Lesson: Shaking It Up with Earthquake Engineering

Grade Level: 3

Content Area: Earth Science

Core Areas: Earth's Materials and Processes

Lesson Overview: Students will use the engineering design process to design solutions related to earthquakes. After a short introduction and explanation of the engineering design process and criteria, students will work in small groups to build structures with toothpicks and marshmallows that can withstand damage on an earthquake shake table. They will communicate their designs to the class.

2005 Standards Correlation:
Grade 3 Earth Science
Standard 3-3: The student will demonstrate an understanding of Earth’s composition and the changes that occur to the features of Earth’s surface.
Indicators: none

2014 Standards Correlation:
Grade 3 Earth Science: Earth's Materials and Processes

<table>
<thead>
<tr>
<th>Standard</th>
<th>3.E.4: The student will demonstrate an understanding of the composition of Earth and the processes that shape features of Earth’s surface.</th>
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Conceptual Understanding
3.E.4A. Earth is made of materials (including rocks, minerals, soil, and water) that have distinct properties. These materials provide resources for human activities.

Performance Indicators: Students who demonstrate this understanding can:
3.E.4B.4 Define problems caused by a natural event or human activity and design devices or solutions to reduce the impact on the environment.

Ancillary SCCCR 2015 Math Standards:
3.MDA.5 Understand the concept of area measurement.
   a. Recognize area as an attribute of plane figures;
   b. Measure area by building arrays and counting standard unit squares;
   c. Determine the area of a rectilinear polygon and relate to multiplication and addition.

3.G.4 Identify a three-dimensional shape (i.e., right rectangular prism, right triangular prism, pyramid) based on a given two-dimensional net and explain the relationship between the shape and the net.

Grouping: 2-3 students per group
**Materials:**

For teacher demo:
- Hot pot
- Sauce pan of boiling water
- Plate
- PowerPoint

Wave Motion Simulation Activity
Per table of 4-6 students:
- Slinky
- Masking tape
- Metric ruler
- Timer
- Student Sheet 11.1: Simulating the Motion of Earthquakes
- 20 wooden blocks or cubes

Engineering Earthquakes Activity
Per group of 2-3 students:
- 30 toothpicks
- 30 miniature marshmallows
- 1 sheet of graph paper
- Centimeter ruler
- Data collection sheet

For the class to share
- 3 timers
- 3 8 ½-inch square aluminum baking pans, each filled with prepared Jello
- 3 9x13 pans
- 3 Shake Tables:
  - Packing tape
  - Coffee can lid, or any flat plastic lid with approximately 3/8” lip
  - Marbles, or any small balls of the same size (1-2 dozen)
  - Shallow box or tub, like the lid on a board game box

For extension activity
- Stream table (paint trays may be substituted as a cheap and easily obtained alternative)
- Dirt/clay mixture
Blocks (for houses)
Squirt bottles
Plastic bottles with caps with different sizes of flow holes
Assortment of items: modeling clay, popsicle sticks, sponges, toothpicks, small pebbles, etc.
Bucket
Cotton rope

**Procedures:**

1. **Introduction:** Assess prior knowledge of earthquakes with Structured Paired Brainstorming. Play National Geographic You Tube video. Have water boiling in a pot on a hot plate. Cover the boiling pot with a plate. Observe how the plate starts to rattle and move a bit from the steam pressure under it. Compare this to Earth processes. Heat deep inside the Earth causes tectonic plates at the surface to move. A sudden movement of the plates is called an earthquake. Earthquakes happen when two plates get stuck as they are sliding past each other and then suddenly become unstuck, releasing energy. It’s like trying to open a stuck window that all of a sudden it becomes unstuck and opens quickly. To demonstrate the forces involved in an earthquake, put your two fists together with the back side of your hand up. Each fist represents a tectonic plate. Push your fists together and at the same time, try to make one hand slide with respect to the other. You can feel the stress—the force of your knuckles—just as the force increases on the edges of the tectonic plates that are rubbing against each other. Keep pushing together and sideways until suddenly one fist (plate) slides, releasing the energy accumulated in your hands. This is how an earthquake happens.

2. To show how earthquakes can damage buildings and kill people, pair up with someone at your table. One of you put your fists together with the back of your hands up like we just did. The other will build a tower of several blocks on each fist to represent buildings. Then push your fists together and sideways until they slip. What happened? (The towers collapsed, just as buildings do during an earthquake.)

3. That sudden release of energy when the plates slip is called seismic waves. One type of seismic wave is called an S-wave. Secondary or S-waves are **Side to Side.** Another type of seismic wave is called a Compression or P-wave (remember Push and Pull). Click on the link on the PowerPoint to show the animation. Let’s find out which one is more destructive during an earthquake. Have two students at opposite sides of each table hold the slinky with a piece of tape representing a house in the middle. Have one student move his end back and forth 10 cm to simulate a P-wave. Use the timer to determine the amount of time it takes for the wave to get back to the beginning. Observe the movement of the tape. Do 3 trials and record times on Student Sheet 11.1. Then repeat the activity to simulate S-waves by moving one end side to side 10 cm. Observe the tape movement and record the time it takes to get back to its starting place. Complete Student Sheet 11.1. Although we moved our Slinkys horizontally, P-waves and S-waves are usually vertical, moving from the epicenter out. Lead students to the realization that S-waves are usually more destructive to buildings because they cause horizontal shaking that structures are not build for. In our activity, we will be modeling these S-waves that go side-to-side.

4. Observe pictures of earthquake damage to buildings. Earthquakes cause many deaths and millions of dollars of property damage. Seismic waves can cause entire buildings to fall down. Present the problem: Build a structure that can withstand the S-waves (side-to-side motion) of an earthquake. Show examples of earthquake-proof buildings. Engineers try to find ways to make buildings that can resist crumbling during earthquakes by making them bend with the motion instead of cracking and breaking. What do you notice about these earthquake-proof buildings? (larger base, triangles to cross-brace, shorter rather than taller) This is similar to being high in a tree when the wind blows: the higher you are, the more it sways. As the building gets taller, the earthquake movement is magnified.

5. Today you will be engineers with the task of designing and building a model of a building that can withstand an earthquake. Show the display models and demo how to use the toothpicks and marshmallows to make cubes and triangles.

**Problem:** Build the tallest structure possible that can withstand the S-waves (side-to-side movement) of an earthquake for at least 10 seconds.
Criteria: The base of the structure must not be longer than 15 cm. The area of the base must be no more than 100 cm\(^2\). The building must be at least 10 cm tall. The final design must not use more than 30 marshmallows and 30 toothpicks. Toothpicks may be broken or used full-size. The building must remain intact for at least 10 seconds while the shake table simulates P-waves.

6. Go over the engineering design process. After students have brainstormed their design and built their structure, they will test it on a Jello-filled pan placed on a shake table. After testing, students should refine their design and test again as often as time allows. Students should note the area of the building’s footprint, the length and width of the base, and the height of the building. Students should draw and label their designs.

7. Conclusion: Each group will share their design with the class, pointing out how they revised their designs to make it more stable. Reflect with an elbow partner and then as a whole group how the engineering design process was used to solve the problem of earthquake-proofing buildings. End with the YouTube video “It’s An Earthquake” by Mr. Parr.

6. Extension: If time allows, do a flood solution engineering activity as a whole class. Set up a stream table with dirt/clay molded to have hills with a low place in the middle for a river. Place a bucket under the hole at the end of the stream table with a cotton rope going from the hole to the bucket to direct the flow of water. Place blocks/houses close to the river. Use the spray bottle to simulate rain and the water bottles with smaller flow holes to simulate normal water flow. Then test it with “flood” conditions using larger flow holes, making sure that the flood is big enough to reach the houses. Have students go through the engineering design process to come up with solutions that would protect the houses from flooding using the assortment of materials available.

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<tr>
<th>7E</th>
<th>Procedures</th>
<th>SEPs and Cross Cutting Concepts</th>
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<tr>
<td>Elicit</td>
<td>Assess prior knowledge of earthquakes with Structured Paired Brainstorming.</td>
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<td>Engage</td>
<td>Use a boiling pot with plate to simulate movement of Earth’s tectonic plates during an earthquake. Demo seismic waves with slinky.</td>
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<tr>
<td>Explore</td>
<td>Observe pictures of earthquake damage to buildings and examples of earthquake-proof buildings.</td>
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<tr>
<td>Explain</td>
<td>Discuss engineering design process. Go over problem, criteria, and testing method.</td>
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<tr>
<td>Elaborate</td>
<td>Build structure with marshmallows and toothpicks that will resist P-wave of an earthquake.</td>
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<tr>
<td>Evaluate</td>
<td>Share designs and reflect on the engineering design process.</td>
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<tr>
<td>Extend</td>
<td>1. Engineer a solution for protecting houses from floods. 2. Have students pretend they work for a civil engineering company. They should make an advertising flyer to convince businesses to choose their earthquake-proof designs. 3. Have student teams write a news script about an earthquake in their hometown, comparing the damage of traditional buildings and earthquake-proof buildings.</td>
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References


