"How to Teach with QuakeCaster" Transcript

How to Teach with QuakeCaster: 3 Minute "Trailer"

Approximate Time: 00:00 (Introduction and double-slider earthquakes)
A fundamental riddle of earthquake occurrence is that tectonic motions at plate interiors are steady, changing only subtly over millions of years. But at plate boundary faults, the plates are stuck for hundreds of years and then suddenly slip forward in an earthquake. Why does this happen?

Well, this model, QuakeCaster, seeks to explore and answer this question. This model contains the minimum number of physical processes needed to reproduce an earthquake.

00:45 (QuakeCaster components)
To represent the steady plate motions, we have a fishing reel, which we can crank at a constant speed. The friction within a fault is represented by a granite slider, with a rough bottom surface, in contact with a rough rock surface. The earth's elasticity is represented by a rubber band.

01:05 (Single-slider earthquakes)
At the start of this video, you saw a two-slider earthquake. But what do you think would happen if we had a one-slider earthquake; if we removed half the mass within a fault. Yet, there's the same amount of friction, the same earth elasticity, and the same steady plate tectonic motion. Let's find out. *(Run single-slider experiment)*

So as you can see, the single-slider earthquakes are more frequent, but smaller than the two-slider earthquakes. It's important to note, though, that the single slider earthquake behavior is also irregular.

01:35 (Earthquakes along a fault)
So you've just seen a single-slider earthquake, which represents one earthquake along a fault. However, this rarely happens in an actual fault. Usually, there are multiple earthquakes that occur in series along a fault. And these earthquakes converse with each other through the transfer of stress. QuakeCaster can demonstrate this stress transfer by attaching sliders in series.

Now I'm attaching sliders in series, and I'm using the same rubber band that I used in the previous experiment, which represents the same earth elasticity. The friction hasn't changed, and the constant plate motion is still the same. *(Run sliders in series)*

Now that showed some really interesting earth behavior. What we saw, was tension building up on the first rubber band, which caused on earthquake with the first slider, which increased the tension on the second slider, which eventually slipped, and that reduced tension on the first slider, but increased the tension on the third slider; and the third slider eventually slipped forward. Now sometimes we see really irregular behavior. For example, sometimes we saw, two sliders occurring at the same time, or even three, so that represents two or three earthquakes occurring simultaneously along a fault.

02:55 (iSeismometer)
We have downloaded a free smartphone application, called iSeismometer, which simulates a seismograph. And a seismograph measures the seismic waves generated by earthquakes. So what you can do is put down the smartphone on the rock surface, and run QuakeCaster, and then observe the screen. *(Run double-sliders)*

03:15 (Conclusion)
Even though QuakeCaster is a simple model, it is very true to earthquake behavior, and it clearly and effectively illuminates earth processes for people of all ages.

How to Teach with QuakeCaster: 11 Minute Video

Approximate Time: 00:00 (Introduction)
In this video, we will demonstrate the full potential of QuakeCaster. We will be carrying out experiments testing the four leading earthquake occurrence hypotheses, which are used to try to predict earthquakes. But are these hypotheses accurate? Today, we will see how these hypotheses stack up to QuakeCaster earthquakes and real earthquakes.

00:30 (Earthquake occurrence hypotheses)
Let me start by explaining the four hypotheses. Hypothesis one states that earthquakes are periodic; so all the earthquakes slip the same amount and are separated by the same amount of time. Hypothesis two states that earthquakes are time-predictable. This means that the larger the last earthquake, the longer the wait until the next one. Hypotheses three states that earthquakes are slip-predictable, meaning the longer the amount of time for stress to accumulate, the larger the next earthquake will be. And hypothesis four, known as the "Poisson" hypothesis, states that earthquakes are random in size and time.

01:00 (Slip and time predictability)
Now we will be starting experiment one, and we will be testing slip- and time-predictability. Today we have help from two high school sophomores, Matt and Colin. Matt will be recording the time of each earthquake, and Colin will be marking the rupture length, along this piece of tape that we have placed along the rock surface. It's important to note that Matt will start timing at the first earthquake. *(Run double-slider experiment)*

Now Colin will be measuring the cumulative slip distance in centimeters, and he will be reading these times aloud to Matt, who will record these times on a computer.
7.5
20
32
39.5
54
66
80.5
Matt will now be reading out the cumulative times to Colin, who will record these times on a computer.
1.37
2.84
4.52
6.18
7.84
9.58
10.18

02:45 (Slip and time predictability data)
So we've graphed the data that we collected in the previous experiment, and the x-axis represents the cumulative time in seconds, and the y-axis represents the cumulative slip distance in

centimeters, so how much the earthquake ruptured. Now what we're going to do, is draw in the classic staircase plot. And what the slope represents here, is, we're waiting, and then an earthquake occurs; wait, earthquake, wait, earthquake. You get the idea.

So I've just eyeballed and drawn in the best-fit lines for the slip-predictable hypothesis and the time-predictable hypothesis. The slip-predictable hypothesis states that the longer the wait, the larger the next earthquake will be. And the time hypothesis states that the larger the last earthquake, the longer the wait until the next one.

Now if we look at our data, we see variability in terms of wait time. There's longer wait times and then there's shorter wait times. And there's variability in the slip distance, there's larger and smaller slip distances. So there's not a lot of consistency.

Now if we look at this data in comparison to the hypotheses, we don't see a lot of compatibility. Neither of these hypotheses perfectly fit the data. So it's quite difficult to predict when the next earthquake will be.

04:05 (Comparing QuakeCaster and Parkfield data)
Here we have stair-step diagrams of QuakeCaster earthquakes and earthquakes that occur along the San Andreas Fault. And you can see that the QuakeCaster data is similar to the data collected on the Parkfield section of the fault.

This chart shows magnitude 6 earthquakes, that occur roughly every 20-30 years, along the Parkfield section of the San Andreas. And the dates shown are from the time of the Gold Rush to present day. And we can see that this data does not fit perfectly the slip- or time-predictable hypotheses. It doesn't quite match up. For example, the 1934 earthquake occurred roughly a decade earlier than the average interval. The 2004 earthquake struck one to two decades later than the average interval, and was somewhat larger than its predecessors. So there's variability.

This chart shows magnitude two repeating shocks, which occur quite frequently. And the data shown is from around 1985 to present day. At first glance these earthquakes appear periodic; they look like they fit both the slip- and time-predictable hypotheses. But if you look closely, the data doesn't always perfectly match.

05:15 (Fault gouge)
Even after running QuakeCaster just once, there's a light dusting of powder that appears along the rock surface. And this powder is known as fault gouge, and this actually occurs in real faults, as well. And it's formed when the fault faces slide past each other, and they grind their rocks into a pulverized powder. They've actually found fault gouge in the San Andreas Fault, and it's the mineral talc. And they think this talc decreased the friction within a fault, and is therefore responsible for fault creep. We can visibly demonstrate fault creep by pouring baby powder onto our rock surface.

I've just poured the baby powder onto the porcelain tile. Now, we're going to run QuakeCaster, and we're going to observe the earthquake behavior. *(Run double sliders with baby powder on rock surface)*

Another way to show decreased friction, is to flip over the granite slider to the smooth side, and to run QuakeCaster using it that way. So we're seeing more frequent, but smaller earthquakes. And in some cases, we're seeing the fault creep, where the sliders are moving slowly and steadily along the rock surface. *(Run double sliders using their smooth sides)*

06:30 (Coulomb failure criteria)
QuakeCaster can also demonstrate Coulomb failure criteria, which hold that when a fault is close to failure, either increasing the shear stress or decreasing the fault clamping stress, which is also termed normal stress, will promote fault failure.

To demonstrate increasing the shear stress along a fault that's close to failure, we're going to reel in the line until the sliders are on the verge of an earthquake. *(Reel in the line)* And then, by increasing the shear stress, we're going to pull the rubber band, we trigger an earthquake. To demonstrate decreasing the clamping stress along a fault that's close to failure, again we'll reel in the line until the sliders are on the verge of an earthquake. *(Reel in the line)* And then, we're going to pick up the top slider, and we trigger an earthquake.

07:15 (Foreshocks)
Now I'm going to run QuakeCaster a few more times, and I would like you just to observe the sliders' behavior. Does anything happen before the sliders move forward? *(Run double sliders three times)*

Alright, so there was a little hop. So in that last trial we just observed a foreshock before an earthquake occurred. Now that was the little short hop that you saw before the slider slipped forward. But it's important to note that these foreshocks occur rarely. I mean, we just saw one, or maybe two; so we can't really use these foreshocks as predictors of earthquakes.

08:10 (Constant minimum and constant failure stress)
Now we're moving on to experiment five, and we will be testing to see whether constant failure stress or constant minimum stress is a better predictor of earthquakes. We have help from three USGS employees, Ross, Volkan, and Jake. Volkan will be recording the time, in seconds, of each earthquake. Ross will be recording the force immediately before an earthquake occurs. And Jake will be recording the force immediately after an earthquake occurs. *(Run double-sliders)*

Read me out the numbers and I will put them in the computer.
Alright. So,
1120 grams
1200
1150
1050
and 900.
So those are the before, the stresses just before an earthquake. Now I'm going to read you the stresses just after an earthquake.
620 grams
560

620
380
400
Now here comes the cumulative times.
O.K.
2.84 seconds
4.96
7.14
9.21
That's it.
Great.

09:45 (Birds-eye view of stress experiment)
In order to ensure more accurate data, you can set up a video camera with a shot similar to this one.

09:55 (Constant minimum and constant failure stress data)
I've just graphed the data from this past experiment. And the x-axis represents the cumulative time in seconds. And the y-axis represents the force, or stress, measured in grams. And I've connected the data points. And what we have is stress accumulating until it reaches a failure stress, and an earthquake occurs. And it drops its stress down to a minimum, or background amount. But it's important to note that the stress never completely goes to zero.

Another way of framing the time-predictable hypothesis, is that earthquakes occur when a failure stress is reached. That's what these blue dots represent. And another way of looking at the slip-predictable hypothesis is that earthquakes drop their stress to a minimum or background amount. And that's what these red dots represent.

So I've eyeballed and drawn in best-fit lines for these hypotheses. And how does our data compare? As you can see, neither hypothesis perfectly matches the data. So we can't use constant minimum and constant failure stress as accurate earthquake predictors.

10:50 (Conclusion)
The beauty of QuakeCaster is that every time we run experiments, we see different results. Sometimes certain hypotheses match the data better than others. And that's what makes these experiments so much fun. We hope that this model really illuminates earth processes and encourages experimentation while making learning fun for people of all ages.