Earth and Environmental Science Module 6: Hazards

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## Teaching the Year 12 Modules

The new Stage 6 Earth and Environmental Science course was implemented in NSW schools in 2018-2019. This syllabus incorporates new content and learning activities such as Depth Studies. The syllabus is designed around inquiry questions and formal assessment tasks emphasise the skills for working scientifically.

The Year 12 course investigates how the processes of plate tectonics, the formation of water and the introduction of life interact with the atmosphere, hydrosphere, lithosphere and climate. Investigation of hazards, the mitigation of their effects and resource management are also considered which leads to an understanding of the need to centralise the theme of sustainability for the long term welfare of our planet and all forms of life dependent upon it.

Therefore, pedagogies that promote inquiry and deep learning should be employed in the Earth and Environmental Science classroom. The challenge presented by the additional content and the change in pedagogical approach were the catalysts for the preparation of these module guides for Stage 6. These guides are intended to assist teachers deliver Earth and Environmental Science effectively by outlining overarching concepts (big ideas), core and extended ideas, strategies for teaching the modules, uncovering of alternative conceptions, and strategies to address them. The guides support the teacher in facilitating the development of deep knowledge structures, such as the relationships between concepts. The module guides do not cover all aspects of the syllabus, as that was not within the scope of the project.

It is essential that teachers note that the module guides do not substitute the syllabus, but only support teachers to teach it. The information contained in these documents are correct at the time of publication. While every effort has been made to eliminate errors, any errors or omission that are identified after the release of these documents will be corrected and released as resource updates. It is recommended that teachers access the [Curriculum website](https://education.nsw.gov.au/teaching-and-learning/curriculum/key-learning-areas/science/stage-6/earth-and-environment) for the latest version of these documents.

## Course overview

During the teaching of the Year 11 course, it is expected that students have been provided opportunities to develop all seven of the Working Scientifically skills. Ideally, these would be embedded into the teaching of the Knowledge and Understanding components of the course. In preparation for the Year 12 course, students in Year 11 could benefit from work that engages them in the following areas:

* Propose hypotheses and design and conduct valid and reliable practical investigations that enable the collection and analysis of data. Teachers should look for opportunities to engage students in these beyond where the syllabus explicitly states the need to conduct a practical investigation.
* Construct and analyse graphical data (particularly line graphs) for both primary and secondary sources. This will be essential for an understanding of a changing Earth over time, including geological events and climate changes.
* Assess the uses, benefits and limitations of various types of scientific models. Many of the processes that occur on the Earth are invisible (e.g. convection currents beneath the surface) or happen very slowly (e.g. movement of tectonic plates, the process of evolution over geological time). Models help people to better understand these types of processes.
* Determine the impacts of various technologies in improving the understanding of various concepts, including events that have occurred in the ancient past and potentially those that will occur in the future.
* Collect relevant information from secondary sources and determine the accuracy, reliability and validity. Many of the investigations will require students to obtain information from the Internet or other sources. Students will benefit from learning how to access the correct sort of information and appreciate how new evidence can change prevailing views about aspects of Earth and Environmental Science.
* Understand the major features of the Earth’s spheres and the relationships between each one. This is an underlying theme the spans both the Year 11 and Year 12 courses. It is essential that students understand the components of each one and can appreciate how changes in one can impact on the others.
* Develop skills in numerical scaling, with particular reference to periods of geological time. It is expected that students have developed a good understanding of the divisions of the geological timescale.
* Develop an understanding of relative and absolute dating of rocks and fossils. Using and constructing stratigraphic diagrams where appropriate and numeracy activities to build skills in applying radiometric dating principles.
* Construct simple diagrams of various processes, including tectonic boundary relationships and the geological and/or volcanic features associated with them, the formation of earthquakes at fault zones and the movement of warm and cool water in ocean currents across the Earth.
* Develop a deep understanding of the impacts of humans on the Earth and an appreciation of the importance of sustainability in its various forms. This includes understanding the roles of Aboriginal and Torres Strait Islander Peoples in caring for Country and Place.

## Module summary

This module explores the following inquiry questions:

* IQ6-1: How and why do geological disasters occur?
* IQ6-2: How do natural disasters such as explosive volcanic eruptions, earthquakes and extreme weather events influence the biosphere and atmosphere?
* IQ6-3: What technologies enable prediction of natural disasters and minimisation of their effects on the biosphere?

As energy on the Earth is changed from one form into another, it can result in events that can sometimes be classed as natural disasters. Volcanic eruptions and earthquakes, which may occur due to tectonic processes, and extreme weather events can result in hazards to human life, and also have impacts on natural ecosystems and climate. In turn, many scientists suggest that human activities, including anthropogenic climate variation, could contribute to the severity and frequency of some of these events. Humans have developed technologies which can help to predict the occurrence of some these events, and others which aim to minimise their impacts once they occur.

## Big ideas

* The Earth’s surface is being shaped by natural disaster events which can occur when energy is transformed and released.
* Natural disasters can have impacts on the geosphere (for example landslides), atmosphere (climate changes) and biosphere (ecosystem impacts).
* Some natural disasters are caused by plate movements (for example earthquakes, volcanoes) and others are not (such as extreme weather events like storms, floods, bushfires).
* Natural disasters can pose a serious hazard to human populations in many different ways.
* Prediction and mitigation of natural disasters continues to be extremely challenging.

## Relationships to other modules

Many of the concepts covered in this module relies significantly on presumed knowledge from the Year 11 course. Areas of focus to activate prior knowledge should include:

* The theory of plate tectonics, particularly on interactions at plate boundaries (Module 2).
* The role of energy in the Earth’s processes and geological transformations (Module 3).
* The influence of energy transformations on the oceans (Module 3).

Some potential links to other Modules in the Year 12 course could include:

* Tectonic disasters result from processes related to the plate tectonic supercycle studied in Module 5: Earth’s Processes.
* The impacts of major volcanic eruptions on the atmosphere links to Module 7: Climate Science.
* The magnitude and frequency of some natural disasters may be influenced by human activities, potentially including anthropogenic climate change (links to Module 7).
* Massive volcanic eruptions that formed the Deccan and Siberian Traps could be linked to mass extinction events that may be referenced in Module 5.

## Core concepts

When exploring the inquiry questions within each module, the most important concepts that students need to develop a deep understanding of can be broken down. These include:

* The magnitude and features of an earthquake or volcanic eruption are related to the properties of plate boundary interactions that cause them. Plate boundary features determine how stresses can be built, and how much energy is released during an earthquake or eruption.
* There are many types of hazards associated with earthquakes (for example ground motion, tsunamis) and volcanoes (such as lahars, poisonous gas emissions) that are a threat to human populations. The extent to which these affect human lives determines if these events constitute a natural disaster.
* Volcanic eruptions have played an extremely significant role in shaping past climates, and these have had vast flow on effects in the environment (for example temperature shifts, mass extinctions). Mount Pinatubo is a well-researched recent example of an eruption that has had observed impacts on the biosphere and atmosphere.
* Extreme weather events, including storms, droughts, floods and landslides have various causes and often have significant impacts on the biosphere (natural ecosystems, human populations) and on the atmosphere (climate impacts).
* There is evidence to suggest that human activities may have contributed to the severity and frequency of extreme weather events.
* Technologies exist which attempt to predict the occurrence of volcanoes, earthquakes and storm events. These will vary in their effectiveness. Other technologies exist which attempt to mitigate the effects of these events, including damage to infrastructure and loss of human life.

### Opportunities for extending concepts

These are some suggested pathways students could investigate to allow for a deeper appreciation of the inquiry questions within this module:

* Investigate the use of the Richter and Mercalli scales to measure earthquakes and the Volcanic Explosivity Index (VEI) to measure volcanic eruptions.
* Investigate how information from seismographs ( such as P and S waves) can be used to locate the epicentre of real world earthquake events.
* Research and compare the various ways that tsunamis can form. Relate their formation to properties, with real world historical examples.
* Research the question: [What would happen if a tsunami hit Sydney?](https://www.abc.net.au/news/2018-10-16/what-would-happen-if-a-tsunami-hit-sydney/10376680) From ABC News. Use secondary sources and predict some possible observations.
* Research [Aboriginal legends reveal ancient secrets to science](https://www.bbc.com/news/world-australia-32701311) from BBC News that exists with regards to Aboriginal and Torres Strait Islander Peoples’ observations of large scale natural disasters such as volcanic eruptions, tsunamis, earthquakes and storm events.
* Investigate some of the factors that may increase the likelihood of a bushfire occurring.
* Evaluate the effectiveness of hazard reduction burns in mitigating the effects of bushfires.
* Investigate the effects of droughts in Australia on natural ecosystems, for example the health of the rivers in the Murray-Darling basin.
* Investigate whether there has been an increased frequency of east coast lows in more recent years, i.e. is there a link to human-induced climate change?
* Research practices by Aboriginal Peoples use of fire and its benefits, including reduction of fuel load to minimise spread of natural bushfires.

### Misconceptions and alternative conceptions

* The everyday use of the term “hazard” may differ from the intent it is used for in this module. Students could use the term interchangeably with a disaster itself (e.g. an earthquake) where it should be used as a feature associated with a natural event that causes risk to life (for example ground motion).
* Students should never use the term “epicentre” instead of “focus” when referring to depth of an earthquake. The difference between the two needs to be made clear by the teacher.
* It’s not only the explosive volcanic eruptions that have impacts on the biosphere or on climate. Students should be given the opportunity to investigate effusive eruptions and their impacts.
* Volcanic eruptions can lead to both warming and cooling of the atmosphere. Examples of each of these should be investigated.
* When studying bushfires, students could potentially use the terms “controlled burn”, “back burn” and “hazard reduction burn” interchangeably, possibly due to inaccurate reporting by the media. The difference between these should be made clear by the teacher.
* Human activities affecting frequency and magnitude of natural disasters (droughts, floods, bushfires, and landslides) is a new concept for this course. Accessing information on this could prove to be challenging. Teachers could access recent and reliable journal articles to start the discussion with students around the evidence that exists for any links between human activities (for example climate change) and these events. Students could be given the opportunity to analyse historical graphical data and even pose their own further inquiry questions on specific types of disasters. It could also be useful for the teacher to access relevant past HSC examination questions from the Disasters option from the retired [Senior Science](https://educationstandards.nsw.edu.au/wps/portal/nesa/resource-finder/hsc-exam-papers/2017/senior-science-2017-hsc-exam-pack) examinations.
* There is a considerable difference between the ideas of disaster prediction, prevention and mitigation. These differences do need to be taught clearly, along with different technologies and strategies used in the real world. Students could be given the opportunity to investigate specific devices (for example tsunami detection devices, building codes to withstand earthquakes, evacuation procedures) and their effectiveness.

## Suggested teaching strategies

The structure of this module is relatively straightforward and could successfully be taught in the order of the syllabus without confusion. It may be useful to teach the sections of IQ6-2 and IQ6-3 on natural weather events at the end of the module. This way, the information about earthquakes and volcanoes could be taught together. Alternatively, teachers could easily incorporate the section of IQ6-2 on volcanic eruptions and their impacts on climate with IQ7-1 from Module 7: Climate Science.

Some inquiry-based learning activities that could prompt investigations and address Working Scientifically skills could include:

* Mapping activities relating to locations of tectonic events. Students could relate certain types of volcanoes or earthquakes to specific plate boundaries. This data can often be obtained in various forms, including with interactive software, from reliable sources such as [Earthquakes at GA](https://earthquakes.ga.gov.au/) or [USGS earthquakes](https://earthquake.usgs.gov/earthquakes/map/).
* Plot locations of earthquake foci along a known convergent boundary to predict the existence of a subduction zone. Determine the effectiveness of the activity in modelling the existence of a subduction zone.
* Graphing activities on the composition of volcanic gas emissions from different types of eruptions. Graphs of different types can be made or analysed to investigate types of gases, types or quantities of materials erupted, etc. Links to the VEI scale or to types of boundary could be made.
* Analyse graphical data on global temperature anomalies before and after large eruptions (for example Krakatoa, Tambora, Pinatubo). Predict future changed based on possible eruptions of volcanoes at risk of erupting.
* Students could conduct analyses into the evidence of frequency and magnitude of droughts, floods or bushfires before and after human activities to determine if a cause and effect relationship exists (see appendix).
* Analyse seismograph data to determine the magnitude of an earthquake and predict the location of the epicentre. Students can access real seismic data for this at [Incorporated Research Institutions for Seismology (IRIS)](https://ds.iris.edu/wilber3/find_event).
* Students to research strategies used by communities in earthquake prone regions (such as Japan) such as building codes, evacuation procedures and tsunami walls.
* Conduct a literature review into anomalous animal behaviour preceding earthquakes to determine whether animals can predict or warn about major oncoming earthquakes. Example [Can Animals Predict Earthquakes?](https://www.livescience.com/32156-can-animals-predict-earthquakes.html)
* Research the possibility of [earthquake proof buildings](https://www.imaginationstationtoledo.org/educator/activities/can-you-build-an-earthquake-proof-building).
* Use meteorology maps to investigate natural weather phenomena and make predictions into potential damage to life and infrastructure.

These are some practical investigations that may help to encourage more use of the Working Scientifically skills:

* Design and conduct an experiment to relate viscosity of fluids (such as water, oil, glycerine) to pressure release to model volcano explosivity. Relate this idea to explosive and effusive eruptions at different tectonic settings (see appendix).
* Design and construct different types of volcanoes and model the type of eruption that occurs, depending on the plate boundary on which they form.
* Construct a model seismometer and determine its effectiveness in detecting vibrations.
* Design and conduct an investigation that models whether different types of leaves encourage spread of bushfires.
* Investigate how exposure to smoke (modelled from bushfires) affects the germination rate of Acacia or Grevillea seeds.

## Appendix 1 - Magma viscosity and explosions investigation

### ****Task outline****

This is a series of demonstrations and/or practical activities that could lead students to developing their own first-hand investigation that models the relationship between magma viscosity and volcanic explosivity using laboratory equipment.

### ****Background****

The explosivity of any given volcanic eruption is determined by the features of the magma that is released when it erupts. Viscosity is a measure of a fluid’s resistance to a substance passing through it. For example, syrup is more viscous than water, and water is more viscous than air. More viscous magma has the ability to trap gases from escaping over longer periods of time, allowing for the build-up of pressure and therefore more explosive eruptions. [Magma Viscosity, Gas Content & Milkshakes](https://www.youtube.com/watch?v=2iaqE0xmsHI) (duration 5:15) has more background information on this relationship.

### ****Diagnostic or discussion questions****

These can be used to engage students and test their prior understanding of the concept and also to address any misconceptions. Some of this should be apparent from learning the Year 11 course.

* What do we already know about different types of volcanoes? For example stratovolcanoes, shield. How, where and why do they form in this way?
* What do we already know about plate boundaries and types of volcanic eruptions?
* What do we already know about different types of magma? For example basaltic, andesitic, rhyolitic. Do these differ in viscosity? Would certain types “flow” easier than others?
* What are some more examples of fluids of different viscosities? Which fluids might be available to use in the lab in first hand investigations?

### ****Task 1****

Observe the table below which provides relative viscosities of some common substances. Use secondary source research to rank each fluid from least to most viscous.

|  |  |
| --- | --- |
| Substance | Relative viscocity ranking (1 is lowest) |
| Glycerol |  |
| Ethanol |  |
| Air |  |
| Olive oil |  |
| Water |  |
| Peanut butter |  |
| Corn syrup |  |
| Honey |  |
| Detergent |  |

Some potential follow up discussion with students could include:

* Consider why it may be very difficult to plot this information on a graph.
* How might these values may relate to volcanic eruptions?
* Propose a hypothesis linking viscosity to explosivity of eruptions.

### Task 2

Investigate the concept of viscosity by comparing different fluids (such as water, corn syrup, glycerol, detergent, vegetable oil)

* Example 1 drop a marble into a beaker containing samples of these fluids and observe the rate at which they fall - see [Hands-on Activity: What Makes an Eruption Explosive?](https://www.teachengineering.org/activities/view/rice_erruption_activity1) for some investigations.
* Example 2 compare the flow rates of fluids of different viscosities - see [Volcano under the city pdf](https://www-tc.pbs.org/wgbh/nova/teachers/activities/pdf/3215_volcanoc.pdf) for some investigations.

Discussion from the activities:

* Identify the independent, dependent and controlled variables
* How does viscosity of a fluid affect its rate of flow or the movement of the marble?
* What might it mean for volcanic eruptions?
* What other factors could influence the viscosity of these liquids (for example temperature)?

### Task 3

Conduct an investigation into comparing how fluids of different viscosities are affected when students blow through a straw and into each fluid. Relate this to the escape of gases in magmas of different viscosities.

Discussion from the activity:

* What could be an appropriate hypothesis for this investigation?
* What were some of the observations?
* How did the “bubbling” relate to explosivity of eruptions (how “real-life” is this activity?)
* What were some of the benefits and limitations of this model?
* How did the different fluids relate to “types” of magma?

### Task 4

Construct a specific inquiry question and hypothesis for a first-hand investigation that could model the link between volcanic eruptions and viscosity of magma. Then design and conduct a valid and reliable investigation that could test it out by obtaining quantitative data.

## Appendix 2: Climate change and bushfire intensity

### Task outline

The article discussed below, while does appear to be based on scientific data, provides opportunities for students to question credibility of the website. It also relates to a new content idea in the syllabus and in the scientific world, i.e. is human-induced climate change making bushfires more intense? The open-ended nature of this concept allows students to conduct their own inquiries. The teacher may need to assist in accessing reliable, relevant and current sources of information. The content areas span ideas used in both Module 6 and Module 7.

### Task

This article was a media release from the [Climate Council of Australia](https://www.climatecouncil.org.au/resources/burning-issue-climate-change-driving-earlier-more-dangerous-fire-seasons/) website.

BURNING ISSUE: CLIMATE CHANGE DRIVING EARLIER, MORE DANGEROUS FIRE SEASONS

21.08.18 BY CLIMATE COUNCIL

WORSENING CLIMATE CHANGE is driving earlier and more dangerous bushfire seasons, with the Rural Fire Service declaring the earliest fire danger period on record across a series of local government areas in New South Wales.

Climate Councillor and ecologist Professor Lesley Hughes said the legislated Bushfire Danger Period traditionally commenced from October 1 in New South Wales, but 14 council areas had already declared the season underway due to conditions.

“Climate change is driving Australia’s escalating bushfire threat, creating longer and more dangerous bushfire seasons,” she said.

“Intensifying climate change, caused by rising greenhouse gas pollution levels, is exacerbating extreme weather events across Australia, leading to increasingly hot and dry conditions.

“Dozens of blazes burned across Queensland over the weekend, along with fires placing homes under threat across parts of regional New South Wales.”

Professor Hughes said that Australia needs to take significant action to slash its rising greenhouse gas pollution levels to contribute our share of the global effort to stabilise the climate.

“If greenhouse gas pollution from fossil fuels continues to rise, we will experience an increasing number of dangerous fire weather days, placing fire services and medical professionals under pressure, and communities at risk,” she said.

Climate Councillor and internationally recognised bushfire and natural disaster expert Greg Mullins said that August 15 had seen the earliest declaration of a Total Fire Ban in New South Wales’ history, with homes lost in two of the dozens of fires burning across the state. Conditions have also been bad for Queensland and Northern Territory firefighters.

“New South Wales has had very little respite after a huge fire threatened homes in Sydney just last April,” he said.

“Over almost 50 years as a fire officer, I’ve seen firsthand how the changing climate is driving more intense and severe fire seasons, storms and floods. As we’ve seen last week, fire seasons are commencing earlier than ever before and lasting far longer.”

Mullins said periods of Severe, Extreme and even catastrophic bushfire weather have been increasing in Southeast Australia over the past 40 years due to worsening climate change, which unfortunately has increased the odds of dangerous fires, including the events we have seen across regional New South Wales. “This is a recognised phenomenon around the world with sharing of critical assets like large water bombing aircraft restricted as the northern hemisphere tries to deal with unprecedented fire conditions in places like Greece, Sweden and California, he said.”

Mullins, a former New South Wales Fire and Rescue Commissioner and head of the peak body for Australian fire and emergency services said very high fire danger warnings had been declared for a number of local government areas across New South Wales last week, along with parts of Queensland. Fire danger reached Severe on 15 August in Sydney and the Illawarra.

Possible pathways for investigation with students:

* What are the main points to be taken from this article?
* How could students determine the accuracy of the information from this source? (Consider things like domain “.org” – is this a trustworthy website? Has the information on such sites been reviewed by experts? How recent was the article published?)
* Discuss the credibility of the people who are quoted in the article (e.g. how could you determine each contributor’s qualifications or expertise in the field of research? Are they sources that are qualified to comment on this subject?)
* How could students investigate whether human-induced climate change has been responsible for contributing to the frequency and magnitude of bushfires?
* Consider how students could build an inquiry question on this topic or a related one, then propose an investigation to answer the inquiry question. An example could be “Has the frequency of natural bushfires increased since the Industrial Revolution?”

## Resources

* [The Cataclysmic 1991 Eruption of Mount Pinatubo, Philippines](https://pubs.usgs.gov/fs/1997/fs113-97/) by USGS– factsheet on the eruption at Pinatubo, associated hazards and impacts including on climate. A good starting point for the prescribed case study.
* [Comprehensive monitoring provides timely warnings of volcano reawakening](https://volcanoes.usgs.gov/vhp/monitoring.html) by USGS – provides detailed information about instruments and techniques used to monitor volcanoes in the United States.
* [Fire facts](https://www.environment.nsw.gov.au/topics/parks-reserves-and-protected-areas/fire/fire-facts) by the Office of Environment and Heritage NSW – useful general information on understanding and managing bushfires.
* [Can animals predict earthquakes](https://www.livescience.com/32156-can-animals-predict-earthquakes.html) by Live Science – recently updated article that allows a good starting point for students to investigate the scientific validity of the claim that animals can predict earthquakes.
* [BBC News - Aboriginal legends reveal ancient secrets to science](https://www.bbc.com/news/world-australia-32701311) details examples of how scientists are beginning to access knowledge buried in the ancient stories of Australia's Aboriginal peoples regarding natural disaster events including tsunamis and earthquakes thousands of years in the past.
* [Earthquake-proof Buildings](https://www.imaginationstationtoledo.org/educator/activities/can-you-build-an-earthquake-proof-building) by Imagination Station – provides information, videos and student activities that investigate whether it’s possible to build an earthquake proof building.
* Incorporated Research Institutions for Seismology (IRIS) [Interactive activity](https://ds.iris.edu/wilber3/find_event) on locating earthquakes by– this program, called Wilber, allows the user to locate coordinates, depth and magnitudes of earthquakes, including very recent ones.
* [ABC News - What would happen if a tsunami hit Sydney? Researchers plot possible impacts](https://www.abc.net.au/news/2018-10-16/what-would-happen-if-a-tsunami-hit-sydney/10376680) – details the likelihood of a tsunami reaching Sydney in one’s lifetime and some possible strategies to cope with this.
* [Geoscience Australia - earthquakes](https://earthquakes.ga.gov.au/)
* [United States Geological Service](https://earthquake.usgs.gov/earthquakes/map/)