PRIMARY + STEM

Teaching Resource

ACTIVITY: Earthquake-Resistant Engineering

ACTIVITY OVERVIEW

Let's all become engineers - designing, testing, and rebuilding! This activity highlights the need to construct resilient buildings that can withstand natural disasters, and to prevent the unending cycle of destruction and reconstruction - especially in areas prone to natural disasters. This concept is especially relevant to the eastern coast of Australia that gets battered by severe storms, and in parts of Australia that get engulfed by raging fires. Many cities and towns that must rebuild do so by 'building back better' - putting in place measures that allow for better planning and prioritising measures that make buildings capable of handling stress.

The chosen natural disaster for this activity is the earthquake, with particular focus on the testing and redesigning aspects of the design process. This can be found in the 'evaluate' section of the Design & Technology curriculum. The design process underpins how engineers work towards achieving the best designs and find the most efficient solutions, with multiple iterations of designs or processes to reach the final successful product.

SYNOPSIS

Let's all become engineers - designing, testing, and rebuilding!

This activity highlights the need to construct resilient buildings that can withstand natural disasters, and to prevent the unending cycle of destruction and reconstruction - especially in areas prone to natural disasters. This concept is especially relevant to the eastern coast of Australia that gets battered by severe storms, and in parts of Australia that get engulfed by raging fires. Many cities and towns that must rebuild do so by 'building back better' - putting in place measures that allow for better planning and prioritising measures that make buildings capable of handling stress.

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Although earthquakes aren't a common experience in Australia, they are easy to simulate in the classroom and the activity is a lot of fun. These design ideas, along with the philosophy of building resilience, can be transferred to more common Australian natural disasters, such as bushfires, cyclones and floods. Students work in groups to test their designs, learn from one another, and compare their ideas to the work that architects and engineers do in the real world.

Foundation – Year 2

- Visualise, generate, and communicate design ideas through describing, drawing and modelling (VCDSCD019)
- Use materials, components, tools, equipment and techniques to produce designed solutions safely (VCDSCD020)
- Use personal preferences to evaluate the success of design ideas, processes and solutions including their care for environment (VCDSCD021)
- The way objects move depends on a variety of factors including their size and shape: a push or a pull affects how an object moves or changes shape (VCSSU048)

Year 3 – 4

- Recognise the role of people in design and technologies occupations and explore factors, including sustainability, that impact on the design of solutions to meet community needs (VCDSTS023) Investigate how forces and the properties of materials affect the behaviour of a designed solution (VCDSTC024)
- Generate, develop, and communicate design ideas and decisions using appropriate technical terms and graphical representation techniques (VCDSCD029)
- Select and use materials, components, tools and equipment using safe work practices to produce designed solutions (VCDSCD030)
- Evaluate design ideas, processes and solutions based on criteria for success developed with guidance and including care for the environment and communities (VCDSCD031)
- Forces can be exerted by one object on another through direct contact or from a distance (VCSSU064)

Year 5 - 6

- Generate, develop, communicate and document design ideas and processes for audiences using appropriate technical terms and graphical representation techniques (VCDSCD039)
- Apply safe procedures when using a variety of materials, components, tools, equipment and techniques to produce designed solutions (VCDSCD040)
- Negotiate criteria for success that include consideration of environmental and social sustainability to evaluate design ideas, processes and solutions (VCDSCD041)
- Sudden geological changes or extreme weather conditions can affect Earth's surface (VCSSU079)

ACTIVITY, MATERIALS AND INSTRUCTIONS

Activity - Earthquake-resistant engineering

Students work in small groups to complete a timed building block challenge. Then, surprise them with a simulated earthquake, forcing them to redesign their damaged buildings.

Materials for 30 students (split into 5 groups)

- Building blocks (e.g. Lego), shared between five groups
- Plastic tray/tub x five

Instructions

1. In 10 minutes, each group must build the tallest tower possible with their allocated blocks. Build your tower on or in the tray/tub.
2. Uh-oh - an earthquake is about to hit our city! Each tower tray/tub will be shaken for 10 seconds of sideways movement.
3. Optional – this is quite a severe earthquake. Shake towers for another 10 seconds of greater sideways movement.
4. Back to the drawing board! (This is the place where architects design buildings). Using the same blocks, can you build a tower that will be more earthquake-resistant? Students rebuild their towers with this new design consideration.
5. Re-test the towers with another earthquake.
   Was your tower damaged during the second earthquake?
   How did you change your design?
   Do you have any ideas for further improvements?

Engineers who design buildings for earthquake prone areas use a clever combination of both materials and design to help their buildings survive the repeated sideways shaking caused by earthquakes. Steel, wood, bamboo, and reinforced concrete (concrete with steel bars inside) are strong and stable materials used in construction. Design features, including flexible foundations, cross braces, pendulums, and dampers, are among those commonly used by engineers. Newer technology includes burying concrete and plastic in ring shapes around a building, to change the path of the seismic waves.

HOW TO USE THIS ACTIVITY WITH YOUR STUDENTS

Foundation - Year 2

Taking part in this activity, students begin to put engineering and design vocabulary to processes that they have already encountered. Building with blocks and redesigning a fallen tower are things that many children have done before they start school.

Students at this level are learning about the basic forces of pushes and pulls, which can be related to the sideways movement caused by earthquakes. When the Earth's surface moves, lots of strong little pushes and pulls make buildings shake.

Extend this activity for Foundation to Year two students by trying different sizes of pushes and pulls with your simulated earthquakes. Forces have a strength; we call this their magnitude. Earthquakes also have a strength, or magnitude. The strongest earthquakes measured have magnitudes of greater than eight on the Richter scale. These earthquakes have a big push and pull force on the surface of Earth. The smallest earthquakes that people feel have a magnitude of around two on the Richter scale. These small earthquakes have a smaller push and pull force. Students can explore different magnitude pushes by rolling a ball towards a target on the floor.

Years 3/4

Activities that include investigating materials used for particular purposes will cover both the Design & Technologies and the Science curriculum for Year three and four. These students should learn more about materials used for earthquake-resistant buildings, including steel, wood, bamboo, and reinforced concrete. If possible, find samples of these materials to show the students.

What are the properties of these materials that make them suitable for construction of buildings? We don't want to use materials that will snap or crumble. Bricks are not used in earthquake-resistant building design, as they crumble, due to the movements caused by earthquakes.

Extend learning for Year three and four students by building towers from different materials, then comparing performance during the simulated earthquakes. Can students use some of the design features that engineers use in earthquake-resistant buildings? Is there a way to measure the amount of damage caused to your towers? Students may suggest ideas like measuring the height of the remaining building or counting blocks that have detached from the tower.

Years 5/6

Students in Years five and six are studying the design process in the Technologies curriculum and earthquakes in Science, making this activity a great one to use with these year levels. Acting as earthquake engineers, students will be able to explain the science behind earthquakes, as well as working together to produce designs that can withstand these forces.

This activity could be used to introduce students to different fields of engineering. Historically, engineering has been divided into four main areas: chemical, civil, electrical, and mechanical. Each of these areas include many different types of specialist engineers. In earthquake engineering, we are most likely to encounter civil engineers, those working on physical structures, including buildings, towers, roads, and bridges.

On completion of this activity, Year five and six students should be introduced to plate tectonics, the layers that make up Earth, and the different movements causing earthquakes. Students should study a map of tectonic plate boundaries to understand the distribution of major earthquake locations around Earth.

DISCUSSION SECTION AND KEY THEMES

Engineers

The work of engineers covers many different tasks in many different environments. Some examples of those that work in engineering fields that involve buildings include:

- **Building services engineer** – design all features of buildings that are needed for a functional and safe work environment (e.g. heating, cooling, lighting, plumbing, electricity, phones, computers, lifts)
- **Civil engineer** – design and construct physical infrastructure (e.g. buildings, roads, pipelines, bridges, transport systems)
- **Geotechnical engineer** – provide information on soil and rocks, and their behaviour under expected building conditions, at a proposed building site
- **Hydraulics engineer** – plan and organise how water enters and leaves systems
- **Structural engineer** – consider forces affecting a planned structure, including natural (e.g. wind, waves, earthquakes) and man-made (e.g. people, cars)
- **Electrical engineer** – design and build systems that produce and use electricity
- **Electronics and telecommunications engineer** – design and build devices and systems that analyse, transmit and store data (e.g. phones, radio, satellites)
- **Environmental engineer** – protect the environment by assessing impacts of projects, clean up problems caused by past activities
- **Materials engineer** – test behaviour of materials under specific conditions or when combined with other materials, develop new materials, improve existing materials, improve recycling processes

The Institute of Engineers Australia provide resources about engineering for teachers and students, including some recommended videos. https://www.engineersaustralia.org.au/For-Students-And-Educators/For-Educators

Earthquake-resistant building

When an earthquake happens, buildings are shaken with sideways movement. Buildings are always designed to handle vertical forces (weight, gravity), but not all buildings can remain intact with horizontal forces. Engineers have developed many safety features to improve the resistance of buildings to earthquake movement.

- reinforced structures (cross-bracing in walls and floors)
- flexible foundations (the base moves, but the building doesn't)
- shield building (plastic/concrete buried in rings around a building, to send shockwaves around a building)
- damping, absorbing shockwaves (pistons and oil convert motion into heat and absorb shock, pendulum at the top of the building – a large ball is suspended by cables, it sways in the opposite direction to the building helping to stabilise its movement)
- materials that bend without breaking or are lightweight but strong (steel, wood, bamboo, reinforced concrete, new special materials)

Retrofitting old buildings

Retrofitting is to take an existing thing (e.g. a house) and add modern features. Retrofitting for earthquakes uses today's technology to make old buildings safer.

This includes:

- cripple wall bracing (bracing the short walls between the foundations and the exterior walls)
- foundation bolting (drill holes and put bolts joining the house to the foundations)
- reinforce chimneys (you don't want brick chimneys to fall)
- reinforce brick walls
- garages may need reinforcing around the door

As described in the Rockefeller Foundation in New York City (USA), a resilient building is one that 'rolls with the punches'. A resilient building in a flood zone isn't necessarily designed not to get wet—it can get wet, because it's designed not to fall apart. One solution could be building floating houses like they do in the Netherlands. Likewise, resilient buildings in seismically active zones such as Japan are designed to withstand earthquakes not by being even more rigid and stiff… in fact, they are designed to 'roll with the punches'.

Earthquake science

Earthquakes happen when there is a big movement in part of Earth's crust, making the ground shake. We divide Earth up into layers where the rocks behave differently. There is a core in the centre, then the mantle layer, and the outer layer, the crust. The crust is a thin layer, like the peel on an apple. Earth's crust is not one smooth, unbroken layer, like an apple peel. The crust is broken up into big pieces called plates, which move into, away from or under each other, at their edges, dragged around by the moving mantle layer below. The plates are moving slowly, with pressure building up at these boundaries. Big shifts in the rocks that make up the crust release this pressure as energy in shock waves.

Most earthquakes happen at the boundaries of these plates. You may have heard about earthquakes happening in places like Japan, California (USA) and Christchurch (New Zealand). These locations are all found along tectonic plate boundaries.

The scientific theory that explains the movement of the crust causing earthquakes is called plate tectonics. Scientists put together pieces of evidence (including fossils) to show that the continents had been joined millions of years ago, proposing this theory, which is now widely accepted.

Measuring earthquakes

The Richter scale, used to describe earthquake magnitude (size) is a logarithmic scale. Each increase of one-unit releases 31 times more energy. For example, a magnitude six earthquake has 31 times more energy than a magnitude five earthquake.

Throughout the world between three and twenty major earthquakes happen every year (major is 7.0 – 7.9 magnitude) and less than three earthquakes occur that are stronger than this.

The United States Geological Survey (USGS) website shows the distribution of earthquakes for the last 24 hours. You can sort these by time or magnitude.

https://earthquake.usgs.gov/earthquakes/map/

QUESTIONS AND ANSWERS

What is engineering?

Engineers use science and maths to solve problems and are often described as scientists, inventors, designers, builders, and great thinkers, making people's lives safer and easier. Engineering skills include teamwork, creativity, science, maths, and a knowledge of social, cultural, and economic factors.

What types of engineers work with earthquake building design?

Earthquake engineering uses skills and knowledge from a variety of disciplines, including structural engineers, geotechnical engineers, civil engineers, scientists, sociologists, political scientists, and economists.

What happens to tall buildings in earthquakes?

These days, tall buildings built in earthquake-prone cities have been designed to deal with the shaking movement created by earthquakes. But, in the past, earthquakes were not as well understood as now. Older buildings built from bricks and concrete are more brittle and crumble from stronger earthquake vibrations.

Tall buildings (e.g. 30 storeys) are actually safer in earthquakes than shorter buildings (e.g. three-storey apartment). The taller a structure, the more flexible it is (shorter buildings are stiffer). Taller, more flexible buildings sway as the energy from earthquakes move through them.

The amount of shaking depends on how close you are to the epicentre of the earthquake and the type of ground that a building is sitting on.

Do earthquakes affect us in Australia?

We do not get a lot of earthquakes in Australia, but they do occur. Our location, in the middle of the Indo-Australian tectonic plate, is relatively stable compared to places along the plate boundaries. Geosciences Australia provides earthquake risk information, as well as monitoring all earthquakes that occur.

With a magnitude of 6.6, the largest recorded earthquake in Australia was at Tennant Creek (NT) in 1988. The deadliest earthquake in Australia was a magnitude 5.6 earthquake at Newcastle (NSW) in 1989. Thirteen people died, 160 people were injured and 50,000 buildings were damaged.

Maybe you felt the earthquake in Victoria during the school holidays on 22 September 2021? This was a magnitude 5.9 earthquake that happened east of Melbourne, about 10km below the town of Woods Point. For many Victorians, this was the biggest earthquake they had ever felt. Even though we felt our houses shaking and saw items jiggling on the shelves, not much damage was caused by the earthquake, which was classed as moderate. Watch the ABC news report here https://www.youtube.com/watch?v=epKx07GUne8.

Can poorer countries afford to build earthquake-resistant buildings?

Bamboo is an easy to grow, inexpensive building material that is also suitable for earthquake-resistant building design. Engineers have designed affordable bamboo-based earthquake-resilient houses for people in Indonesia (https://www.dezeen.com/2019/12/31/bamboo-template-houses-ramboll-earthquake-indonesia/#) and have made new foundations from old tyres filled with sand or stone. In India, bamboo has been used to strengthen concrete.

Can we predict earthquakes?

No. The United States Geological Survey has been studying earthquakes for over 100 years and has never predicted a major earthquake. Scientists can calculate the probability that a significant earthquake will happen in a certain area within several years, but nothing as helpful as date, time and location.

Are there special materials that can be used to build earthquake-proof buildings?

Yes, engineers have developed some amazing new materials to help make buildings safer during earthquakes.

Thermocol (Expanded Polystyrene EPS) – could be put between concrete layers and reinforced with a wire mesh; it also provides insulation (India)

Levitating on air – sensors detect earthquake activity, air compressor takes 0.5 seconds to put air between the building and its foundation, air lifts the building 3cm off the ground protecting it from the shaking forces (Japan)

Shape memory alloy – a smart material that can endure heavy strains and still return to its original shape, a nickel-titanium alloy (nitinol) has more elasticity than steel

Carbon fibre wrap – carbon fibres, plus a polymer makes a lightweight and strong material, wrap around columns of old bridges and buildings, pump epoxy in between wrap and column

Biomaterials (materials inspired by nature) – for example mussel threads are a mixture of stiff and rigid, or flexible and elastic. Engineers just need to work out how to put this into a construction material! Or maybe spider silk, which is stretchy and then stiff.

Are there special building designs used for other natural disasters, like cyclones, floods and bushfires?

Yes, in Australia we have good regulations and guidelines to help people be as prepared as possible for natural disasters.

Bushfires (VIC example)

- Australian Standards apply to all new domestic buildings in Victoria
- Recommended precautions (e.g. sealing gaps, vents, roofing, checking gutters, removing overhanging branches)
- Information can be found at https://www.vba.vic.gov.au/consumers/bushfire/areas-overlays
- Bushfire Attack Level (BAL) determines the type of construction required for your area
- Bushfire prone area (BPA) used scientific information to determine the risk in your area
- Go to the VicPlan website to see information on your address (e.g. bushfire, flood risk) https://mapshare.vic.gov.au/vicplan/

Cyclones (QLD example)

- Cyclone Resilient Building Guidelines are provided by the Queensland government (https://www.qra.qld.gov.au/sites/default/files/2019-12/cyclone_resilience_building_guidelines_-_dec19.pdf)

- Lots of information provided about roofs, wind speeds and direction, myths, and advice

Floods (QLD example)

- Flood Resilient Building Guidelines are provided by the Queensland government (https://www.qra.qld.gov.au/resilient-homes/flood-resilient-building-guidance-queensland-homes)

- With serious floods happening in 2022, there will be a lot more talk about flood engineering and buildings in years to come

Here you can explore the "One House" design, made to withstand flood, fire and cyclones https://onehouse.suncorp.com.au/explore.

What should I do if an earthquake happens?

If you are indoors

- stay there until the shaking stops
- get under a desk or table, or into a hallway, against an inside wall
- stay away from windows, fireplaces, heavy furniture/appliances, kitchen (if possible)
- hold on

Don't – run outside, run downstairs (you could fall and get hurt)

If you are outside – get into the open (away from trees/buildings/power lines)

If driving – stop (carefully), but not on bridges or under anything

OUTSIDE OR SUPPLEMENTARY READING

Earthquake-resistant building design

- https://www.bigrentz.com/blog/earthquake-proof-buildings
- https://blog.iseekplant.com.au/blog/5-features-earthquake-proof-building#:~:text=Reinforced%20concrete%20is%20used%20in,high%20winds%20or%20ground%20vibrations.
- https://www.dezeen.com/2019/12/31/bamboo-template-houses-ramboll-earthquake-indonesia/#

Retrofitting earthquake buildings

- https://www.earthquakeauthority.com/Blog/2020/Benefits-Seismic-Upgrades-Why-Retrofit-Your-Home
- Show students Lego Masters "Make & Shake", Series 2, Episode 5. https://www.9now.com.au/lego-masters/season-2

What is engineering?

- https://www.engineersaustralia.org.au/For-Students-And-Educators/Engineering-Careers/What-Is-Engineering

The layers that make up the Earth

- https://www.sciencenewsforstudents.org/article/explainer-earth-layer-layer
- National Geographic – Plate tectonics
  https://education.nationalgeographic.org/resource/plate-tectonics
- Geosciences Australia
  https://www.ga.gov.au/scientific-topics/community-safety/earthquake
- Newcastle earthquake information
  https://newcastle-collections.ncc.nsw.gov.au/

What to do during an earthquake

- https://www.ses.vic.gov.au/plan-and-stay-safe/emergencies/earthquake
- https://www.usgs.gov/faqs/what-should-i-do-during-earthquake

TOPIC WORDS

- Engineer
- Design
- Evaluate
- Earthquake
- Forces
- Materials
- Tectonic
- Crust
- Pressure
- Shockwave
- Magnitude

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