ShakeAlert™
Version of activity from:
IRIS
www.iris.edu/earthquake

Earthquake Machine Model: Activity 2 of 2*

Investigating an earthquake's frequency and magnitude

Version 2.0

Incorporated Research Institutions for Seismology (www.iris.edu/earthquake) activity modified with permission for ShakeAlert (www.shakealert.org). See link in footnotes for educator version.

OVERVIEW

The *Earthquake Machine* (Figure 1) is a mechanical model used to illustrate the earthquake cycle and to investigate the behavior of fault systems.

Two groups of learners are presented with separate claims about earthquakes. Using the model, learners design an investigation to collect data (Figure 2) to either refute or support their claim. After collecting evidence, the information is used to construct an evidence-based response regarding the claim.

The *Earthquake Machine* can be used to demonstrate:

A) magnitude: how far the sandpaper block moves when friction is overcome by the strain of a rubber band pulling on the block and

B) time indicating earthquake frequency: how far the rubber band stretches before the sandpaper block moves. In this investigation, one cm = one year.

OBJECTIVES

Learners should be able to:

- Explain earthquakes as a part of the natural Earth system
- Describe the global trends for earthquakes.
- Critically analyze data generated by the *Earthquake Machine* and use the data to develop an evidence-based response regarding the claim

AUDIENCE

The hands-on manipulation and graphing of this model could be done with most any novice geoscience learning group from late elementary through secondary, or even early college.

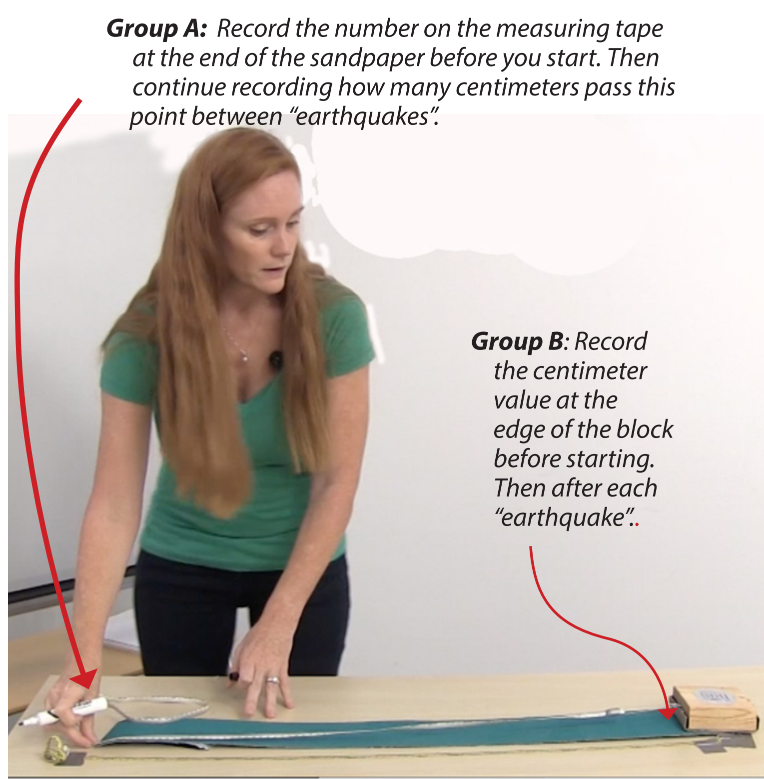


Figure 1: *Dr. Wendy Bohon demonstrates the Earthquake Machine setup with sanding belt duct taped to desk. One tape measure is taped to table adjacent to the duct tape. Groups collect data from opposite ends. Tape measure is tugged slowly and steadily.*

*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/video/583

MATERIALS

- Class set of *Earthquake Machine* set-ups (see *Activity 1: Defining an Earthquake* for how to construct and use the model: www.iris.edu/hq/inclass/video/583
- One model setup for each group of 3-4 learners.
- Equipment to project data graphs.
- Direction sheets for Groups A and B (Pages 5–9)

INSTRUCTOR PREPARATION*

- Appendix A has Instructor background for claim statements for Group A and B.
- Watch video describing this activity: www.iris.edu/hq/inclass/video/584
- Watch two animations of graphing:
  Time vs. Distance:
  www.iris.edu/hq/inclass/animation/129
  Time vs Strain:
  www.iris.edu/hq/inclass/animation/131
- Print Learner Direction sheets (Pages 5–9)

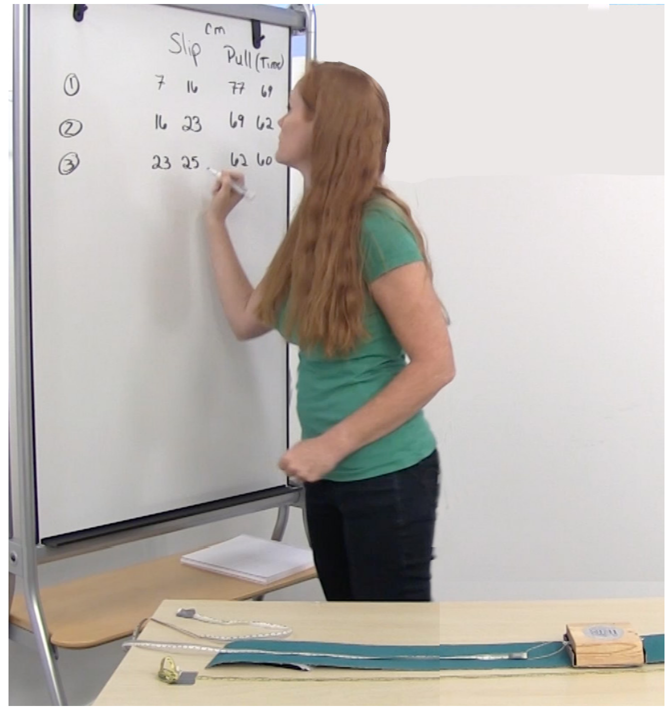


Figure 1. *Recording slip and pull data during the Earthquake Machine tests. Screen grab from the video:* www.iris.edu/hq/inclass/video/584

ACTIVITY DEVELOPMENT

The goal of this section of the activity is for learners to develop an evidence-based response regarding the claim using data they collect using the *Earthquake Machine*

Stages

1. Demonstrate the model as you review the components of the *Earthquake Machine* Model:
   - The sandpaper represents the contact between one plate and another plate
   - The moving block represents an earthquake
   - The distance the block moves is the "magnitude"
   - The block of wood, rubber band and pulling measuring tape represents a single tectonic plate
   - The wood block represents the edge of the edge of the plate that is locked
   - The rubber band represents the elastic materials that are storing potential energy inside the Earth as stress is applied (Vocabulary, Appendix C)
   - Pulling on the measuring tape represents the force causing the plate to move

2. With claim statements on a data projector or board, discuss each claim statement using the instructor background information found in Appendix A (Page 11)

   Statement A: *"There are always long periods of quiet between earthquakes,"*

   Statement B: *"Most earthquakes are huge, deadly, and destructive events."*

3. If this activity is being used in a classroom, use existing lab table arrangements of student learners. One *Earthquake Machine* should be available for each lab table.

   Instruct teams at each table to divide in half. One half, Group A will investigate Claim Statement A. The other half, Group B, will investigate Claim Statement B both with the *Earthquake Machine*.

Instruct learners 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.

For example:

Group A will measure "*Time*" indicating earthquake frequency.

Group B will measure the "Magnitude" of the earthquake events.

(Alternatively, the entire class can investigate both statements and discuss the findings together.)

4. Distribute direction sheets, blank data table, bin/ grouping table, and graph to groups A and B at each table.
5. Have one learner from each team pick up the materials for the model. Teams will assemble their models. Review directions for supplies, assembling the *Earthquake Machine*, and running the investigation.
6. Run the experiment/investigation.
7. Present and discuss the outcomes.

Options for discussing findings about the two statements:

a) The entire class can discuss both statements and discuss the findings together.

b) All Group A members of the teams can get together to discuss their findings, and All Group B members can do the same. Then, learners assigned to each Group will present their response to their investigative question to the entire class using the graph of their investigation.

Use a data projector to display learners' graphs as they present their argument.

Note: The prepared graphs in Appendix B (Page 12) may also be used.

8. Lead a discussion with learners to place the *Earthquake Machine* model in a context of the real world. Guiding questions:

- How frequently do earthquakes occur?
- Are all earthquakes large events?
- How frequently do large events occur?
- Can earthquakes be predicted?
- How does the *Earthquake Machine* model compare to global data?
- What challenges do scientists and emergency managers face when trying to prepare for and recover from earthquakes??

- **Optional claim statement for discussion**: *"There hasn't been an earthquake in a long time, therefore the next one will be huge."*

Note: This question is asked at 7min 55sec into this video: www.iris.edu/hq/inclass/video/584

To respond to this claim, you have to see how often large earthquakes occur. To do this, you would need to combine data from earthquake frequency and magnitude into one new graph. This is done by plotting Group A's X-axis frequency data (Column C from the "Data Table for Earthquake Frequency") against Group B's Y-axis magnitude data (Column C from the "Data Table for Earthquake Magnitude") on the blank graph provided on page 10 (a combined example can be found in Appendix B, page 13). .

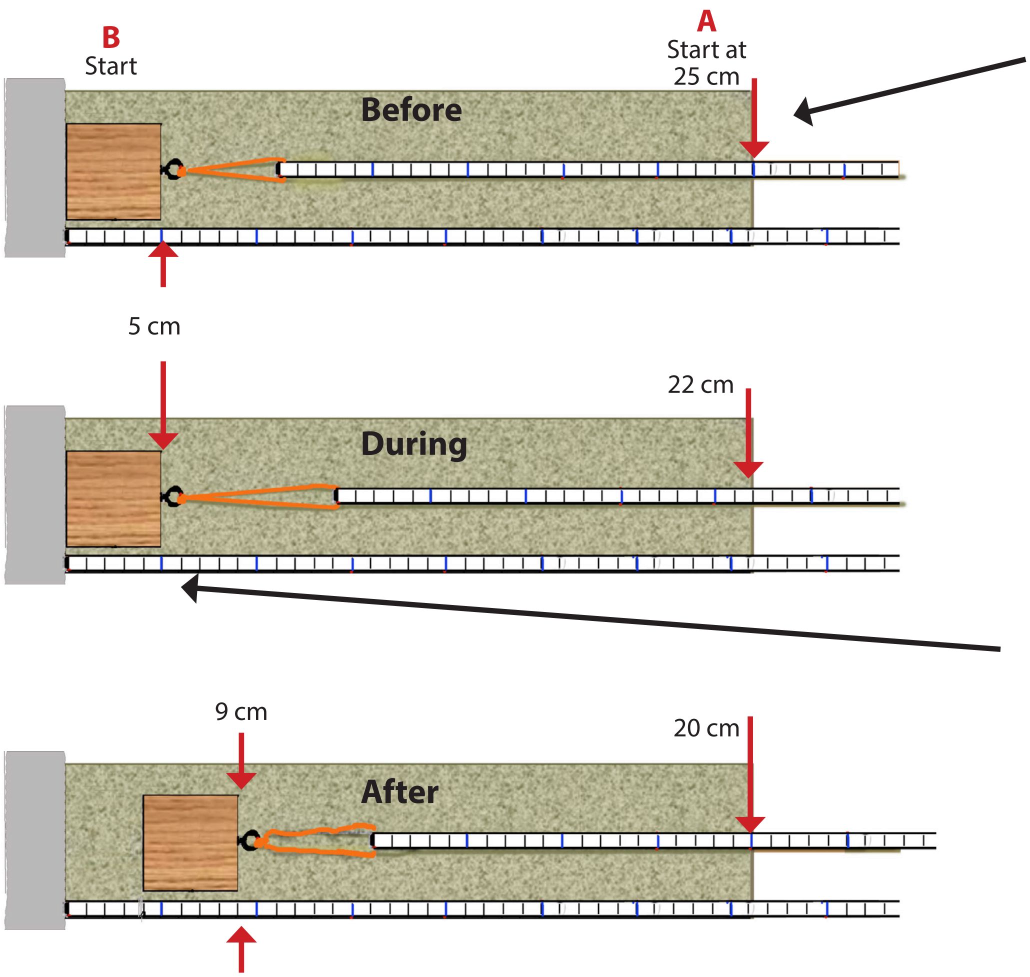
By analyzing the graph, learners can see that large earthquakes are infrequent. It is important to note that earthquake history on known faults help us understand why earthquake preparedness is critically important.

9. **Additional options** for investigation and discussion using the *Earthquake Machine* include changing the friction along the fault surface, and a two block model. For more ideas, please watch all of video Segment 5:

www.iris.edu/hq/inclass/video/584).

Figure 3: *Instructions for before-and-after measurements for groups A and B. Sample graphs of a 30-sample investigation are in Appendix B.*

Using the *Earthquake Machine* in Stage 5



Group A Data:

Measure "**Time**" 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. In this case, it translates to 5 years.

Group B data:

Measure **"Magnitude"** of the block by noting the position of the block before and after an event occurs. In this model distance of slip is proportional to the magnitude of the event. Thus, if 1 cm = M 1, then 4 cm = M 5, or a magnitude of 5.

NOTE: Events are recorded on the data tables *each* time the block moves, even it is only a little bit. See these measurements in the sample data tables below.

Examples of data tables for each group:

Data Table A:

	A	B	C
EQ Event	Starting cm of the rubber band *before* block moves	Ending cm of the rubber band *after* block moves	# of cm/yrs rubber band stretched
1	Ex: 25 cm	Ex: 20 cm	5 cm
2	20 cm		
3			

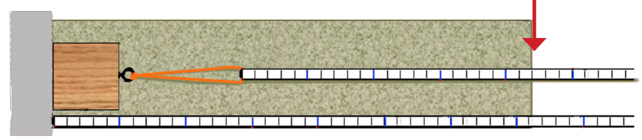
Data Table B

	A	B	C
EQ Event	Starting cm before block moves	Ending cm after block stops	Distance Trav-eled for this event in cm
1	Ex: 5 cm	9 cm	4 cm
2	9 cm		
3			

LEARNER DIRECTIONS

Group A: Time indicates earthquake frequency

Record this starting measurement in Column A of the ***Data Table***



After the block jumps, record the new cm in Column B of the ***Data Table***

Run the investigation:

- Set up the Earthquake Machine by taping the sandpaper strip to the table. Tape a meter stick or measuring tape next to the sandpaper strip. Place the block on the end of the sandpaper strip.
- Record the distance from the leading edge of the block to the edge of the sandpaper, or a fixed mark on the sandpaper or table top in Column A of the Data Table.
- Slowly pull the measuring tape attached to the rubber band until the stress of the stored potential energy in the rubber band overcomes the friction of the block stuck to the sandpaper strip resulting in movement indicating an earthquake.
- Record the distance of the measuring tape moved at the end of the sandpaper strip. (Data table column B)
- Continue pulling and recording until you have completed 30 tests.
- Subtract cm in column B from A (A – B = C) to find the distance the measuring tape and rubber band stretched before the block moved or earthquake event. (Data table column C)

Group the data:

Using the data from column C indicating the frequency of earthquakes in cm = years, bin or group the data by 2 year intervals. For example, there might be 10 events that moved 0 to 2 cm/years.

Graph the data:

Make a bar graph displaying the data you just binned/grouped. Number of earthquakes are on the y axis, and time between earthquakes are on the x axis of the graph.

Analyze the data and prepare a response:

Study the bar graph. Where do most of the earthquakes occur? Prepare a response to the original investigative statement: "There are always long periods of quiet between earthquakes?" Be prepared to make a presentation to the class using your graph.

Group A

Data Table for Earthquake Frequency (How far the rubber band stretches before the block moves indicating an earthquake event). Note: Each cm represents 1 year.

	A	B	C
EQ Event	Starting cm of the rubber band *before* block moves	Ending cm of the rubber band *after* block moves	# of cm/yrs rubber band stretched
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
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23			
24			
25			
26			
27			
28			
29			
30			

Bin/Group Frequency data (Column C from Data Table) into 2 cm/yr categories.

Time between EQ events (distance rubber band stretched in cm/yrs)	# of EQ events in this category
0-2	
3-4	
5-6	
7-8	
9-10	
11-12	
13-14	
15-16	
17-18	
19-20	
21-22	
22-23	
23-24	

Graph your data

Title: **Earthquake Frequency**

y axis label: Number of Earthquakes

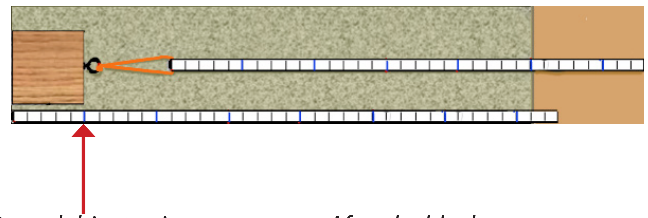
x axis label: Time between Earthquake

LEARNER DIRECTIONS

Directions for Group B: Earthquake Magnitude

Run the experiment/ investigation:

- Set up the Earthquake Machine by taping the sandpaper strip to the table, and taping a meter stick or measuring table next to the sandpaper strip. Place the block on the end of the sandpaper strip.
- Record the distance from the leading edge of the block using the measuring tape or meter stick next to the sandpaper strip. (Data table column A)
- Slowly pull the measuring tape attached to the rubber band until the stress of the stored potential energy in the rubber band overcomes the friction of block stuck to the sandpaper strip resulting in movement indicating an earthquake.
  NOTE: Record all events including very small movements of the block.
- Record the distance of the block moved using the measuring tape or meter stick taped to the edge of the sandpaper strip. (Data table column B)
- Continue pulling and recording until you have completed 30 tests.
- Subtract cm in column A from B to find the distance the block moved or earthquake event. (Data table column C)



*Record this starting measurement in Column A of the **Data Table***

*After the block jumps, record the new cm in Column B of the **Data Table***

Group the data:

Using the data from column C indicating the magnitude of the earthquake event, bin or group the data by 2 cm intervals. For example, there might be 10 events that moved 0 – 1.99 cm.

Graph the data:

Make a bar graph displaying the data you just binned/ grouped. Number of earthquakes are on the y axis, and time between earthquakes are on the x axis of the graph.

Analyze the data and prepare a response:

Study the bar graph. Where do most of the earthquakes occur? Prepare a response to the original investigative statement: *"Most earthquakes are huge, deadly, and destructive events."* Be prepared to make a presentation to the class using your graph

Group B

Data Table for Earthquake Magnitude (how far the block moves)

	A	B	C
EQ Event	Starting cm before block moves	Ending cm after block stops	Distance Traveled for this event in cm
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			

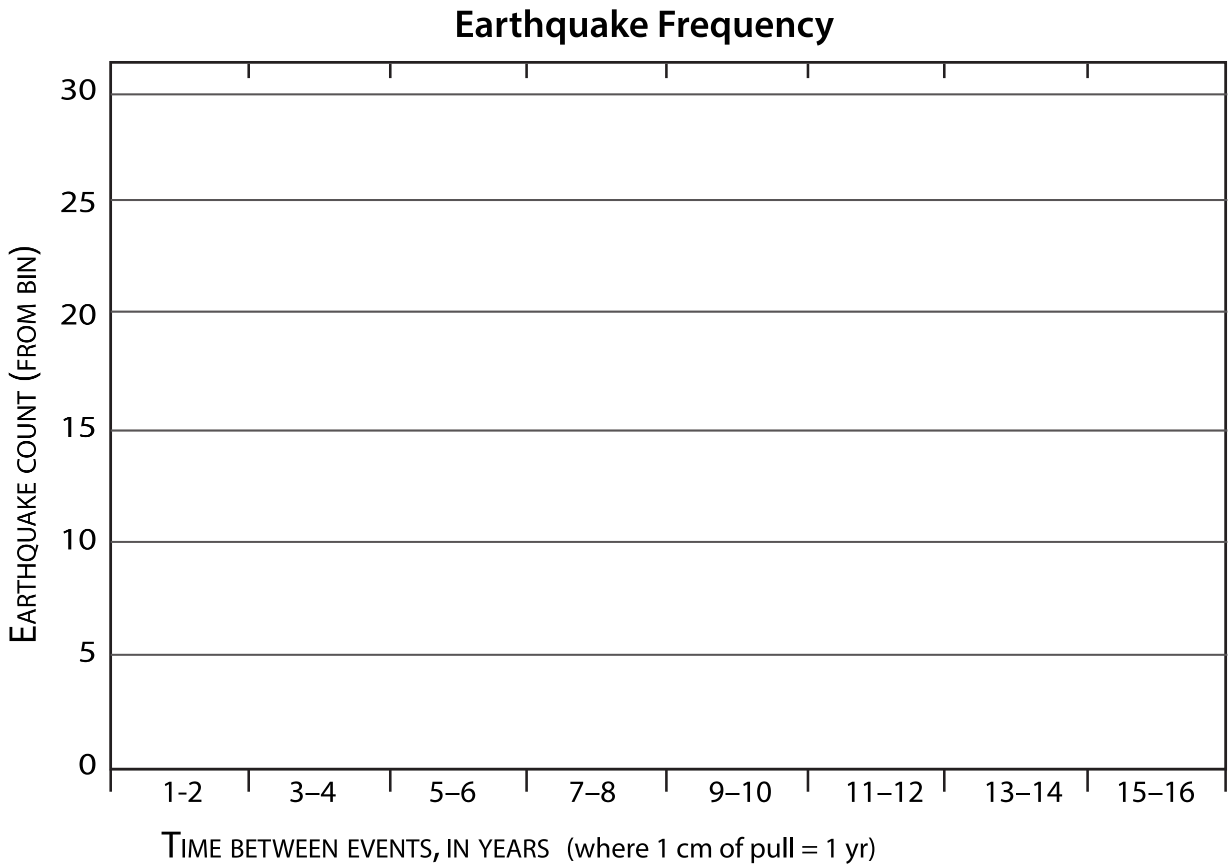
Bin/Group Magnitude data (Column C from Data Table) into 2-cm categories.

Distance Traveled for this event, in cm	# of Earthquake events in this category
0 – 1.99	
2 – 3.99	
4 – 5.99	
6 – 7.99	
8 – 9.99	
10 – 11.99	
12 – 13.99	
14 – 15.99	
16 – 17.99	
18 – 19.99	
20 – 21.99	
22 – 23.99	
24 – 25.99	
26 – 27.99	
28 – 29.99	

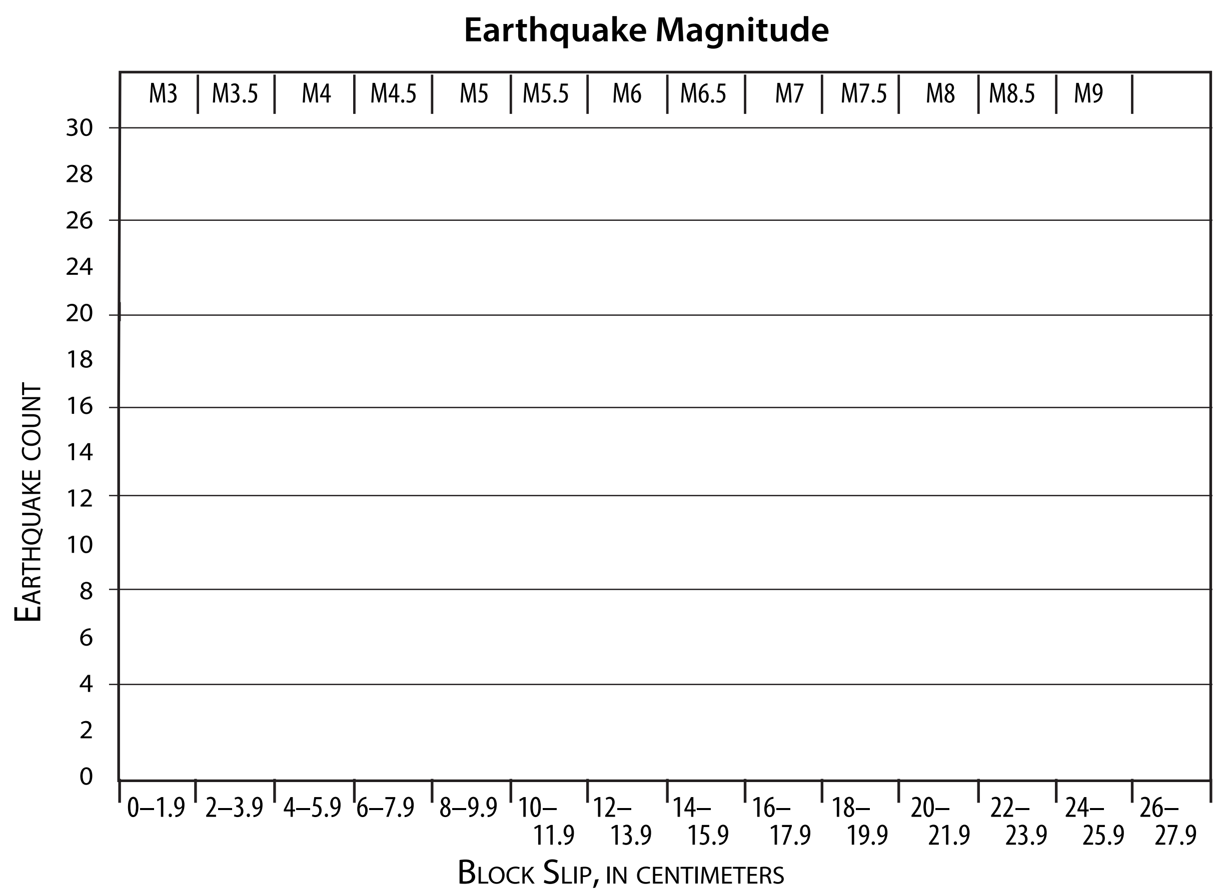
Graph your data

Graph title: **Earthquake Magnitude**
y axis label: Number of Earthquakes
x axis label: Magnitude (movement in cm)

Group A Graph

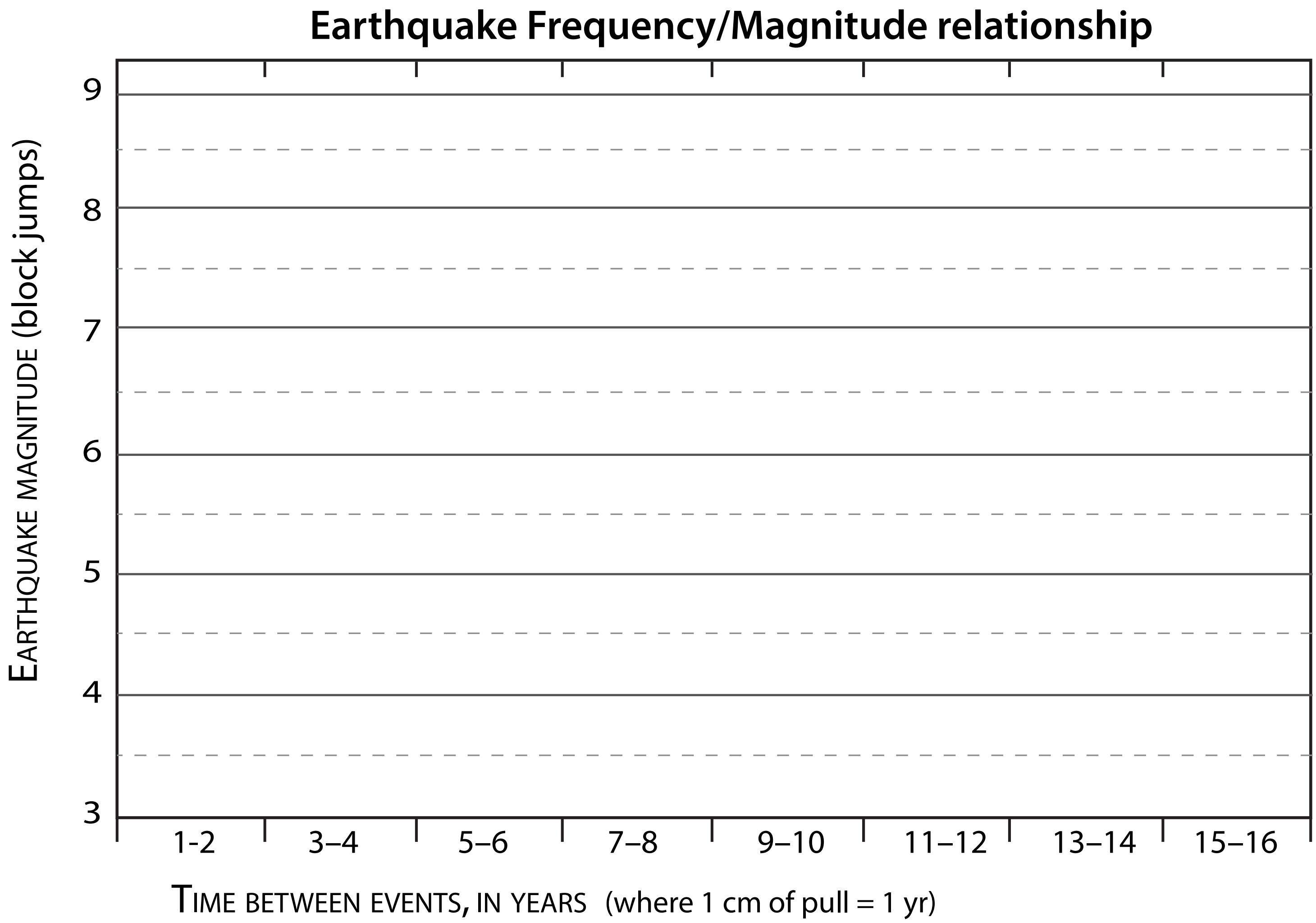


Group B Graph



Blank Graph for plotting Group A (time) on X axis against Magnitude (block jumps) on Y axis

See Appendix B Sample graph of page 13 for example.



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 potentially 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* 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 learner-generated earthquakes occur with a relatively short time interval between events.

Group B:

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

Begin this discussion by asking learners to identify ambiguous terms that may affect the discussion. In this case, the qualifying terms like deadly and destructive are dependent 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 where building codes are much looser and/or less likely to be enforced, loss of life and property could be much greater.

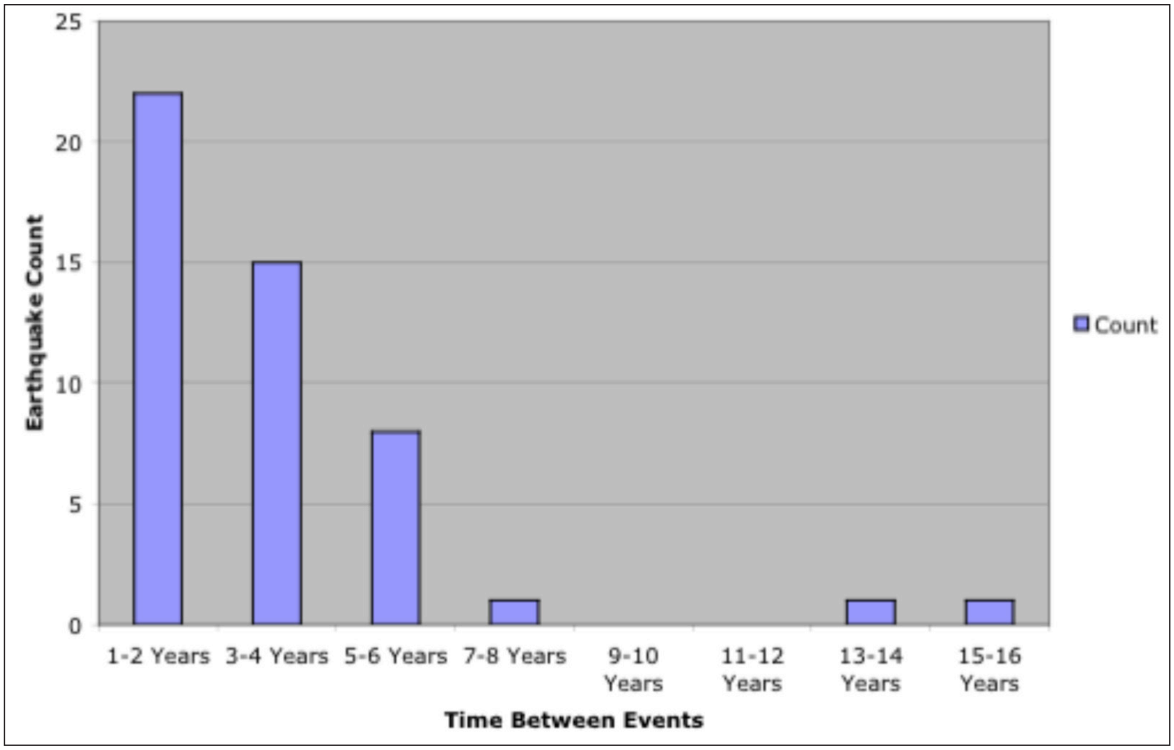
When we examine the size data generated by the *Earthquake Machine* we see that the majority of events that occurred were small events. This should be put in perspective for learners by discussing what types of earthquakes learners hear about. Most often learners only hear about the large magnitude events 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 learner-generated earthquakes are relatively small events.

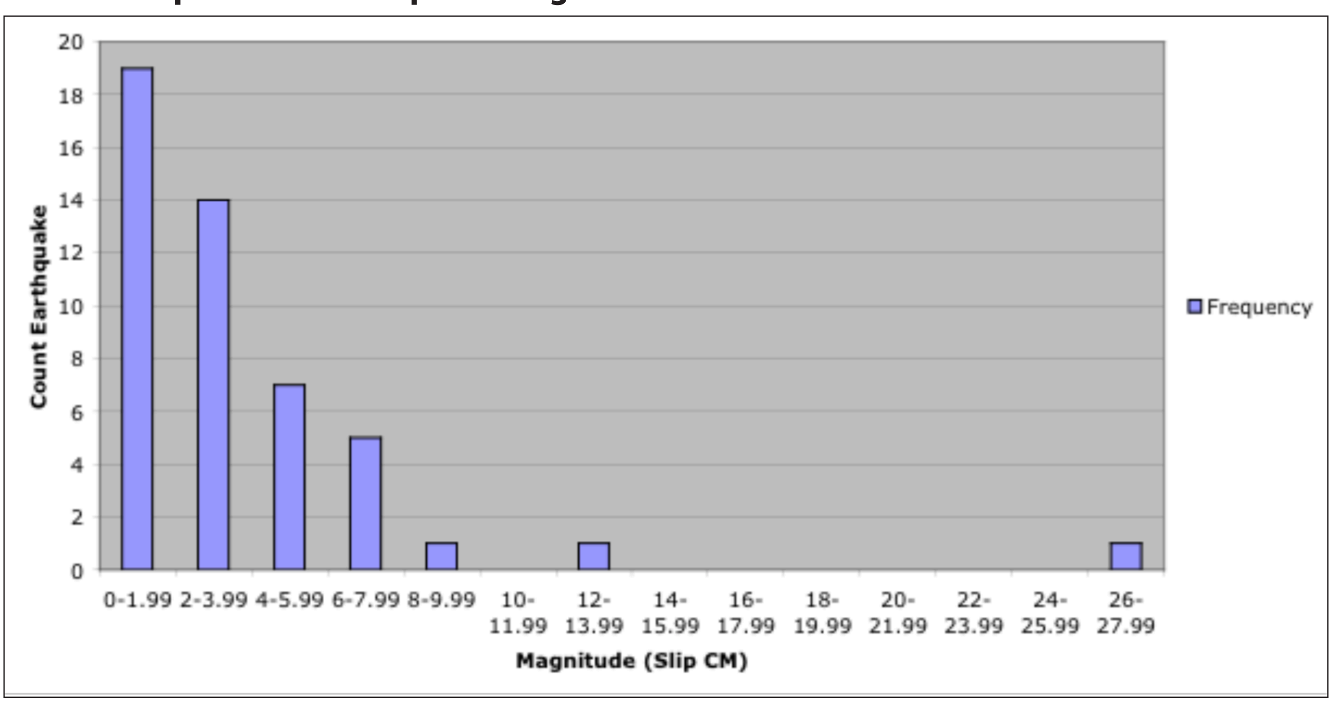
APPENDIX B—SAMPLE GRAPHS

These graphs use a compilation of 50 tests using the *Earthquake Machine*.
See next page for combined data that plots earthquake frequency against earthquake magnitude.in a single graph

Example for Group A data: Earthquake Frequency

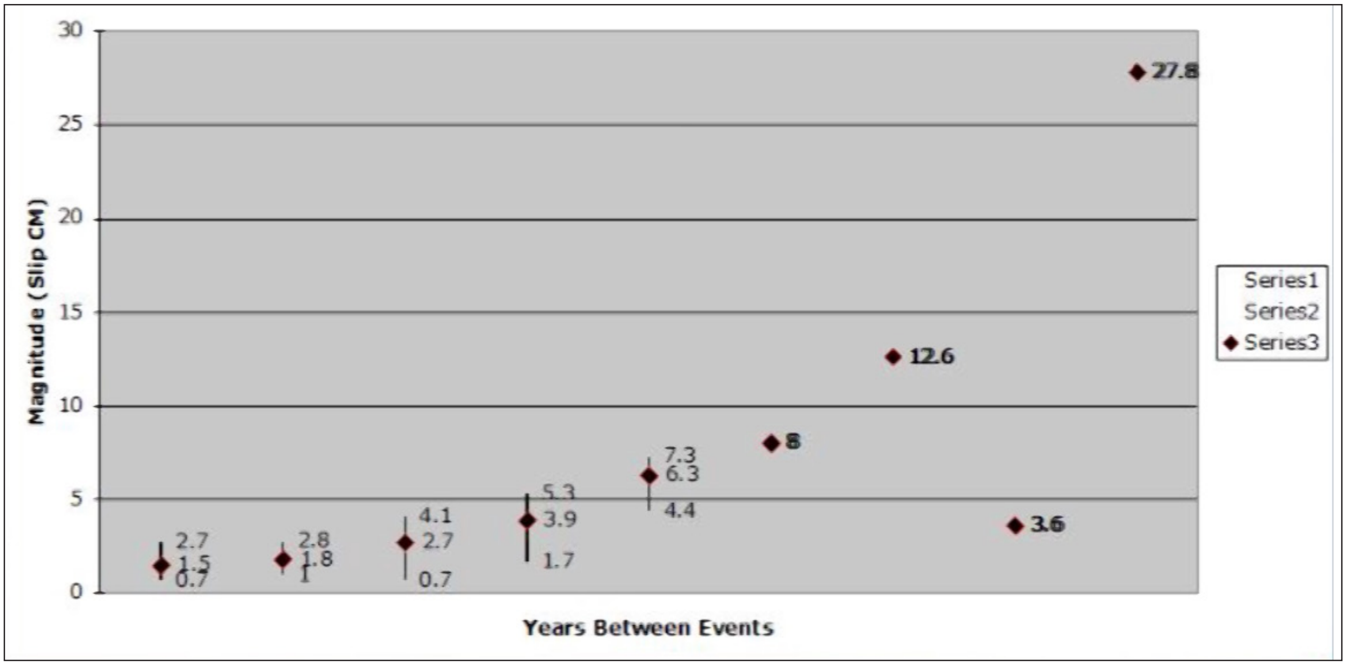


Example for Group B data: Earthquake Magnitude



Data from previous page combined into a single graph. Years (Group A, time in centimeters) on X axis; Magnitude (Group B, distance block jumped on the Y axis)

Frequency/Magnitude relationship



APPENDIX C—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.

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.

Touch the url links to get more information

Motion and Stability: Forces and Interactions

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.
http://ngss.nsta.org/DisplayStandard.aspx?view=dci&id=54

Science and Engineering Practices

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

Disciplinary Core Ideas

PS2.A: Forces and Motion
The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.

All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

Crosscutting Concepts

Stability and Change
Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.