Volcanic Hazards – Teacher Resource

Intended Use of Resources

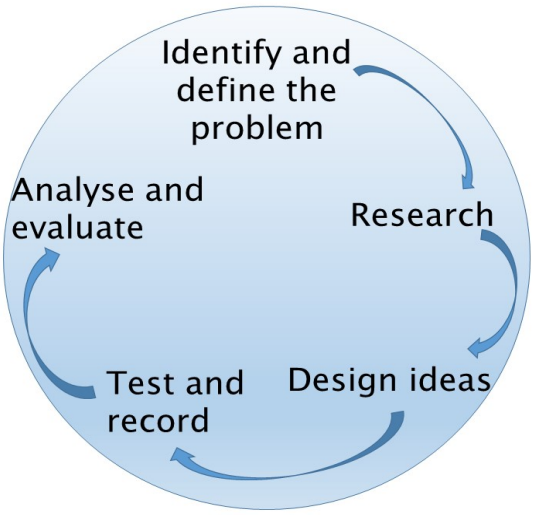
This project has been designed so that teachers from different STEM areas can pick and choose sections relevant to their subject area to work on. All activities in this package do not need to be completed to get value from the package – each activity can be completed as a stand-alone or can be approached, as a team, as a larger project. The package has potential to be extended into a much longer project to include curriculum points from different STEM subjects.

There are three **student workbooks - Open, Guided and Scaffolded,** that go alongside this resource; all have the same suggestions for activities, however, they have been written and edited to provide differentiated learning options to support good teaching practice**.** Teachers may pick and choose which versions they give which students, and may wish to edit them further to address their learning needs. Due to the differentiation of the workbooks, the **Open** activities will enable more syllabus links to be addressed, which is why each activity has its own syllabus links key. However, if you wish to give a truly open ended investigation then you could just give the students the challenge and background information section of the Student Booklet.

The Woodside Australian Science Project (WASP) STEM resources aim to be accessible and supportive for teachers and students, please contact us if you have questions, feedback, require assistance or would like to arrange an incursion or a professional development workshop - www.wasp.edu.au.

The Student Challenge

Understanding the type and eruption history of a volcano is vital in understanding potential volcanic hazards. Volcanoes behave very differently depending on their type and location. The extent of the damage they cause will also depend on their proximity to populations. Your role is to investigate the behaviour of volcanoes and come up with an engineered solution which will help minimise the potential damage of a chosen volcano to local populations, explaining why it is a suitable solution for that area.



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Background Information

Volcanoes are awesome yet powerful forces of nature, which were vital in the creation of Earth's current atmosphere and are important in the production of new, fertile soils, but they can also cause cataclysmic damage. In 1815 Mount Tambora, in Indonesia, erupted causing the 'year without a summer' as the large volume of ash and dust that entered the atmosphere filtered out a large portion of the Sun's rays. Over 71,000 deaths have been attributed to the eruption – the largest number of (human) deaths ever recorded to a volcanic eruption. Even with the best engineering solutions it would have been difficult to prevent death and injury from many of the hazards caused by the Mount Tambora volcano. Less violent eruptions can be easier to manage and predict, however.

Figure 1. Mount Tambora volcano on Indonesia's Sumbawa Island was the site of the world's largest historical eruption in April 1815. This NASA Landsat mosaic shows the 6-km-wide caldera truncating the 2,850-m-high summit of the massive volcano. Pyroclastic flows during the 1815 eruption reached the sea on all sides of the 60-km-wide volcanic peninsula, and the ejection of large amounts of tephra caused world-wide temperature declines in 1815 and 1816 (NASA, 2009).

In 1973 an eruption on the island of Heimaey caused a large lava flow that threatened to close off the harbour – the island's main income source by means of its fishing fleet. By pumping sea water onto the advancing lava flow, it was possible to cool the lava enough to halt its course and save the harbour. Other solutions to minimising the damage caused by volcanoes include creating man made channels to direct the flow of lava or landslides caused by eruptions. A more simple solution can be creating a hazard map, using information known about the volcano and the topography of the region, to show areas that may be at risk and to not allow future building in these areas.

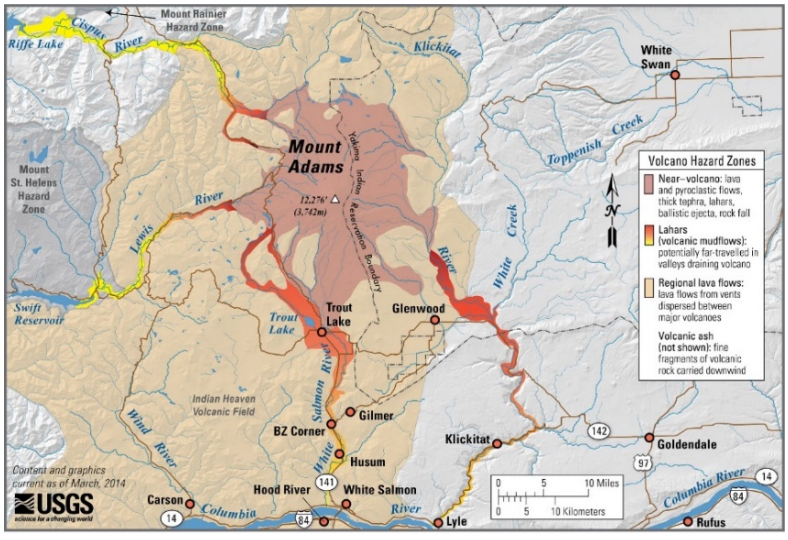

Figure 2 Mount Adams, Washington simplified hazards map showing potential impact area for ground-based hazards during a volcanic event (USGS, 2013).

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Volcanologists will investigate numerous factors to try to predict if, and when, a volcano may erupt again. The historic pattern of activity is a key indicator of when a volcano may erupt again, so by studying the frequency of previous eruptions it may be possible to forecast when one is due. Visible signs of a possible imminent eruption could include ground deformation – where it starts to swell due to rising lava – satellites are used to track this along with temperature changes. The swelling and ground movement can also cause small earthquakes which are tracked using seismometers. An increase or change in the type of gas being released is also an indicator that there is movement below ground and an eruption may be pending.

Activities

This booklet contains extra information on each activity, including syllabus links the overall activity objective, suggestions for recommended equipment or alternative ways to run investigations as well as useful resources and website links*.
The syllabus links have been colour coded. These links to the Australian Curriculum are also relevant to the Western Australian Syllabus. – Please see the colour key below:

Covered in Scaffolded, Guided and Open Student Booklet
Covered in Guided and Open Student Booklet
Covered in Open Student Booklet
Italics – WA syllabus for DT and D and T

List of activities

**Please note that any reference websites provided were accessed in March 2018 – these addresses may change slightly, we would be grateful if you could let us know if these sites are no longer accessible.*

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Background Research

Objective

Students should gain a general understanding of the hazards of volcanic eruptions and the two main types of volcano (stratovolcano and shield).
The background questions should lead them to start thinking about further investigations they could do to find out more about the different types of volcanoes and their behavior and also the different hazards of volcanoes.
The main purpose of this is for students to start considering which countries might be most in need of an engineered solution to minimise financial and social devastation caused by volcanic eruptions. By considering the GDP of a country they should start to realise that not all countries will be able to afford the same type of solution.
Students will learn that very few people are actually killed by volcanic eruptions, and opposed to popular belief you are very unlikely to be killed by a lava flow. They will realise that some hazards are impossible to mitigate, such as ash in the troposphere, whereas lahars and landslides can possibly be predicted and managed.

	Australian Syllabus Links
Science	ACSSU180 The theory of plate tectonics explains global patterns of geological activity and continental movement. ACSHE228 Values and the needs of contemporary society can influence the focus of scientific research.

Useful resources and websites:

- ABC educational video discussing Lahars as a hazard: http://education.abc.net.au/home#!/media/30087/volcanic-eruptions-at-mount-ruapehu
- Volcanic hazards video: http://education.abc.net.au/home#!/media/31149/volcanoes-and-people
- The USGS has lots of information on volcanoes, how they are monitored, where they are and their hazards: https://www.usgs.gov/products/data-and-tools/real-time-data/volcanoes

Where in the World?

Objective

Students will use Geographical Information Systems (GIS) to find the relationship between eruption styles/types of volcanoes and their tectonic location.
This activity can be done online using Google Maps or even Google Earth. Students can either download and import data or add it manually.
If this is not an option you will have to ensure that you have printed out a map of the world with longitudinal and latitudinal lines on it, as well as a tectonic boundary map (showing direction of plate movement), and also a list of active volcanoes – so that students can do this on paper.
Both options are valid for learning depending on which skills you wish the students to practice.
Students should conclude that stratovolcanoes are most commonly found at convergent plate boundaries (especially subduction zones), whereas shield volcanoes do not have a clear relationship with plate boundaries, and are often found as islands (such as Hawaii) – this is because they are more commonly linked to hot spots.

	Australian Syllabus Links
Science	ACSSU180 The theory of plate tectonics explains global patterns of geological activity and continental movement. ACSIC166 Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately.

Useful websites and resources:

- List of active volcanoes, including type and location (longitude and latitude): http://volcano.oregonstate.edu/volcano_table

How Fast will it Flow?

Objective

To determine how different variables effect the flow rate of a lava (temperature, angle of slope and viscosity).
You may prefer to give different groups different investigations, rather than them all completing the same experiment. They may wish to do numerous trials to find averages, or you may prefer them to create a class spreadsheet.
If they completed the background research section it would be very useful to relate their findings to the shape of different volcano types.
Suggested liquids to use: glycerol, honey, tomato ketchup, syrup, molasses, and oil.
Be very aware of liquids getting hot – they should just be warmed, as hot sticky liquid can be very dangerous.

	Australian Syllabus links
Science	ACSIS164 Formulate questions or hypotheses that can be investigated scientifically. ACSIS165 Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods. ACSIC166 Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately. ACSIS169 Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies. ACSIS170 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence. ACSIS171 Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data.
Mathematics	ACMNA208 Solve problems involving direct proportion. Explore the relationship between graphs and equations corresponding to simple rate problems. ACMNA215 Sketch graphs using the coordinates of two points and solve linear equations. ACMMG224 Apply trigonometry to solve right-angled triangle problems. ACMNA294 Find the midpoint and gradient of a line segment on the Cartesian plane using a range of strategies, including graphing software.

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	Australian Syllabus links
Design and Technology	ACTDEP051 Evaluate design ideas, processes and solutions against comprehensive criteria for success recognising the need for sustainability. ACTDEK046 Investigate and make judgements on how the characteristics and properties of materials, systems components, tools and equipment can be combined to make designed solutions. ACTDEP049 Develop, modify and communicate design ideas by applying design thinking , creativity, innovation and enterprise skills of increasing sophistication

Useful websites and resources

- Experimental set up to show the relationship between viscosity and flow rate: https://www.youtube.com/watch?v=FMBCNf_lCdc

VEI Scale

Objective

Students will create visual representations to make comparisons of the explosivity of historic eruptions, using the VEI scale.
The Volcanic Explosivity Index (VEI) is a relative measure of the explosiveness of volcanic eruptions. It was devised by Chris Newhall of the United States Geological Survey and Stephen Self at the University of Hawaii in 1982.
Students can create drawings of ash clouds which increase in size, or simply represent the increase using circles/squares (similar to on the Wikipedia page). They might even like to use plasticine/play dough, or perhaps sandwich bags with volumes of sand/flour to represent the ash. They could make a poster to display the information and calculations.

	Australian Syllabus links
Science	ACSSU180 The theory of plate tectonics explains global patterns of geological activity and continental movement.
Mathematics	ACMNA209 Applying index laws to numerical expressions with integer indices ACMNA210 Express numbers in scientific notation ACMMG221 Solve problems using ratio and scale factors in similar figures ACMMG217 Calculate the surface area and volume of cylinders and solve related problems.

Useful websites and resources

- Wikipedia has a table with the VEI scale on it as well as some examples of where previous eruptions lie on it: https://en.wikipedia.org/wiki/Volcanic_Explosivity_Index

Explosivity V Gas Content

Objective

To investigate if there is a relationship between the gas content of a liquid and explosivity, to relate this to volcanic eruptions

As the gas content increases the distance the water is ejected should also increase. Students could also test the relationship between viscosity and ejecta distance (more viscous fluids should eject materials further, as they will trap the gas creating a more explosive eruption). Students could also test how the temperature of the liquid effects ejecta distance – being careful not to use high temperatures.

Instead of using effervescent powder you could do the classic mentos and coke experiment – make a hole in the top of the coke bottle and you can increase the number of mentos that you add each time by threading some string through them, so they are connected – hold the thread through the hole in the top of bottle so that when you release the thread they will all reach the coke at the same time. This can get really very messy and pretty violent, you will have to use a new bottle of coke each time as well, so it is best to do this as a demonstration rather than allow students to do it. Be prepared to get sticky and make sure you have plenty of space to run away!

	Australian Syllabus links
Science	ACSSU178 Chemical reactions involve rearranging atoms to form new substances; during a chemical reaction mass is not creates or destroyed. ACSSU180 The theory of plate tectonics explains global patterns of geological activity and continental movement. ACSIS165 Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods. ACSIC166 Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately. ACSIS169 Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies. ACSIS170 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence. ACSIS171 Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data.

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	Australian Syllabus links
Mathematics	ACMA214 Find the distance between two points locates on the Cartesian plane using a range of strategies, including graphing software. ACMNA215 Sketch graphs using the coordinates of two points and solve linear equations. ACMNA294 Find the midpoint and gradient of a line segment on the Cartesian plane using a range of strategies, including graphing software.
Design and Technology	ACTDEP049 Develop, modify and communicate design ideas by applying design thinking , creativity, innovation and enterprise skills of increasing sophistication ACTDEP051 Evaluate design ideas, processes and solutions against comprehensive criteria for success recognising the need for sustainability. ACTDEK046 Investigate and make judgements on how the characteristics and properties of materials, systems components, tools and equipment can be combined to make designed solutions.

Useful websites and resources

- In depth and detailed explanation of how viscosity, composition and gas content relate to magma type and eruption type: http://www.tulane.edu/~sanelson/Natural_Disasters/volcan%26magma.htm
- More simple information regarding gas content, magma type and Explosivity: http://volcano.oregonstate.edu/book/export/html/974

Probability of Eruption

Objective

Students will use historical data to determine the likelihood of a volcanic eruption of a particular size occurring.
Students will download data for historic eruptions in a particular country and complete statistical analysis on them to try to predict the possibility of an eruption of a certain VEI occurring. They can then compare their data to other groups who may have studied different locations. They can again relate this to the tectonic settings, looking at the difference in frequency of a low VEI eruption at a hotspot compared to a very explosive eruption at a subduction zone.

	Australian Syllabus links
Science	ACSHE160 People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people' lives including generating new career opportunities.
Mathematics	ACMNA209 Applying index laws to numerical expressions with integer indices ACMNA210 Express numbers in scientific notation ACMSP255 List all outcomes for two-step chance experiments, both with and without replacement using tree diagrams or arrays. Assign probabilities to outcomes and determine probabilities for events. ACMSP226 Calculate relative frequencies from given or collected data to estimate probabilities of events involving "and" or "or" ACMSP283 Compare data displays using mean, median and range to describe and interpret numerical data sets in terms of location (centre) and spread.

Useful websites and resources

- Wikipedia has a table with the VEI scale giving frequency of eruptions of each index https://en.wikipedia.org/wiki/Volcanic_Explosivity_Index

Building a 3D Volcano

Objective

Students will use topographic maps to create a 3D model of an active volcano, to investigate probable routes of a lava/lahar flow and create a basic hazard map.
To get a topographic map using Google Maps – you can select places -> create map -> then select terrain map from the base map selection.
For higher level students you might suggest that they use the same vertical scale as horizontal scale, so that there is no vertical exaggeration to the elevation.
Mt Vesuvius and Vulcan Colima are really classically shaped volcanoes, and it is easy to pick out the contour lines in google maps. A more challenging volcano to make is Moana Loa. Unfortunately it can be difficult to find a good scale to see the contour lines in Iceland using Google Maps, and may be better left to more able students.

	Australian Syllabus links
Science	ACSSU180 The theory of plate tectonics explains global patterns of geological activity and continental movement. ACSIC166 Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately. ACSIS171 Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data.
Design and Technology	ACTDEK046 Investigate and make judgements on how the characteristics and properties of materials, systems components, tools and equipment can be combined to make designed solutions. ACTDEP049 Develop, modify and communicate design ideas by applying design thinking , creativity, innovation and enterprise skills of increasing sophistication ACTDEP050 Work flexibly to effectively and safely test, select, justify and use appropriate technologies and processes to make designed solutions. ACTDEP052 Develop project = plans using digital technologies to plan and manage projects individually and collaboratively taking into consideration time, cost, risk and production processes.
	Australian Syllabus links

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Mathematics	ACMMG221 Solve problems using ratio and scale factors in similar figures

Useful websites and resources

- Short YouTube video explaining and demonstrating how to make a 3D topographic map using cardboard https://www.youtube.com/watch?v=AZ7lWrqidgk
- Tutorial video on how to 3D print topographic models: https://www.youtube.com/watch?v=bSNy9iUqDbI
- Tutorial video explaining how to use Fusion 360 to create a laser cut topographical map: https://www.youtube.com/watch?v=qBEbchypvM4
- Video of students completing opposite activity – cutting up a volcano to create a topographic map (more useful for lower level students): https://www.youtube.com/watch?v=hbk824_1PGs

Designing a Diversion

Objective

Students will design an engineered solution for a chosen volcano which will help minimise the potential damage to local populations, explaining why it is a suitable solution for that area.

Students should realise that different tectonic settings create very different hazards and that the composition of the magma will greatly affect the VEI magnitude. There is very little that can be done to mitigate against the hazards caused by highly explosive volcanic eruptions, however more effusive lava flows can be diverted and lahars and avalanches can also be diverted.

Edfell has been the only lava flow that has been diverted using water to cool it – most lava flows are just too hot to be diverted by this method. High level students should do some calculations to determine how much water is needed to cool lava at different temperatures. Iceland is fortunate enough to be surrounded by icy water which they could pump onto the lava.

One difficulty with diverting lahars is that it is very difficult to determine until close to eruption where the flow may go – Mt St Helens is an example of this where it was the side of the volcano that erupted – not right at the top. Therefore building channels can be expensive yet ineffective.

	Australian Syllabus links
Science	ACSHE228 Values and the needs of contemporary society can influence the focus of scientific research. ACSSU180 The theory of plate tectonics explains global patterns of geological activity and continental movement. ACSIS165 Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods.
Design and Technology	ACTDEK040 Critically analyse factors, including social, ethical and sustainability considerations, that impact on designed solutions for global preferred solutions and the complex design and production processes involved ACTDEK041 Explain how products, services and environments evolve with consideration of preferred futures and the impact of emerging technology on design decisions ACTDEK043 Investigate and make judgments on how the characteristics and properties of materials are combined with force, motion and energy to create engineered solutions

	ACTDEK047 Investigate and make judgements, within a range of technologies specialisations, on how technologies can be combined to create designed solutions. ACTDEP049 Develop, modify and communicate design ideas by applying design thinking , creativity, innovation and enterprise skills of increasing sophistication ACTDEP051 Evaluate design ideas, processes and solutions against comprehensive criteria for success recognising the need for sustainability.
Digital Technology	WATPPS54 Identify and define the needs of stake holders, to create a brief, for a solution. WATPPS55 Investigate a selection of components/ resources to develop solution ideas. WATPPS56 Apply design thinking, creativity and enterprise skills WATPPS57 Design solutions assessing alternative designs against given criteria, using appropriate technical terms and technology. WATPPS59 Evaluate design processes and solutions against student – developed criteria

Useful websites and resources

- Useful article on mitigating hazards from lahars: Reducing risk from lahar hazards: concepts, case studies, and roles for scientists:
  Thomas C Pierson, Journal of Applied Volcanology Society and Volcanoes20143:16
  https://appliedvolc.springeropen.com/articles/10.1186/s13617-014-0016-4
- Cooling calculations
  https://pubs.usgs.gov/of/1997/of97-724/lavacool.html

Bibliography

Figure 1. Mount Tambora Volcano, Sumbawa Island, Indonesia, NASA Earth Observatory (2009), retrieved from https://earthobservatory.nasa.gov/images/39412/mount-tambora-volcano-sumbawa-island-indonesia (2018)

Figure 2. Volcanic Hazards at Mount Adams, USGS (2013), retrieved from https://volcanoes.usgs.gov/volcanoes/adams/adams_hazard_92.html (2018)

Student Booklet (scaffolded)

Figure 13. Volcanic Explosivity Index, Chegg Study (unknown), retrieved from https://www.chegg.com/homework-help/questions-and-answers/consider-volcanic-explosivity-index-tambora-indonesia-based-table-textbook-year-would-expe-q29865629 (2018)

Figure 14. Layers of our Atmosphere, NASA Space Place (2018), retrieved from https://spaceplace.nasa.gov/menu/atmosphere/ (2018)