Donna King, Lyn English, Les Dawes, Peter Hudson

Earthquake Engineering

(adapted from TEACHEngineering*)

Overview

Students will apply their previous knowledge about earthquakes to construct a building that can withstand damage from earthquakes. Students will use the engineering design process to build their own structures with toothpicks and plasticine. The structure will be tested to determine the earthquake-proof capacity of their building through an earthquake simulation using a shaker table.

Prior Knowledge

The following concepts need to be covered prior to the Earthquake Engineering Activity:

- Earthquakes are measured using the Richter and modified Mercalli scales
- Movement of tectonic plates causes earthquakes
- Tectonic plates can slide past each other in three different ways (divergent, convergent and transform)
- Continent formation has occurred over millions of years
- Earthquakes occur around the world but are more common in places near a tectonic plate boundary
- A seismograph measures the intensity of an earthquake (optional)

The concepts above are covered in the Primary Connections and C2C lessons listed below:

Primary Connections – Earthquake Explorers	C2C – Earthquakes
Lesson 1 – Earthquake Encounters	Lesson 1 – Exploring volcanoes (not that relevant)
Lesson 2 – Energetic Earthquakes	Lesson 2 – Examining the effects of earthquakes (relevant)
Lesson 3 – Unearthing Earthquakes	Lesson 3 – Exploring how people prepare for geological disaster (relevant)
Lesson 4 – Explaining Earthquakes	Lesson 4 – Exploring an earthquake in Australia (relevant)
Lesson 5 – Earthquakes Down Under (optional)	Lessons 5-14 Other natural disasters (not relevant)
Lesson 6 – So you want to be a seismologist? (optional)	Lesson 15 – Researching extreme weather events in Australia (optional)
Lesson 7 – On location (optional)	Lesson 16 – Identifying preparation for extreme weather events (optional)

Teachers may use other resources in addition to or in place of the above suggestions.

Objectives

Students will:

- Engage in the Engineering Design Process
- Learn about the factors that make buildings earthquake-proof, including cross-bracing, large 'footprints', base isolation and tapered geometry
- Model an earthquake-proof structure using simple materials
- Understand the importance of engineering for designing earthquake-proof buildings
- Understand the properties of shapes, and how combining shapes yields new properties and relationships
- Explore how combining shapes can increase structural strength

Class Time: 3 hours (approx.)

Materials

- Combined Teaching Notes/Student Workbook
- Student Workbook
- QUT supplied teacher DVD containing:
  - a. Video – Earthquakes 101 – National Geographic (http://video.nationalgeographic.com.au/video/101-videos/earthquake-101)
  - b. Cross-bracing diagram
  - c. Base isolation photograph
  - d. Engineering Design Model
  - e. Engineering Adventures - Shake Things Up – Museum of Science (includes instructions for constructing a shaker table on pp. 10 – 12)
  - f. Link to TEACHEngineering online resource – Hands-on Activity - Earthquake in the Classroom (https://www.teachengineering.org/view_activity.php?url=collection/cub_/activities/cub_natdis/cub_natdis_lesson03_activity1.xml)
- Pack containing: 8 regular toothpicks, 2 x 8cm skewer pieces (for diagonal cross-bracing) and a little plasticine (1 per student)
- Pack containing: 12 regular toothpicks, a little plasticine, 2 metal plates and 6 cylindrical wooden sticks (one per class)
- Toothpicks (about 50 per group)
- Skewers (about 10 per group)
- 2 – 3 shaker tables per class (QUT to supply using instructions included on teacher DVD)
- Plasticine (1 stick per group)
- Pencil, rubber, ruler, scissors – student supplied

*https://www.teachengineering.org/view_activity.php?url=collection/cub_/activities/cub_natdis/cub_natdis_lesson03_activity1.xml

Curriculum Links

<table>
<tr><th>Technology</th><th>Science</th><th>Maths</th></tr>
<tr>
<td>Design and Technologies Knowledge and Understanding
Investigate how people in design and technology occupations address competing considerations, including sustainability in the design of products, services and environments for current and future use (ACTDEK019)
Design and Technologies Processes and Production Skills (ACARA)
Generate, develop, communicate and document design ideas and processes for audiences using appropriate technical terms and graphical representation techniques (ACTDEP025)
Negotiate criteria for success that include consideration of sustainability to evaluate design ideas, processes and solutions (ACTDEP027)</td>
<td>Earth and Space Science
Sudden geological changes or extreme weather conditions can affect Earth’s surface (ACSSU096)
Science as a Human Endeavour
Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena (ACSHE098)
Scientific understandings, discoveries and inventions are used to solve problems that directly affect peoples’ lives (ACSHE100)
Scientific knowledge is used to inform personal and community decisions (ACSHE220)</td>
<td>Measurement and Geometry

Using units of measurement
Convert between common metric units of length, mass and capacity (ACMMG136)
Connect volume and capacity and their units of measurement (ACMMG138)
Shape
Construct simple prisms and pyramids (ACMMG140)
Geometric Reasoning
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)</td>
</tr>
</table>

Part 1: Introduction

- View the video *Earthquakes 101 – National Geographic* in light of the work covered previously and to orient the students to the engineering activity on building design.

  http://video.nationalgeographic.com.au/video/101-videos/earthquake-101

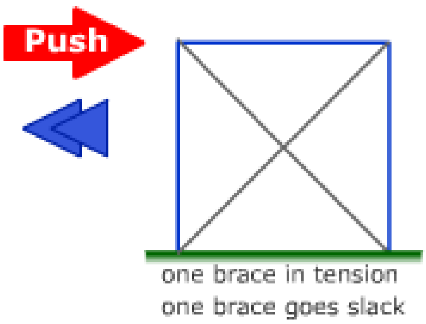
- Discuss with students how earthquakes can cause walls to crack, foundations to move and even entire buildings to crumple, therefore engineers incorporate into their structural design, techniques that can withstand damage from earthquake forces.

  Ask: What are some ideas that engineers may use to make the buildings stronger to withstand the earthquake?

- **Cross-Bracing:** Explain that engineers (in this case mainly structural engineers) are involved in using special design techniques and structures that contribute to a more stable structure that can withstand the damage. Examples of these techniques are cross-bracing, tapered geometry and base isolation.

  Activity: Ask the students to take four toothpicks and some plasticine and make a square. Ask students to push the square sideways to see what happens. Then ask students to take two skewers cut to size (8cm) and cross them in the middle of the square using plasticine to secure. Ask students to push the square sideways again and explain what happens. What was the difference between the two structures?

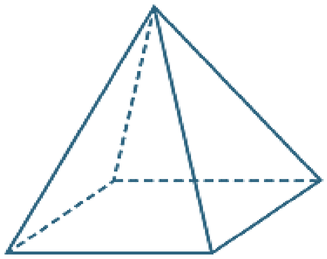
  Explain that cross-bracing is a construction technique in which braces are crossed to form an X shape to support a frame.



The above diagram is included on the teacher DVD if teachers wish to display it to the class.

- **Tapered Geometry:** Explain that engineers can use geometrical shapes that can sustain the movement received from an earthquake.

  Activity: Ask children to build a square-based pyramid with their toothpicks.



This is known as “tapered geometry” where the top of the shape tapers to a point. Such structures decrease in size as the structure gets taller. In other words, shorter buildings are stronger if they have a point at the top.

- **Base Isolation:** Engineers use the word “**footprint**” to represent the base of the building, which can be **large or small**. Earthquake-proof buildings are intended to bend and sway with the motion of earthquakes, or are isolated from the movement by sliders.

The building on the right has used “base isolation” while the building on the left has not.

The above photo is included on the teacher DVD if teachers wish to display it to the class.

Teacher demonstration: Use two metal plates and six cylindrical wooden sticks to model base isolation. Firstly, place a cube made from toothpicks and plasticine on one piece of metal on the table and move vigorously from side to side. What happens to the cube? (It will most likely topple over.) Secondly, put the cylindrical sticks between the two pieces of metal and the cube on top. Move the bottom piece of metal from side to side and ask students to observe what happens to the cube. What is the difference between the first example and the second? (The cylindrical sticks act to isolate the base and allow the top layer to move less.)

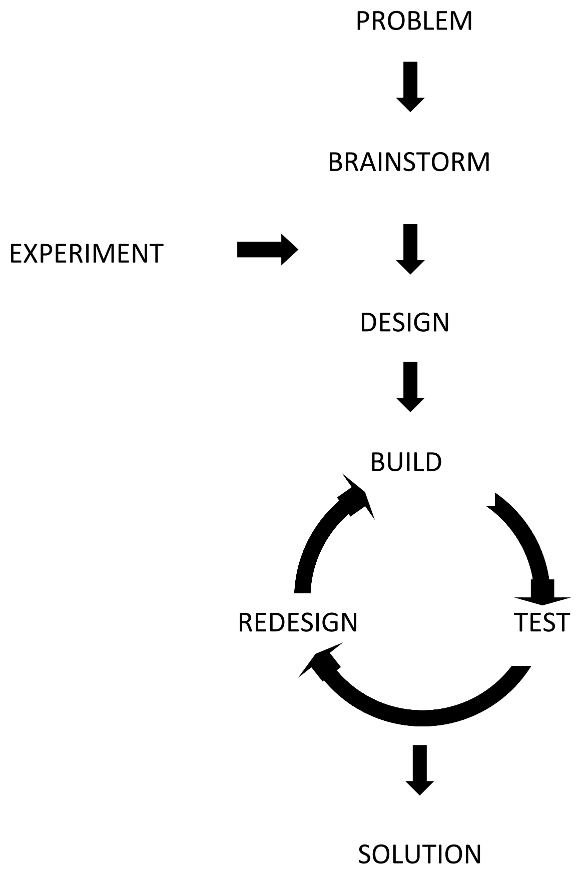
- Summarise with students: Engineers use many special design features to enable buildings to be earthquake resistant. We have seen three examples – cross-bracing, tapered geometry and base isolation.

Part 2: Engineering Design Process

Remind students of the Engineering Design Process that they have done in previous engineering units. Ask students to explain the process to check for understanding. A copy of the process can be found on the teacher DVD. This can be referred to during the discussion and left displayed on the whiteboard for students to access during the challenge.

NOTE: Engineering model has changed – if they wish, students can now experiment with the materials before designing.

Engineering Design Model



Model adapted from pbs.org model

Hand out Student Workbooks and ask students to complete their name, group members, group number, class and school on the front.

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STUDENT WORKBOOK

Year 6

Name: ____

Other group members: ____

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____

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Group Number: ______________________ Class: ______________________

School: ____

Part 3: Designing an Earthquake Resistant Structure

➢ Introduction

Tell students that today they are acting as if they are engineers. They will make models of buildings and conduct an experiment to test how well their structures stand up to the stress of an earthquake. Explain to them that this is similar to what some civil (structural) engineers do as their jobs.

➢ **PROBLEM** (Workbook page 3)

Your team has been asked by AusAid, an organization that manages projects for countries in need, to design a building that can withstand an earthquake in the Philippines. Acting like structural engineers, you will design, build and test a structure that can withstand an earthquake simulated by a table constructed by a QUT engineer. Since the Earth has limited resources, so too do engineers. For this reason you will need to work within a budget.

Remember to follow the Engineering Design Model.

➢ **Materials and Equipment** (Workbook page 3)

- toothpicks ($0.30 each)
- skewers ($1.00 each)
- plasticine ($1.00 per stick)
- scissors
- shaker table

➢ **Challenge** (Workbook page 3)

Using the materials listed, you will design a building with the following constraints:

a. The building must be at least 12cm (two storeys) high
   (Explain to students that one storey = one toothpick.)
b. The building must contain at least one triangle
c. The building must contain at least one square
d. There must be evidence of cross-bracing to reinforce the structure
e. You may use whole toothpicks or skewers cut to size
f. You have a budget of $40.00 (maximum) to spend

The group whose final design does not fall over and remains in the exact shape it was before testing is the winner of the Engineering Challenge. If more than one group achieves this, the highest and/or least expensive structure will win.

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DESIGNING AN EARTHQUAKE RESISTANT BUILDING

1. PROBLEM

Your team has been asked by AusAid, an organization that manages projects for countries in need, to **design a building that can withstand an earthquake** in the Philippines. Acting like structural engineers, you will design, build and test a structure that can withstand an earthquake simulated by a shaker table constructed by a QUT engineer. Since the Earth has limited resources, so too do engineers. For this reason you will need to **work within a budget**.

Remember to follow the **Engineering Design Model**.

2. Materials and Equipment

- toothpicks ($0.30 each)
- skewers ($1.00 each)
- plasticine ($1.00 per stick)
- scissors
- shaker table

3. Challenge

Using the materials listed, you will **design a building with the following constraints**:

g. The building must be **at least 12cm (two storeys) high**
h. The building must contain **at least one triangle**
i. The building must contain **at least one square**
j. There must be **evidence of cross-bracing** to reinforce the structure
k. You may use **whole toothpicks or skewers cut to size**
l. You have a **budget of $40.00** (maximum) to spend

The group whose final design does not fall over and remains in the exact shape it was before testing is the winner of the Engineering Challenge. If more than one group achieves this, the highest and/or least expensive structure will win.

- **BRAINSTORM** (Workbook page 5)

Explain that cubes and triangles are like building blocks that may be stacked to make towers. The towers can have small or large 'footprints' (or bases).

Have students record answers to the following questions in their Student Workbook.

- What shapes will you use for your building?
- How tall will your building be?
- Where will you use either cross-bracing, base isolation or tapered geometry?
- How can you make it strong?
- Draw and label some draft designs in the 'Thinking Space' on page

- **EXPERIMENT** (Workbook page 5)

Explain to students that a toothpick is approximately 6cm long. Also explain that a skewer is 25cm long and a cross-brace for a toothpick square needs to be 8cm long. Students will need to measure and mark the required length on a skewer and see an adult to cut it for them.

Distribute 50 toothpicks, 10 skewers and a stick of plasticine to each group. This is just a starter pack. Students may choose to use more or less of each of the materials.

Ask students to work with the materials and experiment with different construction methods. Students do not have to build their final structure at this stage but should be encouraged to discuss options/cost and start trialing possible designs. The discussion here should be rich as students negotiate with each other. Finally, they should agree on the design they will build from the options they have discussed.

4. BRAINSTORM

Discuss the questions below with your group. **Record** your answers in the box.

- **What shapes** will you use for your building?

___

___

- **How tall** will your building be? ___
- **Where** will you use either **cross-bracing, base isolation or tapered geometry**?

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- **How** will you make it **strong**?

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- **Draw** and **label** some **draft designs** in the 'Thinking Space' on page 4.

5. EXPERIMENT

- You will be given **50 toothpicks, 10 skewers and a stick of plasticine** to start with.
- If you wish, you can work with the materials and **experiment** with different **construction methods**.
- If you need to **cut a skewer**, you will have to **measure the required length** and **mark it** on the skewer. An **adul**t will then **cut the skewer** at the mark.
- **Discuss** possible **designs** with your group, taking into account the **cost** of materials.

- **DESIGN** (Workbook page 7)

After students have experimented and come up with a suitable design, ask them to draw the design in their workbooks. Emphasise the need for students to draw and label the shapes with appropriate geometrical terms and to put measurements on the designs. They also need to be mindful of the amount of materials they use, especially skewers as these will most likely be cut to size.

6. DESIGN

- **Draw** and **label** your first design.
- Make sure you **label the shapes** you used with the correct names.
- **Remember** to put **measurements** on the design.
- **Note** the **amount of materials** you use.

➢ **BUILD** (Workbook page 9)

Allow groups time to build their structures. They may have started this during the 'experiment stage' but encourage students to refine it here and make sure that it is exactly how they would like it before testing.

Groups also need to calculate the total cost of their building using the table below.

Materials	Cost	No. Used	Total
Toothpicks	$0.30 each		
Skewers	$1.00 each		
Plasticine sticks	$1.00 each		
		GRAND TOTAL	

➢ **TEST** (Workbook page 9)

Have groups test their structures on a shaker table with adult supervision. Students record what happens to their building during the simulated earthquake by answering the following questions in their Student Workbooks.

- Place your structure on the shaker table. Pull the tab on the shaker table to represent an earthquake of Richter Scale 4. Describe what happened.
- Repeat at Richter Scale 8. Describe what happened.
- What did you learn about your building from the test (including any maths and science that you used)?

7. **BUILD**

Build your structure using the materials supplied.

Calculate the cost of your building. **Record** the cost in the table below.

Materials	Cost	No. Used	Total
Toothpicks	$0.30 each		
Skewers	$1.00 each		
Plasticine sticks	$1.00 each		
		GRAND TOTAL	

8. **TEST**

Write answers to the following questions.

a. **Place** your structure on the shaker table. **Pull the tab** on the shaker table to represent an earthquake of **Richter Scale 4**. **Describe** what happened.

b. **Repeat** at **Richter Scale 8**. **Describe** what happened.

c. **What** did you **learn** about your building from the test (including any **maths** and **science** that you used)?

- **EXPERIMENT AND REDESIGN** (Workbook page 11)

Students discuss and write answers to the following questions.

- What can you change to improve your design?
- How will these changes make your structure better?

9. EXPERIMENT AND REDESIGN

Write answers to the following questions.

a. **What** can you **change** to improve your design?

____

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b. **How** will these changes make your structure **better**?

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Building models, created by student teams for a design contest, combine structural and cost-benefit considerations to ensure both safety and economic performance.

(Workbook page 13)

Students can experiment with alternative construction methods. They may choose to make changes to their existing structure or build an entirely new structure.

Students then draw and label their improved design.

- **Draw** and **label** your improved design below.

- **REBUILD** (Workbook page 15)

Students build a second building that improves on the first design's weaknesses. They may have started this during the 'experiment and redesign stage' but encourage students to refine it here and make sure that it is exactly how they would like it before testing.

Groups also need to calculate the total cost of their new building using the table below.

Materials	Cost	No. Used	Total
Toothpicks	$0.30 each		
Skewers	$1.00 each		
Plasticine sticks	$1.00 each		
		GRAND TOTAL	

- **RETEST** (Workbook page 15)

Groups test their second building on a shaker table with adult supervision. They record what happens during the simulated earthquake by answering the following questions.

- Place your structure on the shaker table. Pull the tab on the shaker table to represent an earthquake of Richter Scale 4. Describe what happened.
- Repeat at Richter Scale 8. Describe what happened.
- What did you learn about your new building from the test (including any maths and science that you used)?

10. REBUILD

Rebuild your new and improved structure.

Calculate the cost of your new building. **Record** the cost in the table below.

Materials	Cost	No. Used	Total
Toothpicks	$0.30 each		
Skewers	$1.00 each		
Plasticine sticks	$1.00 each		
		GRAND TOTAL	

11. RETEST

Write answers to the following questions.

a. **Place** your structure on the shaker table. **Pull the tab** on the shaker table to represent an earthquake of **Richter Scale 4**. **Describe** what happened.

b. **Repeat** at **Richter Scale 8**. **Describe** what happened.

c. **What** did you **learn** about your new building from the test (including any **maths** and **science** that you used)?

- **Presentation** (Workbook page 17)

The presentation phase is very important to allow students to clarify their thinking and share ideas.

Each group of students is to present their best design to the class. The class acts as representatives of AusAid, asking questions and offering feedback/constructive comments.

Each group should include the following in their presentation:

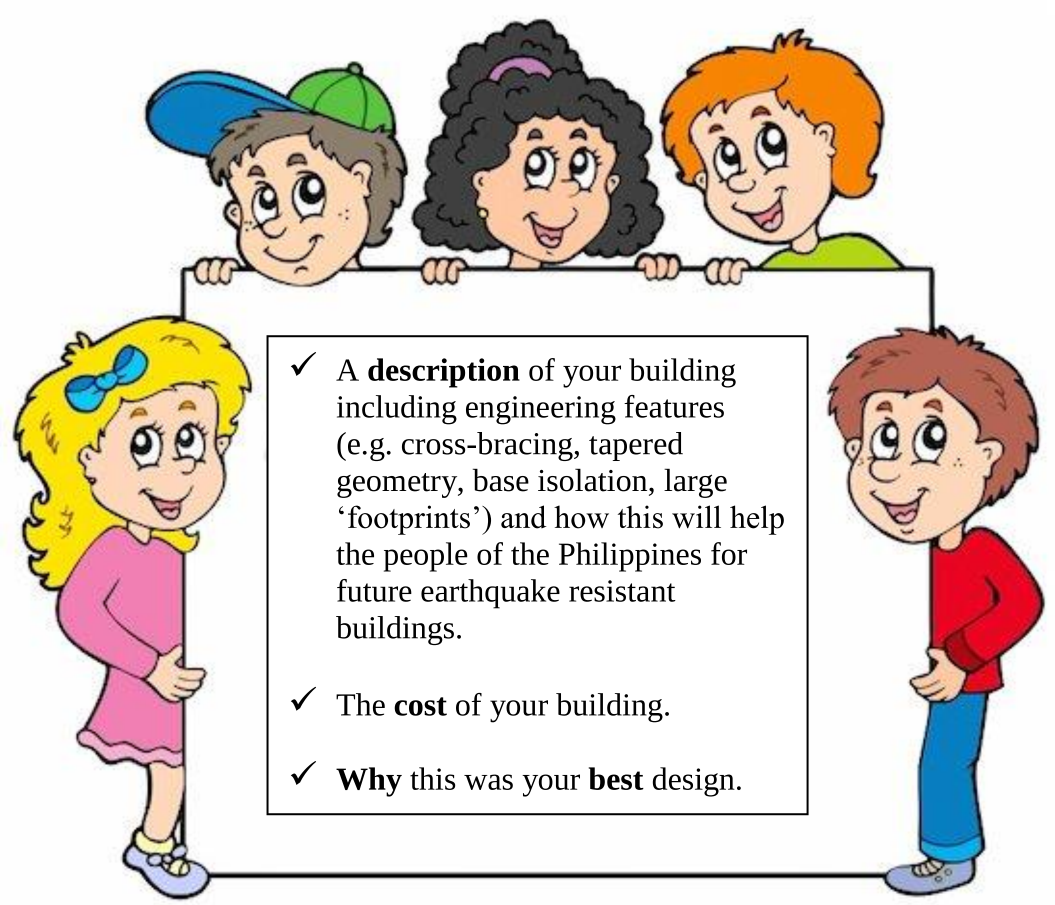
- A description of their building including the engineering features (e.g. cross-bracing, tapered geometry, base isolation, large ‘footprints’) and how this will help the people of the Phillipines for future earthquake resistant buildings.
- The cost of their building.
- Why this was their best design.

The teacher has the final say on which building/s win/s the challenge.

12. Presentation

Present your best design to the class.

- Use the 'Thinking Space' on page 16 to **plan your presentation**.
- **Include the following points** in your presentation.



➢ **Reflecting** (Workbook page 19)

This section can be completed the following day if there is insufficient time.

Allow students time to discuss and write answers to the following questions:

- Which was your best design and why?
- What would you do to further improve your design?
- In what ways were you working like an earthquake engineer today?
- Write down everything about how you were using mathematics today for the design of your building. You can use diagrams in your explanation.

13. **Reflecting**

Write answers to the following questions.

a. **Which** was you **best** design and **why**?

b. **What** would you do to further **improve** your design?

c. In what ways were you **working like an earthquake engineer** today?

d. Write down everything about **how you were using mathematics** today for the design of your building. You can use diagrams in your explanation.

- **Feedback** (Workbook page 21)

This section can also be completed the following day if there is insufficient time.

Finally, have students complete the *Earthquake Engineering Challenge Feedback* by colouring in the face to show how they felt about the different parts of the challenge.

EARTHQUAKE ENGINEERING CHALLENGE FEEDBACK

Please **colour in the face** to show how you felt about the different parts of the *Earthquake Engineering Challenge*

Did you like:	**Did not like it**	**Not sure**	**Liked it**
1. ... the activities about earthquakes?			
2. ... having a real problem to solve?			
3. ... designing a model of an earthquake resistant building?			
4. ... making a model of an earthquake resistant building?			
5. ... testing your model of an earthquake resistant building?			
6. ... recording the results of the test of your model of an earthquake resistant building?			
7. ... doing a presentation about your model of an earthquake resistant building?			
8. ... thinking about how to make your model of an earthquake resistant building better?			

Next time I would like to:

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