, including the terms *evaporation*, *condensation*, *precipitation*, *run-off*, *snowmelt*, *infiltration* and *groundwater storage* • explain and investigate the relationship between thermal and light energy from the Sun and phase changes of water as it relates to the water cycle • construct a flow chart to show the transfer, transformation and storage of energy in the water cycle.	• **Notional time:** 2 hours • Students could create visual representations of the water cycle. • A description of the water cycle should be covered in terms of energy, not change of state as covered in the P–10 curriculum. • **Syllabus link:** The use of thermal and light energy as sources of energy for photosynthesis is covered in Unit 2 Topic 2: Energy for biogeochemical processes.
Energy and the Earth's core • describe how the decay of radioisotopes is the source of heat in the Earth's core • explain how energy is transferred from the core to the crust • examine how transformations of kinetic, gravitational and thermal energy create movement of tectonic plates, including mantle convection, plume formation and slab pull.	• **Notional time:** 5 hours • **Suggested practical:** 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. • **Syllabus link:** Link energy and the Earth's core to the Earth's layered structure in Unit 1 Topic 2: Development of the geosphere. • **Syllabus link:** Link definition of *radioisotopes* to dating of rocks and minerals in Unit 1 Topic 2: Development of the geosphere.

Subject matter	Guidance
Science as Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination but could be used in the development of claims and research questions for a research investigation.	• **Development of plate tectonic theory:** Alfred Wegener, a meteorologist, first proposed a theory of continental drift in 1912 and followed this with publication of an expanded theory in 1915. • **Measuring plate movement:** Heat energy stored and generated in Earth's interior creates convection currents on a massive, continental scale that result in the movement of very large sections of Earth's rigid crust and uppermost mantle. • **Geothermal energy:** Geothermal heat from Earth's interior provides a low-carbon-emission energy source.

3.4 Topic 2: Energy for atmospheric and hydrologic processes

In this topic, students will:

Subject matter	Guidance
Solar energy • describe solar energy as electromagnetic radiation, including ultraviolet radiation • analyse how the transfer of solar energy to the Earth's surface is influenced by: – impeded transfer of ultraviolet radiation due to its interaction with atmospheric ozone – physical characteristics of the Earth's surface – albedo – non-anthropogenic particulate matter – atmospheric reflection.	• **Notional time:** 4 hours • **SHE:** 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). • **SHE:** Advances in science understanding 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. • **Syllabus link:** Link ozone layer to structure of the atmosphere in Unit 1 Topic 3: Development of the atmosphere and hydrosphere. • **Syllabus link:** Link solar energy to renewable resources in Unit 3 Topic 2: Use of renewable Earth resources.

Subject matter	Guidance
Thermal radiation and the greenhouse effect • explain how thermal radiation is absorbed and emitted from the Earth's surface • compare the major greenhouse gases and their sources, including carbon dioxide, methane and water vapour • explain how greenhouse gases can reflect or scatter some infrared radiation, leading to the greenhouse effect • analyse primary and secondary data relevant to the greenhouse effect. • **Mandatory practical:** Identify the effect of greenhouse conditions on temperature, using a model.	• **Notional time:** 6 hours • **Suggested practical**: Use secondary data to compare or contrast Earth's atmosphere with sister planets Venus and Mars to appreciate the impact of greenhouse gases. • **SHE:** Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions about the possible causes and effects of climate change. • **SHE:** The use of scientific knowledge of thermal radiation and the greenhouse effect has beneficial and/or unintended consequences, resulting in a banning of CFCs. • **Syllabus link:** Link greenhouse effect to climate change in Unit 4 Topic 2 The cause and impact of global climate change.

Air pressure
• explain how air pressure is generated
• explain that movement of air is due to equalisation of pressure differences caused by heating and cooling, as well as Earth's rotation and revolution
• apply knowledge of air pressure:
  – to explain patterns of systematic atmospheric circulation
  – to explain the transfer of thermal energy around the Earth's surface via systematic atmospheric circulation
• identify common features on synoptic charts and satellite images, including high and low pressure and isobars.
• **Mandatory practical:** Interpret the features of synoptic charts and satellite images, including high and low pressure and isobars.
	• **Notional time:** 4 hours
	• Students should learn how to read and interpret synoptic charts and satellite images by understanding how features are represented in the charts and images.
	• **Syllabus link:** Link air pressure to structure of the atmosphere in Unit 1 Topic 3: Development of the atmosphere and hydrosphere.

Subject matter	Guidance

Ocean currents
• explain how global oceans act as heat sinks
• explain that movement of systematic ocean currents, including the global ocean conveyor model, is due to:
  – equalisation of temperature differences caused by heating and cooling
  – Earth's rotation, gravity and seasonality.
	• **Notional time:** 2 hours
	• Students should:
	  – understand the role of salinity in producing ocean currents (i.e. changes in water density affect ocean currents)
	  – recognise that large permanent ocean currents move warm water from the equatorial regions towards the poles, as well as cool water from the polar regions towards the equator.
	• Students could construct a visual representation of the global ocean conveyor model.
	• **SHE:** Development of the global ocean conveyor model requires a wide range of evidence from multiple individuals and across scientific disciplines.

Weather patterns • describe *weather* as an interaction between the atmosphere and hydrosphere • explain El Niño and La Niña • compare the conditions causing and effects of El Niño and La Niña at local and global levels, including the Southern Oscillation Index (SOI) • analyse secondary data and make reasoned decisions about El Niño and La Niña patterns.	• **Notional time:** 4 hours • **Suggested practical:** Interpret secondary data, including ocean temperature, air pressure, rainfall and SOI to identify El Niño and La Niña patterns. • **SHE:** Examine how meteorology relies on clear communication and international conventions. • **SHE:** Discuss 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. • **Syllabus link:** Link El Niño and La Niña to climate change in Unit 4, Topic 2: The cause and impact of global climate change.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination but could be used in the development of claims and research questions for a research investigation.	• **Predicting the weather:** 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. • **Climate change and the global ocean conveyor:** The global ocean conveyor is important in regulating global climate.

Topic 3: Energy for biogeochemical processes

In this topic, students will:

Subject matter	Guidance
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 • define *net primary production* as the rate at which new biomass is generated, mainly through photosynthesis • interpret and analyse energy transfer and transformation through food webs, energy pyramids and trophic levels from secondary data.	• **Notional time:** 4 hours • An understanding of light and dark reactions in photosynthesis is not required. • **Suggested practical:** Conduct an investigation into photosynthesis by testing the effect of a limiting factor (e.g. temperature, CO_2 concentration, light intensity) on the process. • **Syllabus link:** Link photosynthesis to the modification of the atmosphere in Unit 1 Topic 3: Development of the atmosphere and hydrosphere. • **Syllabus link:** Link biomass to formation and availability of resources in Unit 1 Topic 3: Development of the atmosphere and hydrosphere.
Ecosystem carrying capacity • define *carrying capacity* in relation to ecosystems • infer how energy and matter directly affect the number of organisms that can be supported in an ecosystem • construct representations to show the differences in carrying capacity between ecosystems.	• **Notional time:** 2 hours • **Suggested practical:** Graph secondary data to compare carrying capacities in different ecosystems (e.g. a desert and tropical rainforest).
Biogeochemical cycling • explain the cycling of nitrogen and phosphorus between Earth systems • analyse secondary data (i.e. 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.	• **Notional time:** 3 hours. • Field and/or laboratory work should be used to develop scientific skills, collect data and to develop student understanding of cycling of nitrogen and phosphorous. • Water samples can include: tap, river, ground, pond, lake, ocean, aquarium, tank, rain, bottled, pool, grey water. • Students could construct representations of the nitrogen and phosphorus cycles to show the flow of energy and matter between the Earth systems (i.e. interactions). • **Suggested practical:** Collect local water samples and compare the levels of nitrogen and phosphorous in each sample.

Subject matter	Guidance
Carbon cycle • explain the cycling of carbon between Earth systems • identify examples of energy storage, transfer and transformation in the carbon cycle • describe 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.	• **Notional time:** 5 hours • Students could construct representations of the carbon cycle to show the flow of energy and matter between the Earth systems (i.e. interactions). • **Suggested practical:** Demonstrate the precipitation of carbonate minerals in solution by bubbling carbon dioxide through limewater. • **SHE:** 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. • **Syllabus link:** Link the carbon cycle to the formation of non-renewable resources in Unit 3 Topic 1: Use of non-renewable Earth resources.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination but could be used in the development of claims and research questions for a research investigation.	• **Biological soil crusts and nutrient cycling in Australian rangelands:** Biological soil crusts play an important role in soil fertility and protect the soil surface from erosion and evaporation. • **Closed ecosystem models:** Artificial ecosystems have been developed to aid research in ecosystem function. • **Marine primary production:** Phytoplankton populations appear to be rising in a number of locations across the globe as they absorb more carbon dioxide from the atmosphere.

3.5 Assessment guidance

In constructing assessment instruments for Unit 2, schools should ensure that the objectives cover, or are chosen from, the unit objectives. If one assessment instrument is developed for a unit, it must assess all the unit objectives; if more than one assessment instrument is developed, the unit objectives must be covered across those instruments.

It is suggested that student performance on Unit 2 is assessed using techniques modelled on the techniques used in Unit 4:

- a research investigation
- an examination that includes some items modelled on the data test.

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

4.1 Unit description

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.

4.2 Unit objectives

Unit objectives are drawn from the syllabus objectives and are contextualised for the subject matter and requirements of the unit. Each unit objective must be assessed at least once.

Students will:

Unit objective	IA1	IA2	EA
1. describe and explain the use of renewable and non-renewable resources			•
2. apply understanding of the use of renewable and non-renewable resources	•	•	•
3. analyse evidence about the use of renewable and non-renewable resources	•	•	•
4. interpret evidence about the use of renewable and non-renewable resources	•	•	•
5. investigate phenomena associated with the use of renewable and non-renewable resources		•	
6. evaluate processes, claims and conclusions about the use of renewable and non-renewable resources		•	
7. communicate understandings, findings, arguments and conclusions about the use of renewable and non-renewable resources.		•	

4.3 Topic 1: Use of non-renewable Earth resources

In this topic, students will:

Subject matter	Guidance
Formation and location of non-renewable mineral and energy resources • describe the differences between metallic, non-metallic and energy resources • explain how non-renewable mineral and energy resources are formed over geological timescales, which means they are not readily replenished within a typical lifetime, including: – metallic resources (bauxite, gold and iron ore) – non-metallic (mineral sands) – fossil fuels (coal, coal seam gas, crude oil and natural gas) • explain how the location of non-renewable mineral and energy resources is related to their geological setting, including: – igneous settings, including magmatic, hydrothermal and exhalative processes – sedimentary settings, including placer deposits, geochemical processes and stratigraphic traps – metamorphic settings • predict the viability of a location as a source of metallic, non-metallic or fossil fuels based on its geological setting.	• **Notional time:** 5 hours • Students could explore non-renewable resources relevant to their geological context. • **Suggested practical:** Model location, exploration and extraction of a metallic resource. Use a locality map to predict the location of a metallic resource. • **SHE:** Models and theories for the formation of fossil fuels are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power. • **Syllabus link:** Link formation of non-renewable resources to the geosphere in Unit 1 Topic 2: Development of the geosphere and carbon cycle in Unit 2 Topic 3: Energy for biogeochemical processes.

Subject matter	Guidance
Exploration of mineral and energy resources • describe the role of licensing and permissions in resource exploration • 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, gravitational and radioactive testing – direct sampling geochemical techniques, including soil, rock sampling, auguring, drilling and core sampling • explore the relationship between methods used to explore for specific resources and the physical properties of those resources • interpret secondary geophysical and geochemical data to predict the presence of a resource. • **Mandatory practical:** Analyse and interpret geophysical and geochemical exploration datasets.	• **Notional time:** 5 hours • **SHE:** 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. • **SHE:** People can use scientific knowledge about exploration for coal seam gas (CSG) to inform the assessment and evaluation of economic risk.
Extraction, separation and processing of mineral and energy resources • explain how the type, volume and location of mineral and energy resources influences the methods of extraction, including: – dredging – open-cut – onshore and offshore drilling – fracking – room and pillar (also known as bord and pillar) – stoping • explain separation and processing techniques for: – metallic and non-metallic resources, including crushing, milling, sluicing, froth flotation and smelting – fossil fuels, including separation, fractional distillation and fracking • analyse the relationship between the physical and chemical properties of Earth resources and extraction, separation and processing techniques used for: – metallic resources (bauxite, gold and iron ore) – non-metallic resources (mineral sands) – fossil fuels (coal and crude oil).	• **Notional time:** 6 hours • Students could investigate how the value of resources fluctuates depending on the: – extent of the resource – market value and associated economic factors – feasibility of the extraction method. • **Suggested practical:** Design and conduct experiments to model other separation or processing techniques (e.g. crushing, smelting and froth flotation, gravitational separation).

Subject matter	Guidance
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, including: – air quality – water quality, including pH, dissolved oxygen, turbidity – soil quality, including pH, erosion, changes in soil structure – distribution and abundance survey of organisms – noise pollution • interpret data from environmental monitoring • analyse and evaluate the effectiveness of the resource industries' environmental monitoring strategies. • **Mandatory practical:** Conduct an experiment to model turbidity management strategies, using settling ponds.	• **Notional time:** 4 hours • **Suggested practical:** Investigate the effect of slope/revegetation on the volume of water run-off and amount of topsoil lost through erosion. • **Suggested practical:** Model distribution and abundance surveys using quadrats or transects. An example could be a survey of weed species in a local area to determine human impact. • **Suggested practical:** Investigate evaporation rates of water (surface area, volume, temperature, turbidity, salinity in lake/dam situation). • **SHE:** Link scientific knowledge about environmental monitoring and management to a social, economic or cultural context in which it is considered. • **SHE:** People can use quantitative data collected from environmental monitoring to assess and evaluate the risk to the environment.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination but could be used in the development of claims and research questions for a research investigation.	• **Locating and assessing resources for extraction:** Modern technologies have had a significant impact on improving the efficiency and effectiveness of locating and extracting resources, including through the use of 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. • **Coal seam gas extraction in Australia:** Community concern over CSG industry development also reflects the limited information available on the long-term effects of CSG industries. • **Carbon pricing:** Carbon pricing can provide funds for investment in cleaner energy, and aims to act as an incentive for businesses to reduce their pollution.

4.4 Topic 2: Use of renewable Earth resources

In this topic, students will:

Subject matter	Guidance
Renewable resources • describe renewable resources as those that are typically replenished at timescales of years to decades: – harvestable resources, including ▪ water, biota ▪ energy resources, including solar, wind and geothermal – ecosystem services, including clean air, food and water as environmental assets.	• **Notional time:** 1 hour • This topic is intended to introduce students to relevant terminology. • Students could look further at: – research to understand how renewable energy (e.g. wind farming, hydropower and solar energy) has a positive effect on Aboriginal communities – the creative ways of recycling through art movements in the Torres Strait Islands – the benefits of Aboriginal ranger programs around Queensland – the pros and cons of commercial production of bush tucker.
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.	• **Notional time:** 1 hour • This topic is intended to introduce students to relevant terminology. • Students could look at: – the local knowledge of community for sustainable hunting, protection and recordkeeping for animals, fish and birds – the connection to country that Aboriginal peoples and Torres Strait Islander peoples have that enables a sustainable environment – the intricate way that culture and a community's country (land, environment) is part of who they are (e.g. highlight links between land management tasks and how the oral tradition of storytelling enables survival of a community) – the scope for sustainable farming using the Kununurra seasonal calendar. • **Syllabus link:** Link supporting services to soil formation in Unit 1 Topic 2: Development of the geosphere.

Subject matter	Guidance
Replenishment of renewable resources • explain how the sustainable use of a resource is dependent on abundance and its replenishment rate at local, regional and global scales for: – biota, including marine species and forestry – surface water and groundwater – geothermal • investigate sustainability of renewable resources at a local, regional and global scale • **Mandatory practical:** Use secondary data to investigate sustainability for one of the following: – biota, including marine species and forestry – surface water and groundwater – geothermal.	• **Notional time:** 4 hours • **SHE:** Scientific knowledge about renewable resources can be used to develop and evaluate projected economic, social and environmental effects and to design action for sustainability. • **Syllabus link**: Link geothermal energy to radioisotopes as the source of Earth's energy in Unit 2 Topic 1: Energy for Earth processes. • **Syllabus link:** Link replenishment of renewable resources to net primary production in Unit 2 Topic 3: Energy for biogeochemical processes.
Energy transfer and storage • investigate 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 – evaluating their relative potential as an energy source. • **Mandatory practical:** Conduct an experiment to calculate and compare the efficiency of renewable energy sources (units such as kW/hr will allow direct comparison between renewable energy sources) including solar, wind and hydroelectric, evaluating their relative potential as an energy source.	• **Notional time:** 4 hours • **Syllabus link:** Link solar energy to thermal radiation in Unit 2 Topic 1: Energy for Earth processes. • **Syllabus link:** Link transfer and storage of energy to methods of energy transfer (e.g. conduction, convection, radiation) in Unit 2 Topic 1: Energy for Earth processes.
Availability of fresh water • explain how the availability and quality of fresh water at local and regional scales is influenced by: – human activities, including provisioning of dams, urbanisation, over-extraction and pollution – natural processes, including salinity, siltation, drought and algal blooms • compare local and regional issues that affect availability and quality of fresh water • predict and propose solutions relating to siltation, drought and algal blooms.	• **Notional time:** 5 hours • Students could use secondary data available about the quality and availability of fresh water in the Murray–Darling River Basin. • Appropriate representations (e.g. flow charts, concept maps or diagrams) should be used to explain how the availability of fresh water is influenced by human activities and natural processes. • **Suggested practical:** Conduct an analysis of local water samples using standard water quality testing. This could be compared to secondary data from other waterways, or historical data of the same waterway.

Subject matter	Guidance
Human impact on ecosystems • explain how human activities, including species removal, habitat destruction, pest introduction and dryland salinity, can affect ecosystems • compare case studies of positive and negative human influences on ecosystem viability at local, regional and global scales.	• **Notional time:** 4 hours • The negative effect of human activities on ecosystems should focus on how these activities can directly or indirectly reduce animal and plant populations to beneath the threshold of population viability at a local, regional and global scale. Responsive human activities can take up to 100 years to fully restore ecosystems. • Examples of case studies could include species removal, habitat destruction, pest introduction and dryland salinity, as well as integrated pest management, beneficial introduction of species and Aboriginal sustainability practices and Torres Strait Islander sustainability practices. • **SHE:** The negative impact of human activities on ecosystems could be contextualised with 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.
Sustainable harvesting of biota • explain how over-harvesting biota reduces populations to beneath the threshold of population viability, including native fisheries • describe how population size and nomadic culture of Aboriginal peoples and Torres Strait Islander peoples allowed sustainable harvesting of Australian biota • determine the maximum sustainable yield of relevant aquatic or terrestrial Australian biota using secondary data.	• **Notional time:** 3 hours • **SHE:** Scientific knowledge about sustainable harvesting of aquacultural 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.
Ecological footprint • explain the concept of an ecological footprint (i.e. magnitude of demand for ecological resources) • describe how the demand for ecological resources must be balanced against producing, harvesting, transporting and processing, as well as associated wastes • make reasoned judgments about the viability of using resources relative to maintaining a sustainable ecological footprint.	• **Notional time:** 3 hours. • **Suggested practical:** Students could compare the ecological footprint in different countries using secondary data. • **SHE:** 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.

Subject matter	Guidance
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination but could be used in the development of claims and research questions for a research investigation.	• **Maximum sustainable yield models and fisheries:** 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. • **Putting a dollar value on ecosystem services:** An economic value for ecosystem services could 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. • **Food security and protecting agricultural biodiversity:** 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.

4.5 Assessment

4.5.1 Summative internal assessment 1 (IA1): Data test (10%)

Description

This assessment focuses on the application of a range of cognitions to multiple provided items.

Student responses must be completed individually, under supervised conditions, and in a set timeframe.

Assessment objectives

This assessment technique is used to determine student achievement in the following objectives:

2. apply understanding of the 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 evidence about the use of renewable or non-renewable resources to identify trends, patterns, relationships, limitations or uncertainty in datasets
4. interpret evidence about the use of renewable or non-renewable resources to draw conclusions based on analysis of datasets.

Note: Objectives 1, 5, 6 and 7 are not assessed in this instrument.

Specifications

Description

Students respond to items using qualtitative data and/or quantitative data derived from the mandatory or suggested practicals, activities or case studies from the unit being studied.

The data test contains two to four datasets and consists of a number of different types of items, which include:

- short response items requiring single-word, sentence or short paragraph responses
- calculating using algorithms
- interpreting datasets.

Mark allocations

Percentage of marks	Objective	Cognition and nature of response
~ 30%	2. apply understanding of the 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	Students calculate, identify, recognise and use evidence to determine unknown scientific quantities or features.
~ 30%	3. analyse evidence about the use of renewable or non-renewable resources to identify trends, patterns, relationships, limitations or uncertainty in datasets	Students categorise, classify, contrast, distinguish, organise or sequence evidence to identify trends, patterns, relationships, limitations or uncertainty in datasets.

Percentage of marks	Objective	Cognition and nature of response
~ 40%	4. interpret evidence about the use of renewable or non-renewable resources to draw conclusions based on analysis of datasets.	Students compare, deduce extrapolate, infer, justify or predict using evidence to draw conclusions based on analysis of the datasets.

Conditions

- Time: 60 minutes plus 10 minutes perusal.
- Length: up to 500 words in total, consisting of
  - short responses, i.e. single words, sentences or short paragraphs (fewer than 50 words)
  - paragraphs, 50–250 words per item
  - other types of item responses (e.g. interpreting and calculating) should allow students to complete the response in the set time.
- Other:
  - QCAA-approved graphics calculator permitted
  - unseen stimulus.

Summary of the instrument-specific marking guide

The following table summarises the criteria, assessment objectives and mark allocation for the data test.

Criterion	Objectives	Marks
Data test	2, 3, 4	10
Total		**10**

Note: Unit objectives 1, 5, 6 and 7 are not assessed in this instrument.

Instrument-specific marking guide

Criterion: Data test

Assessment objectives

2. apply understanding of the 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 evidence about the use of renewable or non-renewable resources to identify trends, patterns, relationships, limitations or uncertainty in datasets
4. interpret evidence about the use of renewable or non-renewable resources to draw conclusions based on analysis of datasets

The student work has the following characteristics:	Cut-off	Marks
• consistent demonstration, across a range of scenarios about the use of renewable or non-renewable resources, of – selection and correct application of scientific concepts, theories,	> 90%	10

The student work has the following characteristics:	Cut-off	Marks
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.	> 80%	9
• consistent demonstration, in scenarios about the use of renewable or non-renewable resources, 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, in scenarios about the use of renewable or non-renewable resources, 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, in scenarios about the use of renewable or non-renewable resources, 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, in scenarios about the use of renewable or non-renewable resources, 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
• does not satisfy any of the descriptors above.	≤ 1%	0

4.5.2 Summative internal assessment 2 (IA2): Student experiment (20%)

Description

This assessment requires students to research a question or hypothesis through collection, analysis and synthesis of primary data. A student experiment uses investigative practices to assess a range of cognitions in a particular context. Investigative practices include locating and using information beyond students' own knowledge and the data they have been given.

Research conventions must be adhered to. This assessment occurs over an extended and defined period of time. Students may use class time and their own time to develop a response.

Assessment objectives

This assessment technique is used to determine student achievement in the following objectives:

2. apply understanding of the use of renewable or non-renewable resources to modify experimental methodologies and process primary data
3. analyse experimental evidence about the use of renewable or non-renewable resources
4. interpret experimental evidence about the use of renewable or non-renewable resources
5. investigate phenomena associated with the use of renewable or non-renewable resources through an experiment
6. evaluate experimental processes and conclusions about the use of renewable or non-renewable resources
7. communicate understandings and experimental findings, arguments and conclusions about the use of renewable or non-renewable resources.

Note: Objective 1 is not assessed in this instrument.

Specifications

Description

In the student experiment, students modify (i.e. refine, extend or redirect) an experiment in order to address their own related hypothesis or question. It is sufficient that students use a practical performed in class or a simulation as the basis for their methodology and research question.

In order to complete the assessment task, students must:

- 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 sufficient and 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 extensions to the experiment
- communicate findings in an appropriate scientific genre (e.g. report, poster presentation, journal article, conference presentation).

*The steps indicated with an asterisk above may be completed in groups. All other elements must be completed individually.

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.

Conditions

- Time: 10 hours class time. This time will not necessarily be sequential. Students must perform the majority of the task during class time, including
  - performing background research and developing the methodology
  - conducting the experiment
  - processing and analysing evidence and evaluating the methodology
  - preparing and presenting the response (e.g. writing the scientific report, constructing and presenting the scientific poster).
- Length:
  - written (e.g. scientific report), 1500–2000 words

    or
  - multimodal presentation (e.g. scientific poster presentation), 9–11 minutes.
- Other:
  - students may work collaboratively with other students to develop the methodology and perform the experiment; all other stages (e.g. processing of data, analysis of evidence and evaluation of the experimental process) must be carried out individually
  - the response must be presented using an appropriate scientific genre (e.g. report, poster presentation, journal article, conference presentation) and contain
    - a research question
    - a rationale for the experiment
    - reference to the initial experiment and identification and justification of modifications to the methodology
    - raw and processed qualitative data and/or quantitative data
    - analysis of the evidence
    - conclusion/s based on the interpretation of the evidence
    - evaluation of the methodology and suggestions of improvements and extensions to the experiment
    - a reference list.

Summary of the instrument-specific marking guide

The following table summarises the criteria, assessment objectives and mark allocation for the student experiment.

Criterion	Objectives	Marks
Research and planning	2, 5	6
Analysis of evidence	2, 3, 5	6
Interpretation and evaluation	4, 6	6
Communication	7	2
Total		**20**

Note: Unit objective 1 is not assessed in this instrument.

Instrument-specific marking guide

Criterion: Research and planning

Assessment objectives

2. apply understanding of the use of renewable or non-renewable resources to modify experimental methodologies and process primary data
5. investigate phenomena associated with the use of renewable or non-renewable resources through an experiment

The student work has the following characteristics:	Marks
• informed application of understanding of the use of renewable or non-renewable resources to modify experimental methodologies demonstrated by – a considered rationale for the experiment – justified modifications to the methodology • effective and efficient investigation of phenomena associated with the use of renewable or non-renewable resources demonstrated by – a specific and relevant research question – a methodology that enables the collection of sufficient, relevant data – considered management of risks and ethical or environmental issues.	5–6
• adequate application of understanding of the use of renewable or non-renewable resources to modify experimental methodologies demonstrated by – a reasonable rationale for the experiment – feasible modifications to the methodology • effective investigation of phenomena associated with the use of renewable or non-renewable resources demonstrated by – a relevant research question – a methodology that enables the collection of relevant data – management of risks and ethical or environmental issues.	3–4
• rudimentary application of understanding of the use of renewable or non-renewable resources to modify experimental methodologies demonstrated by – a vague or irrelevant rationale for the experiment – inappropriate modifications to the methodology	1–2

The student work has the following characteristics:	Marks
• ineffective investigation of phenomena associated with the use of renewable or non-renewable resources demonstrated by – an inappropriate research question – a methodology that causes the collection of insufficient and irrelevant data – inadequate management of risks and ethical or environmental issues.	
• does not satisfy any of the descriptors above.	0

Criterion: Analysis of evidence

Assessment objectives

2. apply understanding of the use of renewable or non-renewable resources to modify experimental methodologies and process primary data
3. analyse experimental evidence about the use of renewable or non-renewable resources
5. investigate phenomena associated with the use of renewable or non-renewable resources through an experiment

The student work has the following characteristics:	Marks
• appropriate application of algorithms, visual and graphical representations of data about the use of renewable or non-renewable resources demonstrated by correct and relevant processing of data • systematic and effective analysis of experimental evidence about the use of renewable or non-renewable resources demonstrated by – thorough identification of relevant trends, patterns or relationships – thorough and appropriate identification of the uncertainty and limitations of evidence • effective and efficient investigation of phenomena associated with the use of renewable or non-renewable resources demonstrated by the collection of sufficient and relevant raw data.	5–6
• adequate application of algorithms, visual and graphical representations of data about the use of renewable or non-renewable resources demonstrated by basic processing of data • effective analysis of experimental evidence about the use of renewable or non-renewable resources demonstrated by – identification of obvious trends, patterns or relationships – basic identification of uncertainty and limitations of evidence • effective investigation of phenomena associated with the use of renewable or non-renewable demonstrated by the collection of relevant raw data.	3–4
• rudimentary application of algorithms, visual and graphical representations of data about the use of renewable or non-renewable resources demonstrated by incorrect or irrelevant processing of data • ineffective analysis of experimental evidence about the use of renewable or non-renewable resources demonstrated by – identification of incorrect or irrelevant trends, patterns or relationships – incorrect or insufficient identification of uncertainty and limitations of evidence • ineffective investigation of phenomena associated with the use of renewable or non-renewable resources demonstrated by the collection of insufficient and irrelevant raw data.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Interpretation and evaluation

Assessment objectives

4. interpret experimental evidence about the use of renewable or non-renewable resources
6. evaluate experimental processes and conclusions about the use of renewable or non-renewable resources

The student work has the following characteristics:	Marks
• insightful interpretation of experimental evidence about the use of renewable or non-renewable resources demonstrated by justified conclusion/s linked to the research question • critical evaluation of experimental processes about the use of renewable or non-renewable resources demonstrated by – 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.	5–6
• adequate interpretation of experimental evidence about the use of renewable or non-renewable resources demonstrated by reasonable conclusion/s relevant to the research question • basic evaluation of experimental processes about the use of renewable or non-renewable resources demonstrated by – reasonable description of the reliability and validity of the experimental process – suggested improvements and extensions to the experiment that are related to the analysis of evidence.	3–4
• invalid interpretation of experimental evidence about the use of renewable or non-renewable resources demonstrated by inappropriate or irrelevant conclusion/s • superficial evaluation of experimental processes about the use of renewable or non-renewable resources demonstrated by – cursory or simplistic statements about the reliability and validity of the experimental process – ineffective or irrelevant suggestions.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Communication

Assessment objective

7. communicate understandings and experimental findings, arguments and conclusions about the use of renewable or non-renewable resources

The student work has the following characteristics:	Marks
• effective communication of understandings and experimental findings, arguments and conclusions about the use of renewable or non-renewable resources demonstrated by – fluent and concise use of scientific language and representations – appropriate use of genre conventions – acknowledgment of sources of information through appropriate use of referencing conventions.	2
• adequate communication of understandings and experimental findings, arguments and conclusions about the use of renewable or non-renewable resources demonstrated by – competent use of scientific language and representations – use of basic genre conventions – use of basic referencing conventions.	1
• does not satisfy any of the descriptors above.	0

4.5.3 Summative external assessment (EA): Examination (50%)

General information

Summative external assessment is developed and marked by the QCAA. In Earth & Environmental Science, it contributes 50% to a student's overall subject result.

Summative external assessment assesses learning from both Units 3 and 4.

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.

See Section 5.5.2.

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

5.1 Unit description

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.

5.2 Unit objectives

Unit objectives are drawn from the syllabus objectives and are contextualised for the subject matter and requirements of the unit. Each unit objective must be assessed at least once.

Students will:

Unit objective	IA3	EA
1. describe and explain 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 evidence 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. investigate phenomena associated with the cause and impact of Earth hazards and global climate change	•	
6. evaluate processes, claims and conclusions about the cause and impact of Earth hazards and global climate change	•	
7. communicate understandings, findings, arguments and conclusions about the cause and impact of Earth hazards and global climate change.	•	

5.3 Topic 1: The cause and impact of Earth hazards

In this topic, students will:

Subject matter	Guidance
Earth hazards and plate tectonic processes • describe what occurs at plate boundaries, including divergent, convergent and transform boundaries • explain how earthquakes, volcanoes and tsunamis are the result of: – plate tectonics – interactions between Earth's systems • explain how hazardous outcomes of earthquakes, volcanoes and tsunamis can affect life, health, property and the environment (biosphere) • explain and investigate how the occurrence of these events influences other Earth processes in the atmosphere, hydrosphere and lithosphere, including the effect of ash clouds on global weather patterns • evaluate 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. • **Mandatory practical:** Gather and analyse secondary data on recent and/or historic volcanic activity to evaluate the relationship between volcanic eruptions and the effect of ash clouds on global temperature patterns.	• **Notional time:** 6 hours • Students could use geological maps of the Earth to locate boundary types and model the processes that have contributed to their formation, including: – divergent boundaries – convergent boundaries – transform boundaries. • **Suggested practical:** Model the design and location of buildings to mitigate against hazards, such as earthquakes and tsunamis. • **SHE:** Scientific knowledge can be used to evaluate projected environmental impacts of earthquakes, volcanic eruptions and tsunamis and to design strategies to limit environmental, social and economic consequences on a community or specific geographical location. • **Syllabus link:** Link to Unit 1: Interactions of spheres. • **Syllabus link:** Link to Unit 2: Driving forces of plate tectonics.
Predicting Earth hazards • analyse data, including earthquake location and frequency data, and ground motion monitoring to map potentially hazardous zones for earthquakes, volcanic eruptions and tsunamis • evaluate secondary data and use it to predict the location and probability of repeat occurrences of hazardous Earth events, including volcanic eruptions, earthquakes and tsunamis. • **Mandatory practical:** Construct a map of hazardous zones by using secondary data sources and research from valid historical records to predict possible future volcanic activity, earthquakes and tsunamis.	• **Notional time:** 3 hours • Resources for the mandatory practical could include the US Geological Survey's *Latest earthquakes map*: http://earthquake.usgs.gov/earthquakes/map. • **SHE:** 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.

Subject matter	Guidance
Effects of cyclones, flood events and droughts • describe the naming and classification systems of cyclones • explain the causes of major weather systems, including cyclones, flood events and droughts • identify and explain the likely location of major weather hazards, including cyclones, flood events and droughts, using topographic maps and meteorological data • 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.	• **Notional time:** 4 hours • Meteorological data could include rainfall, synoptic charts, the Southern Oscillation Index (SOI), historic records and sea and air temperature data. • **SHE:** 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. • **SHE:** 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. • **Suggested practical:** Design suitable strategies to develop an action plan for sustainable development in defined hazardous areas of major weather systems, including cyclones, flood events and droughts. • **Suggested practicals:** Investigate historical data and case studies about major weather systems and evaluate the impacts on Earth processes and interactions. This could include: – the effects cyclones have on habitat destruction in rainforest and reef communities – the effects flood events have on erosion and river structure – the effects drought has on vegetation distribution.
Human activities and 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.	• **Notional time:** 1 hour • Students could explore fire-stick farming as practised by Aboriginal peoples. • **SHE:** 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.

Subject matter	Guidance

Impact of natural hazards
• explain how organisms, including humans and ecosystems, are affected by:
  − the location, magnitude and intensity of droughts, floods and bushfires
  − the configuration of Earth materials that influence droughts, floods and bushfires, including biomass and substrate.
• **Mandatory practical:** Model the influence of run-off coefficient of different substrates on the run-off rate in a flood event.
	• **Notional time:** 5 hours
	• The effects of volcanic action, earthquakes and tsunamis are not required in this section as they are classified as Earth hazards.
	• Frequency of droughts, floods and bushfires could be considered when discussing the effect of natural hazard.
	• **Suggested practical:** Investigate examples of natural hazards (i.e. droughts, floods and bushfires) using secondary data and relevant case studies to identify the link between location and magnitude and the impact of the event.
	• **SHE:** 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.

Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination but could be used in the development of claims and research questions for the research investigation.	• **Should scientists be held responsible for evaluation of earthquake risk?:** 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. • **Urban-development planning for severe weather events:** Governments should create stricter restrictions on urban development in high-risk areas given the significant costs of managing mitigation of and recovery from severe weather events. • **Salinity in Australia:** Mitigation activities, including planting trees and planting deep-rooted crops or salt-adapted species, can reduce loss of agricultural land and remnant native vegetation.

5.4 Topic 2: The cause and impact of global climate change

In this topic, students will:

Subject matter	Guidance
Contributions to climate changes • explain how natural processes contribute to global climate changes, including: – oceanic circulation – orbitally induced solar radiation fluctuations – the plate tectonic super-cycle • explain how human activities, including land clearing, fossil fuel consumption and gas production contribute to global climate changes • compare the effects of natural processes and human activities on global climate changes at a variety of timescales.	• **Notional time:** 3 hours • **SHE:** Acceptance of scientific knowledge regarding causes of global climate change can be influenced by the social, economic and cultural context in which it is considered. • **SHE:** 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.
The effect of human activities on atmosphere and climatic conditions • explain how human activities contribute to changes to the composition of the atmosphere and climatic conditions including: – land clearing – fossil fuel consumption – gas production (including carbon dioxide, methane, nitrous oxide and hydrofluorocarbons) – particulate materials in the atmosphere • compare the influence of both human and natural processes on the generation and increase of gases into the atmosphere • draw conclusions about the extent to which human and natural processes contribute to the generation and release of gases into the atmosphere. • **Mandatory practical:** Analyse secondary data to evaluate the impact of changes in atmospheric carbon dioxide concentration over time to global temperatures.	• **Notional time:** 5 hours • **Suggested practical:** Analyse secondary scientific data to determine how particulate materials and/or gases affect the atmosphere. • **Syllabus link:** Link effect of human activities on atmospheric conditions to Unit 2 Topic 2: Energy for atmospheric and hydrologic processes.

Subject matter	Guidance
Effect of climate change on the systems • explain how climate change affects the biosphere, atmosphere, geosphere and hydrosphere • identify and explore, using secondary data, the influence of climate change on: – species distribution patterns – crop productivity changes – sea level changes – rainfall patterns – surface temperature changes – extent of ice sheets.	• **Notional time:** 6 hours • **Suggested practical:** Use secondary data and climate-modelling technology to 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. • **Suggested practical:** Use dry ice in an alkaline solution to model acidification of oceans by CO_2. • **Syllabus link:** Link effect of climate change to Unit 1: Introduction to Earth systems.
Impacts of climate change • analyse and evaluate the geological, prehistorical and historical records that provide evidence for climate change, including: – fossils – pollen grains – ice core data – isotopic ratios • analyse the evidence that demonstrates how climate change has affected different regions and species differently over time.	• **Notional time:** 4 hours • Aboriginal art sites could be used to provide evidence for climate change. • **Suggested practical:** Analyse CO_2 data from ice core data simulation models as evidence for changing atmospheric conditions over time. • **SHE:** People can use scientific geological, prehistorical and historical knowledge to inform the monitoring, assessment and evaluation of risk of climate change over time.

Subject matter	Guidance
Climate change models • identify how climate change models describe the behaviour and interactions of the oceans and atmosphere, including: – general circulation models – models of El Niño and La Niña • examine who has developed these models, where they have been developed and how long these models have been used for • explain that climate change models are used to make predictions in response to changes in contributing components, including atmospheric composition and global ice cover • evaluate the validity of various models, including general circulation, El Niño and La Niña models • appreciate the importance of the information these predictions provide to evaluate government decisions.	• **Notional time:** 6 hours • **SHE**: 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. • **SHE:** 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. • **Suggested practical:** Use secondary data to model patterns of El Niño and La Niña and predict future cycles and environmental implications.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination but could be used in the development of claims and research questions for the research investigation.	• **Anthropogenic climate change — what's the evidence?:** 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 twentieth century. • **Predicting future climate change and identifying action:** 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. • **Uncertainty and climate change science:** 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.

5.5 Assessment

5.5.1 Summative internal assessment 3 (IA3): Research investigation (20%)

Description

This assessment requires students to evaluate a claim. They will do this by researching, analysing and interpreting secondary evidence from scientific texts to form the basis for a justified conclusion about the claim. A research investigation uses research practices to assess a range of cognitions in a particular context. Research practices include locating and using information beyond students' own knowledge and the data they have been given.

Research conventions must be adhered to. This assessment occurs over an extended and defined period of time. Students may use class time and their own time to develop a response.

Assessment objectives

This assessment technique is used to determine student achievement in the following objectives:

2. apply understanding of the cause and impact of Earth hazards or global climate change to develop research questions
3. analyse research evidence 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. investigate phenomena associated with the cause and impact of Earth hazards or global climate change through research
6. evaluate research processes, claims and conclusions about the cause and impact of Earth hazards or global climate change
7. communicate understandings and research findings, arguments and conclusions about the cause and impact of Earth hazards or global climate change.

Note: Objective 1 is not assessed in this instrument.

Specifications

Description

In the research investigation, students gather secondary evidence related to a research question in order to evaluate the claim. The students develop their research question based on a number of possible claims provided by their teacher. Students work individually throughout this task.

Evidence must be obtained by researching scientifically credible sources, such as scientific journals, books by well-credentialed scientists and websites of governments, universities, independent research bodies or science and technology manufacturers.

In order to complete the assessment task, students must:

- select a claim to be evaluated
- identify the relevant scientific concepts associated with the claim
- pose a research question addressing an aspect of the claim

- conduct research to gather scientific evidence that may be used to address the research question and subsequently evaluate the claim
- analyse the data to identify sufficient and relevant evidence
- identify the trends, patterns or relationships in the evidence
- analyse the evidence to identify limitations
- interpret the evidence to construct justified scientific arguments
- interpret the evidence to form a justified conclusion to the research question
- discuss the quality of evidence
- evaluate the claim by extrapolating the findings of the research question to the claim
- suggest improvements and 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.

Conditions

- Time: 10 hours class time. This time will not necessarily be sequential. Students must perform the majority of the task during class time, including
  - performing background research
  - developing the research question
  - collecting scientific evidence
  - analysing and interpreting evidence and evaluating the claim
  - preparing and presenting the response (e.g. writing the scientific essay,).
- Length:
  - written (e.g. scientific essay), 1500–2000 words

    or
  - multimodal presentation (e.g. scientific conference presentation), 9–11 minutes.
- Other:
  - students are to work individually throughout this task
  - the response must be presented using an appropriate scientific genre (e.g. report, journal article, essay, conference presentation) and contain
    - a claim
    - a research question
    - a rationale for the investigation
    - justified scientific arguments using evidence
    - a conclusion to the research question based on the interpretation of the evidence
    - evaluation of the claim and suggestions of improvements and extensions to the investigation
    - a reference list.

Summary of the instrument-specific marking guide

The following table summarises the criteria, assessment onjectives and mark allocation for the research investigation.

Criterion	Objectives	Marks
Research and planning	2, 5	6
Analysis and interpretation	3, 4	6
Conclusion and evaluation	4, 6	6
Communication	7	2
Total		**20**

Note: Unit objective 1 is not assessed in this instrument.

Instrument-specific marking guide

Criterion: Research and planning

Assessment objectives

2. apply understanding of the cause and impact of Earth hazards or global climate change to develop research questions
5. investigate phenomena associated with the cause and impact of Earth hazards or global climate change through research

The student work has the following characteristics:	Marks
• informed application of understanding of the cause and impact of Earth hazards or global climate change demonstrated by a considered rationale identifying clear development of the research question from the claim • effective and efficient investigation of phenomena associated with the cause and impact of Earth hazards or global climate change demonstrated by – a specific and relevant research question – selection of sufficient and relevant sources.	5–6
• adequate application of understanding of the cause and impact of Earth hazards or global climate change demonstrated by a reasonable rationale that links the research question and the claim • effective investigation of phenomena associated with the cause and impact of Earth hazards or global climate change demonstrated by – a relevant research question – selection of relevant sources.	3–4
• rudimentary application of understanding of the cause and impact of Earth hazards or global climate change demonstrated by a vague or irrelevant rationale for the investigation • ineffective investigation of phenomena associated with the cause and impact of Earth hazards or global climate change demonstrated by – an inappropriate research question – selection of insufficient and irrelevant sources.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Analysis and interpretation

Assessment objectives

3. analyse research evidence 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

The student work has the following characteristics:	Marks
• systematic and effective analysis of qualitative data and/or quantitative data within the sources about the cause and impact of Earth hazards or global climate change demonstrated by – the identification of sufficient and relevant evidence – thorough identification of relevant trends, patterns or relationships – thorough and appropriate identification of limitations of evidence • insightful interpretation of research evidence about the cause and impact of Earth hazards or global climate change demonstrated by justified scientific argument/s.	5–6
• effective analysis of qualitative data and/or quantitative data within the sources about the cause and impact of Earth hazards or global climate change demonstrated by – the identification of relevant evidence – identification of obvious trends, patterns or relationships – basic identification of limitations of evidence • adequate interpretation of research evidence about the cause and impact of Earth hazards or global climate change demonstrated by reasonable scientific argument/s.	3–4
• rudimentary analysis of qualitative data and/or quantitative data within the sources about the cause and impact of Earth hazards or global climate change demonstrated by – the identification of insufficient and irrelevant evidence – identification of incorrect or irrelevant trends, patterns or relationships – incorrect or insufficient identification of limitations of evidence • invalid interpretation of research evidence about the cause and impact of Earth hazards or global climate change demonstrated by inappropriate or irrelevant argument/s.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Conclusion and evaluation

Assessment objectives

4. interpret research evidence about the cause and impact of Earth hazards or global climate change
6. evaluate research processes, claims and conclusions about the cause and impact of Earth hazards or global climate change

The student work has the following characteristics:	Marks
• insightful interpretation of research evidence about the cause and impact of Earth hazards or global climate change demonstrated by justified conclusion/s linked to the research question • critical evaluation of the research processes, claims and conclusions about the cause and impact of Earth hazards or global climate change demonstrated by – insightful discussion of the quality of evidence – 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.	5–6
• adequate interpretation of research evidence about the cause and impact of Earth hazards or global climate change demonstrated by reasonable conclusion/s relevant to the research question • basic evaluation of the research processes, claims and conclusions about the cause and impact of Earth hazards or global climate change demonstrated by – reasonable description of the quality of evidence – application of relevant findings of the research to the claim – suggested improvements and extensions to the investigation that are relevant to the claim.	3–4
• invalid interpretation of research evidence about the cause and impact of Earth hazards or global climate change demonstrated by inappropriate or irrelevant conclusion/s • superficial evaluation of the research processes, claims and conclusions about the cause and impact of Earth hazards or global climate change demonstrated by – cursory or simplistic statements about the quality of evidence – application of insufficient or inappropriate findings of the research to the claim – ineffective or irrelevant suggestions.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Communication

Assessment objective

7. communicate understandings and research findings, arguments and conclusions about the cause and impact of Earth hazards or global climate change

The student work has the following characteristics:	Marks
• effective communication of understandings and research findings, arguments and conclusions about the cause and impact of Earth hazards or global climate change demonstrated by – fluent and concise use of scientific language and representations – appropriate use of genre conventions – acknowledgment of sources of information through appropriate use of referencing conventions.	2
• adequate communication of understandings and research findings, arguments and conclusions about the cause and impact of Earth hazards or global climate change demonstrated by – competent use of scientific language and representations – use of basic genre conventions – use of basic referencing conventions.	1
• does not satisfy any of the descriptors above.	0

5.5.2 Summative external assessment (EA): Examination (50%)

General information

Summative external assessment is developed and marked by the QCAA. In Earth & Environmental Science it contributes 50% to a student's overall subject result.

Summative external assessment assesses learning from both Units 3 and 4.

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.

Description

The examination assesses the application of a range of cognitions to multiple provided items — questions, scenarios and problems.

Student responses must be completed individually, under supervised conditions, and in a set timeframe.

Assessment objectives

This assessment technique is used to determine student achievement in the following objectives:

1. describe and explain the 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 evidence about the 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.

Note: Objectives 5, 6 and 7 are not assessed in this instrument.

Specifications

Description

This examination will include two papers. Each paper consists of a number of different types of possible items:

- multiple choice
- short response items requiring single-word, sentence or paragraph responses
- calculating using algorithms
- interpreting graphs, tables or diagrams
- responding to unseen data and/or stimulus
- extended response (300–350 words or equivalent).

Conditions

Paper 1

- Time: 90 minutes plus 10 minutes perusal.
- Other: QCAA-approved graphics calculator permitted.

Paper 2

- Time: 90 minutes plus 10 minutes perusal.
- Other: QCAA-approved graphics calculator permitted.

Instrument-specific marking guide

No ISMG is provided for the external assessment.

6 Glossary

Term	Explanation
A	
accomplished	highly trained or skilled in a particular activity; perfected in knowledge or training; expert
accuracy	the condition or quality of being true, correct or exact; freedom from error or defect; precision or exactness; correctness; in science, the extent to which a measurement result represents the quantity it purports to measure; an accurate measurement result includes an estimate of the true value and an estimate of the uncertainty
accurate	precise and exact; to the point; consistent with or exactly conforming to a truth, standard, rule, model, convention or known facts; free from error or defect; meticulous; correct in all details
acknowledgment	recognition of the authority or validity of something
actualism	the theory or principle that changes in the geological past can be explained in terms of processes observable in the present
adept	very/highly skilled or proficient at something; expert
adequate	satisfactory or acceptable in quality or quantity equal to the requirement or occasion
albedo	the fraction of solar energy (shortwave radiation) reflected from the Earth back into space; it is a measure of the reflectivity of the Earth's surface
algebraic representation	a set of symbols linked by mathematical operations; the set of symbols summarises relationships between variables (ACARA 2015c)
algorithm	an effective procedure for solving a particular mathematical problem in a finite number of steps
analyse	dissect to ascertain and examine constituent parts and/or their relationships; break down or examine in order to identify the essential elements, features, components or structure; determine the logic and reasonableness of information; examine or consider something in order to explain and interpret it, for the purpose of finding meaning or relationships and identifying patterns, similarities and differences
analysis	examination of evidence to identify the essential features, components, elements or structure; identification of patterns, similarities and differences
analytical technique	a procedure or method for analysing data
anomaly	something that deviates from what is standard, normal or expected (Taylor 1982)

Term	Explanation
applied learning	the acquisition and application of knowledge, understanding and skills in real-world or lifelike contexts that may encompass workplace, industry and community situations; it emphasises learning through doing and includes both theory and the application of theory, connecting subject knowledge and understanding with the development of practical skills
Applied subject	a subject whose primary pathway is work and vocational education; it emphasises applied learning and community connections; a subject for which a syllabus has been developed by the QCAA with the following characteristics: results from courses developed from Applied syllabuses contribute to the QCE; results may contribute to ATAR calculations
apply	use knowledge and understanding in response to a given situation or circumstance; carry out or use a procedure in a given or particular situation
appraise	evaluate the worth, significance or status of something; judge or consider a text or piece of work
appreciate	recognise or make a judgment about the value or worth of something; understand fully; grasp the full implications of
appropriate	acceptable; suitable or fitting for a particular purpose, circumstance, context, etc.
apt	suitable to the purpose or occasion; fitting, appropriate
area of study	a division of, or a section within a unit
argue	give reasons for or against something; challenge or debate an issue or idea; persuade, prove or try to prove by giving reasons
argument	process of reasoning; series of reasons; a statement or fact tending to support a point
aspect	a particular part of a feature of something; a facet, phase or part of a whole
assess	measure, determine, evaluate, estimate or make a judgment about the value, quality, outcomes, results, size, significance, nature or extent of something
assessment	purposeful and systematic collection of information about students' achievements
assessment instrument	a tool or device used to gather information about student achievement
assessment objectives	drawn from the unit objectives and contextualised for the requirements of the assessment instrument (see also 'syllabus objectives', 'unit objectives')
assessment technique	the method used to gather evidence about student achievement (e.g. examination, project, investigation)
astute	showing an ability to accurately assess situations or people; of keen discernment

Term	Explanation
ATAR	Australian Tertiary Admission Rank
atmosphere	the layer of gases surrounding the planet
authoritative	able to be trusted as being accurate or true; reliable; commanding and self-confident; likely to be respected and obeyed
B	
balanced	keeping or showing a balance; not biased; fairly judged or presented; taking everything into account in a fair, well-judged way
basic	fundamental
behaviour	in science, the action of any material; the action or activity of an individual
biomass	the mass of living biological organisms in a given area or ecosystem at a given time; can refer to species biomass, which is the mass of one or more species, or to community biomass, which is the mass of all species in the community
biosphere	the parts of the land, sea, and atmosphere in which organisms are able to live; an irregularly shaped, relatively thin zone in which life is concentrated, on or near the Earth's surface and throughout its waters
C	
calculate	determine or find (e.g. a number, answer) by using mathematical processes; obtain a numerical answer showing the relevant stages in the working; ascertain/determine from given facts, figures or information
carbon sink	a forest, ocean, or other natural environment viewed in terms of its ability to absorb carbon dioxide from the atmosphere
categorise	place in or assign to a particular class or group; arrange or order by classes or categories; classify, sort out, sort, separate
carrying capacity	the maximum population size of a biological species that an environment can sustain indefinitely, given the food, habitat, water, and other necessities available in the environment
challenging	difficult but interesting; testing one's abilities; demanding and thought-provoking; usually involving unfamiliar or less familiar elements
characteristic	a typical feature or quality
claim	an assertion made without any accompanying evidence to support it
clarify	make clear or intelligible; explain; make a statement or situation less confused and more comprehensible
clarity	clearness of thought or expression; the quality of being coherent and intelligible; free from obscurity of sense; without ambiguity; explicit; easy to perceive, understand or interpret

Term	Explanation
classify	arrange, distribute or order in classes or categories according to shared qualities or characteristics
clastic	a sedimentary rock texture consisting of broken fragments of pre-existing rock (Tarbuck, Lutgens & Tasa 2008)
clear	free from confusion, uncertainty, or doubt; easily seen, heard or understood
clearly	in a clear manner; plainly and openly, without ambiguity
closed system	a system whose boundaries allow the exchange of energy, but not matter, with the surrounding environment; a system in which the amount of matter is fixed and its contents cycle within the boundaries of the system (Murck, Skinner & Porter 1995)
coherent	having a natural or due agreement of parts; connected; consistent; logical, orderly; well-structured and makes sense; rational, with parts that are harmonious; having an internally consistent relation of parts
cohesive	characterised by being united, bound together or having integrated meaning; forming a united whole
collate	to put together; to compare
collection	In science, a systematic approach to gathering and measuring evidence from a variety of sources in order to evaluate outcomes and make predictions
comment	express an opinion, observation or reaction in speech or writing; give a judgment based on a given statement or result of a calculation
communicate	convey knowledge and/or understandings to others; make known; transmit
compare	display recognition of similarities and differences and recognise the significance of these similarities and differences
competent	having suitable or sufficient skills, knowledge, experience, etc. for some purpose; adequate but not exceptional; capable; suitable or sufficient for the purpose; having the necessary ability, knowledge or skill to do something successfully; efficient and capable (of a person); acceptable and satisfactory, though not outstanding
competently	in an efficient and capable way; in an acceptable and satisfactory, though not outstanding, way
complex	composed or consisting of many different and interconnected parts or factors; compound; composite; characterised by an involved combination of parts; complicated; intricate; a complex whole or system; a complicated assembly of particulars
comprehend	understand the meaning or nature of; grasp mentally
comprehensive	inclusive; of large content or scope; including or dealing with all or nearly all elements or aspects of something; wide-ranging; detailed and thorough, including all that is relevant

Term	Explanation
concept	in science, an idea or model explaining some natural phenomenon; a theoretical construct; a thought, idea or notion
concise	expressing much in few words; giving a lot of information clearly and in a few words; brief, comprehensive and to the point; succinct, clear, without repetition of information
concisely	in a way that is brief but comprehensive; expressing much in few words; clearly and succinctly
conclusion	a judgment based on evidence (ACARA 2015c)
conduct	direct in action or course; manage; organise; carry out
conformable	(layers) rock layers that were deposited without interruption (Tarbuck, Lutgens & Tasa 2008)
consider	think deliberately or carefully about something, typically before making a decision; take something into account when making a judgment; view attentively or scrutinise; reflect on
considerable	fairly large or great; thought about deliberately and with a purpose
considered	formed after careful and deliberate thought
consistent	agreeing or accordant; compatible; not self-opposed or self-contradictory, constantly adhering to the same principles; acting in the same way over time, especially so as to be fair or accurate; unchanging in nature, standard, or effect over time; not containing any logical contradictions (of an argument); constant in achievement or effect over a period of time
construct	create or put together (e.g. an argument) by arranging ideas or items; display information in a diagrammatic or logical form; make; build
contrast	display recognition of differences by deliberate juxtaposition of contrary elements; show how things are different or opposite; give an account of the differences between two or more items or situations, referring to both or all of them throughout
controlled	shows the exercise of restraint or direction over; held in check; restrained, managed or kept within certain bounds
convincing	persuaded by argument or proof; leaving no margin of doubt; clear; capable of causing someone to believe that something is true or real; persuading or assuring by argument or evidence; appearing worthy of belief; credible or plausible
core sampling	a vertical, cylindrical-shaped boring used to determine composition and stratification (Heffernan 2009)
correct	conforming to fact or truth; accurate
course	a defined amount of learning developed from a subject syllabus
create	bring something into being or existence; produce or evolve from one's own thought or imagination; reorganise or put elements together into a new pattern or structure or to form a coherent or functional whole

Term	Explanation
creative	resulting from originality of thought or expression; relating to or involving the use of the imagination or original ideas to create something; having good imagination or original ideas
credible	capable or worthy of being believed; believable; convincing
criterion	the property or characteristic by which something is judged or appraised
critical	involving skilful judgment as to truth, merit, etc.; involving the objective analysis and evaluation of an issue in order to form a judgment; expressing or involving an analysis of the merits and faults of a work of literature, music, or art; incorporating a detailed and scholarly analysis and commentary (of a text); rationally appraising for logical consistency and merit
critique	review (e.g. a theory, practice, performance) in a detailed, analytical and critical way
cursory	hasty, and therefore not thorough or detailed; performed with little attention to detail; going rapidly over something, without noticing details; hasty; superficial
D	
data	in science, measurements of an attribute or attributes; data may be quantitative or qualitative and be from primary or secondary sources (ACARA 2015c)
dataset	qualitative data and/or quantitative data (e.g. diagram, graph, image, map, photograph, table) derived from a practical, activity or case study
decide	reach a resolution as a result of consideration; make a choice from a number of alternatives
deduce	reach a conclusion that is necessarily true, provided a given set of assumptions is true; arrive at, reach or draw a logical conclusion from reasoning and the information given
defensible	justifiable by argument; capable of being defended in argument
define	give the meaning of a word, phrase, concept or physical quantity; state meaning and identify or describe qualities
demonstrate	prove or make clear by argument, reasoning or evidence, illustrating with practical example; show by example; give a practical exhibition
derive	arrive at by reasoning; manipulate a mathematical relationship to give a new equation or relationship; in mathematics, obtain the derivative of a function
describe	give an account (written or spoken) of a situation, event, pattern or process, or of the characteristics or features of something

Term	Explanation
design	produce a plan, simulation, model or similar; plan, form or conceive in the mind; in English, select, organise and use particular elements in the process of text construction for particular purposes; these elements may be linguistic (words), visual (images), audio (sounds), gestural (body language), spatial (arrangement on the page or screen) and multimodal (a combination of more than one)
detailed	executed with great attention to the fine points; meticulous; including many of the parts or facts
determine	establish, conclude or ascertain after consideration, observation, investigation or calculation; decide or come to a resolution
develop	elaborate, expand or enlarge in detail; add detail and fullness to; cause to become more complex or intricate
devise	think out; plan; contrive; invent
differentiate	identify the difference/s in or between two or more things; distinguish, discriminate; recognise or ascertain what makes something distinct from similar things; in mathematics, obtain the derivative of a function
discerning	discriminating; showing intellectual perception; showing good judgment; making thoughtful and astute choices; selected for value or relevance
discriminate	note, observe or recognise a difference; make or constitute a distinction in or between; differentiate; note or distinguish as different
discriminating	differentiating; distinctive; perceiving differences or distinctions with nicety; possessing discrimination; perceptive and judicious; making judgments about quality; having or showing refined taste or good judgment
discuss	examine by argument; sift the considerations for and against; debate; talk or write about a topic, including a range of arguments, factors or hypotheses; consider, taking into account different issues and ideas, points for and/or against, and supporting opinions or conclusions with evidence
disjointed	disconnected; incoherent; lacking a coherent order/sequence or connection
distinguish	recognise as distinct or different; note points of difference between; discriminate; discern; make clear a difference/s between two or more concepts or items
diverse	of various kinds or forms; different from each other
document	support (e.g. an assertion, claim, statement) with evidence (e.g. decisive information, written references, citations)
draw conclusions	make a judgment based on reasoning and evidence

Term	Explanation
E	
ecological footprint	the impact of a person or community on the environment, expressed as the amount of land required to sustain their use of natural resources
ecological validity	the degree to which results obtained from research are representative of the wider world
ecosystem services	the benefits provided to humans through the transformations of resources (or environmental assets, including land, water, vegetation and atmosphere) into a flow of essential goods and services, e.g. clean air, water and food
effective	successful in producing the intended, desired or expected result; meeting the assigned purpose
efficient	working in a well-organised and competent way; maximum productivity with minimal expenditure of effort; acting or producing effectively with a minimum of waste, expense or unnecessary effort
element	a component or constituent part of a complex whole; a fundamental, essential or irreducible part of a composite entity
elementary	simple or uncompounded; relating to or dealing with elements, rudiments or first principles (of a subject); of the most basic kind; straightforward and uncomplicated
El Niño	a change in the normal atmospheric pressure patterns that allows warmer waters from the Australia–Indonesia region to move towards South America, resulting in droughts in Australia–Indonesia and flooding in South America (Pohl 2003)
electromagnetic radiation	energy that travels through space in the form of waves at the speed of light, including both visible and invisible waves (Pohl 2003)
erroneous	based on or containing error; mistaken; incorrect
essential	absolutely necessary; indispensable; of critical importance for achieving something
evaluate	make an appraisal by weighing up or assessing strengths, implications and limitations; make judgments about ideas, works, solutions or methods in relation to selected criteria; examine and determine the merit, value or significance of something, based on criteria
evidence	in science, evidence is data that has been selected as it is considered reliable and valid and can be used to support a particular idea, conclusion or decision; evidence gives weight or value to data by considering its credibility, acceptance, bias, status, appropriateness and reasonableness (ACARA 2015c)
examination	a supervised test that assesses the application of a range of cognitions to one or more provided items such as questions, scenarios and/or problems; student responses are completed individually, under supervised conditions, and in a set timeframe

Term	Explanation
examine	investigate, inspect or scrutinise; inquire or search into; consider or discuss an argument or concept in a way that uncovers the assumptions and interrelationships of the issue
exhalative processes	processes associated with volcanicity that produce sulphide ore deposits, often lenticular in cross-section and commonly located above mineralised stockworks (the probable channelways to the sea floor)
experiment	try out or test new ideas or methods, especially in order to discover or prove something; undertake or perform a scientific procedure to test a hypothesis, make a discovery or demonstrate a known fact in science, an investigation that involves carrying out a practical activity
experimental	relating to, derived from, or founded on experiment
explain	make an idea or situation plain or clear by describing it in more detail or revealing relevant facts; give an account; provide additional information
explicit	clearly and distinctly expressing all that is meant; unequivocal; clearly developed or formulated; leaving nothing merely implied or suggested
explore	look into both closely and broadly; scrutinise; inquire into or discuss something in detail
express	convey, show or communicate (e.g. a thought, opinion, feeling, emotion, idea or viewpoint); in words, art, music or movement, convey or suggest a representation of; depict
extend	in science, to extend an experiment is to modify the methodology to overcome limitations of the scope or applicability of the data
extended response	an open-ended assessment technique that focuses on the interpretation, analysis, examination and/or evaluation of ideas and information in response to a particular situation or stimulus; while students may undertake some research when writing the extended response, it is not the focus of this technique; an extended response occurs over an extended and defined period of time; an item on an examination may also require an extended response, either written or oral
Extension subject	a two-unit subject for which a syllabus has been developed by QCAA; it is an extension of one or more general or alternative sequence subject/s; studied concurrently with the final two units of that subject/s or after completion of, the final two units of that subject/s
extensions	in science, modifications to an investigation that could be used to further examine a claim
extensive	of great extent; wide; broad; far-reaching; comprehensive; lengthy; detailed; large in amount or scale

Term	Explanation
external assessment	summative assessment that occurs towards the end of a course of study and is common to all schools; developed and marked by the QCAA according to a commonly applied marking scheme
external examination	a supervised test, developed and marked by the QCAA, that assesses the application of a range of cognitions to multiple provided items such as questions, scenarios and/or problems; student responses are completed individually, under supervised conditions, and in a set timeframe
extrapolate	infer or estimate by extending or projecting known information; conjecture; infer from what is known; extend the application of something (e.g. a method or conclusion) to an unknown situation by assuming that existing trends will continue or similar methods will be applicable
extrapolation	extension of a conclusion to a new situation with the assumption that existing trends will continue
F	
factual	relating to or based on facts; concerned with what is actually the case; actually occurring; having verified existence
familiar	well-acquainted; thoroughly conversant with; well known from long or close association; often encountered or experienced; common; (of materials, texts, skills or circumstances) having been the focus of learning experiences or previously encountered in prior learning activities
feasible	capable of being achieved, accomplished or put into effect; reasonable enough to be believed or accepted; probable; likely
feature	distinctive attribute, characteristic, property or quality of evidence
fieldwork	research carried out in the field (i.e. beyond the classroom) which includes data collection
findings	in science, the outcomes of research, investigation or experimentation, including facts or principles established in these ways
fluent	spoken or written with ease; able to speak or write smoothly, easily or readily; articulate; eloquent; in artistic performance, characteristic of a highly developed and excellently controlled technique; flowing; polished; flowing smoothly, easily and effortlessly
fluently	in a graceful and seemingly effortless manner; in a way that progresses smoothly and readily
formative assessment	assessment whose major purpose is to improve teaching and student achievement
fracking	the process of injecting liquid at high pressure into subterranean rocks, boreholes, etc. to force open existing fissures and extract oil or gas
fragmented	disorganised; broken down; disjointed or isolated

Term	Explanation
frequent	happening or occurring often at short intervals; constant, habitual, or regular
froth flotation	valuable minerals or coal stick to bubbles and float to the surface, where they are skimmed off (Pohl 2003)
fundamental	forming a necessary base or core; of central importance; affecting or relating to the essential nature of something; part of a foundation or basis
G	
geosphere	the solid Earth; one of Earth’s four basic spheres (Tarbuck, Lutgens & Tasa 2008)
General subject	a subject for which a syllabus has been developed by the QCAA with the following characteristics: results from courses developed from General syllabuses contribute to the QCE; General subjects have an external assessment component; results may contribute to ATAR calculations
generate	produce; create; bring into existence
genre conventions	agreed and acceptable conditions; a style or category
graphical representation	in science, a visual representation of the relationship between quantities plotted with reference to a set of axes; also known as a graph (ACARA 2015c)
greenhouse gases	gases that increase the heat retained in the atmosphere
H	
heat sink	an environment or medium that absorbs excess heat
hydrocarbons	compounds that only contain carbon and hydrogen (Hubble, Huxley & Imlay-Gillespie 2011)
hydrosphere	all liquid and frozen surface waters, groundwater held in soil and rock and atmospheric water vapour (Hubble, Huxley & Imlay-Gillespie 2011)
hydrothermal	relating to or denoting the action of heated water in the Earth's crust
hypothesis	in science, a tentative explanation for an observed phenomenon, expressed as a precise and unambiguous statement that can be supported or refuted by experiment (ACARA 2015c)
hypothesise	formulate a supposition to account for known facts or observed occurrences; conjecture, theorise, speculate; especially on uncertain or tentative grounds

Term	Explanation
I	
identify	distinguish; locate, recognise and name; establish or indicate who or what someone or something is; provide an answer from a number of possibilities; recognise and state a distinguishing factor or feature
igneous settings	the production of igneous rocks related to tectonic settings; igneous rocks are products of partial melting in the upper mantle, subducted oceanic crust or lower continental crust; individual igneous suites may be produced exclusively by one such process, or may represent the product of more than one operating in concert (Hubble, Huxley & Imlay-Gillespie 2011)
infrared radiation	a type of electromagnetic radiation
illogical	lacking sense or sound reasoning; contrary to or disregardful of the rules of logic; unreasonable
implement	put something into effect, e.g. a plan or proposal
implication	a likely consequence of something; a conclusion that may be drawn though it is implied rather than explicit
implicit	implied, rather than expressly stated; not plainly expressed; capable of being inferred from something else
improbable	not probable; unlikely to be true or to happen; not easy to believe
improvements	in science, modifications to an investigation that mitigate the limitations of the evidence, method or design
inaccurate	not accurate
inadequate	not satisfactory or acceptable in quality and/or quantity to the requirements of the situation
inappropriate	not suitable or proper in the circumstances
inconsistent	lacking agreement, as one thing with another, or two or more things in relation to each other; at variance; not consistent; not in keeping; not in accordance; incompatible, incongruous
incorrect	not conforming to fact or truth
independent	thinking or acting for oneself, not influenced by others
in-depth	comprehensive and with thorough coverage; extensive or profound; well-balanced or fully developed
ineffective	not producing a result, or not producing any significant result; not producing the intended, desired or expected result
infer	derive or conclude something from evidence and reasoning, rather than from explicit statements; listen or read beyond what has been literally expressed; imply or hint at
informed	knowledgeable; learned; having relevant knowledge; being conversant with the topic; based on an understanding of the facts of the situation (of a decision or judgment)
infrared radiation	a type of electromagnetic radiation

Term	Explanation
innovative	new and original; introducing new ideas; original and creative in thinking
insightful	showing understanding of a situation or process; understanding relationships in complex situations; informed by observation and deduction
instrument-specific marking guide	ISMG; a tool for marking that describes the characteristics evident in student responses and aligns with the identified objectives for the assessment (see 'assessment objectives')
insufficient	not enough; inadequate for the purpose
integral	*adjective* necessary for the completeness of the whole; essential or fundamental; *noun* in mathematics, the result of integration; an expression from which a given function, equation, or system of equations is derived by differentiation
intended	designed; meant; done on purpose; intentional
internal assessment	assessments that are developed by schools; summative internal assessments are endorsed by the QCAA before use in schools and results externally confirmed; contributes towards a student's final result
interpret	use knowledge and understanding to recognise trends and draw conclusions from given information; make clear or explicit; elucidate or understand in a particular way; bring out the meaning of, e.g. a dramatic or musical work, by performance or execution; bring out the meaning of an artwork by artistic representation or performance; give one's own interpretation of; identify or draw meaning from, or give meaning to, information presented in various forms, such as words, symbols, pictures or graphs
invalid	not sound, just or well-founded; not having a sound basis in logic or fact (of an argument or point); not reasonable or cogent; not able to be supported; not legitimate or defensible; not applicable
investigate	carry out an examination or formal inquiry in order to establish or obtain facts and reach new conclusions; search, inquire into, interpret and draw conclusions about data and information
investigation	an assessment technique that requires students to research a specific problem, question, issue, design challenge or hypothesis through the collection, analysis and synthesis of primary and/or secondary data; it uses research or investigative practices to assess a range of cognitions in a particular context; an investigation occurs over an extended and defined period of time in science, a scientific process of answering a question, exploring an idea or solving a problem that requires activities such as planning a course of action, collecting data, interpreting data, reaching a conclusion and communicating these activities (ACARA 2015c)

Term	Explanation
irrelevant	not relevant; not applicable or pertinent; not connected with or relevant to something
ISMG	instrument-specific marking guide; a tool for marking that describes the characteristics evident in student responses and aligns with the identified objectives for the assessment (see 'assessment objectives')
isobars	a line on a map connecting points that have the same atmospheric pressure at a given time or on average over a given period
isolated	detached, separate, or unconnected with other things; one-off; something set apart or characterised as different in some way
isolated system	a thermodynamic system that cannot exchange either energy or matter outside the boundaries of the system; an isolated system differs from a closed system by the transfer of energy; closed systems are only closed to matter, but energy can be exchanged across the system's boundaries
J	
judge	form an opinion or conclusion about; apply both procedural and deliberative operations to make a determination
justified	sound reasons or evidence are provided to support an argument, statement or conclusion
justify	give reasons or evidence to support an answer, response or conclusion; show or prove how an argument, statement or conclusion is right or reasonable
K	
kerogens	raw organic material from which petroleum forms (Hubble, Huxley & Imlay-Gillespie 2011)
L	
La Niña	the reverse of an extreme of the Southern Oscillation that causes extreme rainfall in parts of Australia
learning area	a grouping of subjects, with related characteristics, within a broad field of learning, e.g. the Arts, sciences, languages
limitation	a weak point or disadvantage that makes evidence less effective
link	anything serving to connect one part or thing with another
logical	rational and valid; internally consistent; reasonable; reasoning in accordance with the principles/rules of logic or formal argument; characterised by or capable of clear, sound reasoning; (of an action, decision, etc.) expected or sensible under the circumstances
logically	according to the rules of logic or formal argument; in a way that shows clear, sound reasoning; in a way that is expected or sensible

Term	Explanation
longwall mining	a form of underground coal mining where a long wall of coal is mined in a single slice (typically 0.6–1.0 m thick). The longwall panel (the block of coal that is being mined) is typically 3–4 km long and 250-400 m wide
M	
magmatic	production of ore deposits from processes that occur within a magma chamber (Hubble, Huxley & Imlay-Gillespie 2011)
make decisions	select from available options; weigh up positives and negatives of each option and consider all the alternatives to arrive at a position
management	handling, direction or control
manipulate	adapt or change to suit one's purpose
maximum sustainable yield	the maximum level at which a natural resource can be routinely exploited without long-term depletion
mental procedures	a domain of knowledge in Marzano's taxonomy, and acted upon by the cognitive, metacognitive and self-systems; sometimes referred to as 'procedural knowledge' there are three distinct phases to the acquisition of mental procedures — the cognitive stage, the associative stage, and the autonomous stage; the two categories of mental procedures are skills (single rules, algorithms and tactics) and processes (macroprocedures)
mesosphere	directly above the stratosphere and below the thermosphere; extends from about 50 to 85 km above the Earth
metamorphic settings	production of mineral deposits based on metamorphic processes (Hubble, Huxley & Imlay-Gillespie 2011)
methodical	performed, disposed or acting in a systematic way; orderly; characterised by method or order; performed or carried out systematically
methodology	a systematic, ordered approach to gathering data in a scientific experiment or investigation
minimal	least possible; small, the least amount; negligible
model	in science, a systematic description of an object or phenomenon that shares important characteristics with the object or phenomenon; scientific models can be material, visual, mathematical or computational; geomodelling is the Applied science of creating computerised representations of portions of the Earth's crust based on geophysical and geological observations made on and below the Earth's surface

Term	Explanation
modifications	in science, changes to methodology to extend, refine or redirect the research focus
modify	change the form or qualities of; make partial or minor changes to something
multimodal	uses a combination of at least two modes (e.g. spoken, written), delivered at the same time, to communicate ideas and information to a live or virtual audience, for a particular purpose; the selected modes are integrated so that each mode contributes significantly to the response
N	
narrow	limited in range or scope; lacking breadth of view; limited in amount; barely sufficient or adequate; restricted
net primary production	the rate at which new biomass is generated, mainly through photosynthesis
nuanced	showing a subtle difference or distinction in expression, meaning, response, etc.; finely differentiated; characterised by subtle shades of meaning or expression; a subtle distinction, variation or quality; sensibility to, awareness of, or ability to express delicate shadings, as of meaning, feeling, or value
O	
objectives	see ‘syllabus objectives’, ‘unit objectives’, ‘assessment objectives’
obvious	clearly perceptible or evident; easily seen, recognised or understood
open system	a system in which energy and matter are exchanged between the system and its environment
optimal	best, most favourable, under a particular set of circumstances
organise	arrange, order; form as or into a whole consisting of interdependent or coordinated parts, especially for harmonious or united action
organised	systematically ordered and arranged; having a formal organisational structure to arrange, coordinate and carry out activities
outcome	result of something; a consequence
outlier	a value that ‘lies outside’ (is much smaller or larger than) most of the other values in a set of data
outstanding	exceptionally good; clearly noticeable; prominent; conspicuous; striking
ozone	a form of oxygen that forms a molecule consisting of three oxygen molecules (Hubble, Huxley & Imlay-Gillespie 2011)

Term	Explanation
P	
P- and S-wave shadow zones	the shadow zone is the area of the Earth from angular distances of 104° to 140° from a given earthquake that does not receive any direct P-waves; the shadow zone results from S-waves being stopped entirely by the liquid core and P-waves being bent (refracted) by the liquid core
partial	not total or general; existing only in part; attempted, but incomplete
particular	distinguished or different from others or from the ordinary; noteworthy
pattern	a repeated occurrence or sequence (ACARA 2015c)
perceptive	having or showing insight and the ability to perceive or understand; discerning (see also 'discriminating')
performance	an assessment technique that requires students to demonstrate a range of cognitive, technical, creative and/or expressive skills and to apply theoretical and conceptual understandings, through the psychomotor domain; it involves student application of identified skills when responding to a task that involves solving a problem, providing a solution or conveying meaning or intent; a performance is developed over an extended and defined period of time
persuasive	capable of changing someone's ideas, opinions or beliefs; appearing worthy of approval or acceptance; (of an argument or statement) communicating reasonably or credibly (see also 'convincing')
perusal time	time allocated in an assessment to reading items and tasks and associated assessment materials; no writing is allowed; students may not make notes and may not commence responding to the assessment in the response space/book
phenomena	events that are not artificial and can be observed through the senses or can be scientifically described or explained
placer deposit	mass of gravel, sand or similar material containing particles of gold or other minerals
planning time	time allocated in an assessment to planning how to respond to items and tasks and associated assessment materials; students may make notes but may not commence responding to the assessment in the response space/book; notes made during planning are not collected, nor are they graded or used as evidence of achievement
plutonic	relating to or denoting igneous rock formed by solidification at considerable depth beneath the Earth's surface
polished	flawless or excellent; performed with skilful ease
population validity	a of type external validity that describes how well the sample used can be extrapolated to the population as a whole
practical	in science, an activity that produces primary data

Term	Explanation
precise	definite or exact; definitely or strictly stated, defined or fixed; characterised by definite or exact expression or execution
precision	accuracy; exactness; exact observance of forms in conduct or actions in science, exactness; how close two or more measurements of the same object or phenomena are to each other
predict	give an expected result of an upcoming action or event; suggest what may happen based on available information
primary data	data collected directly by a person or group (ACARA 2015c)
process	in science, to collect and manipulate data to produce meaningful information; operate on a set of data to extract the required information in an appropriate form such as tables or graphs
processes	operations performed on a set of data to extract the required information in an appropriate form such as tables or graphs
product	an assessment technique that focuses on the output or result of a process requiring the application of a range of cognitive, physical, technical, creative and/or expressive skills, and theoretical and conceptual understandings; a product is developed over an extended and defined period of time
proficient	well advanced or expert in any art, science or subject; competent, skilled or adept in doing or using something
project	an assessment technique that focuses on a problem-solving process requiring the application of a range of cognitive, technical and creative skills and theoretical understandings; the response is a coherent work that documents the iterative process undertaken to develop a solution and includes written paragraphs and annotations, diagrams, sketches, drawings, photographs, video, spoken presentations, physical prototypes and/or models; a project is developed over an extended and defined period of time
propose	put forward (e.g. a point of view, idea, argument, suggestion) for consideration or action
prove	use a sequence of steps to obtain the required result in a formal way
psychomotor procedures	a domain of knowledge in Marzano's taxonomy, and acted upon by the cognitive, metacognitive and self-systems; these are physical procedures used to negotiate daily life and to engage in complex physical activities; the two categories of psychomotor procedures are skills (foundational procedures and simple combination procedures) and processes (complex combination procedures)
purposeful	having an intended or desired result; having a useful purpose; determined; resolute; full of meaning; significant; intentional
Q	
QCE	Queensland Certificate of Education
qualitative data	information that is not numerical in nature
quality of evidence	the standard of evidence, as measured against relevant criteria

Term	Explanation
quantitative data	numerical information (Taylor 1982)
quantity	in science, having magnitude, size, extent, amount or the like
R	
radioisotope	an isotope of an element that emits radioactive particles (Heffernan 2009)
rationale	a set of reasons, or logical basis for a course of action or decision
raw data	unprocessed and/or unanalysed data; data that has been collected without any additional processing (Taylor 1982)
realise	create or make (e.g. a musical, artistic or dramatic work); actualise; make real or concrete; give reality or substance to
reasonable	endowed with reason; having sound judgment; fair and sensible; based on good sense; average; appropriate, moderate
reasoned	logical and sound; based on logic or good sense; logically thought out and presented with justification; guided by reason; well-grounded; considered
recall	remember; present remembered ideas, facts or experiences; bring something back into thought, attention or into one's mind
recognise	identify or recall particular features of information from knowledge; identify that an item, characteristic or quality exists; perceive as existing or true; be aware of or acknowledge
redirect	in science, to redirect an experiment is to modify the methodology to gain further insight into the phenomena observed in the original experiment
referencing conventions	agreed, consistent ways of referencing a source of information
refine	in science, to refine an experiment is to modify the methodology to obtain more accurate or precise data
refined	developed or improved so as to be precise, exact or subtle
reflect on	think about deeply and carefully
rehearsed	practised; previously experienced; practised extensively
related	associated with or linked to
relationship	scientific relationships are a connection or association between ideas or between components of systems and structures (ACARA 2015c)
relevance	being related to the matter at hand
relevant	bearing upon or connected with the matter in hand; to the purpose; applicable and pertinent; having a direct bearing on
reliable	constant and dependable or consistent and repeatable

Term	Explanation
reliability	in science, the likelihood that another experimenter will obtain the same results (or very similar results) if they perform exactly the same experiment under the same conditions (ACARA 2015c, Taylor 1982)
repetitive	containing or characterised by repetition, especially when unnecessary or tiresome
reporting	providing information that succinctly describes student performance at different junctures throughout a course of study
representation	in science, verbal, physical or mathematical demonstration of understanding of a science concept or concepts; a concept can be represented in a range of ways and using multiple models (ACARA 2015c)
research	to locate, gather, record, and analyse information in order to develop understanding (ACARA 2015c)
research ethics	norms of conduct that determine ethical research behaviour; research ethics are governed by principles such as honesty, objectivity, integrity, openness and respect for intellectual property and include consideration of animal ethics (ACARA 2015c)
research question	a question that directs the scientific inquiry activity; it focuses the research investigation or student experiment, informing the direction of the research, and guiding all stages of inquiry, analysis, interpretation and evaluation
residency period	the average length of time a substance remains in a particular reservoir
resolve	in the Arts, consolidate and communicate intent through a synthesis of ideas and application of media to express meaning
risk assessment	evaluations performed to identify, assess and control hazards in a systematic way that is consistent, relevant and applicable to all school activities; requirements for risk assessments related to particular activities will be determined by jurisdictions, schools or teachers as appropriate (ACARA 2015c)
routine	often encountered, previously experienced; commonplace; customary and regular; well-practised; performed as part of a regular procedure, rather than for a special reason
rudimentary	relating to rudiments or first principles; elementary; undeveloped; involving or limited to basic principles; relating to an immature, undeveloped or basic form
S	
safe	secure; not risky
scientific language	terminology that has specific meaning in a scientific context
scrutinise	to examine closely or critically
secondary data	data collected by a person or group other than the person or group using the data (ACARA 2015c, Macquarie 1981)

Term	Explanation
secure	sure; certain; able to be counted on; self-confident; poised; dependable; confident; assured; not liable to fail
sedimentary settings	the combination of physical, chemical and biological processes associated with the deposition of a particular type of sediment and, therefore, the rock types that will be formed after lithification (Hubble, Huxley & Imlay-Gillespie 2011)
seismic velocity discontinuities	sudden jumps in seismic velocities across geological layers
select	choose in preference to another or others; pick out
sensitive	capable of perceiving with a sense or senses; aware of the attitudes, feelings or circumstances of others; having acute mental or emotional sensibility; relating to or connected with the senses or sensation
sequence	place in a continuous or connected series; arrange in a particular order
show	provide the relevant reasoning to support a response
significant	important; of consequence; expressing a meaning; indicative; includes all that is important; sufficiently great or important to be worthy of attention; noteworthy; having a particular meaning; indicative of something
significant figures	the use of place value to represent a measurement result accurately and precisely (ACARA 2015c)
simple	easy to understand, deal with and use; not complex or complicated; plain; not elaborate or artificial; may concern a single or basic aspect; involving few elements, components or steps
simplistic	characterised by extreme simplification, especially if misleading; oversimplified
simulation	a representation of a process, event or system which imitates a real or idealised situation (ACARA 2015c)
sketch	execute a drawing or painting in simple form, giving essential features but not necessarily with detail or accuracy; in mathematics, represent by means of a diagram or graph; the sketch should give a general idea of the required shape or relationship and should include features
skilful	having technical facility or practical ability; possessing, showing, involving or requiring skill; expert, dexterous; demonstrating the knowledge, ability or training to perform a certain activity or task well; trained, practised or experienced
skilled	having or showing the knowledge, ability or training to perform a certain activity or task well; having skill; trained or experienced; showing, involving or requiring skill
slab pull	the concept that subducting plates are pulled along by their dense leading edges (Pohl 2003)
sluicing	wash or rinse freely with a stream or shower of water (e.g. the use of a ‘sluice box’ in a creek or river to separate gold from gravel)

Term	Explanation
smelting	extract (metal) from its ore by a process involving heating and melting
solve	find an answer to, explanation for, or means of dealing with (e.g. a problem); work out the answer or solution to (e.g. a mathematical problem); obtain the answer/s using algebraic, numerical and/or graphical methods
sophisticated	of intellectual complexity; reflecting a high degree of skill, intelligence, etc.; employing advanced or refined methods or concepts; highly developed or complicated
source	any piece of scientific literature or text from which scientific evidence is drawn
Southern Oscillation Index	a measure of changes in air pressure at sea level that describes the cyclic warming and cooling of the Eastern and Central Pacific Ocean (Hubble, Huxley & Imlay-Gillespie 2011)
specific	clearly defined or identified; precise and clear in making statements or issuing instructions; having a special application or reference; explicit, or definite; peculiar or proper to something, as qualities, characteristics, effects, etc.
sporadic	happening now and again or at intervals; irregular or occasional; appearing in scattered or isolated instances
statement	a communication or declaration setting forth facts, particulars; an expression
stoping	the loosening and removal of ore in a mine, usually by working upward (Pohl 2003)
straightforward	without difficulty; uncomplicated; direct; easy to do or understand
stratigraphic traps	a change in physical properties of the reservoir layer that traps gas and oil (Pohl 2003)
stratigraphy	study of rock layers and layering of materials such as sediments including ash, meteoritic impact ejecta layers and soils
stratosphere	the layer of the Earth's atmosphere above the troposphere, extending to about 50 km above the Earth's surface (the lower boundary of the mesosphere)
structure	*verb* give a pattern, organisation or arrangement to; construct or arrange according to a plan; *noun* in languages, arrangement of words into larger units, e.g. phrases, clauses, sentences, paragraphs and whole texts, in line with cultural, intercultural and textual conventions
structured	organised or arranged so as to produce a desired result
subduction	the sliding of the sea floor beneath a continent or island arc (Pohl 2003)

Term	Explanation
subject	a branch or area of knowledge or learning defined by a syllabus; school subjects are usually based in a discipline or field of study (see also 'course')
subject matter	the subject-specific body of information, mental procedures and psychomotor procedures that are necessary for students' learning and engagement within that subject
substantial	of ample or considerable amount, quantity, size, etc.; of real worth or value; firmly or solidly established; of real significance; reliable; important, worthwhile
substantiated	established by proof or competent evidence
subtle	fine or delicate in meaning or intent; making use of indirect methods; not straightforward or obvious
successful	achieving or having achieved success; accomplishing a desired aim or result
succinct	expressed in few words; concise; terse; characterised by conciseness or brevity; brief and clear
sufficient	enough or adequate for the purpose
suitable	appropriate; fitting; conforming or agreeing in nature, condition, or action
summarise	give a brief statement of a general theme or major point/s; present ideas and information in fewer words and in sequence
summative assessment	assessment whose major purpose is to indicate student achievement; summative assessments contribute towards a student's subject result
superficial	concerned with or comprehending only what is on the surface or obvious; shallow; not profound, thorough, deep or complete; existing or occurring at or on the surface; cursory; lacking depth of character or understanding; apparent and sometimes trivial
supported	corroborated; given greater credibility by providing evidence
sustainability	in science, the quality of not being harmful to the environment or depleting natural resources, and therefore supporting long-term ecological balance
sustained	carried on continuously, without interruption, or without any diminishing of intensity or extent
syllabus	a document that prescribes the curriculum for a course of study
syllabus objectives	outline what the school is required to teach and what students have the opportunity to learn; described in terms of actions that operate on the subject matter; the overarching objectives for a course of study (see also 'unit objectives', 'assessment objectives')
symbolise	represent or identify by a symbol or symbols

Term	Explanation
synoptic charts	the scientific term for a weather map; provides information on the distribution, movement and patterns of air pressure, rainfall, wind and temperature; information is conveyed using symbols, which are explained in a legend
synthesise	combine different parts or elements (e.g. information, ideas, components) into a whole, in order to create new understanding
system	a group of interacting objects, materials or processes that form an integrated whole; systems can be open or closed (ACARA 2015c)
systematic	done or acting according to a fixed plan or system; methodical; organised and logical; having, showing, or involving a system, method, or plan; characterised by system or method; methodical; arranged in, or comprising an ordered system
T	
test	take measures to check the quality, performance or reliability of something
theory	in science, a set of concepts, claims and/or laws that can be used to explain and predict a wide range of related observed or observable phenomena; theories are typically founded on clearly identified assumptions, are testable, produce reproducible results and have explanatory power (ACARA 2015c)
thermosphere	the thermosphere is the layer of the Earth's atmosphere directly above the mesosphere and directly below the exosphere
thorough	carried out through, or applied to the whole of something; carried out completely and carefully; including all that is required; complete with attention to every detail; not superficial or partial; performed or written with care and completeness; taking pains to do something carefully and completely
thoughtful	occupied with, or given to thought; contemplative; meditative; reflective; characterised by or manifesting thought
topic	a division of, or sub-section within a unit; all topics/sub-topics within a unit are interrelated
trend	general direction in which something is changing (ACARA 2015c)
troposphere	one of the four thermal layers of the atmosphere; the layer of the atmosphere in which clouds form
trophic levels	the position that an organism occupies in a food chain or web

Term	Explanation
U	
ultraviolet radiation	non-visible electromagnetic radiation with a shorter wavelength than visible violet light (Hubble, Huxley & Imlay-Gillespie 2011)
uncertainty	range of values for a measurement result, taking account of the likely values that could be attributed to the measurement result given the measurement equipment, procedure and environment (ACARA 2015c); indicators of uncertainty may include percentage, and/or absolute measurement uncertainty, confidence intervals, inferential statistics, statistical measure of spread, e.g. range, standard deviation
unclear	not clear or distinct; not easy to understand; obscure
unconformable	a surface that represents a break in the geologic record with the rock unit immediately above it being considerably younger than the rock beneath
understand	perceive what is meant by something; grasp; be familiar with (e.g. an idea); construct meaning from messages, including oral, written and graphic communication
understanding	perception of what is meant by something
uneven	unequal; not properly corresponding or agreeing; irregular; varying; not uniform; not equally balanced
unfamiliar	not previously encountered; situations or materials that have not been the focus of prior learning experiences or activities
uniformitarianism	the principle that all geologic phenomena may be explained as the result of existing forces having operated similarly from the origin of Earth to the present time
unit	a defined amount of subject matter delivered in a specific context or with a particular focus; it includes unit objectives particular to the unit, subject matter and assessment direction
unit objectives	drawn from the syllabus objectives and contextualised for the subject matter and requirements of a particular unit; they are assessed at least once in the unit (see also 'syllabus objectives', 'assessment objectives')
unrelated	having no relationship; unconnected
use	operate or put into effect; apply knowledge or rules to put theory into practice
V	
vague	not definite in statement or meaning; not explicit or precise; not definitely fixed, determined or known; of uncertain, indefinite or unclear character or meaning; not clear in thought or understanding; couched in general or indefinite terms; not definitely or precisely expressed; deficient in details or particulars; thinking or communicating in an unfocused or imprecise way

Term	Explanation
valid	sound, just or well-founded; authoritative; having a sound basis in logic or fact (of an argument or point); reasonable or cogent; able to be supported; legitimate and defensible; applicable
validity	in science, the extent to which tests measure what was intended; the extent to which data, inferences and actions produced from tests and other processes are accurate (ACARA 2015c)
variable	*adjective* apt or liable to vary or change; changeable; inconsistent; (readily) susceptible or capable of variation; fluctuating, uncertain; *noun* in mathematics, a symbol, or the quantity it signifies, that may represent any one of a given set of number and other objects in science, a factor that can be changed, kept the same or measured in an investigation, e.g. time, distance, light, temperature
variety	a number or range of things of different kinds, or the same general class, that are distinct in character or quality; (of sources) a number of different modes or references
visual representations	in science, an image that shows relationships within scientific evidence
W	
wide	of great range or scope; embracing a great number or variety of subjects, cases, etc.; of full extent
with expression	in words, art, music or movement, conveying or indicating feeling, spirit, character, etc.; a way of expressing or representing something; vivid, effective or persuasive communication

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8 Version history

Version	Date of change	Update
1.1	June 2017	Minor editorial changes
1.2	December 2017	Editorial changes
		Syllabus objective 2: Amendment to explanatory paragraph
		Subject matter • Unit 2: Topic 2 Weather patterns — ‘define’ changed to ‘describe’ weather as an interaction between the atmosphere and hydrosphere
		IA1: Data test • Minor amendments to Assessment objectives 2,3 & 4 • Percentage of marks modified – objective 3 — 40% changed to 30% – objective 4 — 30% changed to 40% • Condition amendment (Length) — 400 words changed to ‘up to 500 words’
		IA2: Student experiment • Minor amendment to Assessment objective 5
		IA3: Research investigation • Minor amendment to Assessment objective 5
		Amendments to ISMGs to reflect modifications to objectives
		Glossary update
1.3	June 2018	Editorial changes
		IA1: Data test • Minor amendments to Assessment objective 2 • Minor amendments to description and conditions • Addition of information about cognition and nature of response for each objective
		IA2: Student experiment • Minor editorial changes to ISMG
		IA3: Research investigation • Minor editorial changes to ISMG
		EA: Examination • Minor amendments to Assessment objectives 3 and 4 • Minor amendments to description and conditions
		Glossary update
1.4	July 2022	Amendments to Unit 1 and Unit 2 Assessment guidance

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