Earthquake science: Turning students into seismologists

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Scripps Classroom Connection

The Scripps Classroom Connection is based on a close collaboration between Scripps Institution of Oceanography (SIO), a world-class research institute in Earth and ocean science, and the San Diego Unified School District, the 8th largest urban school district in the US. Graduate students are given the opportunity to practice and improve their communication skills, while local high schools are provided with content experts to work with teachers and students in earth and environmental science classes. Earth Science literacy is fundamental for future success in effective stewardship of our planet and students need to understand how Earth works as an integrated chemical, physical, and biological system. Key efforts and outcomes of SCC include: (1) Development of an enduring, pedagogically-robust curriculum in Earth Sciences through a collaboration between scientists, teacher-educators, teachers and graduate students; (2) Training of a new breed of graduate students equally comfortable communicating their science to their specialist peers and to lay audiences; and (3) Effectively raising Earth Science literacy in schools.

San Diego School of Creative and Performing Arts

These activities were implemented in 9th grade Earth Science classes at the San Diego School of Creative and Performing Arts (SCPA). SCPA is a comprehensive and culturally diverse Title I magnet school serving students with a primary focus in the arts. Students are selected for the earth science class based on demonstrated dificulties in previous math classes.

This Project

We have developed and implemented a three week curricular unit on earthquakes. This unit followed a unit on plate tectonics and covers three specific topics:

1) Earthquakes, faults, and the relationship between these and plate boundaries
2) Recording earthquakes and using seismic data to determine earthquake location and size
3) Earthquake hazards, forecasting, and safety

In this poster, we highlight two student-centered activities focusing on how earthquakes occur and how earthquakes are recorded and studied by seismologists.

Education Standards

This curricular unit addresses the following standards:

California, 3d: *Students know why and how earthquakes occur and the scales used to measure their intensity and magnitude.*

California, 9b: *Students know the principal natural hazards in different California regions and the geological basis of those hazards.*

Earth Science Literacy Principles, 4.5: *Many active geological processes occur at plate boundaries.*

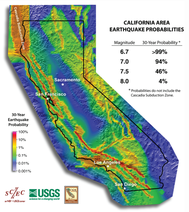
Earth Science Literacy Principes, 8: *Natural hazards pose risks to humans.*

Seismic Hazard in California

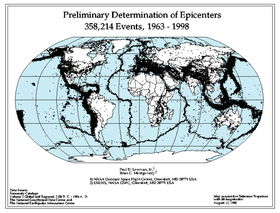
California is likely to have a significant earthquake affecting a highly populated region in the next 30 years. The latest forecast from the Working Group on California Earthquake Probabilities identifies several major faults capable of having M 6.7 or larger earthquakes.

Preparing the public for such an event is an important aspect of seismology.

The Great California ShakeOut each October is working to improve public awareness of how to prepare for and respond in an earthquake. See http://www.shakeout.org/ for more information.



Earthquakes: Where, Why, How?



Earthquake locations tend to be on or near the boundaries of tectonic plates. This realization was a key part of developing the theory of plate tectonics.

Elastic rebound describes the sudden return of deformed rock to its undeformed shape. In this pictorial example, the tectonic plates move relative to each other and cause the fence line to deform with time.

At some point, an earthquake occurs and the fault surface ruptures. The two plates now show a complete offset at the surface, as indicated by the break in the fence line.

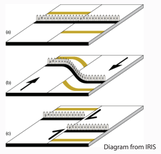


Diagram from IRIS

A photograph of a fence in Pt. Reyes shows a clear example of this following the 1906 San Francisco Earthquake (M 7.7 to M 8.3, magnitude uncertain due to lack of data).

Photo from USGS

Friction is important in considering how earthquakes occur. If faults were frictionless, then the plates would simply slide past each other smoothly. With friction, stress builds up on the plates until at some point this is overcome in an earthquake.

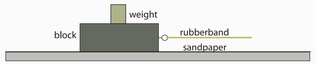
This activity begins with introductory questions directing the students to think about friction and elasticity:

1) Why did the polar bear slip and fall? What evidence in the photo suggests this?
2) Rub your palms together quickly. What happens?
3) Imagine stretching a rubberband between your hands (without breaking it!) and then letting go of one side. Why doesn't the rubberband stay stretched?

Materials for Experiment

- Sheets of sandpaper
- Tape
- Thumbtacks
- Wooden board
- Rubber bands of various strengths
- Weights
- Wooden block with eyehook
- Yardstick
- Motion detector or other means of measuring motion

Experimental Setup and Procedure



a. Pull the block along the strip of sandpaper by advancing the end of the rubber band at a constant speed.

b. Using a motion sensor, measure the position of the block as it moves. Sometimes the block will stay in the same place while the rubber band stretches, but sometimes the block will move.

c. Record what set of sandpaper, rubberband, and added weight were used. Copy the data table from the motion sensor.

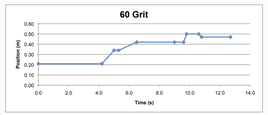
d. Plot the motion of the block versus time. (This activity can be modified to use a yardstick instead of a motion sensor, in which case the position of the end of the rubberband is recorded instead of time.)

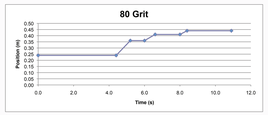
e. Repeat for 3 additional trials using a different rubber band, type of sandpaper, or weight on top of the block.

Example Results and Analysis Questions

Students are asked to analyze their resulting graphs and compare the motion of the block under varying conditions. The block should move in jumps of varying size, similar to faults producing earthquakes of different sizes (rather than always having repeatable motion).

Students are asked to consider what would happen if the contact between the block was smooth rather than rough. This is analagous to somewhat unique conditions on a section of the San Andreas Fault where very few earthquakes occur and the fault *creeps* rather than producing earthquakes.





Extension of Experiment

Faults are not smooth surfaces and the amount of friction on the fault surface is not the same everywhere. Instead, faults are subject to varying amounts of stress on surfaces with different frictional properties.

With our experimental setup, we can create a better model of a real fault by pulling the block along a strip with varying types of sandpaper.

Students are asked to predict how the block will move in this situation, and then consider how this experiment models actual fault movement.

Working with Seismic Data

Recording Earthquakes

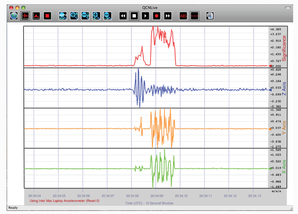
Earthquakes are recorded by seismometers, but it is difficult to find a seismometer to bring to the classroom! We use USB accelerometer sensors from the Quake-Catcher Network (QCN) to teach how earthquakes are recorded.

We obtained 3 sensors from QCN (these are inexpensive for classrooms at only $5 each) and set each up at a laptop computer in the classroom. These sensors record acceleration and provided us with the opportunity to teach acceleration. We developed a worksheet for each group to follow, instructing them to experiment with moving the sensor around to learn how the graphs on the computer respond.

An additional experiment focused on comparing the amplitude of the recorded signals created by dropping objects at varying distances from the sensor; the amplitude is expected to be smaller as the object is dropped from a greater distance. This teaches the difference between earthquake magnitude (the actual size of the earthquake, which in this case is a constant when a single object is dropped from a consistent height) and intensity (which describes how much motion was actually observed at a given location and relates in this case to the varying amplitude with distance). The success of this activity is somewhat dependent on the floors of the classroom.

One of the QCN sensors will be setup to run on a desktop computer in the classroom and collect seismic data for the QCN project.

http://qcn.stanford.edu



An example of output from the QCN sensor. The top graph plots the "Significance" of the motion below. If the motion is comparable to that of the last minute, then the significance is very low. When the motion is different from past motion the significance registers as a larger value. This is used to detect earthquakes instead of noise.

The 3 lower graphs show the acceleration recorded in each of 3 axes.

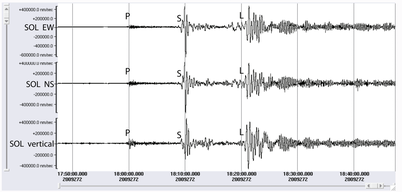
The QCNLive software is free to download, simple to use, and works with either the QCN sensors or with laptops already equipped with accelerometers.

QCN uses low-cost, Micro-electro-mechanical Systems (MEMS) accelerometers to increase the density of strong motion observations in California and throughout the world. Currently, QCN uses MEMS sensors internal to laptop computers or external to desktop computer. Participants can purchase external sensors that can be attached to any desktop computer (all operating systems are supported). K-12 classrooms can request sensors for use as both an interactive teaching tool and to record earthquakes.

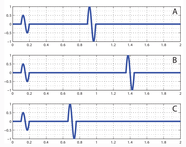
For further information about QCN or to acquire sensors for the classroom, visit http://qcn.stanford.edu

Locating and Measuring Earthquakes

09/29/09 M 8.0 earthquake in Samoa



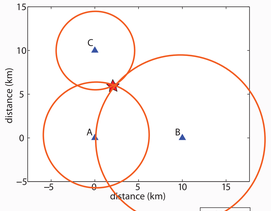
Earthquake #1



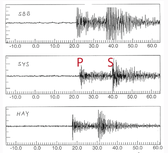
Students are first taught about the different types of seismic waves (P, S, and surface waves) using examples from actual earthquakes.

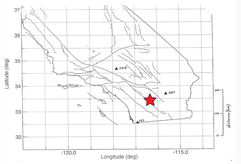
Earthquake location can be done using triangulation. We teach this concept first with synthetic data (the pulses shown in the waveforms to the left represent P and S waves). Students determine the separation in time of these two waves and then calculate how far away the earthquake is from each station.

They must then scale this to the map and use a compass to draw a circle of that radius around the station. Using 3 stations, the circles should intersect at the location of the earthquake.



This exercise is repeated using actual seismic data. Here, we show the location of an earthquake in southern California near the San Jacinto Fault.





Additional information on these classroom activities and materials for the complete curricular unit will be available at:

http://earthref.org/SCC

Deborah Kane is a 5th year geophysics graduate student. Her primary research interests are in observational seismology and earthquake source physics, and her research focuses on small earthquakes in southern California. She is interested in linking differences in earthquakes to spatial variations in Earth's crust and ultimately improving our understanding of seismic hazard.

Dave Van Dusen has been teaching physics and earth sciences to middle and high school students for sixteen years. He is currently the department chair at the San Diego School of Creative and Performing Arts, a public magnet school for the arts serving a diverse student population.

Acknowledgments

We thank the Quake-Catcher Network for providing sensors, software, and helpful advice. Seismic data come from the ANZA and SCSN seismic networks; Guy Masters provided the triangulation example. We thank Frank Vernon for his support. The SIO graduate fellows and SDUSD teachers participating in SCC provided valuable advice and feedback on our activities, as well as an opportunity to test them in additional classrooms. We thank the SCC PIs and the contributors to the summer program and communications seminar for their support and comments.

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