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Earthquake MachineLite: Activity 1 of 2*

Defining an Earthquake

www.iris.edu/hq/inclass/lesson/15

Version 2.0

Incorporated Research Institutions for Seismology
Thank you to Larry Braile, Purdue University for input into the design and testing of the Earthquake Machine.

OVERVIEW

In this activity, students work collaboratively in small groups to explore the earthquake cycle (Teacher Background, Appendix A) by using a mechanical model. Attention is captured through several short video clips illustrating the awe-inspiring power of ground shaking resulting from earthquakes. To make students' prior knowledge explicit and activate their thinking about the topic of earthquakes, each student writes their definition of an earthquake on a sticky note.

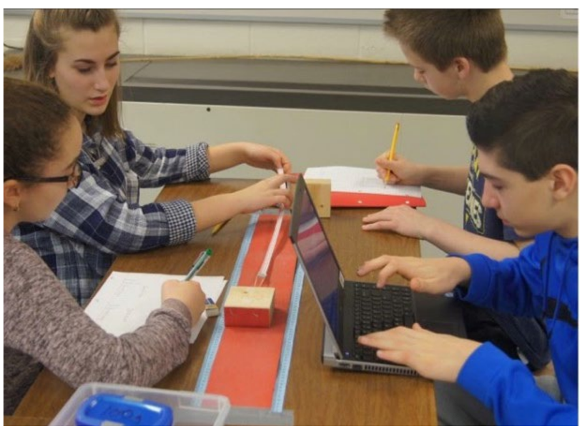


Figure 1: *Students using the Earthquake Machine and recording the data on worksheets and computer.*

Next, through a collaborative process, small groups of students combine their individual definitions to create a consensus definition for an earthquake.

Using an open-inquiry approach, they then experiment with the Earthquake Machine and compare their group's definition of an earthquake to the behavior of the model. Through this inquiry process, students are asked to map the construct of an earthquake to the elements of the mechanical model. Finally, the entire class discusses how the model is both like and unlike the actual phenomena of an earthquake. This explicit mapping process offers opportunities for students to summarize their findings.

Beginner

45 min

Small Group

Student Investigation

Significant Prep

Materials

OBJECTIVES

Students will be able to:

- Summarize the earthquake cycle in a short paragraph
- Use the Earthquake Machine model to demonstrate the causes of earthquakes, noting the flow of energy through the system
- Illustrate the role of models in the process of science in a short description

TABLE OF CONTENTS

*Activity 2 (www.iris.edu/hq/inclass/lesson/419) is not a required followup.

MATERIALS

- One Earthquake Machine for every group of 3 to 4 students. Materials list at right, and prep below.
- Computer w/ projection system
- Slide presentation: **EQMachine_Slides.pptx**
- Videos downloaded and embedded in PowerPoint: **Store.mp4** and **Kathmandu_2015_UNAVCO.mp4**
- Class set of student worksheets Pages SW-2 and SW-3
- 5-8 small sticky notes (or scrap paper and tape) per student.

TEACHER PREPARATION

Background Information

Teacher Background (Appendix A) has a "Science of the Model" description.

Watch a video of an introduction to the model: www.iris.edu/hq/inclass/video/66

Watch a video of the construction and use of the model (click related-resources tabs above video to learn more): http://www.iris.edu/hq/inclass/video/earthquake_machine_parts_and_construction

Construction:

1) Trace one of the 4" wood blocks on the back of the sheet of sandpaper, adding one inch to the length.
2) Place the sandpaper over the bottom of the block and fold the long edges up on to the ends of the block. Staple the sandpaper to the edges (Figure 2).
3) Screw one 12x1-3/16 screw eye into the cut end of the block about 1/2 inch from the base (Figure 2).
4) Feed rubber band into the screw eye and loop to knot.
5) Attach the first cloth tape measure by folding 1/2" of the end of it through the rubber band loop and back on itself. Use duct tape to secure it to the rubber band.
6) Use scissors to cut the sanding belt so it is no longer a loop.

Setting up the Earthquake Machine for use

1) Smooth the sanding belt out on the lab table grit side up so that there are no waves in it. It helps to roll it backwards on itself to help flatten it.
2) Use duct tape to secure each end to the table.
3) Parallel to the sanding belt, tape down the second measuring tape in the same fashion as the sanding belt. (Be sure the metric side is up!)
4) Place **the block** on one end of the sanding belt (Figure 3).

MATERIALS & TOOLS FOR EACH EARTHQUAKE MACHINE

- 1 – 4" blocks cut from 2x4 lumber
- 1 – 4"x36" Sanding belt w/ the heaviest grit possible (50-60 Grit)
- 1 – Sheet of sandpaper, w/ the heaviest grit possible (e.g. 60 Grit)
- 4 – Screw eyes 12x1-3/16 (or similar)
- 1 – Rubber band (size 19 is best)
- 1 – 16-in strip of Duct Tape
- 2 – Cloth tape measure w/ metric markings

Tools:

- Saw
- Scissors
- Heavy-duty staple Gun & Staples

Time Required for construction:

~ 2 hours for a class set

OPTIONAL

Appendix A (Figure 5) has a model for a paper building to affix to the block to show how the building shakes during an earthquake.

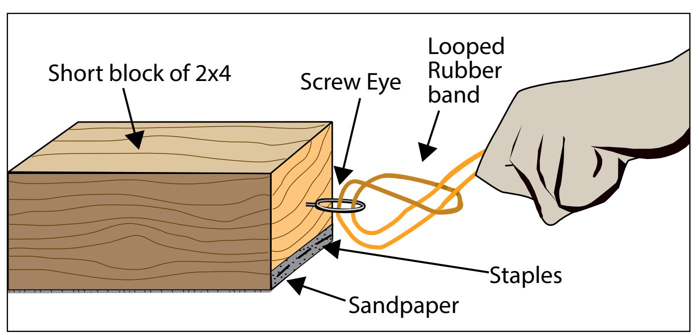


Figure 2: *Block A setup with looped rubber band and sandpaper.*

LESSON DEVELOPMENT

This activity is structured using the "**OPERA**" system described in Appendix B where you can find potential questioning sequences (including taxonomy, questions, and answers) to augment the lesson development below.

An elastic rebound concept map (Appendix C) shows the relationships between force, stress, strain, and energy release.

Either begin class with the videos (Open), or see Page 11 for potential "warm up" questions.

1) Open

Have only **Slide 3** of the PowerPoint videos projected. Next play the videos: **Kathmandu_2015_UNAVCO.mp4** and **Store.mp4** .
Ask the class:

?? **"***What could cause people and objects to behave like that?***"**
Allow for all options included a train or explosion, etc.

2) Prior Knowledge

a) Ask participants to individually answer the following question:
?? "*What is an earthquake*?"

They will write their answer on 3x5 sticky notes with one idea per note (e.g. sudden release of energy = one note; ground shaking = one note, etc).

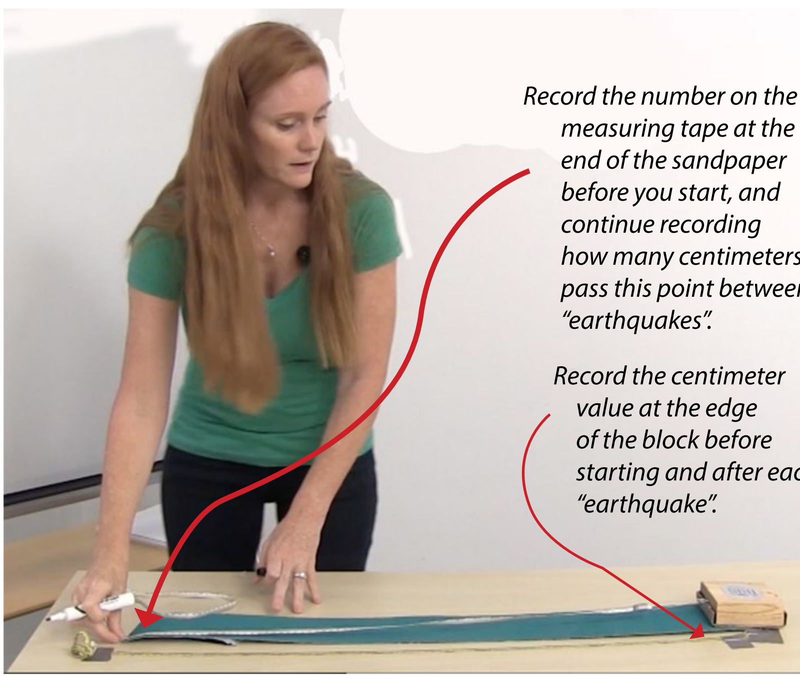


Figure 3: *Earthquake Machine Lite setup with green sanding belt duct taped to desk. One tape measure is taped to table adjacent to the duct tape. Tape measure is tugged slowly and steadily.*

VOCABULARY

Affinity diagram: organizes a large number of ideas into natural relationships. Brainstormed ideas can be sorted into groups.

Potential Energy: The energy of an object due to its position or condition

Kinetic Energy: The energy an object possesses due to its motion

Earthquake: The sudden sudden release of potential energy stored elastically in a fault, and the result¬ing ground shaking and radiated seismic energy caused by the slip.

Reversible strain. This means that when stress is removed the material will return to its original position or shape

Stress: The amount of force applied across the area of an object

Strain: Changes in size, shape, or volume of an object due to stress

TEACHING TIP

For using the hands-on model, groups of 3 to 4 work best.

For discussion groups in "2. Prior Knowledge" , "b.", groups of 8–10 work well.

b) Next, have students work in groups of 8-10 students to create a single consensus definition that accounts for everyone's ideas in the group. This can be efficiently accomplished by creating an affinity diagram (see Vocabulary) to organize by similar ideas. Here the first participant reads one of his/her notes and places it on the table top or wall. If other students in the group have a similar idea, their note is read and grouped with the original.
Ask the group to name the natural relationship between the ideas and record it with an additional sticky note. These identified natural relationships can be referred to as themes. Continue to call and sort ideas until all sticky notes are posted on flipcharts. Allow sticky notes to be moved as the group refines the natural relationships between their ideas. The group should come to consensus on one definition of an earthquake that includes the entire group's idea. All group participants record this definition on their student worksheets.

c) Show and describe the materials and assembly of Earthquake Machine model. Before communicating how the setup models earthquakes, demonstrate what happens when you pull slowly on the tape connected to the block on the sandpaper.

NOTE: Slowly pull the measuring tape parallel to the surface of the sanding belt (Figure 3). The block should stick in place initially and the rubber band will stretch. When a threshold is reached, block will slip forward as the potential energy stored in the rubber band is suddenly converted to kinetic energy. Once the block stops, the stick slip process begins again.

3) Explore/Explain (Potential question sequence Page 11)

a) Divide class into groups of 3 to 4. Have one student from each group come up and pick up the materials for the model. Groups should assemble their models.

b) Allow adequate time for groups to freely explore the behavior of the model and answer questions 2 through 7 on their student worksheet.

c) Once groups have had an opportunity to explore the model, remind them that this setup models an earthquake. Discuss their answers to questions 2 through 7 as a class using suggestions in Table 1.

Emphasize the following two questions in your discussion.

?? *How might the model be like a real fault?* [Left side Table 1.]

ANSWER: The stick-slip behavior of the block is similar to the earthquake cycle where earth materials to store energy elastically over a period of time. When a threshold is reached, the stored energy is suddenly released as an earthquake, which causes seismic waves to propagate outward in all directions like the sound waves that radiate away from the sandpaper.

?? *How might the model be unlike a real fault?*
ANSWER: Right side of Table 1.

GUIDING QUESTIONS

In this model, what does the wood block represent? (*The plates*)

What does the hand represent? (*The forces acting on the plate*)

What does the sandpaper represent? (*The contact between one plate and another plate*)

What does a moving block represent? (*An earthquake*)

What does the rubber band represent? (*Stored energy*)

What kind of energy does the rubber band have? (*Potential OR elastic potential*)

What kind of energy does the moving block have? (*Kinetic;*)

Describe the energy changes that occur with the model. (*The potential energy in the rubber band is transformed into kinetic energy when the block moves. When a deformation threshold is reached, the Earth materials fracture and potential energy is suddenly converted to kinetic energy as the Earth materials move to a position with less stress*)

TIP 2

During open exploration students tend to want to pull aggressively on the tape. If this is occurring, guide them to see that the model behaves differently (and more interestingly) with a slower rate of pull.

TIP 3

If the block tends to creep along slowly rather than slip suddenly, you can add weight to the block.

***Table 1**. Whereas the Earthquake Machine has many features that are* LIKE REALITY, *it also has a number of features that are UNLIKE REALITY that also must be made explicit to students.*

LIKE REALITY	UNLIKE REALITY
The wood block represents the edge of the plate that is locked.	The materials are notably different.
The measuring tape represents the bulk of the plate where plate motion is constant.	The temporal and physical scale the model operates on is notably different.
Slow pulling on the measuring tape represents the force causing the plate to move.	In Earth, elastic energy is stored over tens to hundreds of years in rocks spanning an area of up to hundreds of kilometers rather than the seconds it takes to store energy in the small rubber band.
The rubber band and its deformation represents he elastic materials inside Earth that also store potential energy.	The block always has fixed dimensions while a fault may by much larger and could slip at any point along it and vary for each earthquake.
The sandpaper represents the contact between one plate and another plate.	In the model, the boundary between the two plates (or sides of the fault) is parallel to the surface. However, in Earth, plate boundaries (and fault planes) are not this horizontal.
When the locking (frictional in this case) forces are overcome, the potential energy is suddenly converted to kinetic energy.	Friction only occurs along the bottom of the wooden block in the model but in a fault, the friction is much more complex and likely on the sides.
The moving block represents an earthquake.	Energy in the model comes from our hands, but in the Earth the internal heat of the earth drives the downward pull of subducting slabs.
Vibrations from the block moving are elastic waves, like seismic waves these radiate out in all directions.	

3 F'S

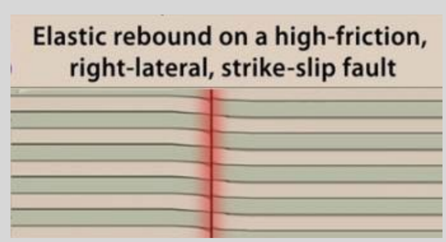
Forces, Faults, & Friction

The Earthquake Machine is effective at illustrating the interplay of:

- *Forces*: proportional to extension of the rubber bands
- *Faults*: represented by the interface between the strip of sandpaper on the board and the sandpaper on the brick
- *Friction*: between the two pieces of sandpaper in contact with each other.

ANIMATION

Elastic rebound on strike-slip fault: www.iris.edu/hq/inclass/animation/63



For more information on Elastic Rebound see Appendix A.

4) Reflect (Potential question sequence Page 11)

Have students complete questions 8 and 9 on their student worksheets.

5) Apply

a) Assign a reading on the Elastic Rebound Theory (Appendix A).
Ask students to reflect on the reading and their experience with the Earthquake Machine in their science notebooks.

b) Formative assessment—Ask students:

?? *How could you modify the model so that it no longer stored energy?*

?? *Based on this (and assuming superhuman powers, perhaps) what would you change about Earth to prevent all future earthquakes?*

ANSWER:

- **Option 1:** Don't pull the measuring tape. In Earth, this would be analogous to cooling Earth's interior thereby removing the driving force on the plates.
- **Option 2:** Eliminate the friction between the block and the sandpaper base. In Earth, this would be analogous to removing the locking forces (friction, pressure, etc) at a plate boundary or fault.
- **Option 3:** Remove the rubber band or replace it with string. In Earth, this would be analogous to making rocks and other Earth materials inelastic and unable to store the potential energy for an earthquake.

EXTRA: Looking Ahead—Thinking Beyond

?? *Energy in the model comes from you, but where might this same energy come from in the Earth?*

ANSWER:

As a lead into future lessons on plate tectonics, you may mention that in Earth, the energy that drives the tectonic plates, thus the generation of earthquakes, comes from heat stored and generated within Earth.

?? "*How could you modify the model so that earthquakes no longer occur?*"

ANSWERS:

- Option 1: Don't pull the measuring tape. In Earth, this would be analogous to cooling Earth's interior thereby removing the driving force on the plates
- Option 2: Eliminate friction between the block and the sandpaper base. In Earth, this would be analogous to removing the locking forces (friction, pressure, etc) at a plate boundary or fault.
- Option 3: Remove the rubber band or replace it with string. In Earth, this would be analogous to making rocks and other Earth materials inelastic and unable to store the potential energy for an earthquake.
- Others?

?? "*How can you modify the model to make bigger earthquakes?*"

ANSWERS:

- Option 1: Add to the mass on the block. This increases the locking friction between the block and sliding surface. As a result, more potential energy builds before the block slips. If potential energy gets larger, the block may slip farther once it starts to move.
- Option 2: Use a weaker (more elastic) rubber band.
- Option 3: Use coarser grit sandpaper.
- Others?

APPENDIX A

TEACHER BACKGROUND

Changing the focus of earthquake instruction

Earthquakes are a highly engaging topic for students. The suddenness and awe-inspiring power of an earthquake, whether experienced directly or via various media outlets, both captures students' attention and focuses our conceptualization of earthquakes as the impact they can have on society. As a result, students as young as third grade conclude that an earthquake is destruction, injury, and confusion, and the causes are unknown. While the interest is good for learning, such focus on damage and destruction can become an obstacle that limiting learners' ability to critically and carefully develop an understanding of the actual earthquake and its causes.

Several studies have established that traditional instructional methods for earthquakes are not adequate to allow students to construct coherent explanations about the causes of earthquakes, nor to reduce students' misconceptions about earthquakes. This activity has been designed to make students' initial conceptions of earthquakes explicit and then allow them to test these ideas through a hands-on, minds-on exploration of the Earthquake Machine. In this way, students are able to visualize the physical system, including energy inputs and outputs, of a fault system that can lead to earthquakes. The following discussion deemphasizes the damage and destruction that occurs when earthquakes occur near large population centers, and increases the focus on helping students' construct/expand/replace their own mental models for earthquakes.

The science of the model

The simplicity of the Earthquake Machine allows students to visualize the inputs and outputs of a fault system and explore stick-slip fault behavior. The model's wooden block and sandpaper base represent an active fault section. Students' pull on the measuring tape attached to the block is analogous to continuous plate motions away from the boundaries. For example, this represents the downward pull of a subducting slab of lithospheric plate, which is continuously adding tension to the system. The rubber band represents the elastic properties of the surrounding lithosphere, storing potential energy. When the frictional forces between the block and sandpaper are overcome, the block lurches forward with a stick-slip motion. Students get to "experience" an earthquake by seeing the release of energy stored in the rubber band and feeling the propagation of seismic waves from an elastic source. Visualizing the energy released by the slip of the block is further enhanced by the motion of the optional model building, made of strips of lightweight poster board or manila folder material (Figure 5).

***Figure 4**: Teachers learn to use the Earthquake Machine at an IRIS workshop.*

OPTIONAL

Cardboard Building

(1) Cut four strips out of the manila folder; two that are ½" wide and 5" long (floor and roof), and two that are ½" wide and 12" long (vertical uprights).

(2) Fold ½" on each end of the roof and tape it to the top of the uprights.

(3) Fold ½" on each end of the floor and tape it inside of the upright about halfway up the structure.

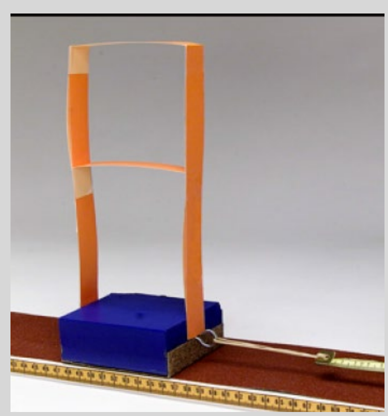


***Figure 5:** Optional building*

While this model accurately simulates the strain energy that slowly accumulates in rock surrounding a locked fault that is released in a sudden slip event, a process known as the elastic rebound theory [next section], it is ultimately a simplification of a complex Earth system. Such simplifications must be understood to interpret the model accurately. Therefore, the relationship between the model and reality should be clearly emphasized to students (Table 1). This is particularly important for high school-aged students, who often think of physical models as copies of reality rather than representations.

The model not only provides a physical perspective on the generation of earthquakes, but it also illustrates the concept of an earthquake's magnitude, and how this can be calculated based on the physical features of the fault (see inset Vocabulary box right, *Seismic Moment*). In our model, the length and width (area; A) of the fault section that slips during an event (represented by the dimensions of the block of wood) as well as the rigidity of Earth materials (μ, represented by the elasticity of the rubber band) are constant for every event generated. The only factor that can vary is the displacement (D) or slip of the fault. As a result, there is a direct correlation between the amount of slip of the block and the moment magnitude of the event. While aspects of the mathematical relationship discussed in the inset box may be premature for some students' experience, all students will physically see this relationship by noting how much the "building" on top of the block moves in relation to the amount the block slips. T he further the block slips, the more energy is released, and the more violently the building shakes.

VOCABULARY

Seismic Moment (M_o) is a measure of the size of an earthquake based the physical characteristics of the fault and can be determined either from seismograms or fault dimensions. The equation is:

$$M_o = A \times D \times \mu$$

A = Area
D = Displacement
μ = Rigidity

Moment Magnitude (M_w) based on the concept of *Seismic Moment* where constants in the equation have been chosen so the moment magnitude scale correlates with other magnitude scales.

$$M_w = 2/3 \log M_o - 10.7$$

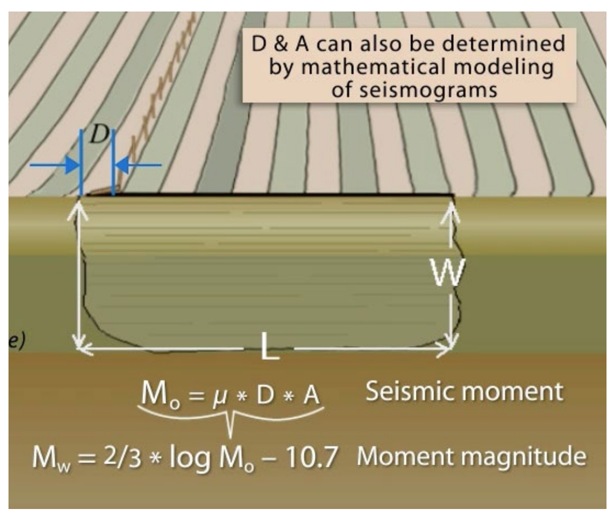


*Figure 6: Cross section of a fault surface (**L** x **W**) plugged into the equations in the Vocabulary box above. **D** is how far the fault slipped. Screen grab from animation "**Moment Magnitudes Explained**" available here: www.iris.edu/hq/inclass/animation/205*

What is "Elastic Rebound Theory"?

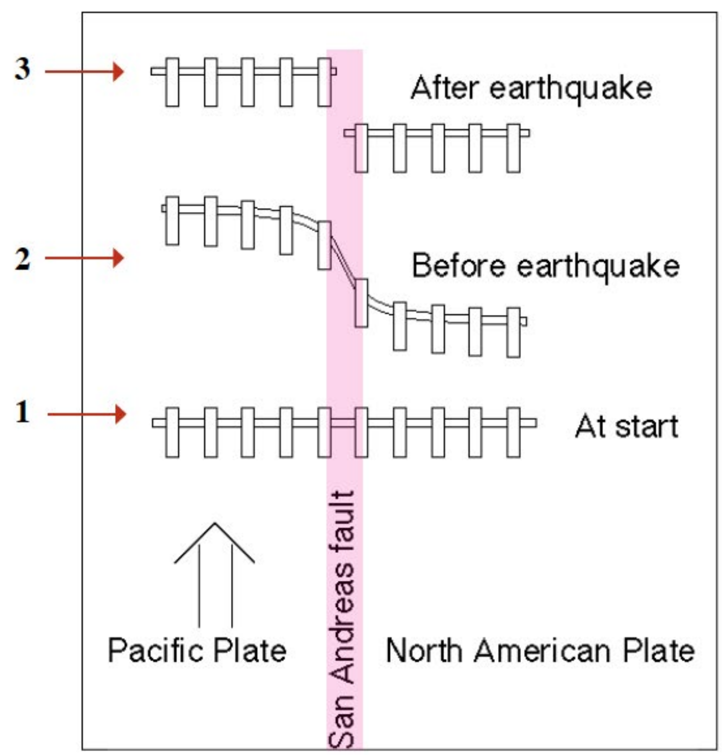
Elastic rebound is what happens to the crustal material on either side of a fault during an earthquake (Figure 6). The idea is that a fault, stuck by friction, undergoes immense pressure and stress while strain accumulates. The rock distorts (strain), or bends under applied stress until friction is overcome, at which point the rock snaps to an un-strained position, releasing energy in an earthquake that produces seismic waves over the duration of the seismic event. (https://earthquake.usgs.gov/learn/animations/elasticrebound.php)

The crust of the earth can gradually store elastic stress over long periods of time. Stress is force divided by the area of the fault (or wood block in this case). The frictional strength of the fault depends on the roughness of the sandpaper on the block and the board, on the area of the block, and on the force pushing the block against the board.

As the Earth's tectonic plates move, the capping crust distorts. When the pressure of the tectonic plates exceeds the force holding the crust together, elastic rebound occurs. Objects that are more brittle are more likely to demonstrate elastic rebound. This gradual accumulation and release of stress and strain is now referred to as the "*elastic rebound theory*" of earthquakes. Most earthquakes are the result of the sudden elastic rebound of previously stored energy.

The diagram below illustrates the process. Start at the bottom. A straight fence is built across the San Andreas fault. As the Pacific plate moves northwest, it gradually distorts the fence. Just before an earthquake, the fence has an "S" shape. When the earthquake occurs the distortion is released and the two parts of the fence are again straight; but now there is an offset. This diagram greatly exaggerates the distortion. Actually, the distortion is spread over many miles and can only be seen with precise instrumentation (e.g. GPS).

This picture, taken near Bolinas in Marin County by G.K. Gilbert, shows a fence that was offset about 8.5 feet along the trace of the fault (from Steinbrugge Collection of the UC Berkeley Earthquake Engineering Research Center



Text and graphics modified from: https://earthquake.usgs.gov/earthquakes/events/1906calif/18april/reid.php

APPENDIX B

OPERA Learning Cycle w/ Potential Questioning Sequences (next pages)

A learning cycle is a model of instruction based on scientific inquiry or learning from experience. Learning cycles have been shown to be effective at enhancing learning because by providing students with opportunities to develop their own understanding of a scientific concept, explore and deepen that understanding, and then apply the concept to new situations. A number of different learning cycles have been developed. However, all are closely related to one another conceptually, and differ primarily in how many steps the cycle is broken into. The "flavor" of learning cycle that you choose is primarily up to what works best for you, just pick one or two and use it as the basic formula for all your instruction.

This lesson is designed around a learning cycle that can be remembered as O-P-E-R-A. OPERA is convenient when designing lesson-level instruction because one can generally incorporate all the major components into the single experience. Each phase of the OPERA cycle is briefly outlined below.

	Instructional Stage
Open	**Open** the lesson with something that captures students' attention. For example, showing the videos of the store shaking during an earthquake in Japan and the ground throwing the people in the Kathmandu plaza is an invitation for learning and leaves students wanting to know more. Ask: "*What could cause people and objects to behave like that?*" [See potential questions on next page.]
Prior knowledge	Assess students' **Prior Knowledge** and employ strategies that make this prior knowledge explicit to both the instructor and the learner
Explore	Plan and implement a minds-on experience for students to **Explor**e the content. [See potential questions on next page.]
Reflect	**Reflect** on the concepts the students have been exploring. Students verbalize their conceptual understanding or demonstrate new skills and behaviors. Teachers introduce formal terms, definitions, and explanations for concepts, processes, skills, or behaviors. [See potential questions on Page 10.]
Apply	Practice concepts, skills and behaviors by **Applying** the knowledge gained in a novel situation to extend students' conceptual understanding.

Open

A. Taxonomy	Question	Answer
Knowledge	Have you ever been outside at night and been nervous or frightened?	Yes
Comprehension	Why do you think you were afraid of or nervous in the dark?	Answers will vary but lead the discussion to the idea, that people are fearful because they cannot define their surroundings.
Knowledge	What might help people to be less afraid in the dark?	Answers will vary but a flashlight is a great example
Knowledge	If you were out in the dark, would a flashlight help you to feel less anxious?	Yes
Comprehension	Why does the flashlight help?	It allows people to see their surroundings & understand them better
Show the videos:		
Knowledge	What could cause the objects those rooms to behave like that?	An earthquake. Other options could include train or explosion.
Knowledge	How does seeing video like that make you feel about earthquakes?	Answers will vary, but guide the discussion so that students have an opportunity to express fear or nervousness.
Comprehension	You agreed that a flashlight would help you feel less nervous in the dark. Do you think it might help here? Why?	No, because they do not need to be able to see in the dark.
Application	What if, like the flashlight you were able to better understand an earthquake, do you think that might help you be less anxious?	Lead students to the idea that understanding their world is important, if for no other reason than to make them safer and more comfortable. People can plan for protective or corrective action if a threat is known or at least somewhat understood.

Explore/Explain

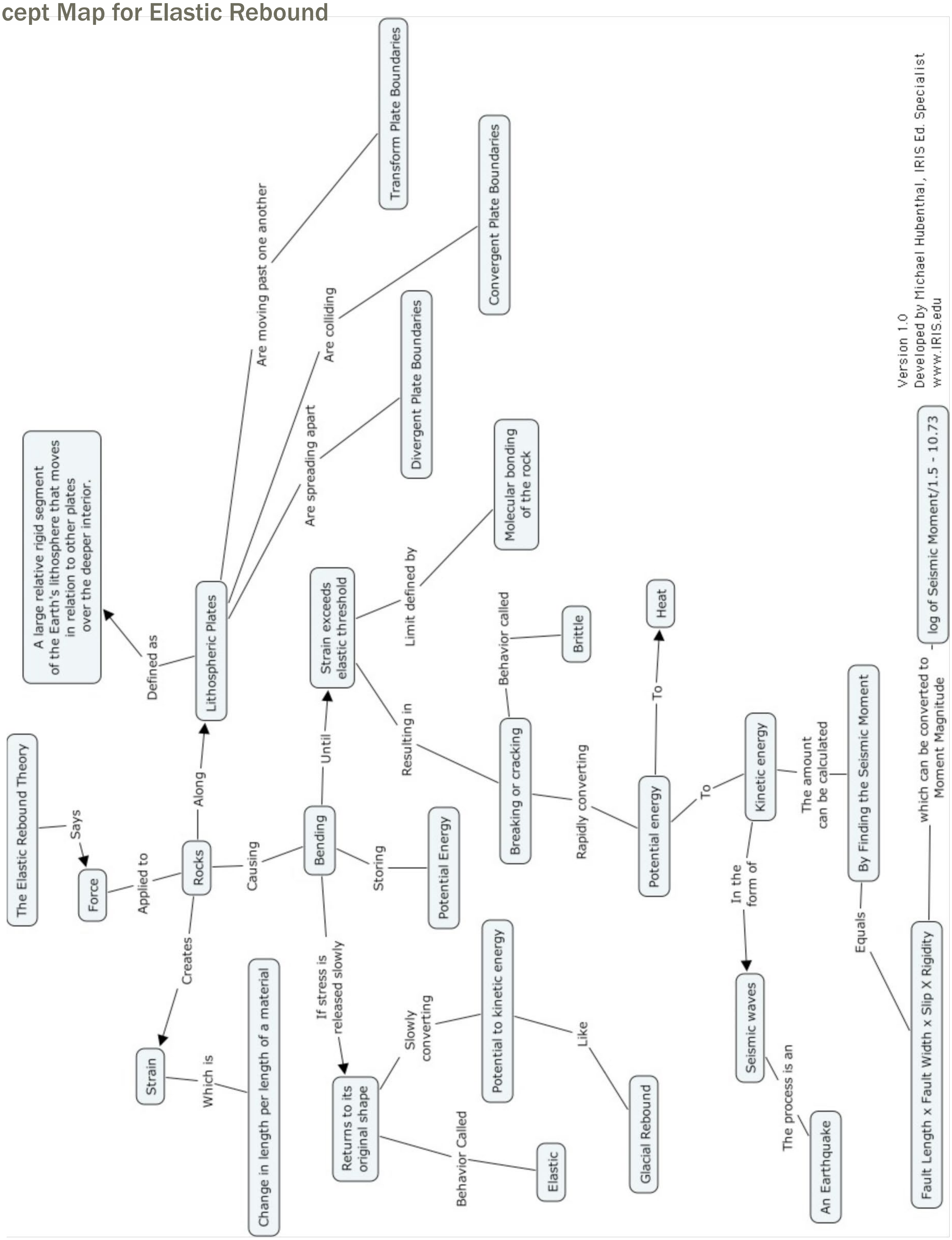
B. Taxonomy	Question	Answer
Knowledge	Today we want to explore your definitions for an earthquake in the lab, does that sound possible or safe?	No. Earthquakes are too big and unsafe for a classroom.
Comprehension	How could we explore something that is too big and unsafe for the laboratory?	Use a model
Knowledge	Are models and the real thing usually identical?	No
Comprehension	Give me an example of a model	Model airplane or other
Application	Why is it good that is not exactly the same?	It is too large, expensive etc.
Application	What can we not learn about the real thing from this model?	Answers will vary depending on the model
Application	What can we not learn about the real thing because it is not exactly the same?	Answers will vary depending on the model
Comprehension	For this model (indicate the Earthquake Machine setup), do you think it is exactly the same as a real fault?	No
Application	How might the use of a model help us develop a definition of an earthquake?	The model is safe, inexpensive, and will give us new information by helping to simplify a large complex system to the key components. Thus, scientific inquiry allows us to develop explanations of natural phenomena in a continuing, creative process

Reflect

Taxonomy	*Question*	*Answer*
Knowledge	How many of you, now have a different definition of an earthquake?	Most should raise their hands
Comprehension	What is the difference between your original definition of an earthquake and your new definition	Original explained the effects on people, while the new one explains what actually happens in a physical sense.
Application	So the next time you see a video clip like (Show Clip) what will you say that you are seeing?	The effects of an earthquake.
Analysis	Why do you think you defined an earthquake as _____ (likely to be shaking of the ground) at the beginning of class?	Elicit the idea that their original definition was based on the information they had, such as news video clips like the ones I showed at the beginning of class.
Evaluation	How does the definition you developed compare to your original definition?	More precise. Scientific inquiry allows us to develop explanations of natural phenomena in a continuing, creative process

APPENDIX C

Concept Map for Elastic Rebound



APPENDIX D

NGSS Science Standards

From Molecules to Organisms—Structures and Processes

- MS-LS1-8 Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

Motion and Stability—Forces and Interactions

- HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes themathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
- MS-PS2-2 Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Energy

- MS-PS3-1 Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.
- MS-PS3-2 Develop a model to describe that when the arrangement of objects interacting at a distance changes, differentamounts of potential energy are stored in the system.
- HS-PS3-2 Develop and use models to illustrate that energy at the macroscopic scale can be accounted foras a combination of energy associated with the motions of particles (objects) and energy associated withthe relative positions of particles (objects).
- MS-PS3-5 Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

Earth's Systems

- HS-ESS2-1 Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.
- MS-ESS2-2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.
- HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
- MS-ESS2-3 Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.
- HS-ESS2-3 Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.

NAME: ______________________________

PERIOD: ________ DATE:_______________

DEFINING AN EARTHQUAKE USING THE EARTHQUAKE MACHINE

PART 1

1. What is an earthquake? Record your consensus definition here:

2. **DIRECTIONS**: Position the block at one end of the sand paper. Using a *slow*, steady pulling motion, pull the measuring tape until the block moves at least 5 times, then draw a diagram indicating the operation of the Earthquake Machine:

3. Describe energy (e.g. potential/kinetic) changes that occur within the model

4. Describe or sketch when the forces in the model are balanced:

5. Describe or sketch when the forces in the model are unbalanced:

6. Hypothesize how this setup might be modeling an earthquake?

7. Describe where the energy came from to make the block move?

PART 2

8. Reassess your consensus definition in Question 1 above. Based on the model and its behavior, describe what you got right. What would you change or add to your definition to improve it?

9. What did this model allow you to see that you don't think you would be able to see if looking at a real fault?

INSTRUCTOR ANSWER KEY

DEFINING AN EARTHQUAKE

1. What is an earthquake? (Record your consensus definition here)

2. Draw a diagram indicating the operation of the Earthquake Machine:

3. Describe energy (e.g. potential/kinetic) changes that occur within the model:

   ANSWER: *The potential energy in the rubber band is transformed into kinetic energy when the block moves.*

4. Describe or sketch when the forces in the model are balanced:

   ANSWER: *When the block is a rest the ...*

5. Describe or sketch when the forces in the model are unbalanced:

   ANSWER: *When the block accelerates from rest and then stops.*

6. Hypothesize how this setup might be modeling an earthquake?

   ANSWER: *The block slips forward converting stored energy into kinetic energy, heat, and seismic waves.* ***Definition of an Earthquake -*** *The sudden release of stored energy and propagation of seismic waves from an elastic source .*

7. Describe where the energy came from to make the block move?

   ANSWER: *For the model, the energy originates from the students constant forward motion of the measuring tape, but it was temporarily stored in the rubber band.*

8. Reassess your consensus definition in Question 1 above. Based on the model and its behavior, describe what you got right. What would you change or add to your definition to improve it?

   ANSWER: *Answers will vary.*

9. What did this model allow you to see that you don't think you would be able to see if looking at a real fault?

   ANSWER: *Answers will vary.*

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