Earthquake Engineering – Teacher Resource

Intended Use of Resources

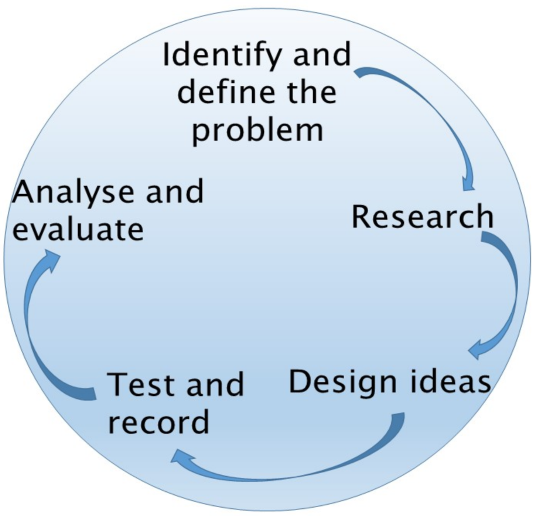
This project has been designed so that teachers from different STEM areas can pick and choose sections relevant to their subject area to work on. All activities in this package do not need to be completed to get value from the package – each activity can be completed as a stand-alone or can be approached,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

Designing earthquake resistant buildings can be lifesaving, especially for people living near tectonic boundaries. Your job is to investigate the causes of earthquakes and their effects on different ground types and building designs. You should select a particular location that you think would benefit from better earthquake engineering and design a building that would be suitable for this location, explaining why this a suitable design for this area.



Background Information

Earthquakes can be devastating, destroying structures and buildings and taking lives. In 2017 there were 12,527 earthquakes recorded with a magnitude of 4 or higher globally. The deadliest of which was a 7.3 magnitude earthquake which occurred on November 12, killing 630 people in Iran and 10 in Iraq. Interestingly, Russia and New Caledonia both experienced earthquakes of similar depth and magnitude and had no fatalities.

Figure 1. Devastation caused by the Iran - Iraq Earthquake of 2017. (Tasnim News Agency, 2017)

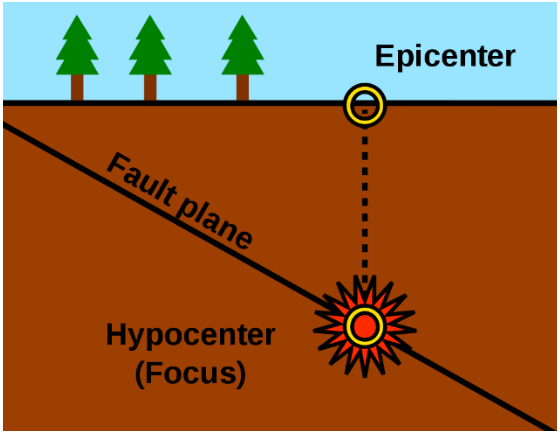


Figure 2. Diagram of the epicenter of an earthquake, where movement along a fault plane is the cause. (Hocevar, 2014)

Earthquakes are caused by fault movement. This can occur on a micro to mega scale. Most earthquakes that cause damage are due to movement of tectonic plates, however volcanic activity, and crustal adjustments can also cause earthquakes. Earthquakes have also been linked to anthropogenic causes, such as fracking and mining.

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Figure 3. Three story building on springs in North Carolina to dampen the effect of earthquake waves. (Shustov, 1999)

Damage caused by earthquakes can be economically catastrophic for families, businesses and whole countries. With infrastructure and buildings often having to be completely rebuilt. The design of buildings is therefore of paramount importance to avoid damage.
Some countries are much more likely to experience earthquakes than others. This makes it easier for governments to decide if they should make earthquake engineering a priority to protect their population. Unfortunately a lot of the current earthquake resistant building designs that do work well are very costly, and unaffordable for many.

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

Background Research
Where in the World?
Earthquake Energy
Case Studies
Flexural Strength Testing
Modelling Liquefaction
Strength of Shapes
Protostorming
Designing and Building an Earthquake Resistant Building

**Please note that these 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.*

An initiative supported by Woodside and ESWA

Background Research

Objective

Students will gain a general understanding of the causes of earthquakes, how they can cause damage and the hazards of earthquakes.

The background questions should lead them to start thinking about further investigations they could do to find out more about the effects of earthquakes on buildings, as well as the different hazards associated with them, such as tsunamis and landslides. Thinking about other hazards caused by earthquakes, such as fires, tsunamis and landslides will hopefully help students think about which building materials and styles of building would be best for different locations. For example, wood is very flexible but also burns easily. It may be more difficult to build a structurally secure tower, however, a taller building may be important for an area where a tsunami is possible.

The students should begin to understand that some countries are more earthquake prone than others, which they will develop more if they conduct the "where in the world" activity. They are "teaser" questions which students will be able to find out more about through the other activities. Therefore if you do not have time to complete all the activities you may wish to add to the background questions. Having students think about less economically developed countries compared to more economically developed countries and why housing is more poorly built in particular countries will get them to start thinking about designing cheaper options. There are lots of great engineering ideas but a lot of them are just too expensive for most people.

Students will find that most earthquakes are caused by movements at plate boundaries, especially destructive plate boundaries, where plates collide. They should find that the main types of earthquake waves are P, S and surface waves – it is the surface waves which cause the most damage to infrastructure. The waves can cause pipes to burst, which can cause flooding or if they are gas pipes can lead to major fires. They make the surface of the earth move, so can warp roads and train lines and topple buildings.

Architects must consider the area where they are building – ground type is very important (see liquefaction activity), as well as building material and building shape. However, architects must also think about the population concentration and societal living preferences – a small timber house won't suffice for a building design for a city with a population of millions, were space is limited.

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	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. ACSSU182 Energy transfer through different mediums can be explained using wave and particle models.
Design and Technology	ACTDEK046 Investigate and make judgments on how the characteristics and properties of materials, systems, components tools and equipment can be combined to create designed solutions

Useful resources and websites:

- Teaching resources and background information, and activities for students relating to earthquakes can be found on the WASP and ESWA websites: http://www.wasp.edu.au/course/view.php?id=15, http://www.earthsciencewa.com.au/course/view.php?id=16 and http://www.earthsciencewa.com.au/course/view.php?id=21
- Geoscience Australia has information on causes of earthquakes: http://www.ga.gov.au/scientific-topics/hazards/earthquake
- USGS provides statistics, maps and information on what causes earthquakes in student friendly language: www.usgs.gov

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Where in the World?

Objective

Students will explore the relationship between earthquake location and tectonic plates through use of GIS (Geographical Information Systems) and secondary data.
Students will plot earthquake data on a world map to see that there are some areas much more earthquake prone than others, and link this to where the tectonic boundaries are.
Students can complete this either by using a map of the world and a list of the 30 most recent earthquakes as an exercise looking at longitude and latitude.
Or
This can be completed using Google Maps and Excel.
Depending on how much you would like your students to practice inputting data they can either plot each earthquake individually onto Google Maps, to slowly build up the picture of where the tectonic plates are, they can manually input the data onto an Excel spreadsheet and import that into Google Maps all in one go, or they can just download the data from Geoscience Australia as one file and import that file straight into Google Maps.

	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. ACSHE157 Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community.

Useful websites and resources:

- To get a recent list (past 30 days) of Earthquakes over magnitude 6 you can use: http://www.ga.gov.au/earthquakes/initRecentQuakes.do
  You may wish to start collecting the data earlier to have more of it.
- A fantastic program to download which gives information about plate boundary types and also shows all the volcanic and earthquakes happening in sequence dated all the way back to 1960 can be downloaded from Alan. L. Jones profile at Bingham University: https://www.binghamton.edu/geology/people/faculty/jones.html
  This allows students to change the speed, select dates and look at the cross-sections of the Earth to investigate plate dip at subduction zones. The programme is completely free.

Earthquake Energy

Objective

To be able to calculate the energy released by different magnitude earthquakes and discuss this in relation to building design for a particular region.

	Australian Syllabus links
Mathematics	ACMNA208 Solve problems involving direct proportion. Explore the relationship between graphs and equations corresponding to simple rate problems ACMNA209 Apply index laws to numerical expressions with integer indices ASMNA210 Express numbers in scientific notation ACMMG219 Investigate very small and very large time scales and intervals. ACMMG221 Solve problems using ration and scale factors in similar figures.

Earthquakes are generally reported by their magnitude, or more correctly – Moment Magnitude. This is a modified version of the Richter scale which was devised in the 1930s by Charles Richter. Moment Magnitude is not a linear scale, in fact for each unit of increase (1, 2, 3…) the earthquake will be 10 times bigger and release around 31.6 times more energy.

Although earthquakes with larger magnitude release more energy, there are numerous other factors, such as ground type which will have a large impact on the effect felt by the earthquake.

The scaffolding in this activity is very similar – however the mathematics involved is harder for each level.

Useful websites and resources

- For students struggling with calculations, they may wish to use the USGS “How Much Bigger…..” Calculator: https://earthquake.usgs.gov/learn/topics/calculator.php

Case Studies

Objective

Students will research historic earthquakes and different building designs to explain the design features of buildings which have enabled them to withstand earthquakes.
There are buildings which are hundreds of years old still standing in seismically active areas, such as pagodas in China. With increasing population size more and more people are living in seismically unstable areas and are at risk of being affected by earthquakes. Better building designs and better understanding of older designs, are becoming much more in demand, and new ideas of how to prevent building collapse are being engineered. Such as, building more flexible buildings that can sway with the waves, and adding dampers to buildings, such as large springs underneath, which will absorb a lot of the energy of the quake. In some earthquake prone areas buildings also need to be very high to withstand tsunamis.
When students are looking at different building designs they should also consider the location of the buildings and how much they cost – the best designs are not always viable.

	Australian Syllabus links
Science	ACSSU180 The theory of plate tectonics explains global patterns of geological activity and continental movement. ACSSU 182 Energy transfer through different mediums can be explained using wave and particle models. ACSHE160 People use scientific knowledge to evaluate whether they accept claims, explanations or predictions and advances in science can affect people's lives, including generating new career opportunities.
Design and Technology	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

Useful websites and resources

- Short YouTube vide on the design of pagodas and how they withstand earthquakes. https://www.youtube.com/watch?v=0tFWn_e71qc

Flexural Strength Testing

Objective

Students will investigate the flexibility of different materials, and analyse their suitability as a building material for earthquake prone zones.

The flexural strength of materials is very important – if a building can flex and sway a little it is much less likely to collapse. A rigid building is more likely to crumble in an earthquake. However, too much flexibility will make it less supportive for furniture inside the building, and shelving etc. attached to walls, as well as dangerous for the inhabitants inside. A very flexible building could end up knocking into another building if they are built very close together.

	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. ACSIS171 Evacuate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data.
Design and Technology	ACTDEK043 Investigate and make judgments on how the characteristics and properties of materials are combined with force, motion and energy to create engineered solutions ACTDEK046 Investigate and make judgments on how the characteristics and properties of materials, systems, components tools and equipment can be combined to create designed solutions WATPPS56 Apply design thinking, creativity and enterprise skills.

Modelling Liquefaction

Objective

Students will observe the behaviour of different ground types when shaken, and relate that to engineering considerations for building in an earthquake prone zone.

This investigation will show the effects of liquefaction (the ground behaving like a liquid as water that was trapped in pore spaces rises to the surface). When modelling liquefaction in sand, the ping pong balls should rise to the surface as they are full of air – therefore less dense than the surrounding sand. The more unconsolidated the ground is, the more it will liquefy, likewise, the more water it has in it the more it will liquefy.

You may wish to do this outside to avoid too much mess inside. It is important not to use too much sand and water as it will get quite heavy and be difficult to move.

A simple way to ensure the frequency of shaking is kept the same is to have a student count out loud or clap a rhythm (if you have a drummer in the class they could assist with this).

	Australian Syllabus links
Science	ACSSU180 The theory of plate tectonics explains global patterns of geological activity and continental movement. ACSSU 182 Energy transfer through different mediums can be explained using wave and particle models. ACSHE228 Values and the needs of contemporary society can influence the focus of scientific research 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. ACSIS170 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence. ACSIS171 Evacuate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data.
Design and Technology	WATPPS56 Apply design thinking, creativity and enterprise skills.

Useful websites and resources

- Demonstration on how liquefaction occurs.
  https://www.youtube.com/watch?v=tvYKcCS_J7Y
- Information on liquefaction: causes and hazards.
  https://geology.com/usgs/liquefaction/

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Strength of Shapes

Objective

Students will investigate which shapes are strongest and most likely to withstand applied forces from different directions and relate this to building design in an earthquake prone area, by building shapes using straws and string.

Higher level students will investigate the amount of material needed to build the different shapes, as well as the liveability of the shapes (furnishing a sphere could be difficult!) and consider why cubes and cuboids are more commonly built structures even though not the strongest shapes. Students should find that the pyramid is the strongest shape – however in terms of functionality it is not the best shape. It also leads to a lot of wasted space vertically. However, building a rectangular shaped building then using diagonal support braces to create lots of triangles will strengthen the building.

Plastic straws are very easy to use – although not biodegradable. You may prefer to paper straws, although these may not be as strong they should give similar results.

	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.
Design and Technology	ACTDEK043 Investigate and make judgments on how the characteristics and properties of materials are combined with force, motion and energy to create engineered solutions WATPPS55 Investigate a selection of components/ resources to develop solution ideas, identifying and considering constraints. WATPPS56 Apply design thinking, creativity and enterprise skills.
Mathematics	ACMMG217 Calculate the surface area and volume of cylinders and solve related problems. ACMMG222 Investigate Pythagoras' Theorem and its application to solving simple problems involving right angles triangles. ACMMG223 Apply trigonometry to solve right- angled triangles. ACMMG218 Solve problems involving the surface area and volume of right prisms

An initiative supported by Woodside and ESWA

Useful websites and resources:

- TedEx talk from Ross Stein- a geophysicist with the US Geological Survey in California, who studies how earthquakes interact by the transfer of stress. He wants everyone to be able to learn what their seismic risk is.
  https://www.youtube.com/watch?v=Bg4kSIgn67I

- BBC bitesize revision, activity and test on geometry of 3D shapes:
  http://www.bbc.co.uk/schools/gcsebitesize/maths/geometry/

Protostorming

Objective

Students will work in groups to protostorm a model of a building to be tested on a "shake plate", to gain better understanding of structural strength and consider how to improve designs.

Protostorming is a technique where you stretch your creative problem solving skills to create models, prototypes and conceptual representation of ideas very rapidly. Students work in teams, to quickly come up with models to test. The aim of a protostorm is to learn through failure "#flearning", gaining confidence to try out prototypes and not worry if the designs are not perfect first time.

There is no differentiation for this activity as it is really a "warm up" for the students to start considering more complex design ideas.

Depending on resources and time available these can be built using a wide variety of materials – suggestions of building materials:

newspaper, straws, paper, toothpicks, marshmallows, balsa wood, paddle pop sticks, springs, pipe cleaners, plasticine, sticky tape, (slotted masses to show effects of dampers).

The "shake plate" can be made of a variety of materials. Suggestions on what to use to create the earthquakes – jelly, Jenga © quake board, loudspeaker (frequency can be altered, to show different magnitudes), a layer of marbles in a shoebox with a piece of card on top of them.

	Australian Syllabus links
Design and Technology	ACTDEK043 Investigate and make judgments on how the characteristics and properties of materials are combined with force, motion and energy to create engineered 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. WATPPS56 Apply design thinking, creativity and enterprise skills.

Useful websites and resources

- Here is a suggestion of how to build a shake table – you can even buy a kit: https://www.youtube.com/watch?v=6HgxiYBkh3U

Designing and Building an Earthquake Resistant Building

Objective

Students will select a particular global location that they think would benefit from better earthquake engineering and design and create a model building that would be ***suitable for this location***.

This activity should take a lot longer than the protostorming with students really considering the location of their building and what that means in relation to their design. For example, how important is the cost, and what is the population density of the area (do they need to make a tower)?

For this activity much higher quality material should be used than in the protostorming. Students should design a building and then scale it down to size – working on their mathematical skills, as well as design and technology skills. Students should consider the height of the building and number of floors and give an estimated number of people that could live in the building. Students may wish to include model furniture to see what happens to it when the building is tested.

Extension ideas

- Give monetary values to the materials, so that they can score points for the price of their building – this is an extremely important part of engineering, as clients always want the best value for money, and many earthquake prone areas are in countries with low GDP.
- Students get points on the height of the building, but have a set base size – or get "charged" more for a larger base.
- Students get points for the amount of mass their structure can support.
- Investigate the effects of dampers on the buildings, by adding slotted masses suspended from the middle of their buildings.
- Build a bridge or a more complicated structure.
- Consider evacuation measures – how easy is it for people to get out of the building, or get to the top of the building if there is a tsunami? Where is the safest place to put a staircase?

	Australian Syllabus links
Science	ACSHE228 Values and the needs of contemporary society can influence the focus of scientific research 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 ACTDEK043 Investigate and make judgments on how the characteristics and properties of materials are combined with force, motion and energy to create engineered solutions ACTDEK046 Investigate and make judgments on how the characteristics and properties of materials,

	systems, components tools and equipment 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 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 WATPPS54 Identify and define the needs of a stakeholder, to create a brief, for a solution. WATPPS57 Design solutions assessing alternative designs against given criteria, using appropriate technical terms and technology. WATPPS60 Work independently, and collaboratively to manage projects, using digital technology and an iterative and collaborative approach. Considers time, cost, risk and safety.
Mathematics	ACMMG216 Calculate areas of composite shapes. ACMMG219 Investigate very small and very large time scales and intervals.

Useful websites and resources

BBC bitesize revision, activity and test on product design methods:
http://www.bbc.co.uk/schools/gcsebitesize/design/resistantmaterials/designanalysisevaluationrev1.shtml

Bibliography

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