

Authorised and published by the Victorian Curriculum and Assessment Authority  
Level 7, 2 Lonsdale Street  
Melbourne VIC 3000

Cover artwork  
Detail from a VCE work of Alexandra Syme: ‘Suburban Landscape’ 2017, enamel paint on stoneware,  
13.0 x 70.0 x 70.0 cm (variable). Copyright remains the property of the artist.

ISBN: 978-1-74010-089-2

© Victorian Curriculum and Assessment Authority 2020

No part of this publication may be reproduced except as specified under the *Copyright Act 1968* or by permission from the VCAA. Excepting third-party elements, schools may use this resource in accordance with the [VCAA educational allowance](https://www.vcaa.vic.edu.au/Footer/Pages/Copyright.aspx). For more information go to <https://www.vcaa.vic.edu.au/Footer/Pages/Copyright.aspx>.

The VCAA provides the only official, up-to-date versions of VCAA publications. Details of updates can be found on the VCAA website at [www.vcaa.vic.edu.au](https://www.vcaa.vic.edu.au/Pages/HomePage.aspx).

This publication may contain copyright material belonging to a third party. Every effort has been made to contact all copyright owners. If you believe that material in this publication is an infringement of your copyright, please email the Copyright Officer [vcaa.copyright@education.vic.gov.au](mailto:vcaa.media.publications@education.vic.gov.au)

Copyright in materials appearing at any sites linked to this document rests with the copyright owner/s of those materials, subject to the Copyright Act. The VCAA recommends you refer to copyright statements at linked sites before using such materials.

The VCAA logo is a registered trademark of the Victorian Curriculum and Assessment Authority.

|  |
| --- |
| Contact us if you need this information in an accessible format; for example, large print or audio.  Telephone (03) 9032 1635 or email [vcaa.media.publications@education.vic.gov.au](mailto:vcaa.media.publications@education.vic.gov.au) |

Contents

[Important information 1](#_Toc24380209)

[Introduction 2](#_Toc24380212)

[Scope of study 2](#_Toc24380213)

[Rationale 2](#_Toc24380214)

[Aims 3](#_Toc24380215)

[Structure 4](#_Toc24380216)

[Entry 4](#_Toc24380217)

[Duration 4](#_Toc24380218)

[Changes to the study design 4](#_Toc24380219)

[Monitoring for quality 4](#_Toc24380220)

[Safety and wellbeing 4](#_Toc24380221)

[Ethical conduct of scientific investigations 5](#_Toc24380222)

[Employability skills 5](#_Toc24380223)

[Legislative compliance 5](#_Toc24380224)

[Assessment and reporting 6](#_Toc24380225)

[Satisfactory completion 6](#_Toc24380226)

[Levels of achievement 6](#_Toc24380227)

[Authentication 6](#_Toc24380230)

[Cross-study specifications 7](#_Toc24380231)

[Terms used in this study 15](#_Toc24380239)

[Unit 1: How are Earth’s dynamic systems interconnected to support life? 19](#_Toc24380247)

[Area of Study 1 19](#_Toc24380248)

[Area of Study 2 20](#_Toc24380251)

[Area of Study 3 21](#_Toc24380254)

[Assessment 22](#_Toc24380257)

[Unit 2: What affects Earth’s capacity to sustain life? 24](#_Toc24380258)

[Area of Study 1 24](#_Toc24380259)

[Area of Study 2 25](#_Toc24380262)

[Area of Study 3 26](#_Toc24380265)

[Assessment 28](#_Toc24380268)

[Unit 3: How can biodiversity and development be sustained? 30](#_Toc24380269)

[Area of Study 1 30](#_Toc24380270)

[Area of Study 2 32](#_Toc24380273)

[School-based assessment 34](#_Toc24380276)

[External assessment 34](#_Toc24380276)

[Unit 4: How can climate change and the impacts of human energy use be managed? 36](#_Toc24380279)

[Area of Study 1 36](#_Toc24380280)

[Area of Study 2 38](#_Toc24380283)

[Area of Study 3 39](#_Toc24380286)

[School-based assessment 40](#_Toc24380289)

[External assessment 42](#_Toc24380291)

Important information

Accreditation period

Units 1–4: 1 January 2022 – 31 December 2026

Implementation of this study commences in 2022.

Other sources of information

The [*VCAA Bulletin*](https://www.vcaa.vic.edu.au/news-and-events/bulletins-and-updates/bulletin/Pages/index.aspx) is the only official source of changes to regulations and accredited studies. The Bulletin also regularly includes advice on VCE studies. It is the responsibility of each VCE teacher to refer to each issue of the Bulletin. The Bulletin is available as an e-newsletter via [free subscription](https://www.vcaa.vic.edu.au/Footer/Pages/Subscribe.aspx) on the VCAA’s website.

To assist teachers in developing courses, the VCAA publishes online the Advice for teachers, which includes teaching and learning activities for Units 1–4, and advice on assessment tasks and performance level descriptors for School-assessed Coursework in Units 3 and 4.

The current [*VCE and VCAL Administrative Handbook*](https://www.vcaa.vic.edu.au/administration/vce-vcal-handbook/Pages/index.aspx) contains essential information on assessment processes and other procedures.

VCE providers

Throughout this study design the term ‘school’ is intended to include both schools and other VCE providers.

Copyright

VCE schools may reproduce parts of this study design for use by teachers. The full [VCAA Copyright Policy](https://www.vcaa.vic.edu.au/Footer/Pages/Copyright.aspx) is available on the VCAA website.

Introduction

Scope of study

Environmental science is an interdisciplinary, investigative science that explores the interactions and interconnectedness between humans and their environments, and analyses the functions of both living and non-living elements that sustain Earth systems.

In VCE Environmental Science, Earth is understood as a set of four interrelated systems: the atmosphere, the biosphere, the hydrosphere and the lithosphere. This study explores how the relationships between these systems produce natural environmental change over a variety of time scales and how these systems respond to change and disruption. Students investigate the extent to which humans modify their environments and the consequences of these changes in local and global contexts with a focus on biodiversity, pollution, food and water security, climate change and energy use. Students examine the challenges and opportunities presented by selected environmental issues and case studies, and consider how different value systems, priorities, knowledge and regulatory frameworks affect environmental decision-making and planning for a sustainable future.

An important feature of undertaking a VCE science study is the opportunity for students to engage in a range of scientific investigation methodologies, to develop key science skills, and to interrogate the links between theory, knowledge and practice. Students work collaboratively as well as independently on a range of tasks involving controlled experiments, fieldwork, case studies, correlational studies, classification and identification, modelling, simulations, literature reviews, and the development of a product, process or system. Knowledge and application of the safety and ethical guidelines associated with undertaking investigations is integral to the study of VCE Environmental Science.

As well as increasing their understanding of scientific processes, students develop insights into how knowledge in environmental science has changed, and continues to change, in response to new evidence, discoveries and thinking. They develop capacities that enable them to critically assess the strengths and the limitations of science, respect evidence-based conclusions and gain an awareness of the ethical contexts of scientific endeavours, including sociocultural, economic, political and legal factors. Students consider the role of innovation and science in addressing contemporary environmental challenges.

Rationale

VCE Environmental Science enables students to explore the interrelationships between Earth’s four systems. Students examine how past and current human activities affect the environment and how future challenges can be managed sustainably. In undertaking this study, students gain an understanding of the complexity of environmental decision-making, and how innovative responses to environmental challenges can reduce pressure on Earth’s natural resources and ecosystem services.

In VCE Environmental Science, students develop a range of scientific inquiry skills including practical experimentation, research and analytical skills, problem-solving skills including critical and creative thinking, and communication skills. Students pose questions, formulate hypotheses, conduct investigations, and analyse and critically interpret qualitative and quantitative data. They assess the limitations of data, evaluate methodologies and results, justify their conclusions, make recommendations and communicate their findings. Students investigate and evaluate environment-related issues, alternative proposals and responses to challenges by considering both short- and long-term consequences for the individual, the environment and society.

VCE Environmental Science provides direct pathways to a range of careers related to atmospheric sciences, ecology, environmental chemistry and geosciences. The interdisciplinary nature of the study leads to pathways including, but not limited to, architecture, environmental law, engineering, environmental consultancy, environmental advocacy, government policy development, industrial management, landscape design, regional and urban planning, and teaching and research. Environmental scientists also work in cross-disciplinary solutions-oriented areas such as coastal management, climate risk management and disaster risk management.

Aims

This study enables students to:

* develop knowledge and understanding of Earth as a dynamic and complex set of four interrelated systems – atmosphere, biosphere, hydrosphere and lithosphere – that undergo natural change over various time scales and that affect, and are affected by, human activities
* understand that sustainable, solutions-focused responses to environmental challenges involve innovative thinking as well as responsible decision-making that is influenced by both regulatory frameworks and the values, knowledge and priorities of multiple stakeholders

and more broadly to:

* develop attitudes that include curiosity, open-mindedness, creativity, flexibility, integrity, attention to detail and respect for evidence-based conclusions
* develop an understanding of the cooperative, cumulative, iterative and interdisciplinary nature of science as a human endeavour, including its possibilities, limitations and sociocultural, economic, political and legal influences and consequences
* develop a range of individual and collaborative science inquiry skills through a variety of investigation methodologies in the laboratory and field, refining investigations to improve data quality
* understand the research, ethical and safety guidelines that govern the study and practice of the discipline and apply these guidelines to generate, collate, analyse, critically evaluate and report data
* analyse and interpret qualitative and quantitative data to provide evidence, recognising patterns, relationships and limitations of data
* develop an informed and critical perspective, as local and global citizens, on contemporary science-based issues
* develop knowledge and understanding of key models, concepts, theories and laws of science to explain scientific processes and phenomena, and apply this understanding in familiar and unfamiliar situations, including personal, sociocultural, environmental and technological contexts
* communicate clearly and accurately an understanding of the discipline using appropriate terminology, conventions and formats.

Structure

The study is made up of four units, structured under a series of curriculum-framing questions that reflect the inquiry nature of the discipline.

Unit 1: How are Earth’s dynamic systems interconnected to support life?

Unit 2: What affects Earth’s capacity to sustain life?

Unit 3: How can biodiversity and development be sustained?

Unit 4: How can climate change and energy impacts be managed?

Each unit deals with specific content contained in areas of study and is designed to enable students to achieve a set of outcomes for that unit. Each outcome is described in terms of key knowledge and is complemented by a set of key science skills.

Entry

There are no prerequisites for entry to Units 1, 2 and 3. Students must undertake Unit 3 and Unit 4 as a sequence. Units 1 to 4 are designed to a standard equivalent to the final two years of secondary education. All VCE studies are benchmarked against comparable national and international curriculum.

Duration

Each unit involves at least 50 hours of scheduled classroom instruction.

Changes to the study design

During its period of accreditation minor changes to the study will be announced in the [*VCAA Bulletin*](https://www.vcaa.vic.edu.au/news-and-events/bulletins-and-updates/bulletin/Pages/index.aspx). The Bulletin is the only source of changes to regulations and accredited studies. It is the responsibility of each VCE teacher to monitor changes or advice about VCE studies published in the Bulletin.

Monitoring for quality

As part of ongoing monitoring and quality assurance, the VCAA will periodically undertake an audit of VCE Environmental Science to ensure the study is being taught and assessed as accredited. The details of the audit procedures and requirements are published annually in the [*VCE and VCAL Administrative Handbook*](https://www.vcaa.vic.edu.au/administration/vce-vcal-handbook/Pages/index.aspx). Schools will be notified if they are required to submit material to be audited.

Safety and wellbeing

This study may involve the handling of potentially hazardous substances and the use of potentially hazardous equipment. It is the responsibility of the school to ensure that duty of care is exercised in relation to the health and safety of all students undertaking the study. Teachers and students should observe appropriate safety precautions when undertaking practical work. All laboratory work should be supervised by the teacher. It is the responsibility of schools to ensure that they comply with health and safety requirements.

Relevant acts and regulations include:

* *Occupational Health and Safety Act 2004*
* *Occupational Health and Safety Regulations 2017*
* *Occupational Health and Safety Management Systems (AS/NZ 4801)*
* *Dangerous Goods (Storage and Handling) Regulations 2012*
* *Dangerous Goods Storage and Handling Code of Practice 2000*
* *Hazardous Substances Code of Practice 2000*
* *Electrical Safety Act 1998*

Ethical conduct of scientific investigations

As part of this study, teachers and students may be involved in teaching and learning activities that include scientific investigations using human subjects. Teachers and schools have a legal and moral responsibility to ensure that students demonstrate ethical conduct at all times when undertaking such investigations. Teachers should refer to the following documents for detailed advice:

* the *National Statement on Ethical Conduct in Human Research (2007) – Updated 2018*, issued by the National Health and Medical Research Council (NHMRC) in accordance with the *NHMRC Act 1992* (Cwlth), [www.nhmrc.gov.au/about-us/publications/national-statement-ethical-conduct-human-research-2007-updated-2018](http://www.nhmrc.gov.au/about-us/publications/national-statement-ethical-conduct-human-research-2007-updated-2018)
* the *Australian Privacy Principles* *from the Privacy Amendment (Enhancing Privacy Protection) Act 2012*, [www.oaic.gov.au/individuals/privacy-fact-sheets/general/privacy-fact-sheet-17-australian-privacy-principles](http://www.oaic.gov.au/individuals/privacy-fact-sheets/general/privacy-fact-sheet-17-australian-privacy-principles)
* the *Australian Psychological Society* (APS) *Code of Ethics*, [www.psychology.org.au/About-Us/What-we-do/ethics-and-practice-standards/APS-Code-of-Ethics](http://www.psychology.org.au/About-Us/What-we-do/ethics-and-practice-standards/APS-Code-of-Ethics)

It is not expected that animals will be used in the teaching of this study. If using animals in teaching, schools must comply with the current legislation including:

* the *Prevention of Cruelty to Animals Act 1986* and its *Extension Regulations 2018*
* the *Australian Code of Practice for the Care and Use of Animals for Scientific Purposes 2013* (8th edition), [www.nhmrc.gov.au/about-us/publications/australian-code-care-and-use-animals-scientific-purposes](http://www.nhmrc.gov.au/about-us/publications/australian-code-care-and-use-animals-scientific-purposes)

Employability skills

This study offers a number of opportunities for students to develop employability skills. The *Advice for teachers* companion document provides specific examples of how students can develop employability skills during learning activities and assessment tasks.

Legislative compliance

When collecting and using information, the provisions of privacy and copyright legislation, such as the Victorian *Privacy and Data Protection Act 2014* and *Health Records Act 2001*, and the federal *Privacy Act 1988* and *Copyright Act 1968*, must be met.

Assessment and reporting

Satisfactory completion

The award of satisfactory completion for a unit is based on the teacher’s decision that the student has demonstrated achievement of the set of outcomes specified for the unit. Demonstration of achievement of outcomes and satisfactory completion of a unit are determined by evidence gained through the assessment of a range of learning activities and tasks.

Teachers must develop courses that provide appropriate opportunities for students to demonstrate satisfactory achievement of outcomes.

The decision about satisfactory completion of a unit is distinct from the assessment of levels of achievement. Schools will report a student’s result for each unit to the VCAA as S (Satisfactory) or N (Not Satisfactory).

Levels of achievement

Units 1 and 2

Procedures for the assessment of levels of achievement in Units 1 and 2 are a matter for school decision. Assessment of levels of achievement for these units will not be reported to the VCAA. Schools may choose to report levels of achievement using grades, descriptive statements or other indicators.

Units 3 and 4

The VCAA specifies the assessment procedures for students undertaking scored assessment in Units 3 and 4. Designated assessment tasks are provided in the details for each unit in VCE study designs.

The student’s level of achievement in Units 3 and 4 will be determined by School-assessed Coursework (SAC) as specified in the VCE study design, and external assessment.

The VCAA will report the student’s level of achievement on each assessment component as a grade from A+ to E or UG (ungraded). To receive a study score the student must achieve two or more graded assessments and receive S for both Units 3 and 4. The study score is reported on a scale of 0–50; it is a measure of how well the student performed in relation to all others who completed the study. Teachers should refer to the current [*VCE and VCAL Administrative Handbook*](https://www.vcaa.vic.edu.au/administration/vce-vcal-handbook/Pages/index.aspx) for details on graded assessment and calculation of the study score. Percentage contributions to the study score in VCE Environmental Science are as follows:

* Unit 3 School-assessed Coursework: 20 per cent
* Unit 4 School-assessed Coursework: 30 per cent
* End-of-year examination: 50 per cent.

Details of the assessment program are described in the sections on Units 3 and 4 in this study design.

Authentication

Work related to the outcomes of each unit will be accepted only if the teacher can attest that, to the best of their knowledge, all unacknowledged work is the student’s own. Teachers need to refer to the current [*VCE and VCAL Administrative Handbook*](https://www.vcaa.vic.edu.au/administration/vce-vcal-handbook/Pages/index.aspx) for authentication procedures.

Cross-study specifications

Key science skills

The key science skills are a core component of the study of VCE Environmental Science and apply across Units 1 to 4 in all areas of study. In designing teaching and learning programs for each unit and in assessing student learning for each outcome, teachers should ensure that students are given the opportunity to develop, use and demonstrate these skills in a variety of contexts, including when undertaking their own investigations and when evaluating the research of others. As the complexity of key knowledge increases from Units 1 to 4, and as opportunities are provided to undertake investigations, students should aim to demonstrate the key science skills at a progressively higher level.

The key science skills are common to all VCE science studies and have been contextualised in the following table for VCE Environmental Science.

|  |  |  |
| --- | --- | --- |
| **Key science skill** | | **VCE Environmental Science Units 1–4** |
| Develop aims and questions, formulate hypotheses and make predictions | * identify, research and construct aims and questions for investigation * identify independent, dependent and controlled variables in controlled experiments * formulate hypotheses to focus investigations * predict possible outcomes of investigations | |
| Plan and conduct investigations | * determine appropriate investigation methodology: case study; classification and identification; controlled experiment; correlational study; fieldwork; literature review; modelling; product, process or system development; simulation * design and conduct investigations: select and use methods appropriate to the selected investigation methodology, including consideration of sampling technique and size, equipment and procedures, taking into account potential sources of error and uncertainty; determine the type and amount of qualitative and/or quantitative data to be generated or collated * select appropriate sampling techniques in fieldwork (including grids, quadrats, transects and mark-recapture) * explain the effects of varying sample sizes in obtaining robust data * work independently and collaboratively as appropriate and within identified research constraints, adapting or extending processes as required and recording such modifications | |

|  |  |  |
| --- | --- | --- |
| Comply with safety and ethical guidelines | | * demonstrate safe laboratory practices when planning and conducting investigations by using risk assessments that are informed by safety data sheets (SDS), and accounting for risks * apply relevant occupational health and safety guidelines while undertaking practical investigations * demonstrate ethical conduct when undertaking and reporting investigations |
| Generate, collate and record data | * systematically generate and record primary data, and collate secondary data, appropriate to the investigation, including use of databases and reputable online data sources * record and summarise both qualitative and quantitative data, including use of a logbook as an authentication of generated or collated data * organise and present data in useful and meaningful ways, including schematic diagrams, flow charts, tables, bar charts and line graphs | | |
| Analyse and evaluate data and investigation methods | * process quantitative data using appropriate mathematical relationships and units, including calculations of ratios, percentages, percentage change and mean * extrapolate and interpolate data points from graphs * identify and analyse experimental data qualitatively, handling, where appropriate, concepts of: accuracy, precision, repeatability, reproducibility and validity of measurements; errors (random and systematic); and degree of confidence and certainty in data, including confidence ratings of climate projections * identify outliers, and contradictory, provisional or incomplete data * repeat experiments to ensure findings are robust * process and analyse data to identify cause-and-effect relationships, correlations, and linear, non-linear or cyclical patterns * evaluate investigation methods and possible sources of error, and suggest improvements to increase accuracy and precision, and to reduce the likelihood of errors | | |
| Construct evidence-based arguments and draw conclusions | * distinguish between opinion, anecdote and evidence (including weak and strong evidence), and scientific and non-scientific ideas * evaluate data to determine the degree to which the evidence supports the aim of the investigation, and make recommendations, as appropriate, for modifying or extending the investigation * evaluate data to determine the degree to which the evidence supports or refutes the initial prediction or hypothesis * use reasoning to construct scientific arguments, and to draw and justify conclusions consistent with evidence and relevant to the question under investigation * identify, describe and explain the limitations of conclusions, including identification of further evidence required * discuss the implications of research findings and proposals | | |

|  |  |
| --- | --- |
| Analyse, evaluate and communicate scientific ideas | * use appropriate environmental science terminology, representations and conventions, including standard abbreviations, graphing conventions and units of measurement * discuss relevant environmental science information, ideas, concepts, theories and models and the connections between them * analyse and explain how models and theories are used to organise and understand observed phenomena and concepts related to environmental science, identifying limitations of selected models/theories * critically evaluate and interpret a range of scientific and media texts (including journal articles, mass media communications and opinions in the public domain), processes, claims and conclusions related to environmental science by considering the quality of available evidence * analyse and evaluate environmental science scenarios, case studies, issues and challenges using the sustainability principles of conservation of biodiversity and ecological integrity, efficiency of resource use, intergenerational equity, intragenerational equity, precautionary principle, and user pays principle * apply Earth systems thinking to analyse and evaluate responses to environmental science scenarios, case studies, issues and challenges in terms of supporting and sustaining ecological integrity * identify and explain when judgments or decisions associated with issues related to environmental science may be based on sociocultural, economic, political, legal and/or ethical factors and not solely on scientific evidence * use clear, coherent and concise expression to communicate to specific audiences and for specific purposes in appropriate scientific genres, including scientific reports and posters * acknowledge sources of information and assistance, and use standard scientific referencing conventions |

Scientific investigation

Students undertake scientific investigations across Units 1 to 4 of this study. Scientific investigations may be undertaken in groups, but all work for assessment must be completed individually.

All VCE science studies include scientific investigations that are student-designed. In approving student-designed investigation topics, teachers and schools must ensure that an investigation proposed by a student for a VCE Environmental Science assessment task is not able to be presented as an assessment task in another VCE study at the school.

Scientific investigation methodologies

Scientific investigations can be undertaken in a variety of ways depending on the aim of the investigation and the question under investigation. For the purposes of VCE Environmental Science, the planning and conducting of scientific investigations will require consideration of the following investigation methodologies:

* **Case study:** An investigation of a particular activity, behaviour, event or problem that contains a real or hypothetical situation and includes the complexities that would be encountered in the real world. Case studies can take various forms: historical, involving the analysis of causes and consequences, and discussion of knowledge learned from the situation; a real situation or a role-play of an imagined situation, where plausible recommendations are to made; or problem-solving, where developing a new design, methodology or method is required.
* **Classification and identification:** Classification is the arrangement of phenomena, objects or events into manageable sets, whereas identification is a process of recognition of phenomena as belonging to particular sets or possibly being part of a new or unique set.
* **Controlled experiment:** An experimental investigation of the relationship between an independent variable and a dependent variable, controlling all other variables.
* **Correlational study:** Planned observation and recording of events and behaviours that have not been manipulated or controlled to understand the relationships/associations that exist between variables, to identify which factors may be of greater importance, and to make predictions.
* **Fieldwork:** Based on inquiry or the investigation of an issue, fieldwork involves observing and interacting with a selected environment beyond the classroom, usually in an attempt to determine correlation, rather than a causal relationship. It may be conducted through direct qualitative and/or quantitative observations and sampling, participant observation, interviews and questionnaires.
* **Literature review**: Involves the collation and analysis of secondary data related to other people’s scientific findings and/or viewpoints in order to answer a question or provide background information to help explain observed events, or as preparation for an investigation to generate primary data.
* **Modelling:** Involves the construction of: a physical model, such as a small- or large-scale representation of an object; a conceptual model, which represents a system involving concepts that help people know, understand or simulate the system; or a mathematical model, which describes a system using mathematical equations that involve relationships between variables and that can be used to make predictions.
* **Product, process or system development:** Design of an artefact, process or system to meet a human need, which may involve technological applications in addition to scientific knowledge and procedures.
* **Simulation:** A process of using a model to study the behaviour of a real or theoretical system. The modelling and manipulation of variables in a real system is useful because often the variables cannot be controlled as the system may be too complex, too large or small, too fast or slow, not accessible or too dangerous.

Logbooks

The use of a logbook reflects standard scientific practice. Students undertaking this study must maintain a logbook of practical activities in each of Units 1 to 4 for recording, authentication and assessment purposes. All items in the logbook must be dated and clearly documented.

The logbook is submitted as a requirement for satisfactory completion in each of Units 1 to 4. Teachers must regularly sight and monitor the logbook, particularly for the student-designed practical and/or research investigations in Outcome 3 of Units 1 and 2, and Outcome 3 of Unit 4.

The logbook may be maintained in hard copy or electronic form. However, in order to avoid falsification and/or alteration of results, for assessment tasks it is recommended that students maintain a hard copy, as is commonly the practice in scientific research.

Unit 4 Scientific poster

In Unit 4, Area of Study 3, students demonstrate their science communication skills by presenting the findings of a student-designed scientific investigation and the significance of these findings to both technical and non-technical audiences. The poster may be produced electronically or in hard-copy format and should not exceed 600 words.

Students will use the following scientific poster format when reporting on their investigation:

|  |  |  |  |
| --- | --- | --- | --- |
|  | Title Student name | |  |
| Introduction  Methodology and methods  Results | Communication statement reporting the key finding  of the investigation as a one-sentence summary | Discussion  Conclusion | |
| References and acknowledgements | | | |

The centre of the poster will occupy between 20 to 25 per cent of the poster space and will be a one-sentence summary of the major finding of the investigation that answers the investigation question.

The presentation format of the poster will include the following sections:

|  |  |  |
| --- | --- | --- |
| **Poster section** | **Content** | |
| Title | Question under investigation | |
| Introduction | Brief explanation or reason for undertaking the investigation, including a clear aim, a hypothesis and/or prediction and relevant background environmental science concepts | |
| Methodology and methods | Brief outline of the selected methodology used to address the investigation question | |
| Summary of data generation method/s and data analysis method/s | |
| Results | Presentation of generated data/evidence in appropriate format to illustrate trends, patterns and/or relationships | |
| Discussion | Interpretation and evaluation of analysed primary data | |
| Identification of limitations in data and methods, and suggested improvements | |
| Cross-referencing of results to relevant environmental science concepts | |
| Linking of results to investigation question and to the aim to explain whether or not the investigation data and findings support the hypothesis | |
| Conclusion | | Conclusion that provides a response to the investigation question |
| Identification of the extent to which the analysis has answered the investigation question, with no new information being introduced |
| Implications of the investigation and/or suggestions as to further investigations that may be undertaken |
| References and acknowledgements | | Referencing and acknowledgement of all quotations and sourced content relevant to the investigation. |

Students record in their logbooks all elements of their investigation planning, comprising identification and management of relevant risks, recording of raw data, and preliminary analysis and evaluation of results, including identification of outliers and their subsequent treatment. Both the students’ poster and logbook enries are assessed as part of Unit 4, Area of Study 3.

Critical and creative thinking

Critical and creative thinking are embedded in key science skills and applied across the VCE sciences during learning experiences where students develop questions and hypotheses, design and undertake investigations, make reasoned predictions, generate and evaluate knowledge, clarify concepts and ideas, seek possibilities, consider alternatives and consequences, make evidence-based decisions, devise real or imagined solutions, and solve problems.

Students may engage in scientific investigations involving both primary and secondary data after they identify an aim and methodology, and develop a specific investigation method that includes consideration of participants, sampling technique and size, equipment and procedure.   
A commitment to accuracy, precision and integrity in observation is an important precursor to critical thinking when generating primary data.

Problem solving of any kind requires initial deconstruction to identify an appropriate methodology, followed by consideration of potential risks, and perseverance in adopting different strategies to develop a solution or to reach a conclusion.

In VCE Environmental Science, students also consider how critical and creative thinking has been applied by others in the development of knowledge and applications related to addressing environmental challenges.

Ethical understanding

Ethical understanding is applied across Units 1 to 4 of the VCE sciences. Students apply an ethical understanding when they undertake their own investigations, analyse their own and others’ data, and identify and investigate issues relating to the application of scientific knowledge in society. Applying the knowledge and skills of ethical understanding enables students to:

* consider the implications of their own and others’ investigations on living things and the environment
* apply integrity when recording and reporting the outcomes of their own investigations, and when using their own and others’ data
* reach a position about science-related ethical issues based on an understanding of ethical concepts and scientific knowledge and skills, considering current and future needs
* recognise the importance of values, and of sociocultural, economic, political and legal factors in responsible science-related decision-making.

Five ethical concepts are pertinent to Units 1 to 4 VCE Environmental Science: integrity, justice, beneficence, non-maleficence and respect. These are embedded when considering:

* six sustainability principles: conservation of biodiversity and ecological integrity; efficiency of resource use; intergenerational equity; intragenerational equity; precautionary principle; and user pays principle
* environmental decision-making that involves stakeholders who are influenced by their own set of values, knowledge and priorities. Stakeholders may also hold different value systems (anthropocentrism, biocentrism, ecocentrism and technocentrism) that vary in the emphasis that they place on the different ethical concepts.

Further explanation of these terms can be found in the ‘Terms used in this study’ section on   
[pages 15–18](#Terms).

Individual and collaborative scientific endeavour

Scientific endeavour is commonly a collaborative, and often global, undertaking that draws on the knowledge and skills of individuals. Units 1 to 4 of VCE Environmental Science provides students with opportunities to manage themselves and their interactions with others through activities that include discussions about scientific concepts, problem-solving and decision-making, and to undertake individual and group practical work.

In working individually, students should be encouraged to plan and manage their time effectively, work safely, make responsible decisions and constructively handle challenging situations.

When working with others, students are expected to actively participate, share ideas, and offer viewpoints and suggestions while respecting the perspectives of others. In group work, students should identify collective goals and make use of strategies to work effectively as a group member to complete tasks and solve problems.

Students learn to seek, value and act on feedback when undertaking both individual and collaborative endeavours.

Aboriginal and Torres Strait Islander knowledge, cultures and history

Aboriginal and Torres Strait Islander peoples have diverse cultures, social structures and a history of unique, complex knowledge systems. In VCE Environmental Science, students consider how science thinking can be informed and enhanced by considering how Aboriginal and Torres Strait Islander peoples have developed and refined their own knowledge about the world through: observation, using all the senses; prediction and hypothesis testing, including trial-and-error; and making generalisations within specific contexts including the use of food, water and natural materials, land management and environmental sustainability.

Teachers are encouraged to include Aboriginal and Torres Strait Islander knowledge and perspectives in the design and the delivery of teaching and learning programs related to VCE Environmental Science. Many local Aboriginal and Torres Strait Islander communities have protocols that they have developed in relation to education. The Victorian Koorie community-preferred education model enables teachers to focus inclusively on supporting students to consider Victorian Koorie education matters, and systematically support students to learn about local, regional, state and national Indigenous perspectives. VCE studies involve a focused extension of this model and include a broader application of national and international perspectives.

*Protocols for Koorie education in Victorian schools*, developed through the Yalca policy, and other resources relating to the inclusion of Aboriginal and Torres Strait Islander knowledge and perspectives may be accessed at [www.vaeai.org.au/documents/](http://www.vaeai.org.au/documents/)

Terms used in this study

For the purposes of this study design and associated assessment, the following definitions will apply. The *Advice for teachers* provides additional guidance and should be used in conjunction with this study design.

Data and measurement

A major aim of science is to develop explanations that are supported by evidence for natural phenomena and events. This involves evaluating the quality and quantity of evidence, and before conclusions are drawn from data, considering questions such as: ‘Can I rely on the data I have generated when drawing conclusions?’, and, ‘Does the difference between one measurement and another indicate a real change in what is being measured?’.

When analysing and discussing investigations of a quantitative nature, the following terms require consideration:

* **Accuracy:** a measurement value is considered to be accurate if it is judged to be close to the ‘true’ value of the quantity being measured. Accuracy is not quantifiable; measurement values may be described as being more accurate or less accurate.
* **Precision:** refers to how closely a set of measurement values agree with each other. Precision gives no indication of how close the measurements are to the true value and is therefore a separate consideration to accuracy.
* **Repeatability:** the closeness of the agreement between the results of successive measurements of the same quantity being measured, carried out under the same conditions of measurement. These conditions include the same measurement procedure, the same observer, the same measuring instrument used under the same conditions, the same location, and repetition over a short period of time.
* **Reproducibility:** the closeness of the agreement between the results of measurements of the same quantity being measured, carried out under changed conditions of measurement. These changed conditions include a different method of measurement, different observer, different measuring instrument, different location, different conditions of use, and different time.
* **True value:** the value that would be found if the quantity could be measured perfectly.
* **Validity:** a measurement is said to be valid if it measures what it is supposed to be measuring. An experiment is said to be valid if it investigates what it sets out and/or claims to investigate.

Errors, uncertainty and outliers

It is important not to confuse the terms measurement error and personal error in the sense of a mistake. Error, from a scientific measurement perspective, is the difference between the measured value and the true value of what is being measured. For the purposes of VCE Environmental Science, two types of measurement error should be considered when evaluating the quality of data: systematic errors and random errors. Personal errors should be eliminated by performing the experiment again correctly the next time, and therefore do not form part of an analysis of data quality.

* **Personal errors:** include mistakes, miscalculations and observer errors such as parallax errors.
* **Random errors:** affect the precision of a measurement and are present in all measurements except for measurements involving counting. Random errors are unpredictable variations in the measurement process and result in a spread of readings. The effect of random errors can be reduced by making more or repeated measurements and calculating a new mean and/or by refining the measurement method or technique.
* **Systematic errors:** affect the accuracy of a measurement. Systematic errors cause readings to differ from the true value by a consistent amount each time a measurement is made, so that all the readings are shifted in one direction from the true value. The accuracy of measurements subject to systematic errors cannot be improved by repeating those measurements.

It is also important not to confuse the terms ‘error’ and ‘uncertainty’, which are not synonyms. Outliers in data are a separate consideration, and must be further analysed and accounted for, rather than being automatically dismissed.

* **Uncertainty:** The uncertainty in a measurement indicates the range of values in which the true value is expected to lie. VCE Environmental Sciencerequires only a qualitative treatment of uncertainty. When evaluating personally sourced or provided data, students should be able to identify contradictory, provisional and incomplete data including possible sources of bias.

***Confidence in climate science data***

An appreciation of the degree of confidence and certainty/uncertainty in data is particularly important in the study of climate change. In reports produced by the Intergovernmental Panel on Climate Change (IPCC), confidence is expressed qualitatively, and indicates how certain scientists are that their findings are valid. The IPCC Fifth Assessment Report (AR5) confidence levels are based on the evidence (robust, medium and limited) and the degree of scientific agreement (high, medium and low). The combined evidence and agreement result in five levels of confidence (very high, high, medium, low and very low). If an event is given a very high confidence level, there is a combination of high agreement and robust evidence that the event will occur. The consideration of the ‘likelihood’ of an event occurring, a quantitative measure related to mathematical probabilities, is beyond the scope of VCE Environmental Science.

* **Outliers:** Readings that lie a long way from other results are sometimes called outliers. Repeating readings may be useful in further examining an outlier.

Stakeholders and decision-making

Environmental decision-making often involves multiple stakeholders, each of whom have their own set of values, knowledge and priorities, as well as working within different personal and regulatory boundaries. For the purposes of VCE Environmental Science, the following aspects of environmental decision-making will be considered:

* **Stakeholder:** An individual, group or organisation involved in decision-making related to an environmental case study, project or issue. Stakeholder groups and organisations may include: Aboriginal and Torres Strait Islander peoples; a local or regional community; media; environmental interest groups; industry representatives; and non-government and government agencies.
* **Stakeholder knowledge:** The scientific, technical and experiential knowledge held by a stakeholder.
* **Stakeholder values:** The set of principles, standards and/or qualities that a stakeholder holds in high regard and that determines the way the stakeholder chooses actions and evaluates events.

Sustainability principles

For the purposes of VCE Environmental Science, six sustainability principles will be considered:

* **Conservation of biodiversity and ecological integrity:** Maintenance of the abundance of different species living within a particular region, the genetic diversity in a population and the ability of an ecosystem to maintain its biotic and abiotic organisation and function in the face of changing environmental conditions, including a capacity for self-renewal.
* **Efficiency of resource use:** Use of smaller amounts of physical resources to produce the same product or service while minimising environmental impact.
* **Intergenerational equity:** Preserving natural resources and the environment for the benefit of future generations.
* **Intragenerational equity:** Preserving natural resources and the environment for the benefit of the current generation.
* **Precautionary principle:** A guideline that is triggered when the risk of harm to the environment due to a proposed action is high but the scientific evidence is uncertain, requiring that measures be taken to prevent environmental damage and that the proof of no, or minimal, harm be provided by the proposer.
* **User pays principle:** Calls upon the user of a service or resource to pay directly for the amount they use, rather than the cost being shared by all the users or a community equally.

Sustainable development

Sustainable development is considered to be development that meets the needs of the present without compromising the ability of future generations to meet their own needs, based on *Our Common Future,* World Commission on Environment and Development (WCED),1987 (also referred to as the *Brundtland Report*), and preceding the United Nations *2030 Agenda for Sustainable Development*.

Systems thinking

* **Earth systems thinking:** Consideration of the connections and interactions between Earth’s four systems – atmosphere, biosphere, hydrosphere and lithosphere – that support and sustain ecological integrity.
* **Circular economy thinking:** A circular economy is based on the principles of keeping products and materials in use, designing out waste and pollution, and regenerating natural systems. Circular economy thinking aspires to create a closed-loop system where the waste outputs from one activity become the inputs for a different activity, with the ultimate aim of no waste.

Value systems

For the purposes of VCE Environmental Science, four value systems will be considered:

* **Anthropocentrism:** Regards humankind as the central or most important element of existence.
* **Biocentrism:** Based on the premise that all living things have the right to exist.
* **Ecocentrism:** Recognises the ecosphere as being of central importance, and attempts to redress the impacts associated with anthropocentrism.
* **Technocentrism:** Centred on technology and its ability to control and protect the environment, with environmental problems being seen as challenges to be solved using rational, scientific and technological means.

Unit 1: How are Earth’s dynamic systems interconnected to support life?

Earth has been dramatically altered over the past 4.5 billion years by naturally occurring climate swings, volcanic activity, drifting continents and other transformative processes. Human activities and lifestyles have an impact on, and are impacted by, Earth’s systems both directly and indirectly, and with both immediate and far-reaching effects.

In this unit students examine the processes and interactions occurring within and between Earth’s four interrelated systems – the atmosphere, biosphere, hydrosphere and lithosphere. They focus on how ecosystem functioning can influence many local, regional and global environmental conditions such as plant productivity, soil fertility, water quality and air quality. Students explore how changes that have taken place throughout geological and recent history are fundamental to predicting the likely impact of future changes. They consider a variety of influencing factors in achieving a solutions-focused approach to responsible management of challenges related to natural and human-induced environmental change.

A student-adapted or student-designed scientific investigation is undertaken in Area of Study 3. The investigation involves the generation of primary data and is related to ecosystem components, monitoring and/or change. It draws on the key science skills and key knowledge from Area of   
Study 1 and/or Area of Study 2.

Area of Study 1

How are Earth’s systems organised and connected?

Living organisms are able to survive in ecosystems as diverse as deserts, sea beds, the tropics and Antarctica, as well as in backyard gardens and ponds. In this area of study students analyse the range of components and processes that contribute to ecosystem functioning, and examine how events occurring in one of Earth’s four interrelated systems can affect all systems to support life on Earth.

The selection of learning contexts should allow students to develop practical techniques and undertake fieldwork to monitor and/or assess ecological integrity and to examine the inputs, processes and outputs of ecosystems. Students develop their skills in the use of scientific equipment and apparatus. They simulate or model population changes such as the effects of introduced species on predator–prey relationships, and develop their skills in selecting appropriate sampling methods to determine the number and proportion of different species present, such as transects and quadrats in fieldwork.

Outcome 1

On completion of this unit the student should be able to describe the movement of energy and nutrients across Earth’s four interrelated systems, and analyse how dynamic interactions among biotic and abiotic components of selected local and regional ecosystems contribute to their capacity to support life and sustain ecological integrity.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key science skills on [pages 7–9](#Skills) of the study design.

Key knowledge

Investigation of local ecosystems

* the range of biotic and abiotic components that determine the environmental conditions of varied habitats within aquatic and terrestrial ecosystems
* interrelationships within ecological communities as represented by food chains, food webs, energy and biomass pyramids

Earth systems thinking

* natural interactions between Earth’s four systems – the atmosphere, biosphere, hydrosphere and lithosphere – that support and are affected by the movement of energy and matter within and between local and global ecosystems
* systems thinking as a way of exploring relationships in environmental systems by identifying inputs, outputs, components and processes that may be visible or invisible to the human eye, including representation of a local and regional environmental system.

Area of Study 2

How do Earth’s systems change over time?

Using field data and global satellite imaging, environmental scientists can estimate that more than 80 per cent of Earth’s surface has been transformed by long-extinct volcanoes. Scientists are able to monitor changes in the volume, salinity and rate of evaporation from bodies of water, and track disruptions to the hydrological and carbon cycles associated with large-scale deforestation. A comparison of the Gariwerd seasonal calendar with other Aboriginal and Torres Strait Islander peoples’ seasonal calendars and with Western planting schedules over time illustrates different approaches to crop selection and land management in response to environmental change. In this area of study students compare Earth’s changing features, examine different ways to measure and make predictions about changes in Earth’s four systems, and explore different options for managing environmental changes and challenges.

The selection of learning contexts should allow students to develop practical techniques and undertake fieldwork to examine change or disruption to ecosystems and local landscapes over time. Students develop their skills in the use of scientific equipment and apparatus. They perform comparative tests of ecological function such as measuring the infiltration rates through rocks and soils with different permeabilities, and design practical solutions to challenges such as erosion and curbing water run-off. Students may obtain secondary data for analysis from landscape mapping tools.

Outcome 2

On completion of this unit the student should be able to analyse how changes occurring at various time and spatial scales influence Earth’s characteristics and interrelated systems, and assess the impact of diverse stakeholder values, knowledge and priorities in the solutions-focused management of a selected regional environmental challenge.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key science skills on [pages 7–9](#Skills) of the study design.

Key knowledge

Earth’s dynamic systems

* transformative processes occurring during Earth’s deep history that shaped the formation of Earth’s four interrelated systems
* changes and disruptions to landscapes, ecosystems and biomes that influence their distribution and ecological characteristics

Data and modelling

* ways of using data and models to study Earth’s systems and changes in Earth over time

Managing environmental challenges

* the role of innovation and science in responding to challenges as a result of environmental change and disruption
* the contribution of scientific data, new technologies, regulatory frameworks and diverse stakeholder values, knowledge and priorities in managing environmental challenges of regional relevance.

Area of Study 3

How do scientific investigations develop understanding of how Earth’s systems support life?

Ecosystems are subject to change in response to biotic or abiotic disturbances, or variations in the magnitude or frequency of disturbances, which can have flow-on effects for the atmosphere, biosphere, hydrosphere and lithosphere. In this area of study students adapt or design and then conduct a scientific investigation into the monitoring of ecosystems or their components and/or change in ecosystems. The investigation must include the generation of primary data.

The student-adapted or student-designed scientific investigation should take an Earth systems thinking approach and should relate to knowledge and skills developed in Area of Study 1 and/or Area of Study 2.

Outcome 3

On completion of this unit the student should be able to draw an evidence-based conclusion from primary data generated from a student-designed or student-adapted scientific investigation related to ecosystem components, ecosystem monitoring and/or change affecting Earth's systems.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 3 and the related key science skills on [pages 7–9](#Skills) of the study design.

Key knowledge

Investigation design

* environmental science concepts specific to the scientific investigation and their significance, including definitions of key terms
* scientific methodology relevant to the investigation, selected from: classification and identification; controlled experiment; correlational study; fieldwork; modelling; product, process or system development; or simulation
* techniques of primary qualitative and quantitative data generation relevant to the investigation
* accuracy, precision, reproducibility, repeatability and validity of measurements in relation to the investigation
* health, safety and ethical guidelines relevant to the selected scientific investigation

Scientific evidence

* the distinction between an aim, a hypothesis, a model, a theory and a law
* observations and investigations that are consistent with, or challenge, current scientific models or theories
* the characteristics of primary data
* ways of organising, analysing and evaluating generated primary data to identify patterns and relationships, and to identify sources of error
* the use of a logbook to authenticate generated primary data
* the limitations of investigation methodologies and methods, and of data generation and/or analysis

Science communication

* the conventions of scientific report writing including scientific terminology and representations, standard abbreviations and units of measurement
* ways of presenting key findings and implications of the selected scientific investigation.

Assessment

The award of satisfactory completion for a unit is based on whether the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of learning activities and assessment tasks that provide a range of opportunities for students to demonstrate the key science skills and key knowledge in the outcomes.

The areas of study, including the key science skills and key knowledge listed for the outcomes, should be used for course design and the development of learning activities and assessment tasks. Assessment must be a part of the regular teaching and learning program and should be completed mainly in class and within a limited timeframe.

All assessments at Units 1 and 2 are school-based. Procedures for assessment of levels of achievement in Units 1 and 2 are a matter for school decision.

For this unit students are required to demonstrate three outcomes. As a set these outcomes encompass the areas of study in the unit.

Suitable tasks for assessment in this unit may be selected from the list below.

*For Outcomes 1 and 2*

For each outcome, at least one task selected from:

* a laboratory or fieldwork activity involving the generation, analysis and evaluation of primary data, presented as a report or scientific poster
* an investigation or literature review involving the collation of secondary data
* reflective annotations from a logbook of practical activities
* analysis of data/results including generation of appropriate graphical representations and formulation of generalisations and conclusions
* analysis and evaluation of a case study
* a response to an issue or media article
* a graphic organiser showing how Earth’s systems are impacted by an action, innovation or management strategy
* a photojournalism article, presented as an essay or as a multimedia production
* a modelling or simulation activity
* problem solving involving environmental science concepts, skills and/or issues
* a designed solution to an environmental issue or challenge
* evaluation of stakeholder perspectives in environmental management.

If multiple tasks are selected for Outcome 1 and/or Outcome 2, they must be different. The same task cannot be selected more than once across Outcomes 1 and 2.

Where teachers allow students to choose between tasks, teachers must ensure that the tasks they set are of comparable scope and demand.

*For Outcome 3*

* a report of a student-adapted or student-designed scientific investigation using an appropriate format such as a scientific poster, an article for a scientific publication, a practical report, an oral presentation, a multimedia presentation or a visual representation.

Practical work

Practical work is a central component of learning and assessment and may include activities such as laboratory experiments, fieldwork, simulations, modelling and other direct experiences as described in the scientific investigation methodologies on [pages 9 and](#Investigation) 10. A minimum of ten hours of class time should be devoted to student practical activities and scientific investigations across Areas of Study 1 and 2. For Area of Study 3, a minimum of seven hours of class time should be devoted to undertaking, and communicating findings of, the student-adapted or student-designed scientific investigation.

Unit 2: What affects Earth’s capacity to sustain life?

A sustainable food and water system with a minimal environmental footprint is necessary to secure the food and water supplies that can meet the demands of current and future populations of Earth’s species, including humans. Both natural and human activities can generate pollution that can cause adverse effects across Earth’s four interrelated systems – the atmosphere, biosphere, hydrosphere and lithosphere – and consequently affect food and water security. Pollution can make air and water resources hazardous for plants and animals. It can directly harm soil microorganisms and larger soil-dwelling organisms, with consequences for soil biodiversity, as well as impacting on food security by impairing plant function and reducing food yields.

In this unit students consider pollution as well as food and water security as complex and systemic environmental challenges facing current and future generations. They examine the characteristics, impacts, assessment and management of a range of pollutants that are emitted or discharged into Earth’s air, soil, water and biological systems, and explore factors that limit and enable the sustainable supply of adequate and affordable food and water.

A student-directed investigation is to be undertaken in Area of Study 3. The investigation explores how science can be applied to address Earth’s capacity to sustain life in the context of the management of a selected pollutant and/or the maintenance of food and/or water security.   
The investigation draws on the key science skills and key knowledge from Area of Study 1 and/or Area of Study 2.

Area of Study 1

How can we manage pollution to sustain Earth’s systems?

Even landscapes or ecosystems that appear unspoiled can be adversely affected by pollution emitted from nearby as well as distant sources. The nesting, communication and mating behaviours of certain bird communities can change when exposed to continuous noise generated in human-populated environments. Hazardous waste spills, unsustainable farming practices, strip mining, deforestation and littering may cause soil and water contamination that can lead to poor growth and reduced crop yields, loss of wildlife habitat, water and noise pollution, soil erosion and desertification. The preservation of Earth’s life-supporting systems and the management of pollution are interrelated. In this area of study students link the characteristics of pollutants to their impacts on Earth’s four interrelated systems, and examine emerging opportunities to mitigate pollution discharge and manage the adverse effects of pollution for living and non-living things.

The selection of learning contexts should allow students to develop practical techniques and undertake fieldwork to assess and monitor air, water and soil quality. Students develop their skills in the use of scientific equipment and apparatus. They perform standard laboratory tests for pollution indicators such as dissolved oxygen and phosphate levels, and select sampling techniques that determine the number and relative abundance of introduced species, such as the use of pond nets or kick sampling. Secondary data for analysis may be used to explore environmental relationships between environmental contaminants and selected aspects of Earth’s systems.

Outcome 1

On completion of this unit the student should be able to explain how the chemical and physical characteristics of pollutants impact on Earth’s four systems, and recommend and justify a range of options for managing the local and global impacts of pollution.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key science skills on [pages 7–9](#Skills) of the study design.

Key knowledge

Pollution effects on Earth’s systems

* chemical and physical characteristics of pollutants that influence dispersal of emissions from natural and manufactured sources
* the transport mechanisms, persistence, fate and toxicity of pollutants throughout Earth’s four interrelated systems
* the impacts of a range of pollutants on the health and survival of living things in the biosphere, including humans, and on the quality of the atmosphere, hydrosphere and lithosphere with reference to risk, exposure, dosage, tolerance limits, LD50, chronic and acute toxicity, allergies, disruption of system regulation and synergistic action

Managing pollution

* the contributions of scientific data, new technologies, regulatory frameworks and diverse stakeholder values and priorities when managing pollution
* options for control and treatment of pollution to reduce local and global impacts.

Area of Study 2

How can we manage food and water security to sustain Earth’s systems?

The demand by Earth’s inhabitants for adequate, nutritious food and safe water stocks places increasing pressure on our natural resources. Water is critical for healthy, natural and manufactured ecosystems and determines the availability of food crops, livestock and many services that underpin human well-being. The supply of useable water is, however, influenced by both seasonal and long-term climatic variations. Drought conditions have led to changed practices such as seawater desalination, alternative dietary choices and government-imposed water restrictions. Conversely, flooding has led to adaptive responses such as the Gunditjmara Peoples’ engineering of local wetland swamps and sink-hole depressions, in order to construct eel traps for farming the eels that migrate annually through the system. In this area of study students examine various approaches for meeting the food and water security challenges facing current and future populations of humans and other species, while minimising negative environmental impacts. Students apply ecological footprint analysis to a selected context and explore options for addressing food and water challenges for a nominated region.

The selection of learning contexts should allow students to develop practical techniques and undertake fieldwork to examine the relationship between natural and human activities and the availability of food and water resources. Students develop their skills in the use of scientific equipment and apparatus. They use food and water calculators, and perform comparative analytical tests related to food and water needs, such as determining the organic matter and water contents of soil from fields with different long-term management systems. Students conduct user surveys to determine food and water usage, habits and attitudes, and design practical responses to environmental challenges such as improving water-use efficiency and managing nutrient-deficient soils.

Outcome 2

On completion of this unit the student should be able to compare the advantages and limitations of different agricultural systems for achieving regional and global food security, evaluate the use of ecological footprint analysis for assessing future food and/or water security, and recommend and justify a range of options for improving food and/or water security for a nominated region.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key science skills on [pages 7–9](#Skills) of the study design.

Key knowledge

Sustainable food systems

* challenges to supplying adequate and affordable food in regional and global locations that achieve regional and global food security
* qualitative differences between food produced by conventional monoculture and organic monoculture agricultural systems

Maintaining food and water security

* options for improving food security that consider organisational, political and structural enablers and barriers to change
* the use and limitations of ecological footprint analysis, in terms of the sustainability principles of intragenerational equity and the efficient use of resources
* the ecological footprint of either an individual, local and/or international community or business, or a local or imported raw food and/or food product
* options for decreasing water demand and improving water-use efficiency.

Area of Study 3

How do scientific endeavours contribute to minimising human impacts on Earth’s systems?

Environmental scientists work towards new understanding and insights that can yield innovative solutions to everyday and complex challenges in local, national and global contexts. Making connections between the work of others and their own learning enables students to explore and to compare responses to current and future environmental problems and challenges.

In this area of study students investigate a contemporary example of how science is influenced by, and responds to, the needs and priorities of society in managing a selected pollutant of interest and/or in securing water or food. Students select and explore a recent discovery, innovation, issue, advance or case study linked to their knowledge and skills developed in Area of Study 1 and/or Area of Study 2. Stimulus material for the investigation could include announcements of recent discoveries, an expert’s published point of view, an interview with an expert, an online presentation, an article from a scientific publication, public concern about an issue, ‘green field’ research leading to new technologies, or changes in government funding for environmental science purposes such as maximum sustainable yields in fisheries or the social impacts of resource extraction.

Students apply critical and creative thinking and scientific inquiry skills to prepare a communication to: explain the relevant scientific concepts; identify the sociocultural, economic, political, legal and ethical implications of the selected endeavour for society; and critically examine how science has been used to contribute to addressing the impacts of natural and human activities.

Outcome 3

On completion of this unit the student should be able to investigate and explain how science can be applied to address the impacts of natural and human activities in the context of the management of a selected pollutant and/or the maintenance of food and/or water security.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 3 and the related key science skills on [pages 7–9](#Skills) of the study design.

Key knowledge

Scientific evidence

* the distinction between primary and secondary data
* the nature of evidence and information: distinction between opinion, anecdote and evidence, weak and strong evidence, and scientific and non-scientific ideas
* the quality of evidence, including validity and authority of data and sources of possible errors or bias relating to those who benefit and those whose health or livelihood is impacted
* methods of organising, analysing and evaluating secondary data
* the use of a logbook to authenticate collated secondary data

Science communication

* scientific concepts specific to the investigation: definitions of key terms; and use of appropriate scientific terminology, conventions and representations
* the characteristics of effective science communication: accuracy of scientific information; clarity of explanation of scientific concepts, ideas and models; contextual clarity with reference to importance and implications of findings; conciseness and coherence; and appropriateness for purpose and audience
* the use of data representations, models and theories in organising and explaining observed phenomena and environmental science concepts, and their limitations
* the influence of sociocultural, economic, legal and political factors, and application of ethical understanding to science as a human endeavour
* conventions for referencing and acknowledging sources of information.

Assessment

The award of satisfactory completion for a unit is based on whether the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of learning activities and assessment tasks that provide a range of opportunities for students to demonstrate the key science skills and key knowledge in the outcomes.

The areas of study, including the key science skills and key knowledge listed for the outcomes, should be used for course design and the development of learning activities and assessment tasks. Assessment must be a part of the regular teaching and learning program and should be completed mainly in class and within a limited timeframe.

All assessments at Units 1 and 2 are school-based. Procedures for assessment of levels of achievement in Units 1 and 2 are a matter for school decision.

For this unit students are required to demonstrate three outcomes. As a set these outcomes encompass the areas of study in the unit.

Suitable tasks for assessment in this unit may be selected from the list below.

*For Outcomes 1 and 2*

For each outcome, at least one task selected from:

* a laboratory or fieldwork activity involving the generation, analysis and evaluation of primary data, presented as a report or scientific poster
* an investigation or literature review involving the collation of secondary data
* reflective annotations from a logbook of practical activities
* analysis of data/results including generation of appropriate graphical representations and formulation of generalisations/conclusions
* analysis and evaluation of a case study
* a response to an issue or media article
* a graphic organiser showing how Earth’s systems are impacted by an action, innovation or management strategy
* a photojournalism article, presented as an essay or as a multimedia production
* a modelling or simulation activity
* problem solving involving environmental science concepts, skills and/or issues
* a designed solution to an environmental issue or challenge
* evaluation of stakeholder perspectives in environmental management

If multiple tasks are selected for Outcome 1 and/or Outcome 2, they must be different. The same task cannot be selected more than once across Outcomes 1 and 2.

Where teachers allow students to choose between tasks, teachers must ensure that the tasks they set are of comparable scope and demand.

*For Outcome 3*

A response as to how science can be applied in the management of a selected pollutant or in securing food and/or water, communicated in an appropriate format for a specified audience, chosen from:

* an article for a scientific publication
* an oral or multimedia presentation to a peer group
* a brochure for public information
* a written report for media publication.

Practical work

Practical work is a central component of learning and assessment and may include activities such as laboratory experiments, fieldwork, simulations, modelling and other direct experiences as described in the scientific investigation methodologies on [pages 9 and 10](#Investigation). A minimum of ten hours of class time should be devoted to student practical activities and investigations across Areas of Study 1 and 2. For Area of Study 3, a minimum of seven hours of class time should be devoted to undertaking the investigation and communicating findings.

Unit 3: How can biodiversity and development be sustained?

In this unit students focus on environmental management through the application of sustainability principles. They explore the value of the biosphere to all living things by examining the concept of biodiversity and the ecosystem services important for human health and well-being. They analyse the processes that threaten biodiversity and evaluate biodiversity management strategies for a selected threatened endemic animal or plant species. Students use a selected environmental science case study with reference to sustainability principles and environmental management strategies to explore management from an Earth systems perspective, including impacts on the atmosphere, biosphere, hydrosphere and lithosphere.

A student-designed scientific investigation involving the generation of primary data related to biodiversity, environmental management, climate change and/or energy use is undertaken in either Unit 3 or Unit 4, or across both Units 3 and 4, and is assessed in Unit 4, Outcome 3. The design, analysis and findings of the investigation are presented in a scientific poster format as outlined on [pages 11–12](#Poster).

Area of Study 1

Why is maintaining biodiversity worth a sustained effort?

Australia is one of seventeen countries described as being ‘mega diverse’ in terms of its terrestrial and marine life. While only accounting for 10 per cent of the global surface, this group of seventeen countries contains more than 70 per cent of the biodiversity on the planet. In this area of study students use biodiversity as a lens through which to investigate the management of a single Earth system – the biosphere. They examine the categories of biodiversity, the role of biodiversity in sustaining ecosystems, the provision of ecosystem services for human well-being and the strategies employed to counteract threats, both natural and human-induced, to maintain biodiversity in the short-, medium- and long-term.

The selection of learning contexts should allow students to develop practical techniques and undertake fieldwork and other practical activities to investigate how biodiversity is measured and monitored in the context of a selected threatened species of interest. Students generate primary data, and organise and present this data, to evaluate whether efforts to ensure the long-term survival of the selected species are justified.

Outcome 1

On completion of this unit the student should be able to explain the importance of Earth’s biodiversity and how it has changed over time, analyse the threats to biodiversity, and evaluate management strategies to maintain biodiversity in the context of one selected threatened endemic species.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key science skills on [pages 7–9](#Skills) of the study design.

Key knowledge

Importance of biodiversity

* the definition and categories of biodiversity: genetic, species and ecosystem
* the importance of genetic diversity within a species or population experiencing environmental change
* ecosystems as a source of renewable services that impact on human health and well-being:
* provisioning services: potable water; food; fuel; fibre; and pharmaceuticals
* regulating services: control of climate and disease; pollination; and water purification
* supporting services that maintain conditions for life on Earth: cycling of nutrients; soil formation; and photosynthesis
* cultural services: aesthetic values; recreational benefits; and sense of place

Biodiversity changes over time

* evidence of variation in rate and extent of change in biodiversity over time: significant mass extinctions and periods of rapid species diversification that can be inferred from the fossil record
* natural changes occurring over different time scales that influence ecosystem diversity, species endemism, the formation of diversity hotspots, and rate of extinction: volcanic eruptions; fire; El Niño; tectonic plate movement; and evolution

Assessing changes in species diversity

* practical techniques used for assessing species diversity: sampling with grids, transects and different shaped quadrats, including consideration of edge effects and mark-recapture
* measurement of species diversity, including species richness, endemism and the application   
  of Simpson’s Index of Diversity (SID):

SID = 

* conservation categories for ranking species according to their risk of extinction: extinct in the wild; critically endangered; endangered; vulnerable; near threatened; and least concern
* qualitative assessment of conservation status to identify the species most in need of conservation action: changes in availability of suitable habitat, geographic distribution, and population size

Threats to biodiversity

* human and non-human threats to biodiversity: creation and isolation of small populations through habitat loss and over-exploitation; inbreeding due to small population size; loss of pollinators, dispersal agents, host species or symbionts that affect reproduction and persistence of species; bioaccumulation that concentrates some persistent pollutants within organisms and biomagnification along a food chain; climate change; disease; and introduced species that compete for shelter, food and water

Protection and restoration of biodiversity

* strategies for maintaining and growing populations that also build species resilience to changes in the environment: protected areas; retaining remnant vegetation; wildlife corridors or zones; translocation of animals; captive breeding and reintroduction programs; gene banks for the collection of specimens and genetic material; and reduction and improved targeting of pesticides in agricultural and urbanised areas
* approaches to renewing and regenerating degraded ecosystems: restoration of habitat; erosion control; and reintroduction of previously endemic species
* the application of relevant international, national, state and local legal treaties, agreements and regulatory frameworks that apply to the protection of threatened species: the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); IUCN Red List of Threatened Species; classified World Heritage areas; *Environment Protection and Biodiversity Conservation Act 1999* (Cth); *Flora and Fauna Guarantee Act 1988* (Vic); and local government conservation covenants
* value systems that influence decision-making processes: anthropocentrism, biocentrism, ecocentrism and technocentrism
* sustainability principles as they apply to biodiversity conservation: conservation of biodiversity and ecological integrity; efficiency of resource use; intergenerational equity; intragenerational equity; precautionary principle; and user pays principle.

Area of Study 2

When is development sustainable?

Society requires sustainable solutions for the environmental challenges it is facing today. In this area of study students explore variations in definitions of sustainability and consider how these may be interpreted and applied in addressing a selected environmental science case study.

The selection of learning contexts should allow students to study one environmental science case study in depth using Earth systems thinking. The selected case study should have an environmental management strategy, including risk assessment. Students assess the environmental impacts and risks associated with the environmental science case study, and examine the elements of environmental management and its relationship to sustainability principles. They examine the perspectives of stakeholders involved, analyse scientific data related to the monitoring of the case study, and evaluate the effectiveness of the environmental strategy implemented by the organisation.

Suitable environmental science case studies include:

* *geotechnical and transport engineering activities* that may involve construction of roads, freeways, railways, airports, mines, shopping centres and housing developments
* *environmental engineering* *activities* that may involve coastal erosion protection, mine revegetation, municipal recycling systems and freeway revegetation
* *water conservation and water engineering activities* that may involve studies of pollution in bays and oceans, sewage treatment plants, desalination plants, river diversion tunnels and stormwater drainage systems
* *energy and pollution minimisation activities* that may involve air quality monitoring, electrostatic precipitation in smoke stacks, waste minimisation plans, cleaner production plans, waste heat re-use in industry, and energy efficient housing and commercial buildings
* *soil remediation and soil erosion* *activities* that may involve bioremediation of soils, studies of dryland salinity, and total catchment management to reduce soil erosion
* *broadacre, intensive or alternative agricultural practices* that may involve feedlots, irrigation, organic farming and biological controls in farming
* *land management and development* *practices* that may involve ecotourism, hazard reduction burns in fire-prone landscapes, Aboriginal and Torres Strait Islander restoration projects, plantation forestry, green roofs and infrastructure, and urban housing projects.

Outcome 2

On completion of this unit the student should be able to explain how sustainability principles relate to environmental management, analyse how stakeholder perspectives can influence environmental decision-making, and evaluate the effectiveness of environmental management strategies in a selected case study.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key science skills on [pages 7–9](#Skills) of the study design.

Key knowledge

Case study overview

* the aim and strategies proposed for addressing the environmental science challenges associated with the selected case study

Sustainability principles

* the variations in definitions of sustainability and the distinction between sustainability and sustainable development
* sustainability principles as they apply to environmental management: conservation of biodiversity and ecological integrity; efficiency of resource use; intergenerational equity; intragenerational equity; precautionary principle; and user pays principle
* challenges to upholding sustainability principles, including population, food, water and energy

Environmental decision-making and management

* circular economy thinking and tools for integrated sustainability assessment, including qualitative risk analysis, and cost-benefit analysis
* interconnections and tensions between factors that influence responsible decision-making, including diverse stakeholder values, knowledge and priorities, regulatory frameworks that inform environmental management strategies, use and interpretation of historical and current scientific data, and application of new technologies

Case study evaluation

* the beneficial and harmful impacts of the selected case study on Earth’s four interrelated systems (atmosphere, biosphere, hydrosphere and lithosphere)
* the effectiveness of environmental management strategies implemented in relation to upholding sustainability principles.

School-based assessment

Satisfactory completion

The award of satisfactory completion for a unit is based on whether the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of learning activities and assessment tasks to provide a range of opportunities for students to demonstrate the key science skills and key knowledge in the outcomes.

The areas of study and key knowledge and relevant key science skills listed for the outcomes should be used for course design and the development of learning activities and assessment tasks.

Assessment of levels of achievement

The student’s level of achievement in Unit 3 will be determined by School-assessed Coursework. School-assessed Coursework tasks must be a part of the regular teaching and learning program and must not unduly add to the workload associated with that program. They must be completed mainly in class and within a limited timeframe.

Where teachers provide a range of options for the same School-assessed Coursework task, they should ensure that the options are of comparable scope and demand.

The types and range of forms of School-assessed Coursework for the outcomes are prescribed within the study design. The VCAA publishes *Advice for teachers* for this study, which includes advice on the design of assessment tasks and the assessment of student work for a level of achievement.

Teachers will provide to the VCAA a numerical score representing an assessment of the student’s level of achievement. The score must be based on the teacher’s assessment of the performance of each student on the tasks set out in the following table.

Contribution to final assessment

School-assessed Coursework for Unit 3 will contribute 20 per cent to the study score.

|  |  |  |
| --- | --- | --- |
| **Outcomes** | **Marks allocated** | **Assessment tasks** |
| **Outcome 1**  Explain the importance of Earth’s biodiversity and how it has changed over time, analyse the threats to biodiversity, and evaluate management strategies to maintain biodiversity in the context of one selected threatened endemic species. | 60 | *For Outcomes 1 and 2*  For each outcome, one task selected from:   * presentation of recommendations using evidence-based decision-making including analysis and evaluation of primary data * designed or practical response to  a real or theoretical environmental issue or challenge * analysis and evaluation of a case study, secondary data or a media communication, with reference to sustainability principles and stakeholder perspectives * application of Earth systems thinking in the evaluation of a response to an environmental scenario, case study, issue or challenge.   Each task can only be selected once across Units 3 and 4.  For each task the time allocated should be approximately 50–70 minutes for a written response and 10 minutes for a multimodal  or oral presentation. |
| **Outcome 2**  Explain how sustainability principles relate  to environmental management, analyse how stakeholder perspectives can influence environmental decision-making, and evaluate the effectiveness of environmental management strategies in a selected case study. | 40 |
| **Total marks** | **100** |  |

Practical work

Practical work is a central component of learning and assessment and may include activities such as laboratory experiments, fieldwork, simulations, modellling and other direct experiences as described in the scientific investigation methodologies on [pages 9 and 10](#Methodologies). A minimum of ten hours of class time should be devoted to student practical activities and investigations across Areas of Study 1 and 2.

External assessment

The level of achievement for Units 3 and 4 is also assessed by an end-of-year examination, which will contribute 50 per cent to the study score.

Unit 4: How can climate change and the impacts of human energy use be managed?

In this unit students explore different factors that contribute to the variability of Earth’s climate and that can affect living things, human society and the environment at local, regional and global scales. Students compare sources, availability, reliability and efficiencies of renewable and non-renewable energy resources in order to evaluate the suitability and consequences of their use in terms of upholding sustainability principles. They analyse various factors that are involved in responsible environmental decision-making and consider how science can be used to inform the management of climate change and the impacts of energy production and use.

Measurement of environmental indicators often involves uncertainty. Students develop skills in data interpretation, extrapolation and interpolation and test predictions. They recognise the limitations of contradictory, provisional and incomplete data derived from observations and models. They explore relationships and patterns in data, and make judgments about accuracy and validity of evidence.

A student-designed scientific investigation involving the generation of primary data related to biodiversity, environmental management, climate change and/or energy use is undertaken in either Unit 3 or Unit 4, or across both Units 3 and 4, and is assessed in Unit 4, Outcome 3. The design, analysis and findings of the investigation are presented in a scientific poster format as outlined on [pages 11 and 12](#Poster).

Area of Study 1

How can we respond to climate change?

Climate change is a complex challenge facing today’s society. It is a multi-dimensional and global issue, with regional impacts, including risks and opportunities. Effective adaptation and mitigation options are essential for reducing future risks and realising potential opportunities.

In this area of study students investigate natural as well as human-based factors that affect Earth’s climate. Students compare natural and enhanced greenhouse effects and their significance for sustaining ecological integrity. They explain different methods for measuring and predicting climate change, and consider the degree of certainty associated with climate projections. Students explore risks and opportunities for human societies and ecological systems associated with climate change at a selected region or location, and evaluate mitigation and adaptation strategies for managing climate change.

The selection of learning contexts should allow students to develop practical techniques and undertake fieldwork and other practical activities to model and investigate drivers of climate change. Students develop skills in the use of scientific equipment and apparatus to investigate the effects of altering different climate factors on selected environmental parameters, model different climate scenarios by accessing the internet or using simple climate models, and use practical activities, fieldwork and/or simulations to make and test predictions.

Outcome 1

On completion of this unit the student should be able to analyse the major factors that affect Earth’s climate, explain how past and future climate variability can be measured and modelled, and evaluate options for managing climate change.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key science skills on [pages 7–9](#Skills) of the study design.

Key knowledge

Major factors that affect Earth’s climate

* identification of natural phenomena and anthropogenic factors that affect Earth’s energy balance: volcanic eruptions; solar variability; and changes in atmospheric gas composition due to human activities
* the interactions between solar energy that is absorbed, re-emitted and reflected by atmospheric gases and other matter, including the albedo effect, the natural greenhouse effect, and ocean circulation
* carbon sequestration in land and water that results in short-term (less than 100 years) and long-term (more than 1000 years) changes in the carbon cycle

Understanding climate change

* the differences between natural and enhanced greenhouse effects
* altered greenhouse gas concentrations over different time periods – seasons, years, centuries and millennia – due to natural events, and human activities associated with the combustion of fossil fuels, cement production, agriculture and land use changes
* greenhouse gas warming potential as a measure of the infrared radiation the gas will tend to absorb over its lifetime in the atmosphere
* methods used for measuring past and present changes in the atmosphere: ice core sampling; use of palaeoclimate records; and atmospheric and ocean temperature monitoring
* data accessed through direct measurements and from modelling in assessing the rate of local, global and regional past and future climate variability: global average temperatures; local climate extremes; sea level rise; and snow and ice coverage
* climate change projections: comparison of observed and simulated current and past climate; and rating of confidence in global, regional and local climate projections expressed as very high, high, medium, low or very low, based on Intergovernmental Panel on Climate Change (IPCC) guidelines

Managing climate change

* the risks and opportunities associated with climate change for humans and ecological systems at a selected region or location: increase in range of exotic species; changes in length of plant growing seasons and animal breeding cycles; phenological changes for plant-pollinator interactions; increasing risks to coastal infrastructure from continuing sea level rise; reduction in agricultural production due to warmer and drier conditions
* mitigation options for reducing net greenhouse emissions to slow climate change
* adaptation options for building resilience to the effects of unavoidable climate change at a selected region or location
* interconnections and tensions between factors that influence responsible decision-making around managing climate change: diverse stakeholder values, knowledge and priorities, regulatory frameworks that inform environmental management strategies, use and interpretation of historical and current scientific data, and application of new technologies.

Area of Study 2

What might be a more sustainable mix of energy sources?

In this area of study students explore the concepts associated with the use of different energy sources by human societies. Students develop their understanding of the advantages and disadvantages of the uses of different sources of energy and consider the local and global impacts of these uses, including possible consequences over short (seconds to years), medium (multiple years to hundreds of years) and long (thousands to millions of years) time scales. They investigate the extent, availability and consequences of selecting alternative sources of energy for meeting current and projected energy demands, while considering the environmental, sociocultural, economic and ethical challenges involved in building a sustainable energy future.

The selection of learning contexts should allow students to develop practical techniques and undertake fieldwork and other practical activities to investigate and/or to compare options for building a sustainable energy future. Students develop skills in the use of scientific equipment and apparatus, model different energy scenarios, and use simulations to make and test predictions.

Outcome 2

On completion of this unit the student should be able to compare the advantages and disadvantages of using a range of energy sources, and evaluate the suitability and impacts of their use in terms of upholding sustainability principles.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key science skills on [pages 7–9](#Skills) of the study design.

Key knowledge

Comparison of different energy sources

* non-renewable energy sources: oil, coal, natural gas, coal seam gas and nuclear
* renewable energy sources: biomass, biofuels, solar, hydro-electric, wind, tidal and geothermal
* the consequences of fossil fuel combustion for the carbon cycle
* changes in the rate of the use of fossil fuels over time and the concept of peak oil
* energy efficiency calculations of single and multi-step conversions between different forms of energy, including potential, mechanical, kinetic, thermal, and chemical energy, to generate electricity
* the implications of the first and second laws of thermodynamics in making energy choices
* sustainability principles as they apply to accessing, extracting, processing, transporting, and using energy resources: conservation of biodiversity and ecological integrity; efficiency of resource use; intergenerational equity; intragenerational equity; precautionary principle; and user pays principle

Managing the impacts of human energy use

* mechanical and biological processes involved in rehabilitating sites from which energy has been sourced
* the extent to which different energy sources can supply current and projected base and peak load energy needs, and how these can be met at individual and societal levels
* options for building a sustainable energy future that produces lower greenhouse gas emissions and supplies reliable and affordable energy services: improving resource efficiency; increasing the efficiency of energy conversion devices; replacing fossil fuels with non-fossil fuel energy sources; and reducing personal energy consumption
* interconnections and tensions between factors that influence responsible decision-making around building a sustainable energy future, including diverse stakeholder values, knowledge and priorities, regulatory frameworks that inform environmental management strategies, use and interpretation of historical and current scientific data, and application of new technologies.

Area of Study 3

How is scientific inquiry used to investigate contemporary environmental challenges?

Students undertake a student-designed scientific investigation in either Unit 3 or Unit 4, or across both Units 3 and 4. The investigation involves the generation of primary data related to biodiversity, environmental management, climate change and/or energy use, and should be inspired by a contemporary environmental science challenge or issue. The investigation draws on knowledge and related key science skills developed across Units 3 and 4, and is undertaken by students in the laboratory and/or in the field.

When undertaking the investigation students are required to apply the key science skills to develop a question, state an aim, formulate a hypothesis and plan a course of action to answer the question, while complying with safety and ethical guidelines. Students then undertake a controlled experiment, correlational study or fieldwork to generate primary quantitative data, analyse and evaluate the data, identify limitations of data and methods, link experimental results to scientific ideas, discuss implications of the results, and draw a conclusion in response to the question. The presentation format for the investigation is a scientific poster constructed according to the structure outlined on [pages 11 and 12](#Poster). A logbook is maintained by students for record, assessment and authentication purposes.

Outcome 3

On completion of this unit the student should be able to design and conduct a scientific investigation related to biodiversity, environmental management, climate change and/or energy use, and present an aim, methodology and method, results, discussion and a conclusion in a scientific poster.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 3 and the related key science skills on [pages 7–9](#Skills) of the study design.

Key knowledge

Investigation design

* environmental science concepts specific to the selected scientific investigation and their significance, including definitions of key terms
* characteristics of the selected scientific methodology and method, and appropriateness of the use of independent, dependent and controlled variables in the selected scientific investigation
* techniques of primary qualitative and quantitative data generation relevant to the selected scientific investigation
* the accuracy, precision, reproducibility, repeatability and validity of measurements
* the health, safety and ethical guidelines relevant to the selected scientific investigation

Scientific evidence

* the nature of evidence that supports or refutes a hypothesis, model or theory
* ways of organising, analysing and evaluating primary data to identify patterns and relationships including sources of error and uncertainty
* authentication of generated primary data through the use of a logbook
* assumptions and limitations of investigation methodology and/or data generation and/or analysis methods

Science communication

* conventions of science communication: scientific terminology and representations, symbols, formulas, standard abbreviations and units of measurement
* conventions of scientific poster presentation, including succinct communication of the selected scientific investigation, and acknowledgements and references
* the key findings and implications of the selected scientific investigation.

School-based assessment

Satisfactory completion

The award of satisfactory completion for a unit is based on whether the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of learning activities and assessment tasks to provide a range of opportunities for students to demonstrate the key science skills and key knowledge in the outcomes.

The areas of study and key knowledge and relevant key science skills listed for the outcomes should be used for course design and the development of learning activities and assessment tasks.

Assessment of levels of achievement

The student’s level of achievement in Unit 4 will be determined by School-assessed Coursework. School-assessed Coursework tasks must be a part of the regular teaching and learning program and must not unduly add to the workload associated with that program. They must be completed mainly in class and within a limited timeframe.

Where teachers provide a range of options for the same School-assessed Coursework task, they should ensure that the options are of comparable scope and demand.

The types and range of forms of School-assessed Coursework for the outcomes are prescribed within the study design. The VCAA publishes *Advice for teachers* for this study, which includes advice on the design of assessment tasks and the assessment of student work for a level of achievement.

Teachers will provide to the VCAA a numerical score representing an assessment of the student’s level of achievement. The score must be based on the teacher’s assessment of the performance of each student on the tasks set out in the following table.

Contribution to final assessment

School-assessed Coursework for Unit 4 will contribute 30 per cent to the study score.

|  |  |  |
| --- | --- | --- |
| **Outcomes** | **Marks allocated** | **Assessment tasks** |
| **Outcome 1**  Analyse the major factors that affect Earth’s climate, explain how past and future climate variability can be measured and modelled, and evaluate options for managing climate change. | 40 | *For Outcomes 1 and 2*  For each outcome, one task selected from:   * presentation of recommendations using evidence-based decision-making, including analysis and evaluation of primary data * designed or practical response to  a real or theoretical environmental issue or challenge * analysis and evaluation of a case study, secondary data or a media communication, with reference to sustainability principles and stakeholder perspectives * application of Earth systems thinking in the evaluation of a response to an environmental scenario, case study, issue or challenge.   Each task can only be selected once across Units 3 and 4.  For each task the time allocated should be approximately 50–70 minutes for a written response and 10 minutes for a multimodal  or oral presentation. |
| **Outcome 2**  Compare the advantages and disadvantages of using a range of energy sources, and evaluate the suitability and impacts of their use in terms of upholding sustainability principles. | 40 |
| **Outcome 3**  Design and conduct a scientific investigation related to biodiversity, environmental management, climate change and/or energy use, and present an aim, methodology and method, results, discussion and a conclusion in a scientific poster. | 40 | *For Outcome 3*  Communication of the design, analysis and findings of a student-designed and student-conducted scientific investigation through a structured scientific poster and logbook entries.  The poster should not exceed 600 words. |
| **Total marks** | **120** |  |

Practical work

Practical work is a central component of learning and assessment and may include activities such as laboratory experiments, fieldwork, simulations, modelling and other direct experiences as described in the scientific investigation methodologies on [pages 9 and 10](#Methodologies). A minimum of ten hours of class time should be devoted to student practical activities and investigations across Areas of Study 1 and 2. For Area of Study 3, a minimum of ten hours of class time should be devoted to designing and undertaking the student-designed scientific investigation, and communicating findings.

External assessment

The level of achievement for Units 3 and 4 is also assessed by an end-of-year examination.

Contribution to final assessment

The examination will contribute 50 per cent to the study score.

End-of-year examination

Description

The examination will be set by a panel appointed by the VCAA. All the key knowledge that underpin the outcomes in Units 3 and 4 and the key science skills are examinable.

Conditions

The examination will be completed under the following conditions:

* Duration: two hours.
* Date: end-of-year, on a date to be published annually by the VCAA.
* VCAA examination rules will apply. Details of these rules are published annually in the   
  [*VCE and VCAL Administrative Handbook*](https://www.vcaa.vic.edu.au/administration/vce-vcal-handbook/Pages/index.aspx).
* The examination will be marked by assessors appointed by the VCAA.

Further advice

The VCAA publishes specifications for all VCE examinations on the VCAA website. Examination specifications include details about the sections of the examination, their weighting, the question format/s and any other essential information. The specifications are published in the year prior to implementation of the revised Unit 3 and 4 sequence together with any sample material.