Earthquake-Resistant Building Challenge

YEAR 6 AND 9
EARTH AND SPACE SCIENCES
DESIGN AND TECHNOLOGIES

QGC | FUTUREMAKERS | QUEENSLAND MUSEUM NETWORK | Queensland Government

Future Makers

Future Makers is an innovative partnership between Queensland Museum Network and Shell's QGC business aiming to increase awareness and understanding of the value of science, technology, engineering and maths (STEM) education and skills in Queensland.

This partnership aims to engage and inspire people with the wonder of science, and increase the participation and performance of students in STEM-related subjects and careers — creating a highly capable workforce for the future.

QUEENSLAND MUSEUM NETWORK

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ENGAGE – EXPLORE – EXPLAIN – EVALUATE

Earthquake-Resistant Building Challenge

Teacher Resource

Students are the engineers tasked with designing and building a three story building that can resist large earthquakes. They will follow the design-thinking framework to investigate the problem, design an earthquake-resistant building, create and test the building, and then refine their designs to withstand the maximum acoustic waves.

Designing a cross-disciplinary STEM task

Based on your schools STEM agenda, the Earthquake-Resistant Building Challenge can be incorporated into a lesson or two, or modified to become a cross-disciplinary project-based unit. A cross-disciplinary task will integrate the Australian Curriculum subjects of Science, Technologies and Mathematics to solve the problem – how do we design buildings to resist earthquakes? See suggestions for developing a cross-disciplinary task on page 4 .

Creating a shake table

Shake tables can simulate earthquakes; therefore, they are effective for testing model buildings. There are many different types of shake tables that you can make depending on resources and time. All of these shake tables are effective in testing building strength, and digital technologies can be used to measure the intensity of the earthquake simulation. You may find shake table designs online or students could design and build their own shake tables.

A phone or tablet can be used to measure the size of the earthquake. The phone or tablet should be secured to the shake table. There are many apps to measure the intensity of the earthquake including *Vibration Meter* (Gamma Play, Android) or *Vibration Meter* (Smart Tools, Android) and *Vibration Meter, Seismograph, Seismometer* (ExaMobile S.A., iOS).

Curriculum Links

Science

YEAR 6

Science Understanding

Sudden geological changes and extreme weather events can affect Earth's surface (ACSSU096)

Science Inquiry Skills

Identify, plan and apply the elements of scientific investigations to answer questions and solve problems using equipment and materials safely and identifying potential risks (ACSIS103)

Decide variables to be changed and measured in fair tests, and observe measure and record data with accuracy using digital technologies as appropriate (ACSIS104)

Construct and use a range of representations, including tables and graphs, to represent and describe observations, patterns or relationships in data using digital technologies as appropriate (ACSIS107)

Reflect on and suggest improvements to scientific investigations (ACSIS108)

Compare data with predictions and use as evidence in developing explanations (ACSIS221)

Communicate ideas, explanations and processes using scientific representations in a variety of ways, including multi-modal texts (ACSIS110)

Science as a Human Endeavour

Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contributions (ACSHE098)

Scientific knowledge is used to solve problems and inform personal and community decisions (ACSHE100)

YEAR 9

Science Understanding

The theory of plate tectonics explains global patterns of geological activity and continental movement (ACSSU180)

Science Inquiry Skills

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 (ACSIS165)

Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately (ACSIS166)

Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS170)

Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS174)

Science as a Human Endeavour

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 (ACSHE160)

Values and needs of contemporary society can influence the focus of scientific research (ACSHE228)

Design and Technologies

YEAR 5 AND 6

Design and Technologies: Knowledge and Understanding

Investigate characteristics and properties of a range of materials, systems, components, tools and equipment and evaluate the impact of their use (ACTDEK023)

Design and Technologies: Process and Production Skills

Critique needs or opportunities for designing, and investigate materials, components, tools, equipment and processes to achieve intended designed solutions (ACTDEP024)

Generate, develop and communicate design ideas and processes for audiences using appropriate technical terms and graphical representation techniques (ACTDEP025)

Select appropriate materials, components, tools, equipment and techniques and apply safe procedures to make designed solutions (ACTDEP026)

Negotiate criteria for success that include sustainability to evaluate design ideas, processes and solutions (ACTDEP027)

Develop project plans that include consideration of resources when making designed solutions individually and collaboratively (ACTDEP028)

YEAR 9 AND 10

Design and Technologies: Knowledge and Understanding

Critically analyse factors, including social, ethical and sustainability considerations, that impact on designed solutions for global preferred futures and the complex design and production processes involved (ACTDEK040)

Explain how products, services and environments evolve with consideration of preferred futures and the impact of emerging technologies on design decisions (ACTDEK041)

Investigate and make judgments on how the characteristics and properties of materials are combined with force, motion and energy to create engineered solutions (ACTDEK043)

Design and Technologies: Process and Production Skills

Critique needs or opportunities to develop design briefs and investigate and select an increasingly sophisticated range

of materials, systems, components, tools and equipment to develop design ideas (ACTDEP048)

Develop, modify and communicate design ideas by applying design thinking, creativity, innovation and enterprise skills of increasing sophistication (ACTDEP049)

Work flexibly to effectively and safely test, select, justify and use appropriate technologies and processes to make designed solutions (ACTDEP050)

Evaluate design ideas, processes and solutions against comprehensive criteria for success recognising the need for sustainability (ACTDEP051)

Develop project plans using digital technologies to plan and manage projects individually and collaboratively taking into consideration time, cost, risk and production processes (ACTDEP052)

Curriculum Links

General Capabilities

Numeracy

Using spatial reasoning

Critical and Creative Thinking

Inquiring – identifying, exploring and organising information and ideas

Generating ideas, possibilities and actions

Analysing, synthesising and evaluating reasoning and procedures

Personal and Social Capability

Social management

ICT Capability

Investigating with ICT

Creating with ICT

Communicating with ICT

Managing and operating ICT

Earthquake-Resistant Building Challenge

Suggestions for developing a cross-disciplinary STEM task

YEAR 6 MATHEMATICS

Number and Algebra

- Calculate the scale of the building. According to the Australian building code, ceilings must be 2.4m above the floor. You could measure the ceiling height of the classroom or have students investigate this as part of their design to help students calculate the scale of their building. Once they have calculated the scale, students map out a to-scale plan of one floor. They could use a measuring tape on the oval to complete this task. Students should consider the following during this time:
  Is this an appropriate size for a building? Do you need to rethink the scale? Students can also covert measurements to decimals, fractions and percentages.
- Provide students with a budget and specify costs for materials. You may wish to use the table below.

Item	Cost per Item	Number of Items	Total Cost
		GRAND TOTAL	

If providing students with a budget, you could choose to have 'sales' on some materials e.g. 10%, 20% or 50% off. You could include other discounts such as 'buy two get one free' to encourage the development of financial literacy skills while also teaching Year 6 Number and Algebra.

Curriculum Links

Select and apply efficient mental and written strategies and appropriate digital technologies to solve problems involving all four operations with whole numbers *(ACMNA123)*

Find a simple fraction of a quantity where the result is a whole number, with and without digital technologies *(ACMNA127)*

Add and subtract decimals, with and without digital technologies, and use estimation and rounding to check the reasonableness of answers *(ACMNA128)*

Multiply decimals by whole numbers and perform divisions by non-zero whole numbers where the results are terminating decimals, with and without digital technologies *(ACMNA129)*

Make connections between equivalent fractions, decimals and percentages *(ACMNA131)*

Investigate and calculate percentage discounts of 10%, 25% and 50% on sale items, with and without digital technologies *(ACMNA132)*

Measurement and Geometry

- Convert between units of lengths while designing and constructing the building, and recognise the equivalence of lengths used in construction.
- Calculate the floor or wall area of scale models and life-sized buildings. Such calculations could be used to identify the quantity of carpet needed to cover the floor area. Students could also calculate the volume of the room.
- Construct prisms and pyramids to create their building and then test the strength of these designs.
- Calculate the angles in their construction and label these angles on design plans. Students may use this information to inform the inclusion of any wall bracings used to increase the strength of the building.
- Design the building using digital technologies which have the ability to rotate, reflect and translate buildings. This movement could possibly be used to enhance design features.

Curriculum Links

Connect decimal representations to the metric system *(ACMMG135)*

Construct simple prisms and pyramids *(ACMMG140)*

Convert between common metric units of length, mass and capacity *(ACMMG136)*

Solve problems involving the comparison of lengths and areas using appropriate units *(ACMMG137)*

Investigate combinations of translations, reflections and rotations, with and without the use of digital technologies *(ACMMG142)*

Investigate, with and without digital technologies, angles on a straight line, angles at a point and vertically opposite angles. Use results to find unknown angles *(ACMMG141)*

Statistics and Probability

- Test the building's design and measure how often the building is damaged in earthquakes at different intensities. Describe the probability the building will be damaged in future earthquakes of various intensities. Students may present this information, along with building design proposals, to the class. They may then participate in a class debate to identify which building has the best design. This replicates real-world practice, in which engineers present different designs to their team and the best design selected for construction.
- Data collected on building destruction at different earthquake intensities could be presented using various data displays, including comparisons to other buildings, for instance, the intensity of the earthquake the building can withstand. These data displays should be incorporated into the final proposal.
- Digital technologies can be used to measure earthquake intensities, save and convert collected data into data displays. Alternatively, students could convert the data into data displays using software such as Excel. Students can use this data to analyse the earthquake.
- Real-world data from past earthquakes can be compared to the student-collected data from their shake table tests. For example, students could investigate: Was the shake table earthquake more or less intense than the Christchurch earthquake? Would you building have withstood the Christchurch earthquake? Explain your answer.

Curriculum Links

Describe probabilities using fractions, decimals and percentages *(ACMSP144)*

Interpret and compare a range of data displays, including side-by-side column graphs for two categorical variables *(ACMSP147)*

Interpret secondary data presented in digital media and elsewhere *(ACMSP148)*

YEAR 9 MATHEMATICS

Number and Algebra

- According to the Australian building code, ceilings must be 2.4m above the floor. You could measure the ceiling height of the classroom or have students investigate this as part of their design to help students calculate the scale of their building. They could also investigate the proportions using wooden lengths or floor plans.
- Provide students with a 'loan' to construct the building and specify costs for materials. Students will then to calculate the interest that is charged on their loan and investigate how much they need to rent or sell rooms for to make a profit.

Curriculum Links

Solve problems involving direct proportion. Explore the relationship between graphs and equations corresponding to simple rate problems *(ACMNA208)*

Solve problems involving simple interest *(ACMNA211)*

Measurement and Geometry

Calculate the surface area and/or volume of model buildings and real buildings, such as the classroom.

Curriculum Links

Calculate areas of composite shapes *(ACMMG216)*

Calculate the surface area and volume of cylinders and solve related problems *(ACMMG217)*

Solve problems involving the surface area and volume of right prisms *(ACMMG218)*

Solve problems using ratio and scale factors in similar figures *(ACMMG221)*

Statistics and Probability

- Calculate the frequency of building failure at different earthquake intensities. Numerical data can be collected by identifying angle of torsion after a specified time on the shake table, while categorical data can be collected by identifying if the building has or has not been destroyed.

Curriculum Links

Calculate relative frequencies from given or collected data to estimate probabilities of events involving 'and' or 'or' *(ACMSP226)*

Identify everyday questions and issues involving at least one numerical and at least one categorical variable, and collect data directly and from secondary sources *(ACMSP228)*

YEAR 5-6 DIGITAL TECHNOLOGIES

Digital Technologies Processes and Production Skills

- Use devices to measure earthquake intensity data, and export or insert this data into a spreadsheet. Students can then validate the data, display the data in graph form and use the data to answer a range of questions.
- Compare the historical collection of data by seismometers to student data collection using devices. Students could also create a DIY seismometer and compare collected results, user experience and sustainability to the data collected via Apps on their devices.
- Create a website for the building design proposal, following ethical, social and technical protocols agreed on by the team. You may wish to assign a role for each member of the team.

Curriculum Links

Acquire, store and validate different types of data, and use a range of software to interpret and visualise data to create information *(ACTDIP016)*

Explain how student solutions and existing information systems are sustainable and meet current and future local community needs *(ACTDIP021)*

Plan, create and communicate ideas and information, including collaboratively online, applying agreed ethical, social and technical protocols *(ACTDIP022)*

YEAR 9-10 DIGITAL TECHNOLOGIES

Digital Technologies Processes and Production Skills

- Collect earthquake intensity and building strength data using multiple strategies, and identify the strengths and weakness of each method. This could include a comparison of multiple Apps and physical seismographs, including any DIY seismometers constructed by students.
- Store and display data as visual representations for improved user experience and understanding.

Curriculum Links

Develop techniques for acquiring, storing and validating quantitative and qualitative data from a range of sources, considering privacy and security requirements *(ACTDIP036)*

Analyse and visualise data to create information and address complex problems, and model processes, entities and their relationships using structured data *(ACTDIP037)*

Design and Technologies Knowledge and Understanding

- Students must test different designs, and create a strong building within a set budget. You could give different materials different values so students must consider the cost and properties of materials. When students test their buildings they will notice the advantages and disadvantages of different materials and modify their buildings to according to their observations. Students can also investigate different building locations, and discuss environmental factors that they would need to consider in their building design or investigate the best location for their building. For example, is an area likely to receive large earthquakes, snowfall or flooding? Does a building need to be able to withstand earthquakes if it is in an area of low seismic activity such as Australia?
- Analyse how professionals collect seismographic information, and how scientists are working to improve data collection, storage and understanding. Investigate how seismic measurement systems can also be used to alert populations and emergency services about earthquakes and tsunamis due to seismic activity. Students could also investigate important considerations for disaster management, what disaster management information must be considered for future planning, and identify how disaster management and communication could be improved.
- Students could test and evaluate a range of materials used for beams, struts, bracing and adhesives.

Curriculum Links

Examine how people in design and technologies occupations address competing considerations, including sustainability in the design of products, services, and environments for current and future use *(ACTDEK019)*

Investigate characteristics and properties of a range of materials, systems, components, tools and equipment and evaluate the impact of their use *(ACTDEK023)*

Design and Technologies Processes and Production Skills

- Critique needs of buildings in different geographical areas, and design, create and test buildings for these locations.
- Create a building design proposal justifying why the building design is the best and present the proposal to the class.
- Create and test buildings following proper safety protocols, and select materials which will allow buildings to support mass and withstand an earthquake with an intensity of 9 on the Mercalli scale.
- Students test and refine their designs until their buildings meet the success criteria of withstanding an earthquake of 9 on the Mercalli scale.
- Students develop a project plan for their model, and a project proposal explaining why their design is the best and should be chosen when constructing a full-size building.

Curriculum Links

Critique needs or opportunities for designing, and investigate materials, components, tools, equipment and processes to achieve intended designed solutions *(ACTDEP024)*

Generate, develop and communicate design ideas and processes for audiences using appropriate technical terms and graphical representation techniques *(ACTDEP025)*

Select appropriate materials, components, tools, equipment and techniques and apply safe procedures to make designed solutions *(ACTDEP026)*

Negotiate criteria for success that include sustainability to evaluate design ideas, processes and solutions *(ACTDEP027)*

Develop project plans that include consideration of resources when making designed solutions individually and collaboratively *(ACTDEP028)*

Design and Technologies Knowledge and Understanding

- Students analyse earthquake case studies, investigating why some areas experience more damage than others. Students could also investigate the relationship between socio-economic status and earthquake casualties, and explore what could be done to decrease casualties. They could also evaluate and propose strategies for improved disaster response and management.
- Students explain how strategies for earthquake resistance have evolved over time, why changes and advances in technology occur at different rates in different areas, and how emerging technologies and design decisions allow newer buildings to resist larger earthquakes
- Investigate and make judgments on how the characteristics and properties of materials and building design are combined with force, motion and energy to create buildings that can withstand larger earthquakes.

Curriculum Links

Critically analyse factors, including social, ethical and sustainability considerations, that impact on designed solutions for global preferred futures and the complex design and production processes involved *(ACTDEK040)*

Explain how products, services and environments evolve with consideration of preferred futures and the impact of emerging technologies on design decisions *(ACTDEK041)*

Investigate and make judgments on how the characteristics and properties of materials are combined with force, motion and energy to create engineered solutions *(ACTDEK043)*

Design and Technologies Processes and Production Skills

- Students critique the needs of different areas based on geographical and environmental conditions, and create a building that best meets needs of the community. Students investigate different methods to increase earthquake resistance in buildings, and incorporate these strategies when designing their own buildings.
- Students develop, modify and communicate building design ideas by applying design thinking, creativity, innovation and enterprise skills of increasing sophistication to create and present a building that meets the brief, and justify why their building should be chosen for the full-scale build.
- Students choose, assess and modify building materials and designs based on testing results, and respond flexibly to collected data.
- Students evaluate building design ideas, processes and solutions against comprehensive criteria for success, recognising the need for sustainability. This could include designing a building that: is three stories and at least 30 cm high; can support at least 100 grams; and, can withstand earthquakes up to 9 on the Mercalli Scale. Students could also be required to work within a budget.
- Use software to plan and manage the project. Students could use a Gantt chart to plot progress and timelines, and manage budget in Excel.

Curriculum Links

Critique needs or opportunities to develop design briefs and investigate and select an increasingly sophisticated range of materials, systems, components, tools and equipment to develop design ideas *(ACTDEP048)*

Develop, modify and communicate design ideas by applying design thinking, creativity, innovation and enterprise skills of increasing sophistication *(ACTDEP049)*

Work flexibly to effectively and safely test, select, justify and use appropriate technologies and processes to make designed solutions *(ACTDEP050)*

Evaluate design ideas, processes and solutions against comprehensive criteria for success recognising the need for sustainability *(ACTDEP051)*

Develop project plans using digital technologies to plan and manage projects individually and collaboratively taking into consideration time, cost, risk and production processes *(ACTDEP052)*

Earthquake-Resistant Building Challenge

Suggestions for variables

Independent variable suggestions:

- Effect of building shape on angle of torsion from origin
- Effect of vertical/horizontal mass distribution on number of damage points
- Effect of building shape on number of damage points
- Effect of vertical mass distribution on time to building failure
  (for example, one building could have an open-ground carpark underneath)
- Beam material (for example, do stronger beams result in fewer damage points?)
- Column materials (for example, do more flexible columns result in fewer damage points?)
- Incorporation of cross bracing (for example, does cross bracing reduce the number damage points?)
- The use of a seismic damper (for example, does the use of dampers reduce number of damage points?)
- The use of a base isolation device (for example, do base isolators reduce the number damage points?)
- Soil type (for example, do rocky soils results in less movement compared to sandy soils?)
- Foundation material (for example, does a wooden foundation reduce the number damage points?)

Dependent variable suggestions:

- Angle of torsion from origin
- Movement distance from origin
- Magnitude of building failure
- Intensity of building failure
- Time to building failure
- Distribution of damage
- Number of damage points

Earthquake-Resistant Building Challenge

Student Activity

Imagine...

You are sitting at the table on a computer when suddenly you feel a jolt and the whole house starts to shake. There is a really loud noise, like 30 trains are driving right through your house. You leap under the table and have to hold onto the table legs to stop it from bouncing away. Your computer crashes onto the ground and you see a bookshelf fall nearby. A minute later the shaking stops. You stand up and walk outside. Some buildings have big cracks in them. There are people who have been injured and small children are crying. You see a building that has been completely destroyed.

Later you hear that people were killed when that building was destroyed. Experts are saying that if the building was designed to be more earthquake-resistant it may not have fallen to the ground. They say on the news, 'Earthquakes don't kill people. Buildings do.'

You decide that you are going to work on designing and building earthquake safe buildings so less people are hurt in the future.

Task:

It is ten years later and you are an engineer. You have been tasked with designing and building your first three story building.

You must:

- **Investigate** how buildings can be designed to withstand earthquakes. You should include background information on earthquakes and features that increase the strength of buildings during earthquakes.
- **Design** a three story building that can resist earthquakes up to an intensity of nine on the Mercalli Scale. Your building should also be cost effective and come within the specified budget.
- **Create** a prototype of your building out of balsa wood, masking tape and paper (or other materials provided by your teacher).
- **Test** your prototype on the shake table to simulate a real earthquake. The building will also need to support weights of at least 100 grams.
- **Refine** the building design and construction to increase the strength.
- **Collaborate** in teams of two or three.
- **Evaluate** continuously to create a building that meets the brief. You may also be required to evaluate social interactions to effectively work in a team.

Continue to design, create, test and refine the building to resist earthquakes up to nine on the Mercalli scale (and bigger!).

1. Investigate and Design

Before constructing your building, you must write a proposal to explain the design of the building and get approval from your manager (in this case, your teacher). A proposal should include:

- [ ] Background information on earthquakes and earthquake resistant buildings
- [ ] Labelled sketch or digital representation of building
- [ ] Justification for design
- [ ] Calculated scale of the building (building ceiling heights are usually 2.4 m)
- [ ] Materials required
- [ ] Predicted cost of proposed design based on materials

Once your proposed design has been approved, you can create your building prototype.

2. Create

Create your three story building using the materials provided. Record any modifications required as you build. You may want to test that each floor of building can hold the required weights, and continually test the strength of the building.

Your building should also include a strong foundation that can be attached to the shake table.

3. Test

Attach your building to the shake table. A phone or tablet can be used to measure the size of the earthquake. The phone or tablet should also be secured to the shake table. There are many apps to measure the magnitude of the earthquake including Vibration Meter (Gamma Play, Android) or Vibration Meter (Smart Tools, Android) and Vibration Meter, Seismograph, Seismometer (ExaMobile S.A., iOS).

Place 100 grams of weight on your building and start shaking gently. Increase the magnitude of the earthquake and continue to shake. If you observe any building faults you may want to stop shaking and refine your design to increase the building strength in an earthquake. Once you reach a magnitude of nine, continue to shake for one minute. Record your observations. Record the maximum earthquake that your building will withstand.

4. Refine

Based on your observations, modify your building design to increase its strength, and then re-test it on the shake table. You may want to investigate other strategies to help your building resist earthquakes. Continue to create a building that can resist earthquakes to at least a magnitude of nine on the Mercalli Scale.