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Earthquake Machine Lite: Activity 2 of 2

Developing Arguments about Earthquakes

www.iris.edu/hq/inclass/lesson/419

Version 1.2

Incorporated Research Institutions for Seismology
Development of model courtesy of Larry Braile (Purdue University)

OVERVIEW

The Earthquake Machine is a mechanical model used to illustrate the earthquake cycle and to investigate the behavior of fault systems.

Two groups of students are presented with separate claims about earthquakes. Using the model, students design an investigation to collect data to either refute or support their claim. After collecting evidence, the information is used to construct an argument regarding the claim. Next, students present their work to their now-knowledgeable peers for a skeptical review.

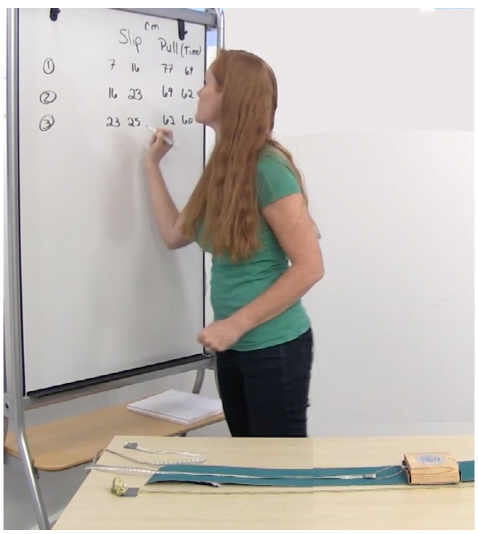


Figure 1. Recording slip and pull data during the Earthquake Machine tests.

Earthquake Machine Lite helps develop student understanding about, and experience with research methods. The simulated scientific-conference aspect of the lab allows students to experience the exciting and stimulating nature of the scientific community, to become experts on an aspect of earthquakes, and participate in the types of dialogue that create new scientific knowledge.

Intermediate

× 3
135 min

Small Group

Student Investigation

Discussion

Significant Prep

Materials

OBJECTIVES

By the end of the exercise, students should be able to::

1. Explain earthquakes as a part of the natural Earth System
2. Describe the global trends for earthquake occurrence and size.
3. Interpret a Gutenberg Richter plot (Frequency vs Magnitude)
4. Critically analyze data generated by the Earthquake Machine and use the data to develop a position
5. Describe the importance of sharing science results with peers in the science process.

TABLE OF CONTENTS

MATERIALS

- Class set of Earthquake Machine set-ups (see *Earthquake Machine Lite—Activity 1 of 2, Defining an Earthquake** for how to construct and use
- One set for each group of 3-4 students.
- Equipment to project slides.
- EQMachineActivity2.ppt

TEACHER PREPARATION*

- Please see Appendix A for Teacher Background discussion.
- Watch animations of the EQ Machine's **Time vs. Distance graph**: www.iris.edu/hq/inclass/animation/129 and **Time vs Strain**: www.iris.edu/hq/inclass/animation/131
- Print Student Worksheets
- Blank spreadsheets and graphs for data collection can be printed as needed. See Appendix B.

LESSON DEVELOPMENT

Teacher Instructions (w/ Potential Questioning Sequences**)**

This activity is structured using the "**OPERA**" system (Appendix C) and additionally offers leveled questions that will move your students from evaluating their knowledge to synthesizing new information.

*Note: The majority of the discussion of the model and the science of the activity is in Teacher Background Part I which is contained in **Earthquake Machine Lite: Activity 1 of 2—Redefining an Earthquake** (available online at www.iris.edu/hq/inclass/lesson/15). .

ACTIVITY STAGES

OPERA	Time (min)
Open	15
Prior knowledge	10
Explore/Explain	45
Reflect	35
Apply	20
TOTAL Time Est.	125 min

VOCABULARY

Earthquake—the release of stored elastic energy caused by sudden fracture and movement of rocks inside the Earth.

Elastic Rebound—an objects ability to return to its original shape after being broken apart.

Elastic Strain— a form of strain that, when the deforming force is removed, the distorted body returns to its original shape and size.

Kinetic Energy— the energy an object possesses due to its motion.

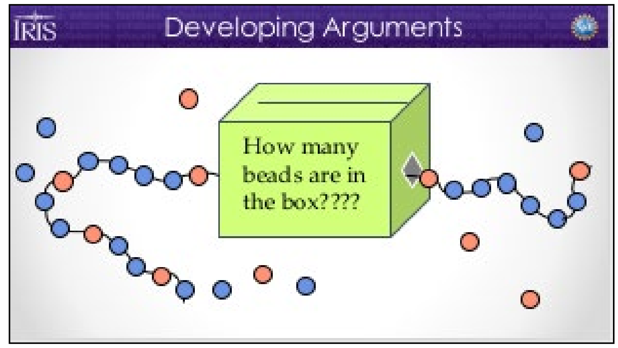
Potential Energy—the stored energy of an object due to its position or condition.

Strain—change in the shape or volume of a material, often recorded in three-dimensions. Strain is defined as the amount of deformation an object experiences compared to its original size and shape.

Stress—a measure of forces acting on a body. Stress is defined as force per unit area.

STAGE 1: OPEN

Project the "mystery box", Slide 3 of the PowerPoint presentation as students enter class (Figure 2). Students should individually develop a hypothesis for how many beads are in the box before beginning the questioning sequence below. The "mystery box" is a useful illustration to guide students as they begin to develop and analyze logical arguments.



Slide 3

Knowledge—(**Slide 3**) Ask the class:

?? *What is mean by the word "argument"?*

Answer: A reason put forward in support of a point of view.

Application— Ask the class:

?? *What would be an example of this type of an argument?*

Answer: Accept all reasonable responses.

Comprehension— Ask the class:

?? *How many beads are in the box?*

Answer: Survey the class and develop a tally on the board. There is no correct answer, but the pattern suggests that there are five blue beads in the box.

Analysis— Ask the class:

?? *Who can give me an "argument" to support their number of beads in the box?*

Answer: Accept all answers, but lead the discussion to show that a logical conclusion is that there are 5 blue beads in the box. Also discuss if there is a "right" answer and what would take to get a "right" answer.

Synthesis—Describe an experiment (without opening the box) that we could perform to help us investigate the argument.

Answer: Accept all answers but lead students to the idea that the observed information must be combined with the new information to either strengthen or weaken the argument.

STAGE 2: PRIOR KNOWLEDGE

Time permitting, discussion questions about earthquakes are in the gray box to the right.

Distribute the materials for groups of 3-4 to assemble the Earthquake Machine Lite at their lab benches. Assembly should go quickly and require few instructions since the students used it in the previous exercise.

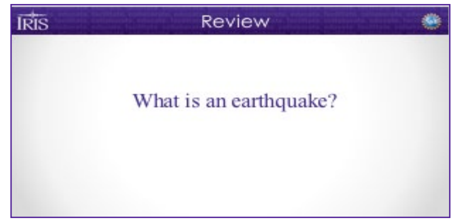
DISCUSSION QUESTIONS

1. How frequently do earthquakes occur?
2. Are all earthquakes large events?
3. How frequently do large events occur?
4. Can earthquakes be predicted?
5. How does the Earthquake Machine model compare to global data?
6. How do scientists strive for objectivity in their results?

Knowledge—(**Slide 4**)

⁇ What is an earthquake?

Answer: The sudden release of seismic energy from an elastic source, causing the Earth to vibrate as they pass.
The vibration of the Earth caused by the passage of seismic waves, radiating from some source of elastic energy

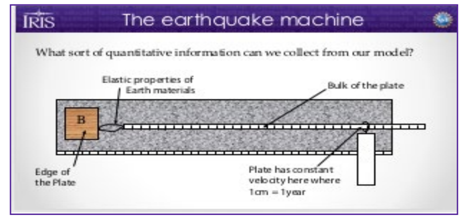


Slide 4

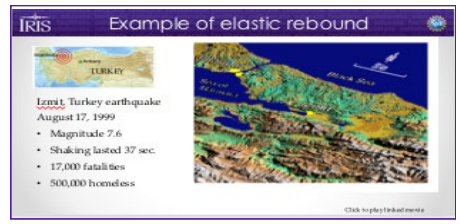
Comprehension— (**Slides 5 & 6**)

⁇ *Who can illustrate that definition using their Earthquake Machine, highlighting the key components of the machine and definition?*

Answer: Students should show at least one stick-slip event with their model and highlight the fact that energy is stored as potential energy in the rubber band and then suddenly released as kinetic energy. Some of the energy is also converted to heat via friction. This should be noted to students as this is an area that is ripe for misconception (see Teacher Background). Slide 6 shows an animation of movement across a fault.



Slide 5

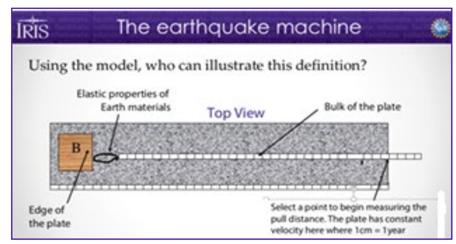


Slide 6

Application—(**Slide 7**)

⁇ *What sort of quantitative information (numeric data) can we collect from the Earthquake machine?*
(Think – Write – Pair – Share)

Note: This should be discovered by the class. We can measure:
1) how far the block slipped,
2) how far the tape measure is pulled before the block slips
3) how many events occur.



Slide 7

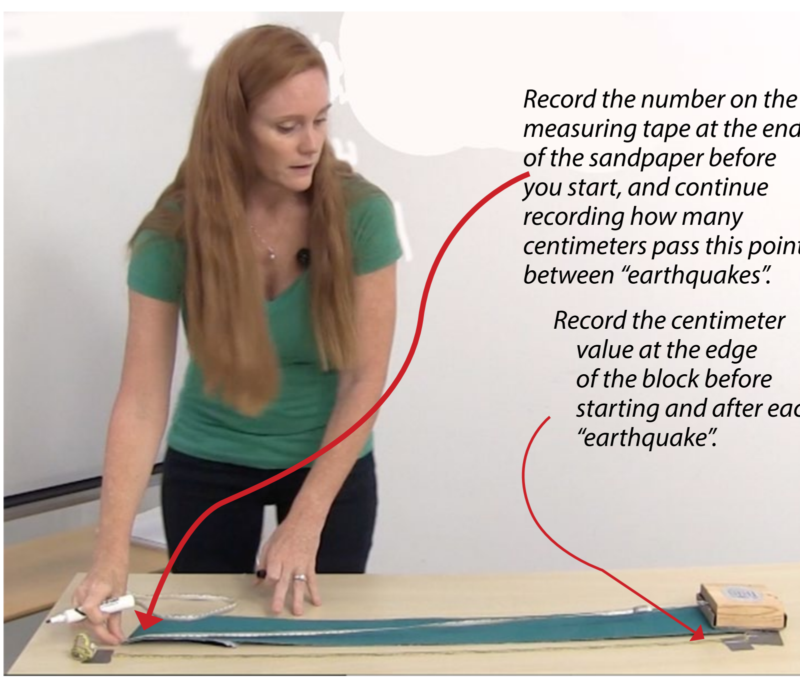
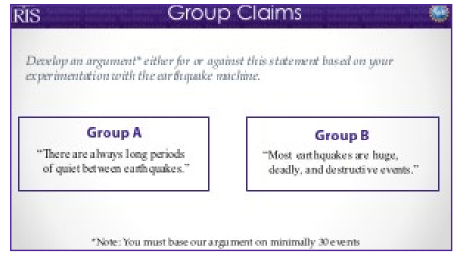


Figure 2: *Tape measure is tugged slowly and steadily.*

Using the Earthquake Machine in Stage 3

1. Measure "**<u>Time"</u>** by measuring how far the tape is pulled. In the model we assume that the measuring tape or plate, is moving at a constant rate of speed; thus distance can be converted into time. For simplicity 1 cm = 1 year is a good rate to use. (Group A data set.)
2. Measure **"Magnitude"** of the block by noting the position of the block before and after an event occurs. As described in Activity 1, in this model distance of slip is proportional to the magnitude of the event. (Group B data set.)
3. Number of Events are recorded on the spreadsheet each time the block moves, even it is only a little bit.



Slide 8

STAGE 3: EXPLORE/EXPLAIN

The goal of this section of the activity is for students to develop an argument either for or against a given statement and support their argument with data they collect using the Earthquake Machine.

Assign Groups A or B—Slide 8

Count-off the sets of students gathered at each Earthquake Machine set-up as either A or B. When finished, approximately half the class will be Group A, and the other half will be Group B.

Each set of students should be given a slip of paper with a statement on it that corresponds to their group letter:

- **Group A:** *"There are always long periods of quiet between earthquakes,"*
- **Group B:** *"Most earthquakes are huge, deadly, and destructive events."*

Instruct students to review the statement, determine which parameters, discussed previously, they think they will need to measure using the Earthquake Machine in order to test the statement. Hand out blank graphs from Appendix B according to their group. Students should have approximately 30 minutes to collect their data (a minimum of 30 data points is recommended for best results), leaving approximately 15 minutes for them to prepare a 3-minute presentation of their argument and data to the class.

This presentation must include either a graph or a data table.

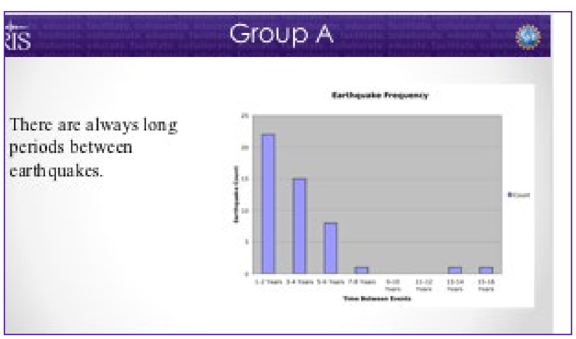
Group A:

"There are always long periods of quiet between earthquakes."

When summarizing the data for this question, begin by discussing the ambiguous phrase "long periods of quiet" and note that long is a relative term. This makes this statement open to lots interpretation and allows many answers to be potential correct depending on your perspective. It may be helpful to point out that pets lives are often much shorter than ours. For example, one year is ~1% of our lives (assuming 80 years), but for a dog that lives to be 10, this is 10% of its life.

When we look at the frequency data generated from the Earthquake Machine (**Slide 9**) to examine this statement, we see a clear trend that suggests that for the majority of the events, a relatively small period of time passes between events. In fact, it is rather rare that a longer period of 13+ years should pass without another event. Remember, the distance that the tape is pulled is converted into time (1 cm = 1 yr).

Like global earthquakes, the majority of student-generated earthquakes occur with a relatively short time interval between events.



Slide 9

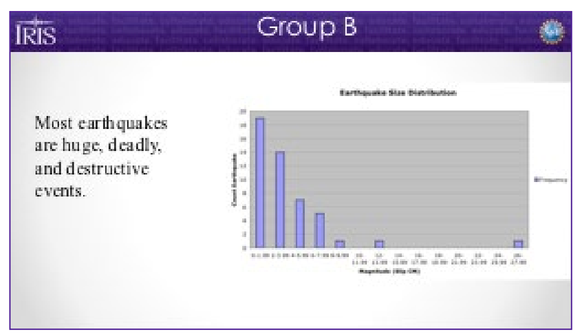
Group B:

"Most earthquakes are huge, deadly, and destructive events."

Begin this discussion by asking students to identify ambiguous terms that may affect the discussion. In this case, the qualifying terms like deadly and destructive are dependant on other factors that are controlled by people and building codes. For example, a magnitude 6 earthquake near Los Angeles may cause some damage and injure some people. If this same earthquake were to occur in Turkey along the North Anatolian fault (**Slide 6**) where building codes are much looser and/or less likely to be enforced, loss of life and property could be much greater.

When we examine the size data generated by the Earthquake Machine (**Slide 10**) we see that the majority of events that occurred were small events. This should be put in perspective for students by discussing what types of earthquakes students hear about. Most often students only hear about the large magnitude events that cause damage because of the nature of newscasts. The regularly occurring Magnitude 2's are rarely newsworthy.

Like global earthquakes, the majority of the student-generated earthquakes are relatively small events



Slide 10

STAGE 4: REFLECT

Allow each group approximately 3 minutes to present their argument and supporting data to the rest of the class (following the model of a scientific conference). A scoring rubric for student presentations is available in Appendix D

Following this report, allow 2 minutes for the audience to ask questions regarding the presentation. All arguments should be accepted but it should be emphasized that the data must support the argument.

> **Modification**: If an additional group leader is available, the class can be divided so that Group A is presenting to the rest of Group A while Group B presents only to Group B. The time saved by having the groups presenting simultaneously can be used to develop a group consensus and then giving a summary presentation to the members of the alternate group.

TIP

*Note: This is an opportunity for working with students to enhance the skills and tact necessary for giving and accepting critical analysis. The process of science as the collection of empirical data, development of logical argument and skeptical review should also be highlighted.

Analyzing Data Collected with the Earthquake Machine

The graphs in **Slides 9 and 10** were constructed from 50 data points collected using the Earthquake Machine. These should be reviewed prior to running the lab, or better yet, use data collected in **Stage 3** to help you discuss the results with your students.

Knowledge—Let's review, from our experience using the Earthquake Machine the first day.

?? *Why are models important in science?*

Answer: They can provide opportunities to explore things that may be too unsafe, expensive, small or large to explore the real things.

Comprehension—Based on your experience with the Earthquake Machine model and our exploration of the definition for an earthquake, explain how new scientific knowledge is generated and monitored.

Answer: In science, the testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to an increasingly better understanding of how things work in the world but not to absolute truth.

Application—Now after conducting additional experiments using the model and sharing your results with your peers, describe why, as a scientist it is important to attend scientific conferences.

Answer: Accept all answers but lead students to consider the role of sharing and analyzing results with other knowledgeable col-leagues. Possible answers include:

1. You provide a level of skeptical re-view for others.
2. You may receive a skeptical review of your own work that may point out possible bias.
3. You may encounter new or related ideas from others working on similar projects that could constructively add to your work thus building knowledge.
4. You could encounter new or related ideas from others that contradicts your work but still stimulates new ideas.

Synthesis—*What happens if several groups disagree? What determines whose argument is correct?*

Answer: Generally, the strongest, most logical argument as determined by the community should be correct, but it is possible that both or neither could be correct as new information about the subject is learned.

Synthesis—*What if the data supports each group's argument, where else could there be a difference between the two groups?*

Answer: Looking only at the data is not enough. The way in which the data was generated must also be considered. What were the methods each group used, were there places where they cut corners, used incorrect assumptions, or made errors?

Synthesis—*How might the sharing of results have been different if the rest of the group had never used the Earthquake Machine?*

Answer: Lead students to see that in that situation the group presenting could easily be considered "experts" because they had used the machine, but that does not put them above skeptical review. Nor does it mean that the audience can't provide meaningful critical analysis of the argument.

STAGE 5: APPLY—DISCUSSION

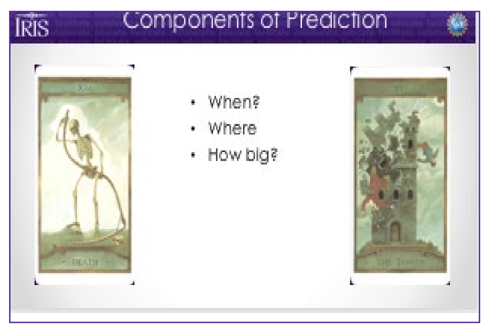
Lead a discussion with students to place the Earthquake Machine model in a context of the real world. This is further supported with the homework (Appendix B).

Knowledge—*Now that you have had lots of experience using the Earthquake Machine, which simulated the real earth, is there anyone ready to begin predicting earthquakes?*

- Answers will vary

Comprehension—(**Slide 11**) *If you were going to receive a "prediction" on TV or the internet, like you do for weather, what information would we need or want to know?*

Accept all responses, but the three aspects to earthquake prediction are size, location and time.



Slide 11

Application—*Would it be adequate for me to predict that there will be an earthquake tomorrow in California?*

This would be a pretty safe bet. The prediction is missing a level of specificity in the location, time and the size of the event.

Analysis—*What would the implications of a prediction like this be on the state and residences of California?*

Discuss the difficulties and logistics of evacuations, the cost associated with them, and the implications of an evacuation for an event that never occurs (public trust)

Analysis—*What if I improved my prediction to say there will be a Magnitude 2 earthquake, tomorrow morning on the Parkfield segment of the San Andreas fault?* Hint: think of your model.

Answer: There are more specifics given in terms of location and time, however students should realize from their Earthquake Machine that Magnitude 2 events happen several times per week! To boot, a Magnitude 2 event is not likely to cause much if any damage at all.

Synthesis—Thus, we really would like to be able to predict the large events that occur less frequently. *Based on your experience with the Earthquake Machine, can we make such predictions?* You may want to review your data to support your answer. Think – Write – Pair – Share.

Answer: The Earthquake machine generally is a slip-predictable fault model (Figure 4). This means that when an earthquake occurs on the fault the stress in the system always releases all the stored energy and the system returns to a "zero" state. Thus, this model cannot be used to predict when the next event will occur, but can be used to predict the magnitude of the earthquake if it were to occur at any given time. For example, if there has only been a short period of time after the last event, we know that the system has only had an opportunity to store a small amount of energy. Thus, if an event were to occur, we could predict just before it slipped that it would be a relatively small event. However, if a long period of time has passed since the last earthquake, we know that the system has stored a substantial amount of energy and could predict that if an event were to occur at that time, it would be a large magnitude event. Students are likely to infer this from their experience with the model but are not likely to have collected adequate data to support this theory.

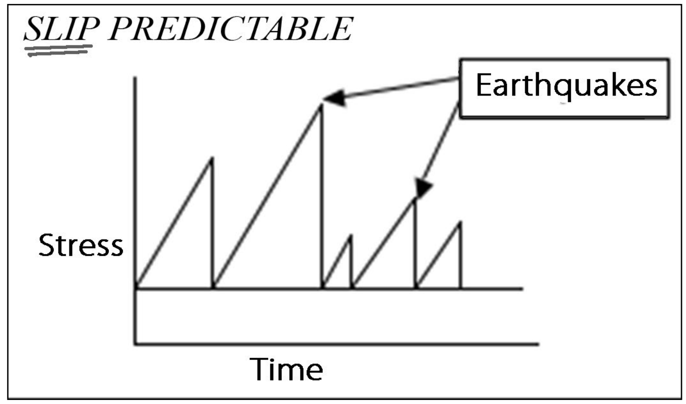


***Figure 4**: In a slip-predictable model the systems stress always returns to the same level following an event. See also Appendix A for time-predictable model.*

It is EXTREMELY important to emphasize to students that most faults DON'T behave this way, and remind students that the model is a simplification of reality. Thus, a fault may behave in a slip-predictable way for a while, and then behave in a different way. A key reason for this is that in the model the fault area is fixed, whereas on a real fault the fault area can vary from earthquake to earthquake. For more detailed discussion of this please see "*Can Earthquakes Be Predicted*": http://tremor.nmt.edu/activities/stick-slip/canpredict.htm

Synthesis—Design an experiment using the Earthquake Machine that could collect the necessary information to test their theory

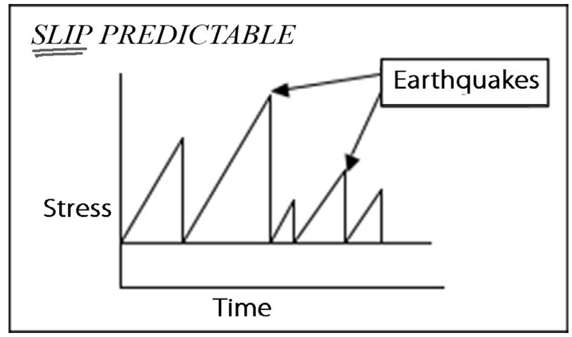
Apply – HOMEWORK

To help students compare the model and reality, assign students to complete the Student Worksheets on Pages SW-1 and SW-2.

APPENDIX A

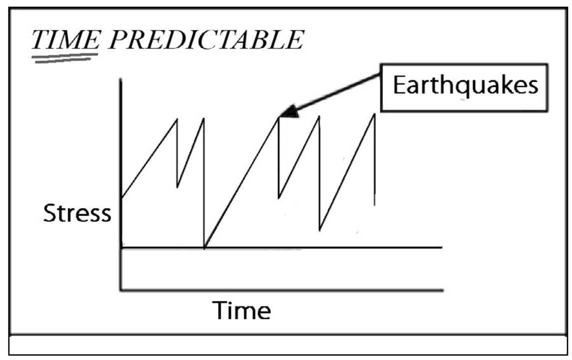
Teacher Background

Whereas exposing students to the occurrence rates, frequency of various sized events, inter-event periodicity, and predictability of earthquakes on a global scale is a major content focus of this activity, another major emphasis is developing students' understandings about and experience with the process of science. Throughout this three-period lab, there are numerous opportunities for students to analyze arguments, collect empirical data while testing an argument, and participating in the peer review process.



"Slip predictable": the stress always drops to the same level after an earthquake. Once an earthquake has occurred, then one knows that the slip during the next earthquake will be equal to the plate motion that has subsequently occurred. The longer the time since the last event, the larger the next event will be.

By the time students reach high school most have some understanding of the process of science. For example, they believe that scientific knowledge changes over time, however they typically think these changes occur mainly in terms of learning new facts and this occur mostly as the result of the invention of improved technology for observation and measurement. What they, as well as their younger peers may not recognize is that changed theories sometimes suggest new observations or reinterpretation of previous observations. Therefore hypothetical questioning, such as the sequence described in the *Reflect* phase of this lab, can help students stretch their understanding of the process of science to include some aspects they may not have directly experienced in the laboratory. Additionally, some research indicates that it is difficult for middle-school students to understand the development of scientific knowledge through the interaction between theory and observation. In the exercise, students do not directly explore the concept of earthquake prediction, however, encouraging students to construct their own theories about earthquake prediction based on their formal and informal observations can reinforce this relationship. Asking how they could test their theory for the ability or inability to predict earthquakes emphasizes the concept.



"Time predictable": an earthquake happens when the stress level reaches the same high value. The slip during each earthquake is variable, so the stress level after each earthquake is not always the same. Once the slip in one event has been measured, then it is known that the next event will happen when exactly this amount of plate motion has occurred.

This lab presents opportunities to help students develop an understanding of who scientists are and how they interact with one another. Students of all ages portray scientists as brilliant, dedicated, and essential to the world, however, when asked about science as a career, they respond with a negative image of scientific work and scientists. Throughout this laboratory, the student-as-scientist concept should be emphasized, especially since this lab, unlike many the students have experience with, does not have a correct solution that must be reached. Rather students are scientists exploring ideas, examining their data for trends and developing limited arguments based on that data. As discussed below, there are certain trends that students should see as they work with the Earthquake Machine. Thus, for this exercise, "wrong" solutions are replaced with faulty logic, and poor data collection techniques; the things that can plague a scientist.

The simulated scientific conference aspect of the lab allows students to experience the exciting and stimulating nature of the scientific community, to become experts on an aspect of earthquakes, and participate in the types of dialogue that creates new scientific knowledge.

Group A

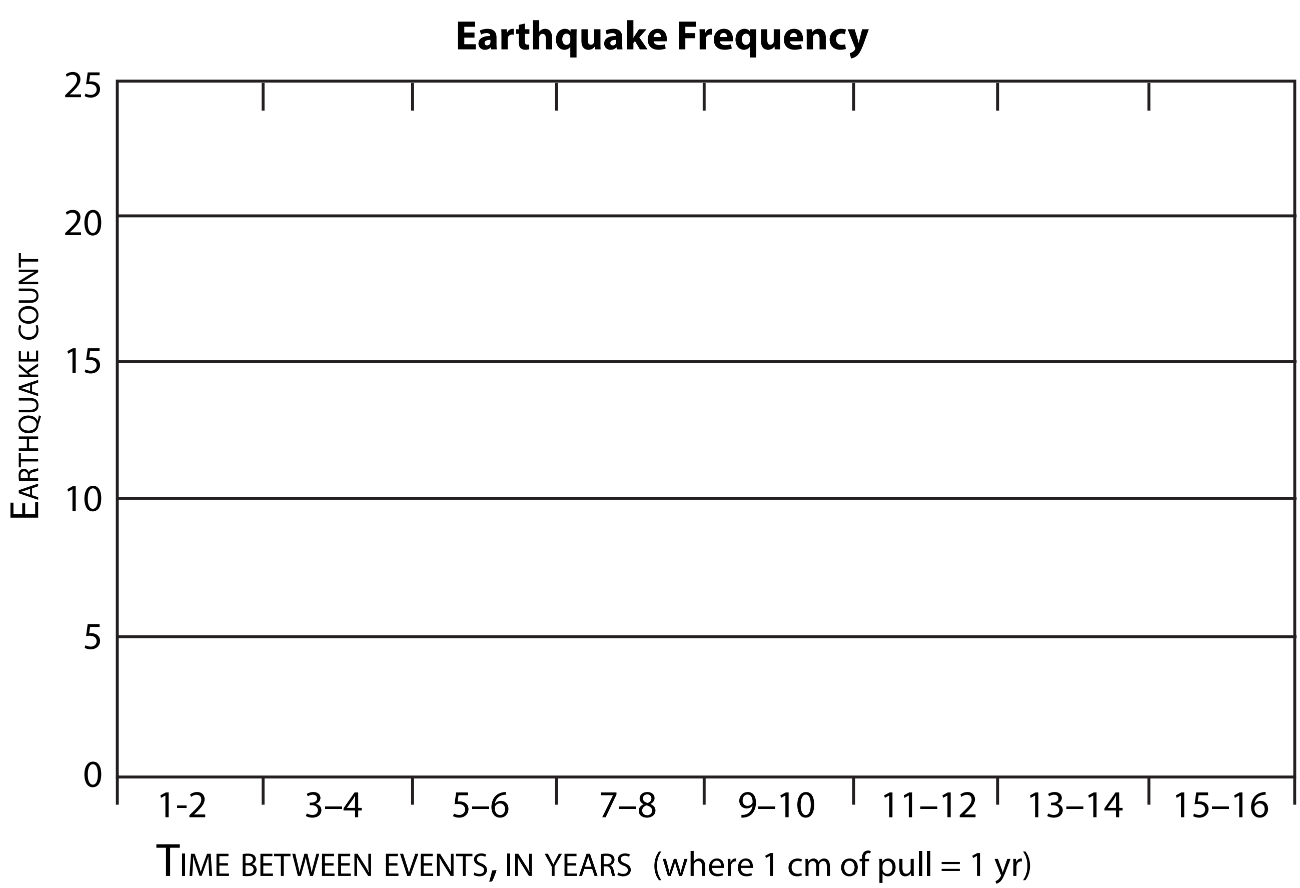
Data spreadsheet and graph

Record the amount of time (number of years, in cm) that passes between each “earthquake”.

Repeat as many times as instructed to get a good data set.

Plot the data on the graph.

Test #	Time (cm)	Test #	Time (cm)
1		16	
2		17	
3		18	
4		19	
5		20	
6		21	
7		22	
8		23	
9		24	
10		25	
11		26	
12		27	
13		28	
14		29	
15		30	



Group B

Data spreadsheet and graph

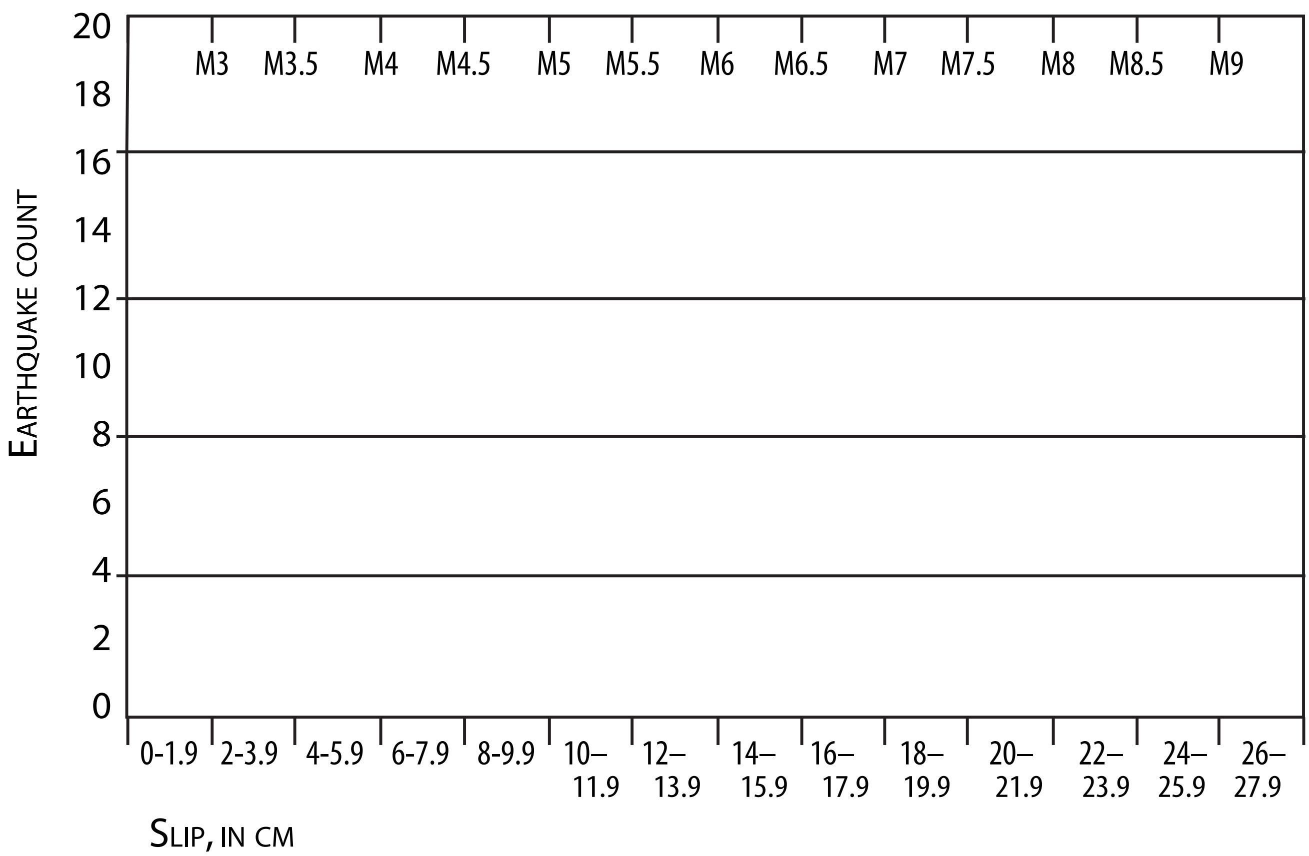
Record the "magnitude" (in cm) of each "earthquake". on the spreadsheet.

Repeat as many times as instructed to get a good data set.

Plot the data on the graph.

Test #	Slip (cm)	Test #	Slip (cm)
1		16	
2		17	
3		18	
4		19	
5		20	
6		21	
7		22	
8		23	
9		24	
10		25	
11		26	
12		27	
13		28	
14		29	
15		30	

Earthquake Size Distribution



APPENDIX C

OPERA Learning Cycle

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. This is an invitation for learning and leaves students wanting to know more.
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
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.
Apply	Practice concepts, skills and behaviors by **Applying** the knowledge gained in a novel situation to extend students’ conceptual understanding.

EQ Machine —Arguing a position Rubric

Name(s)____

	3	2	1	
Position on Statement		Exists	Absent	/2
Argument	Argument is clear and makes sense	Argument is occasionally unclear or difficult to follow	No sense of order or objective	/3
Use of Data	Examples from the data are used to support most points	Few examples from the data are used to support points	Little or no use of data to support points	/3
Graph	Student uses graphs to reinforce the position	Occasionally uses graph that somewhat supports the position	Student has a superfluous graph of no graph	/3
			Total	/11

APPENDIX E

Alignment with NGSS 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 thematrhematical 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.

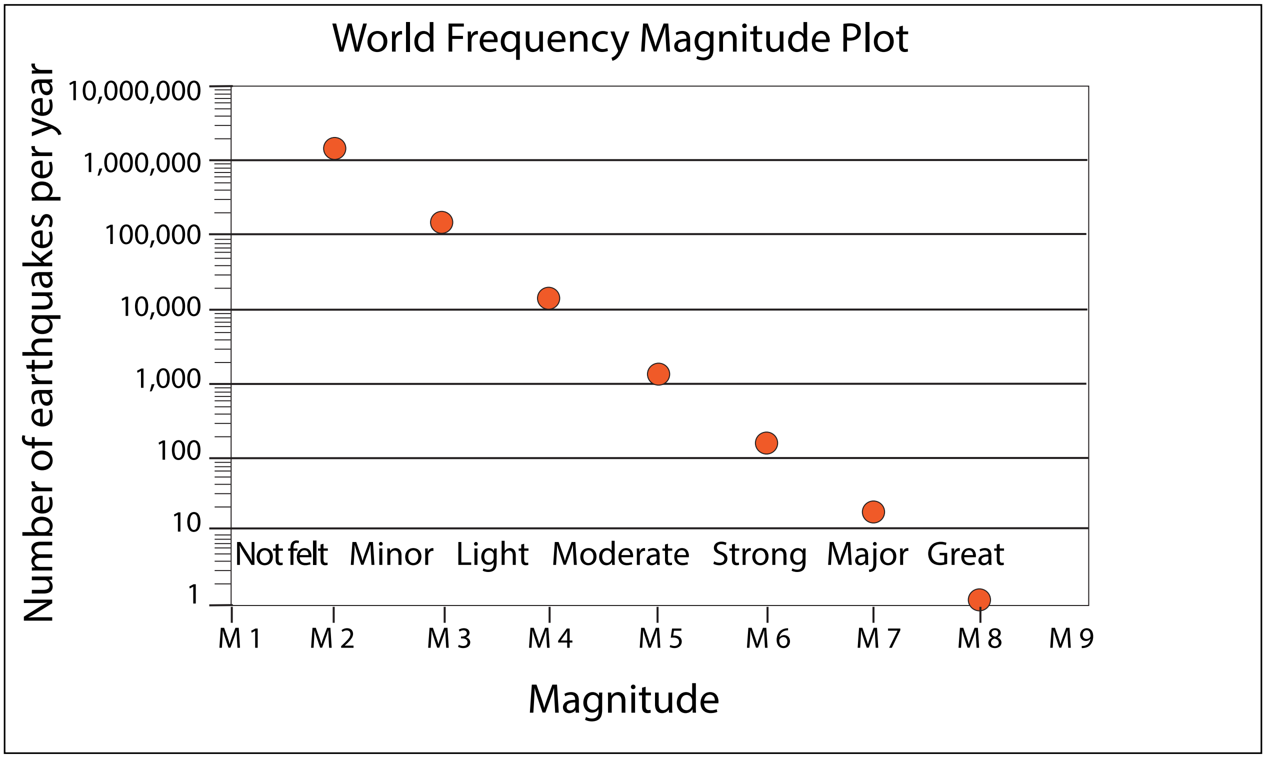
NAME: ______________________________

DATE: ______________________________

EARTHQUAKE MACHINE & EARTHQUAKES

Comparing the model & reality

Review this graph, and answer the questions using complete sentences where appropriate.



Frequency vs magnitude graph of worldwide earthquakes per year.

1. What information does the Y axis tell us?

2. What information does the X axis tell us?

3. On the Y axis, how many small lines are there between 1 and 10?

4. On the Y axis, how many small lines are there between 10,000 and 100,000?

5. With regard to question number 4 above, what is the value of each of the small lines?

6. What is the value of the small lines between 100 and 1000 on the Y axis?

7. According to the graph above, approximately how many Magnitude 8 earthquakes occur each year?

8. Approximately how many Magnitude 3 earthquakes occur each?

9. Keeping your responses to questions #5 and #6 in mind, what would be the next major line on the Y axis below the X,Y intercept?

10. If you were to extrapolate the graph by extending the slope of the line off the bottom of the graph, approximately how frequently would you expect a Magnitude 9 Earthquake to occur?

11. Is the global data shown in the graph above like or unlike the data we collected from the Earthquake Machine model? How? Give specifics.

12. Bonus! By now you have noticed that this graph has a special Y-axis, what is the name of graphs with one special axis like this?

Homework Answer Guide

1. What information does the Y axis tell us?
   A: The Y axis tells us the number of earthquakes of that occur yearly

2. What information does the X axis tell us?
   A: The X axis tells us the magnitude of the events.

3. On the Y axis, how many small lines are there between 1 and 10?
   A: There are eight small lines between 1 and 10 on the Y axis.

4. On the Y axis, how many small lines are there between 10,000 and 100,000?
   A: There are eight small lines between 10,000 and 100,000 on the Y axis.

5. With regard to question number 4 above, what is the value of each of the small lines?
   A: Each small line is equal to 10,000 earthquakes per year.

6. What is the value of the small lines between 100 and 1000 on the Y axis?
   A: Each small line is equal to 100 earthquakes per year.

7. According to the graph above, approximately how many Magnitude 8 earthquakes occur each year?
   A: One Magnitude 8 earthquake should occur annually

8. Approximately how many Magnitude 3 earthquakes occur each year?
   A: Between 100,000 and 200,000 Magnitude 3 earthquakes should occur each year.

9. Keeping your responses to questions #5 and #6 in mind, what would be the next major line on the Y axis below the X,Y intercept?
   A: The next major line on the graph below the X,Y intercept on the graph should be 0.1 earthquakes per year.

10. If you were to extrapolate the graph by extending the slope of the line off the bottom of the graph, approximately how frequently would you expect a Magnitude 9 Earthquake to occur?
    A: One would expect 0.1 Magnitude 9 earthquakes to occur each year, or one every ten.

11. Is the global data shown in the graph above like or unlike the data we collected from the Earthquake Machine model? How? Give specifics.
    A: The data from the Earthquake Machine is quite similar to the global data set. Using the Earthquake Machine we saw that we had a variety of different sized events occur, but there were significantly more small events than large ones. The same thing happens globally as shown by the graph. There are many, many more small events than large ones.

12. Bonus! By now you have noticed that this graph has a special Y-axis, what is the name of graphs with one special axis like this?
    A: Semi-Log Plots

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