The Earthquake Machine Lite: Activity 1 of 2

Redefining an Earthquake v1.2

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Time: 45-50 minutes
Suggested Grade Level: 9th Grade Earth Science

5E Phase: Explore – This lesson is designed for the Explore phase of the 5E Model. The activity Developing Arguments About Earthquake Occurrence v1.2 (available on-line at http://www.iris.edu/edu/lessons.htm)is designed as part two of this activity and is the Explain phase.

Guiding Question(s)

1. What is an earthquake?
2. What is the role of a model in science?
3. How are scientific ideas constantly changing?

Content Objectives (Students will be able to)

1. Define earthquakes and model their occurrence using the earthquake machine.
2. Describe the role of inquiry in the process of science
3. Give examples of why models are important in science
4. Use and explain the Earthquake Machine allowing exploration of additional concepts in future lesson phases

Table of Contents

Materials List

- Class set of Earthquake Machine Set-ups *(see Appendix I for detailed materials and assembly instructions)*
- Video Projector
- Computer
- EQMachineActivity1.ppt *(available online at http://www.iris.edu/edu/lessons.htm)*
- Class set of student worksheets (see Appendix VI)

- Movie clips installed on presentation computer
    - http://www.youtube.com/watch?v=0plbf5w0sbA
    - http://www.youtube.com/watch?v=yJPS4lokxtw

Lesson Description: Quick Summary

OPERA	Time (min)
***O**pen*	10
***P**rior knowledge*	15
***E**xplore/**E**xplain*	15
***R**eflect*	10
***A**pply*	Homework

Lesson Description: Teacher Instructions (*w/ Potential Questioning Sequences*)

Please see Appendix IV for a full Teacher Background discussion

Open – 10 Minutes

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 students the following video clips (7.2 Kobe Earthquake, 1995)
http://www.youtube.com/watch?v=0plbf5w0sbA
http://www.youtube.com/watch?v=yJPS4lokxtw

A. Taxonomy	*Question*	*Answer*
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	Lead students to the idea that

	able to better understand an earthquake, do you think that might help you be less anxious?	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.

***P**rior Knowledge - 15 Minutes*

Affinity Brainstorm (Ray, 1999)
*Note: if you have not already taught your students to Affinity Brainstorm, this can be done as a class exercise, though it will take additional time.

Ask participants to answer the following question on a 3x5 sticky notes (i.e., Post-it notes) – only one idea per note. "What is an earthquake?" *(Knowledge)*

Have students work in groups of 8-10 students. Conduct a Call and Sort activity. The first participant is to read one of his/her notes and place it on a flipchart. If other students have a similar idea their note is read and placed on the flipchart grouped with the original. Ask the group to name the natural relationship between the ideas and record it on the flipchart with the sticky notes. 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 and the group should come to consensus on one definition of an earthquake that includes the entire group's idea. This definition should be written largely on the flip chart.

***E**xplore/Explain - 10 Minutes*

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
Analysis	How might it be like/unlike a real	Like – Stick-slip behavior of block and

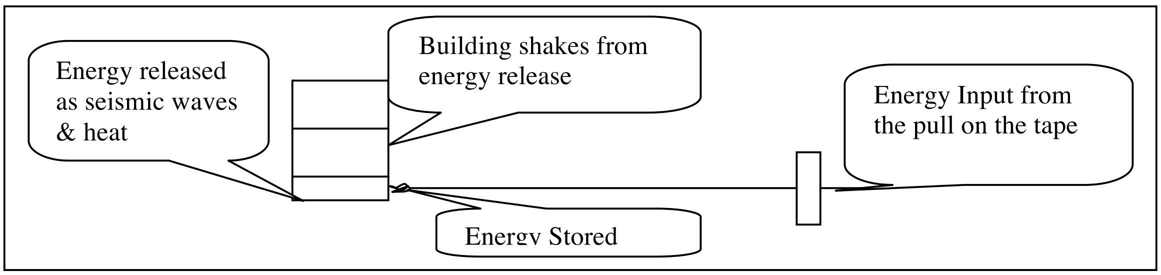
	fault? (Generate a list on board) Use animation to help if necessary. http://quake.wr.usgs.gov/research/deformation/modeling/animations/index.html (Grid_1sq)	faults are similar; elastic properties of earth materials to store energy like rubber band. Energy added over a period of time but released in surges. Propagation of seismic waves through the block to the building and through the table to a hand etc. Unlike – Block is of fixed dimensions where a fault may by much larger and could slip at any point along it. Friction only occurs along the bottom of the block but in a fault the friction is much more complex and likely on the sides. 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.
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

Divide the class into groups of three and assign each group to an Earthquake Machine.
Students will explore the model using the questions on the lab sheet (Pages 12 & 13)

Student Worksheet - Questions and Answers (Pages 12 & 13)

Taxonomy	*Question*	*Abbreviated Answers*
Knowledge	Describe what happened to the building when the block moved?	The building shook
Comprehension	Describe what a video camera inside the paper "Office Building" might have recorded when the block moved.	Similar to what we saw in the video clips
Comprehension	Below sketch the Earthquake machine system.	*See below*
Comprehension	Where did the energy come from that made the block move? Where might this same energy come from in the Earth?	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. *Note: As a lead into future lessons on plate tectonics, you may mention that in the earth, the energy that drives the "pull" of plate comes from heat stored within the earth.
Application	Was the shaking of the building a *cause* or a *result* of the block moving?	The shaking is a result of the block moving.

Synthesis	Below, describe the sequence or steps that occurred to lead up to the building shaking.	Pull on tape Energy stored in rubber band Stress exceeds the rigidity of the fault Block slips forward releasing energy as heat, and seismic waves.
Synthesis	Which section of the steps above models an earthquake?	Block slips forward releasing energy
Synthesis	After using the Earthquake Machine model, refine your definition of an earthquake based on the model.	The release of energy and propagation of seismic waves from an elastic source
Evaluation	How might this be like/unlike an actual fault and earthquake?	



***R**eflect – 10 Minutes*

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

***A**pply – Homework*

Study the map of California; use your new definition of an earthquake to explain why the earthquakes shown are located where they are. *(Application*)

Appendix I: Building & Setting Up Your Earthquake Machine Lite Model

Materials for one EQ Machine	Tools
1 – One foot piece of 2x4 scrap wood (<$1.00 @building supply) 1 – 4”x36” Sanding Belt, 50 Grit ($5.00 @building supply) 1 – 1/3 Sheet of Sandpaper, 60 Grit (<$2.00 @building supply) 4 – Screw Eye 12x1-3/16 ($5 per bag @building supply) 1 – Bag of Rubber bands, varying size ($0.99/ bag @office supply) 16in of Duct Tape ($2.48 per roll @building supply) 2 – Waxed Cloth tape measures in both English and Metric markings ($ 1.20 each @craft store) 1 – Manila Folder	- Saw - Needle Nose Pliers - Scissors - Glue (White or Contact Cement) - Pencil

Preparation BEFORE CLASS (Class set can be made in about 2 hours)

1) Using the tape measure and pencil, divide the one-foot length of 2”x 4” into three 4” blocks.
2) Using the saw cut along your markings to create two 4” x 4” blocks
3) Trace one of the blocks on the back of the sandpaper & use the scissors to cut out squares that fold up over the edges of the block

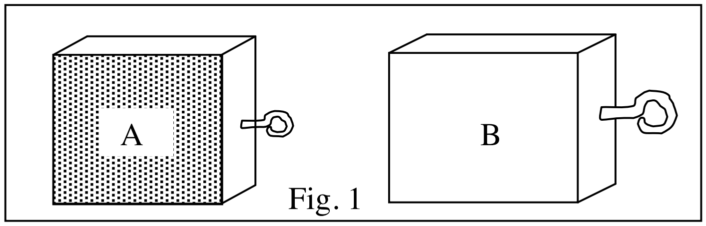


Fig. 1

4) Use a staple gun to attach the sandpaper square to Block A so the staples are in the edges.
5) Screw one 12x1-3/16 screw eye into a cut end of block A (See figure 1.)
6) Screw one 12x1-3/16 screw eye into Block B(See figure 1.)
7) Using the needle nose pliers, carefully bend the eye of the 212x15/16 screw eyes opened just enough to allow a rubber band to fit through.
8) Using scissors cut the sanding belt so it is no longer a connected loop
9) Using pliers remove the metal ends from one of the measuring tapes.

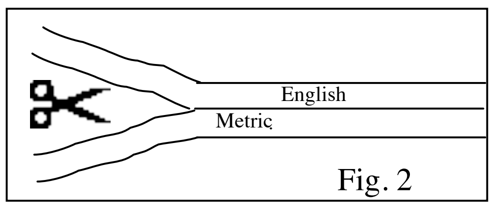
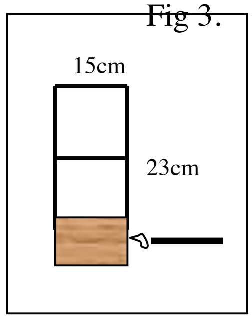


Fig. 2

10) Using scissors cut the measuring tape without the metal ends up the middle lengthwise, being careful to leave the cm markings intact. (See Figure 2)
11) Discard the half of the split measuring tape marked in English.
12) Cut four strips out of the manila folder; two that are 3cm wide and 15cm long, and two that are 3cm wide and 23cm long.
13) Assemble the strips of manila folder with tape as shown if Figure 3 and tape to the top of Block A.

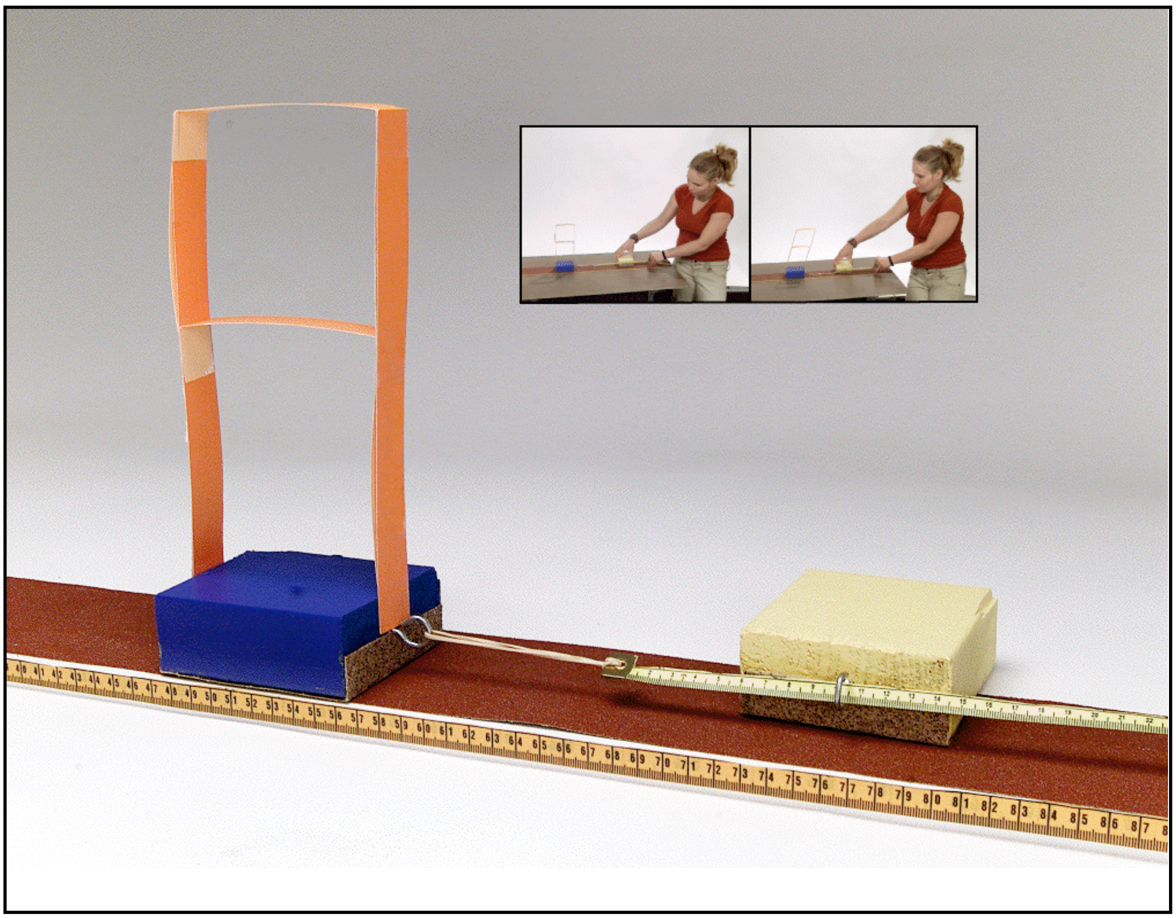
Fig 3.



Set Up for Use In the Lab

1) Using duct tape, secure one end of the sanding belt to the lab table.
2) Stretch the sanding belt out tightly and tape the second end to the lab table so that there are no waves in the sanding belt.

3) On the side of the sanding belt nearest you tape down the uncut measuring tape in the same fashion as the sanding belt. (Be sure the metric side is up!)
4) Place block C on edge, on the right end of the sanding belt so that the screw eye is positioned in the center of the sanding belt.
5) Using a long piece of duct tape, tape block C down to the tabletop for added support.
6) Thread the split measuring tape through the screw eye and pull it to the far left end of the sanding belt.
7) Fold 5 cm of the end of the split measuring tape back on top of itself with a rubber band in the loop. Use duct tape to secure the loop so that the rubber band is attached to the end of the measuring tape.
8) Hook the rubber band into one of the screw eyes of block B. (*Note – If Block does not stick-slip you may need to daisy chain several rubber bands together)



Appendix II Alignment With Standards

AAAS Benchmarks
Reinforces

Common Themes: Models- Kindergarten to Grade 2
Many of the toys children play with are like real things only in some ways. They are not the same size, are missing many details, or are not able to do all of the same things.

A model of something is different from the real thing but can be used to learn something about the real thing.

Common Themes: Models- Grades 6 to 8
Models are often used to think about process that happen too slowly, or too quickly, or on too small a scale to observe directly or that are too vast to be changed deliberately, or that are potentially dangerous.

Supports

The Physical Setting: Processes that Shape the Earth - Grades 9 to 12
Earthquakes often occur along the boundaries between colliding plates, and molten rock from below creates pressure that is released by volcanic eruptions, helping to build up mountains. Under the ocean basins, molten rock may well up between separating plates to create new ocean floor. Volcanic activity along the ocean floor may form undersea mountains, which can thrust above the ocean's surface to become islands.

Appendix III: References and Acknowledgements

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Many thanks to Larry Braile (Prudue University) & John Lahr (Retired USGS) for their help in refining & testing the model, as well as their input to the design of the EQ Machine Lite Activities.

Appendix IV: Teacher Background

If you teach in a seismically active area, such as California or Alaska, your students may have personal experience with earthquakes. However, even though they may have had this experience, the sudden and frightening nature of experiencing an earthquake can limit an observer's ability to critically and carefully develop an understanding of the event. Conversely, if you teach where the seismic hazard is low, such as the East coast or mid-western US, most of the students you encounter will have little to no personal experience with earthquakes. For them, the concept of the ground suddenly beginning to tremble is largely unimaginable and fearful for them. Enhancing this innately discrepant behavior, large earthquakes are represented by various media outlets as mysterious events generated by "unseen, uncontrollable forces deep beneath our feet." The images shown highlight that these forces are so powerful that they can destroy all we believe permanent in a few seconds. Thus between their own fears of the unknown and news media, students at early ages conclude that an earthquake is the destruction of buildings, people getting hurt and confusion (Ross and Shuell, 1993). Therefore transitioning people's preconceived definition of an earthquake, from the effects of an earthquake, to the release and propagation of seismic waves from an elastic source, is both a emotional barrier to cognition as well as a misconception to be overcome anytime you instruct about earthquakes (Bolt, 2004). Naïve beliefs, such as this can present major obstacles to learning, if instruction does not identify and address them explicitly (Snow, 1989). Moreover, it has been shown that middle-school students taught by traditional means are not able to construct coherent explanations about the causes of earthquakes (Duschl et al. 1992). Thus, section one of this lab strives to elicit this students' naïve belief through the use of video footage similar to footage that is the likely basis for their definitions. Section two of the lab uses a modified version of the original the Earthquake Machine Model (Hall-Wallace, 1998) and is an expansion of an undergraduate level implementation of the model (Hall-Wallace & Butler, 2002) to allow students to directly confront their naïve belief by feeling and visualizing an earthquake through the use of a model. Through the use of the model students directly confront the elastic nature of earth materials by clearly seeing that energy is put into the system, stored as potential energy in the rubber band and then suddenly released as an earthquake. Without the elastic component of the system, energy could not be stored and earthquakes could not occur.

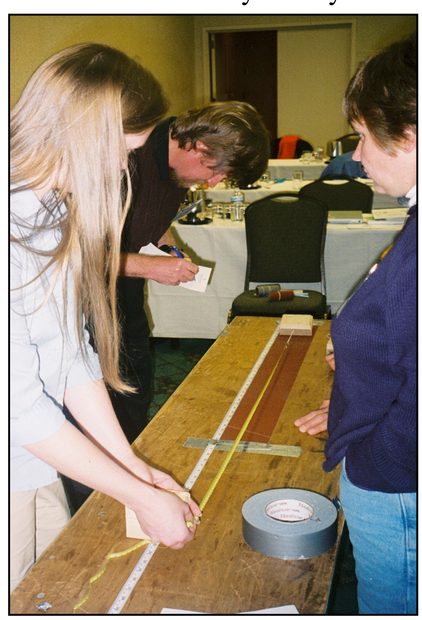


Figure 1. Teachers learn to use the Earthquake Machine Lite at an IRIS workshop.

When discussing energy flow through the model it is important to directly discuss the fact that not all the energy is transferred in the same way e.g. 100% of the stored energy is converted to shaking. The transformation of motion to heat seems to be difficult for students to accept, especially in cases with no obvious temperature increase like the block sliding along the sandpaper (Brook & Driver, 1986; Kesidou & Duit, 1993). For some reason the idea of energy conservation seems counter-intuitive to middle- and high-school students who hold on to the everyday use of the term energy, but teaching heat-dissipation ideas at the same time as energy-conservation ideas may help alleviate this difficulty (Solomon, 1983). Even after instruction, however, students do not seem to appreciate that energy conservation is a useful way to explain phenomena (Brook & Driver, 1984).

Understanding the Model

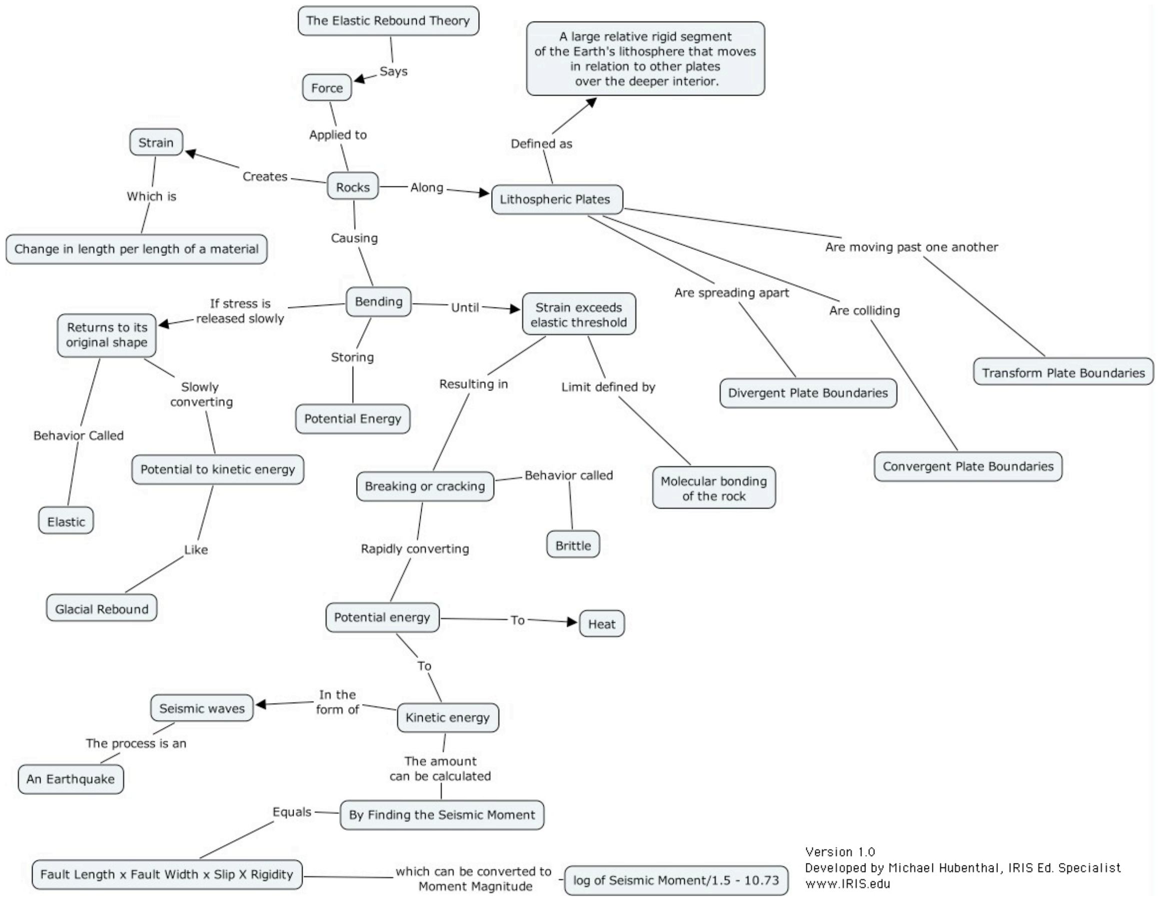
This model (Figure. 1) allows students to explore stick-slip behavior of some faults and to use the representative fault to develop a more accurate definition of an earthquake and its causes. The wood block represents the active section of the fault, while the rubber band represents the elastic properties of the surrounding rock that store potential energy. Each time the block moves the students see and feel the release of energy and propagation of seismic waves from an elastic source, which is the definition of an earthquake (Bolt, 2004).

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, it is ultimately a simplification of a complex earth system (Bolt, 2004). Such simplifications must be understood to interpret the model accurately. Therefore the relationship between the model and reality should be clearly emphasized to students. Especially, since middle and high school aged students often think of physical models as copies of reality rather than representations (Grosslight et al., 1991).

For example, not only does the model provide a physical perspective on the generation of earthquakes, it also illustrates the concept of an earthquake's Magnitude (M_w) and how the M_w can be calculated based on the physical features of the fault (Figure 3). In our model the length and width 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, represented by the elasticity of the rubber band, are constant for every event generated. The only factor that can vary is the displacement 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 Figure 3 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 relationship to the amount the block slips. The further the block slips, the more energy is released, and the more violently the building shakes. Students can actually calculate a magnitude for modeled events by replacing rigidity with the spring constant for the rubber band; however, the constant area of the model fault ultimately limits the magnitude range of events that can be generated by model.

> 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.
> $M_o = L \times W \times D \times \mu$ or Length x Width x Displacement (Slip) x 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. $M_w = \mathit{log}\ M_o/1.5 - 10.7$
>
> Figure 3: Background equations for understanding the Earthquake Machine Lite (Stein & Okal, 2005).

Appendix V: Concept Map



Appendix VI

The Earthquake Machine Lite

Activity 1 of 2: Redefining an Earthquake v1.0 – Student Worksheet

Name _________________________ Period ____________ Date_______________

Directions: Position the block at one end of the sand paper. Using a slow, steady pulling motion, pull the measuring tape through the eyelet until the block moves at least 5 times.

1. Draw 3 "comic strip" frames depicting what a video camera inside the paper "Office Building" might have recorded when the block moved a small slip, medium slip, a big slip.

2. Was the shaking of the building a cause or a result of the block moving?

3. Describe the sequence or steps leading up to the model building shaking.

4. Where did the energy that made the block move come from? Where might this same energy come from in the Earth to create an earthquake?

5. After using the Earthquake Machine model, refine your definition of an earthquake based on the model.

6. 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.

7. How might this model be like/unlike an actual fault and earthquake?

8. How would you modify the model so that it no longer stored energy? How do you think your modification would impact the models overall operation?

9. What aspects of the model do you think could be “measured” quantitatively? Describe how we could do this.

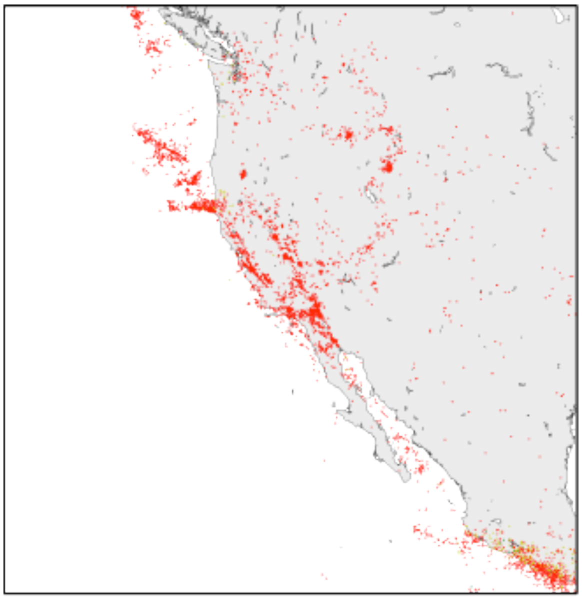
Appendix VII

The Earthquake Machine Lite

Activity 1 of 2: Redefining an Earthquake v1.0 – Homework

Name _________________________ Period ____________ Date_______________

Directions: Study the map of the western United States; use your new definition of an earthquake to explain why the earthquakes shown are located where they are.



Earthquakes of the western United States
(Sawyer, 2005)