



Teacher's Guide for: **Earthquakes**

Note: All activities in this document should be performed with adult supervision. Likewise, common sense and care are essential to the conduct of any and all activities, whether described in this document or otherwise. Parents or guardians should supervise children. Rock-it Science assumes no responsibility for any injuries or damages arising from any activities.

NOTE: This is the transcript of a lesson that was videotaped during an actual Rock-it Science class with real students, not actors. The students' brainstorming comments are included on the video but are not transcribed here because they're not part of the lesson presentation.

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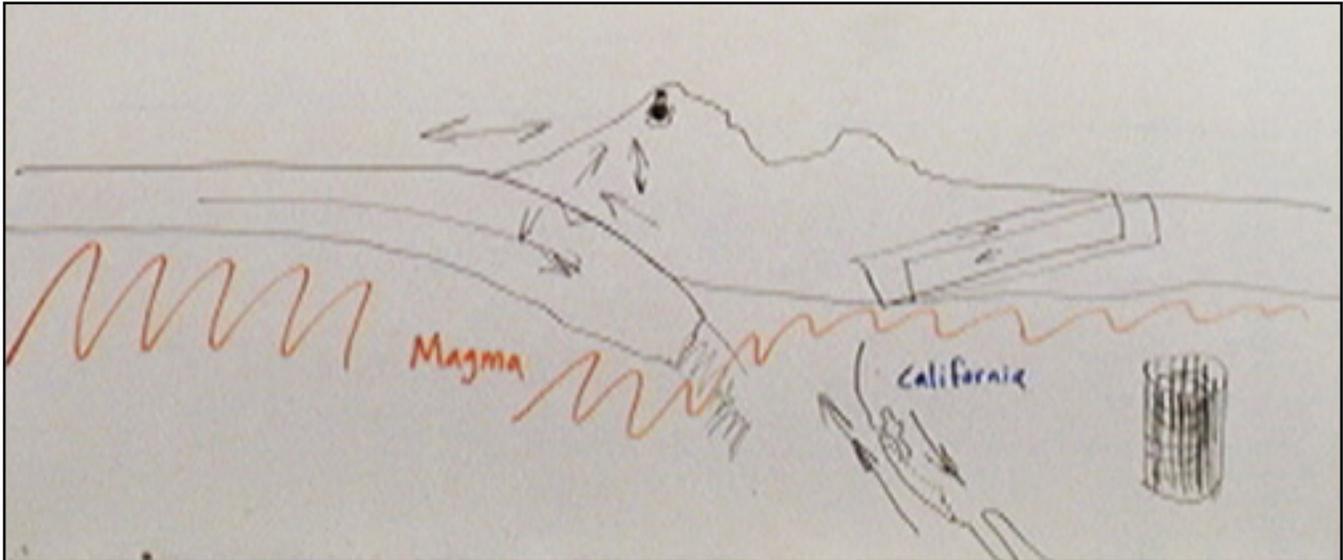
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Earthquakes
A Rock-it Science Lesson
Filmed April, 2012

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Intro Quick Recap:



- The Earth is made up of slowly-moving plates that rest on magma. When one plate goes under another, it's called subduction.
- Sometimes the moving plates get stuck on each other, the forces build up, and then suddenly let loose. That causes an earthquake that goes a little bit up and down like a wave traveling across the land.
- Another kind of earthquake happens when plates slide past each other side-by-side. We can design buildings to withstand this kind of sideways earthquake, but not the really big up-and-down ones.
- If you're on a freeway overpass during an up-and-down earthquake, it throws your car into the air along with the entire freeway. But then the freeway comes down again, and the columns holding it up can collapse and turn to dust. So now they put those columns in steel liners, like a steel can, that holds the dust in even if the column breaks.
- Instructor uses a long flexible spring to represent the ground in order to demonstrate different earthquakes. First, compress and release the spring to generate a compression wave. Second, pull the spring sideways and release it to show sideways motion. Third, shake the spring up and down to show the worst kind of earthquake. Sometimes an earthquake creates a standing wave, where you can walk along the peaks and valleys of the up-and-down earthquake.
- Demonstrate shaking tables and show how a Lego structure shakes apart when placed on the shaking table.

Experiment Quick Recap: "Earthquakes"

- Students will build two kinds of structures, one that will break apart easily into as many parts as possible, and another that will resist breaking apart.
- Instructor puts a Lego structure on the shaking table and turns it on so that the structure starts to shake apart. Then increase the speed of the table so the structure breaks into as many pieces as possible.
- Let students put their hands gently on the table while it's shaking so they can feel the vibrations.
- Give each student a bunch of Legos of various sizes and shapes, and let them create their first structure. Whenever they're ready, they place it on a shaking table and turn it on. They can test it on various speeds. When the structure has finished breaking up, the Instructor counts the number of pieces. Then the student goes back and modifies their design to make one that will break up into even more pieces.
- After each student has had a chance to test at least one unstable design, they can start building one that's intended to be sturdy so it won't break apart. Then test it on the shaking table as before. This time, the teacher counts the number of levels of Lego bricks left on the base. The more levels, the sturdier the structure. Students continue testing various designs as time allows.



Equipment List: "Earthquakes"

Items needed for Instructor:

- Shaking tables, 2
- Spring, long and flexible

Items needed for Students:

Consumables:

- None

Other (per student):

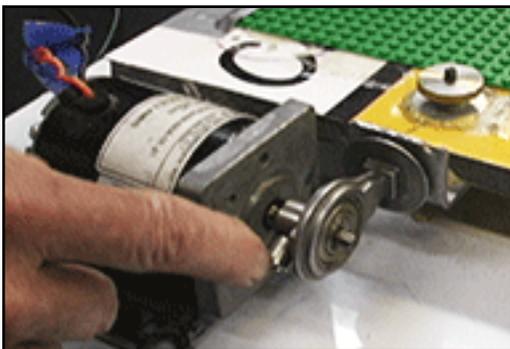
- Assortment of Legos or similar building bricks, about 100 pcs per student.
- Plastic containers to hold the Legos, about 6" x 12" x 4" (size can vary).

Prep Work:

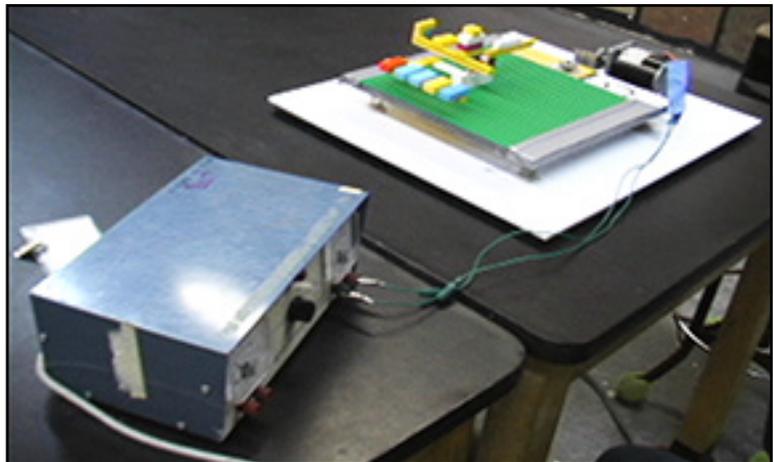
- Construct shaking tables (see Prep video)
- *Note: This lesson also uses a second type of shaking table adapted from a lapidary machine, but this is not required.*
- Construct a few sample Lego structures, both weak and sturdy.
- Put about 100 Legos in each plastic container.



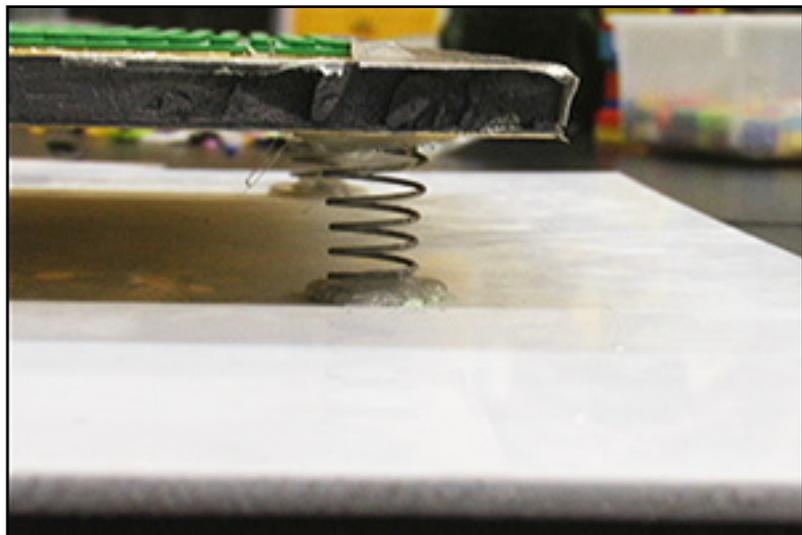
Plastic container with Legos



Motor that spins off-center.



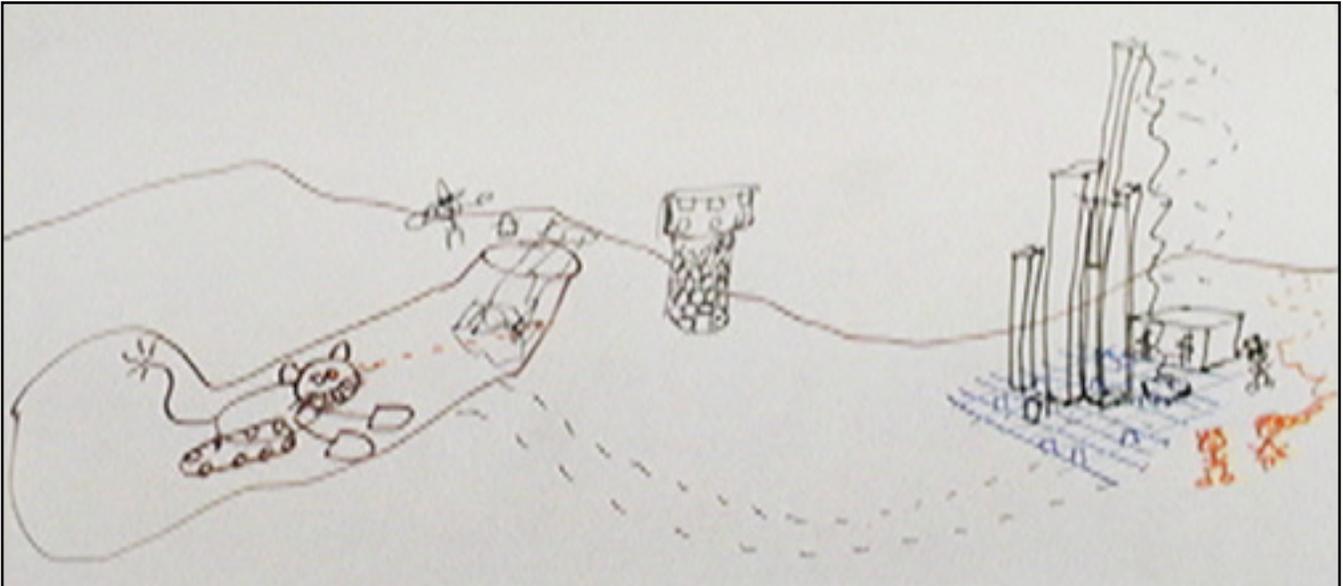
Shaking table with DC power supply to control voltage and speed.



At right, the layers of materials in the shaking table, from top to bottom:

- Legos, single layer
- Plywood
- Springs, hot-glued to base
- Base of plywood or plastic
- Layer of foam under base

Story Recap: "Jack & Jill & the Trembling Gopher"



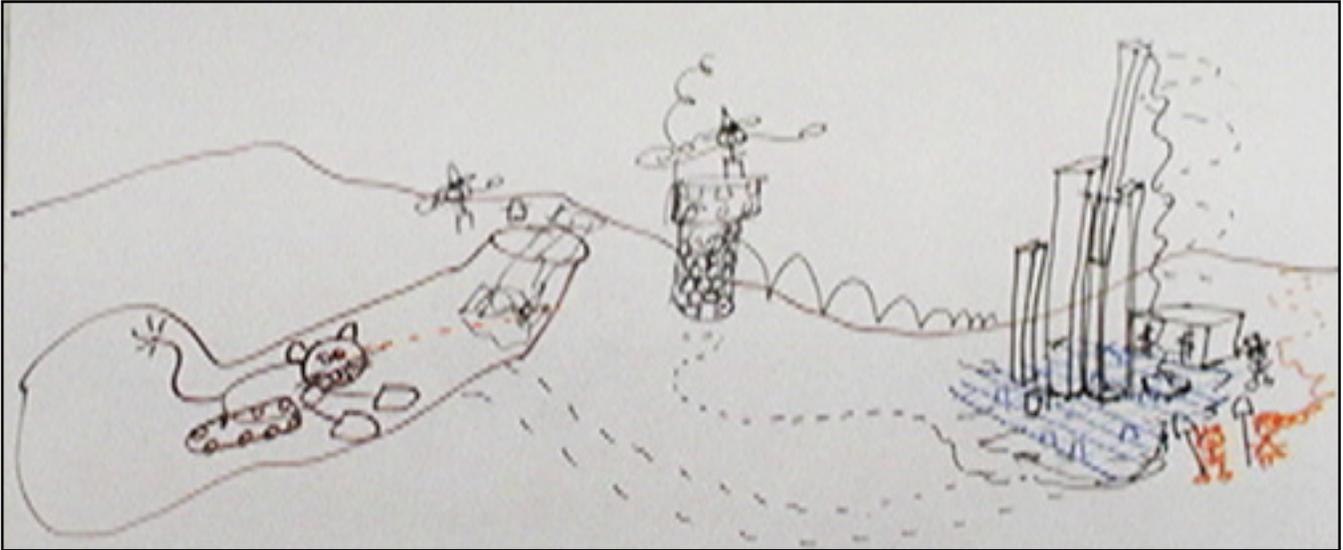
Part 1:

- There was a giant gopher that had nerve problems that made him very shaky. He had shovels for front feet, and his back feet were like tank treads. His tail is like a whip, his teeth can break rocks, and his laser beam eyes can make rocks melt or explode.
- Evil Mister Fred didn't know the gopher was there, and he had his minions build a castle nearby.
- The gopher dug under the castle and it collapsed. At first Evil Mister Fred blamed his minions for building the castle over a hole, but then the gopher popped up its head, so Evil Mister Fred knew he had done it.
- Evil Mister Fred told the gopher he could make up for destroying his castle by doing him a favor.
- Nearby was Goodville, a town that restricted buildings to no more than two stories. But Evil Mister Fred disguised himself and went to the town banker and offered to give money to people to build really tall houses. The banker would get a percentage of the money to keep.
- So the banker went out and encouraged people to build really tall houses. At first, there was a house that was three stories tall. Then someone built one twenty stories tall. But that blocked someone else's view, so they built one forty stories tall. And they kept building taller and taller buildings until there were skyscrapers everywhere.
- The kids liked this because they could throw paper airplanes out the windows of the tall buildings, and they could jump off them using sheets as parachutes.
- Jack and Jill came to visit the city to see all the big buildings. They noticed that not only were they very tall, but they were also rubbery so they could withstand an earthquake. The townspeople bragged that their buildings were absolutely earthquake-proof, and there was no way they could ever fall down. Jack and Jill reminded them that that's how people talked about the Titanic -- and then it sank.

Story Recap (cont.): *"Jack & Jill & the Trembling Gopher"*

- While the people in Goodville were putting up tall buildings, Evil Mister Fred had his minions build a castle out of old car tires. They just stacked them up and held them together with ropes.
 - Then Evil Mister Fred told the gopher to go and dig lots of tunnels under the city. So he did.
 - Some of the buildings started to tilt in different directions, and some were leaning against each other. People's furniture was sliding around.
 - The kids liked this because they could build a swing between two buildings, and it would swing all by itself without any pushing.
 - The people asked Jack and Jill to figure out what was happening.
-

Story Recap (cont.): "Jack & Jill & the Trembling Gopher"



Ending:

- Jack and Jill realized there was something wrong with the ground, but they didn't know what. So they dug a hole to see what was down there. They saw the tunnels all over the place under the city.
- Jill used gopher talk to call to the gopher, but he wouldn't come out. He was hiding.
- Jack and Jill starting running through the tunnels in different directions, and Jack ran into the gopher. The gopher told Jack he was going to eat him. Jack told him to wait for Jill because she would taste better.
- Jill sneaked up on the back side and grabbed the gopher's long tail and yanked on it. The gopher cried out like a little baby. Turns out he was a coward. That's why he always stayed hidden underground.
- Jack and Jill told the gopher that his tunnels were going to make the whole town come down, and they told him to fill in the tunnels. So he did.
- After he finished, the gopher went off and started digging underground again and ended up under Evil Mister Fred's castle again. As he was digging, the gopher found a spot where someone had left a bunch of pepper under the ground, and it made him sneeze.
- He sneezed so hard, he blew Evil Mister Fred's castle up into the air. Since it was rubber, it bounced, and it kept bouncing all the way over the horizon.

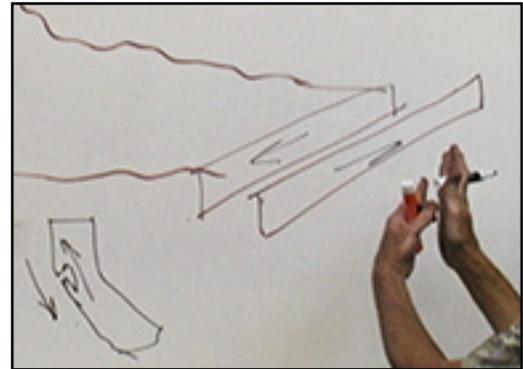
Transcript: Intro

Today we're going to be doing classes on earthquakes. And the earth is made up of a bunch of plates that are all moving. They move really slowly, but they do move. And sometimes they run into each other. And one place here we have a plate coming along this way, and it hits that one, and it goes down under it, and it's resting on magma. Hot lava, when it's under the ground, is called magma. When it squirts out, it's called lava. And this one goes upwards to build some mountain ranges. Sometimes these guys get stuck going past each other. Imagine kind of a chunk in there that gets stuck. And the forces build up and up and up and up and up, and then all of a sudden ba-boom! It lets loose. And it creates an earthquake that usually goes a little bit up and down like a wave as it travels across the land. And they have a funny name for that. They call it subduction.



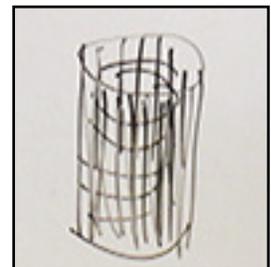
Subduction plate and "stuck" spot

Another kind of earthquake that can happen is when plates slide right by each other. They grind and moan and groan and catch and un-catch. And California has a couple of plates like that that slide past each other at the San Andreas that goes right down from San Francisco, down past San Jose. Usually when those slip -- kchoo! -- there's a side-to-side kind of earthquake. And those aren't so bad. We can design buildings and bridges to take this sideways kind of earthquakes pretty well. But down in Los Angeles, around 1991 I think it was, they had a big earthquake that went up and down. And the ones that go up and down really destroy a lot of stuff, especially freeways on their columns.



Side-by-side plates and California.

Suppose you're driving your car along the freeway on the elevated part above the city, and you get an up-and-down earthquake. Well, it throws you up in the air, but it also throws the entire freeway up into the air. And then the freeway has to come back down again -- ka-boom! And when it comes back down, it breaks the columns that hold it. The columns are made out of a whole bunch of pieces of steel in a circular pattern, like that. And in Los Angeles what happened is, the freeway came down so hard, it turned all the concrete into dust. And these cages of steel rebar weren't strong enough, and they went squash! And the freeways all fell down.



Freeway support.

So now they put the columns in steel liners, like a big steel can that holds, and even if the concrete turns to dust, it holds the dust in there, and the freeway doesn't fall down catastrophically. It's still probably wrecked, but it doesn't fall down completely.

Here's our spring. *[Instructor holds one end of the long flexible spring, and the Assistant holds the other end at the opposite end of the table. If there is no assistant available, a student can hold the other end of the spring.]* This is going to represent dirt. This is the ground. Now, if you have one kind of an earth-



Stretching out the spring to show wave patterns.

quake, where the ground is being compressed and compressed and compressed, and then it lets go -- pshooo! That compression wave can zoom back and forth and hit a mountain range there and a mountain range here.

If you have one that is being pulled sideways, it can go like that and shake the buildings sideways, like this.



Pull spring to show side-to-side.

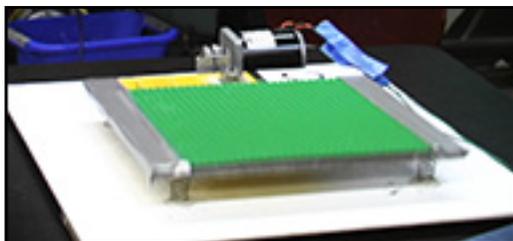
goes up and down -- boinnngggg! And that wave can go right through the ground and literally pick things up and knock them down.

And the worst one is the case where you have the one that

Sometimes you get ones that are called standing waves, like that. And they had a great one in India in the 1800's, where there was -- we can make it look like this so it shows up better on the camera -- like that. And the guy that was there -- there was a British guy there, he was standing on top of the wave part. And he could walk right along with the wave, and then go down into the trough, and then climb up into the next top. This earthquake went on for about four minutes. And he could go up and down these waves, which is just totally bizarre. Things all around him were collapsing, but he was playing around with the waves.



Standing wave.



Shaking table.

Now, we can make waves, we can make shaking forces with things like this table [*turns on shaking table*]. We can go fast or really slow. There's a certain spot where it bounces really cool -- boinnngggg! This end is doing something really great.

And that one kind of goes around. There's a motor down here, and they put a big weight off-center from the motor, so as the motor spins, this weight is going around down in the base, just shakes the whole thing in a kind of circular pattern. So any structures we put on top of that are going to get shaken that way.

And we have that one over there. You can let that go [*assistant turns on second*

We're going to do two kinds. One kind is a structure that falls down on purpose into as many pieces as possible. And the other kind doesn't fall down. But first we need a crazy story.



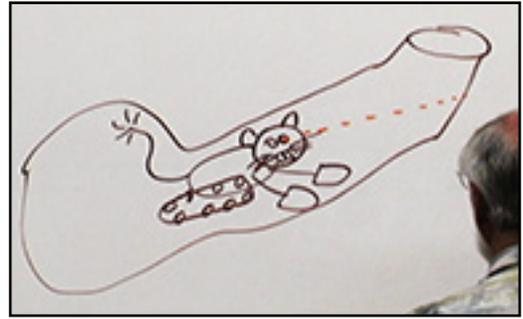
Lapidary tumbler shaker.

Story: "Jack & Jill & the Trembling Gopher"

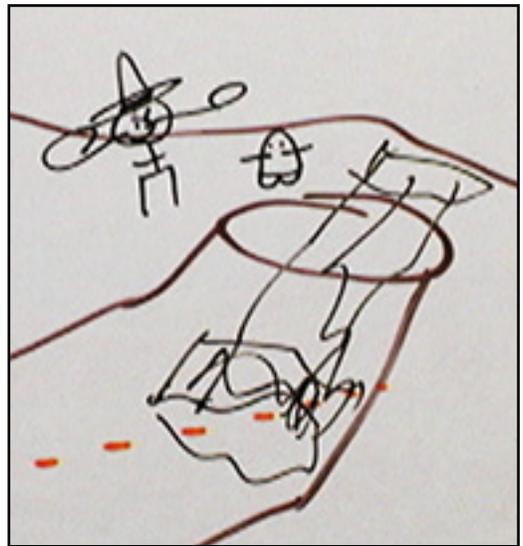
Once upon a time, Evil Mister Fred met a giant gopher. And it was the kind of gopher that had nerve problems. He was a very shaky gopher. And he's got shovels for feet. And for rear feet, he's got conveyer belts, or like tank treads to throw the dirt out in back so he can go through the dirt really well. And if anybody tries to sneak up on him, he's got a tail like a whip so he can smack them. And he can dig these big tunnels under the ground really fast. His teeth can break rocks. And then he's got laser beam eyes so that he could make rocks melt or explode.

And Evil Mister Fred didn't even know he was there until Evil Mister Fred had built a castle there, and the gopher dug under it, and the castle collapsed into the hole. There. So there's all castle pieces, all broken in the hole. And Evil Mister Fred is up here, and he's blaming the minions for building such a bad castle, right over a big hole.

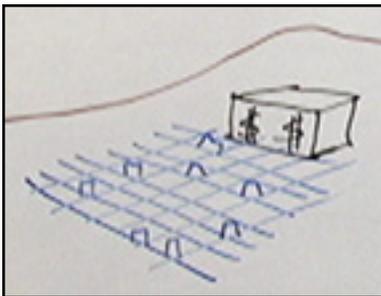
And pretty soon the gopher popped up its head, and the gopher was all shaking, going "Uhhh," and he can't talk well because he shakes a lot. And Evil Mister Fred said, "What did you do that for? You wrecked my castle. We spent a good ten minutes building that castle, and now look at it. It's ruined!" And the gopher said, "Sorrrii!" because that's how he talks. And Evil Mister Fred said, "You're going to have to make up for that. You're going to have to do what I tell you to do. And the gopher says, "Cool! I'll do that." And Evil Mister Fred said, "Now we're talking! This is great."



Giant gopher in his tunnel.



Evil Mister Fred's collapsed castle.



Goodville bank and small houses.

And not too far away is Goodville. Goodville is a planned community, and they have decided they don't want to have too many people come live in their city. So they've restricted the heights of the buildings to two stories. So it's a small town with lots of two-story buildings and lots of one-story buildings. And Evil Mister Fred said, "Huh! Well, that's not going to be any fun. We ought to help them out.

So Evil Mister Fred went into town all disguised, and he made friends with the local banker. And he told the banker at the Dollars Store -- that's where you go to buy dollars -- that he would make sure that he had as much money as they wanted to give away, as long as the people built their houses taller and taller and taller. The guy at the Dollars Store says, "Well, what's in it for me?" And Evil Mister Fred said, "Well, I don't know. You get a percentage of the action, say twenty percent." And the guy says, "Now we're talking."



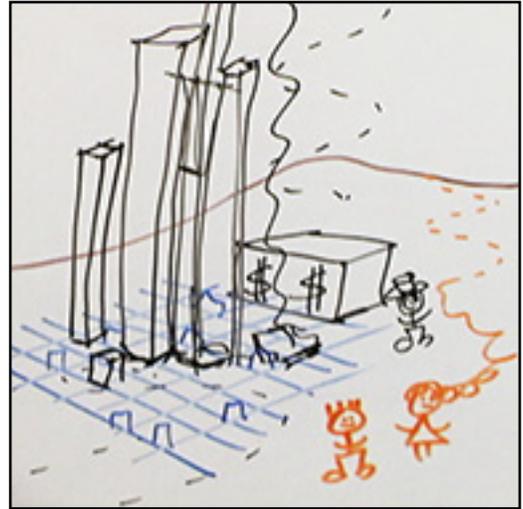
Banker with dollar sign eyes.

So he went out and started offering money to people to build taller houses. He has dollar signs for eyes. And the people said, "Yeah, let's do this!" So somebody built a house that was three stories tall, and nobody complained. So somebody else built one that was twenty stories tall, and everybody said, "Ooh! Aah! I want one like that! You blocked my view. I need a bigger house so that I can see over your house." So he built himself a house that was even taller, forty stories tall.

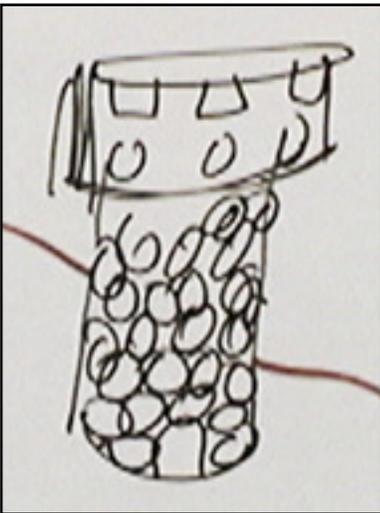
And before long, there were just skyscrapers everywhere. A thousand stories tall, yeah. And when you get buildings that tall, and the wind blows, the top starts to go wshhhh, wshhhh [*leaning side to side*]. And of course, all the kids went up there and they threw paper airplanes out the window. And they would take sheets and jump out, pretend like they're parachutes. And their parents had to put pillows on the ground so they didn't hurt themselves.

And things were pretty good, you know. People had a lot of money, they had these big buildings to play on, and Jack and Jill came to look at the city and see why they were building it so tall. And they said, "Man, that's great. Not only is it tall, your buildings are all kind of rubbery, so they should stand up in an earthquake and stuff." And people said, "Oh, yeah. We had the best engineers design these buildings for us. They're earthquake-proof. There's no way these buildings could ever fall down. Just no chance."

And Jack and Jill said, "Ooh. I wouldn't say that. Remember the Titanic. Everybody said it was unsinkable and then, on its first voyage, bmmmmm -- down it went." And they said, "Oh, yeah, but we planned this all out. We know these buildings will never fall down."



Goodville with tall buildings.



Castle made of rubber tires.

And Evil Mister Fred, of course, was encouraging all this. And he had his minions build himself a new castle out of old car tires. They just stacked up car tires, held them together with ropes. And now he's got this castle that's all rubber. And Evil Mister Fred said, "Now, gopher, I think things are just perfect here. All I want you to do is go dig holes under the city there, and just hang around. Dig anywhere you want. And just sit under there and shake and shiver and do whatever you feel like doing." The gopher said, "Cool!"

So he went over there and started digging holes, all under the city. And pretty soon some of the buildings started to tilt different directions. They were leaning on each other, and the people at the top said, "Whoa, look at that! My furniture is moving across the floor all by itself. What's going on?" And they didn't know. They'd open the refrigerator door and

there'd be stuff all turned and tipped over. They tried to cook stuff in their oven, and it would fall off the shelves and get all messed up in the oven.

But kids liked it, because everything was shaking. They could build a swing between two buildings, put a stick between there, hang some ropes off of it, put a seat on it, and they've got a swing. And they didn't even have to push. They could just make the swing go by itself.

And they said, "Jack and Jill, what's happening? Everything here is moving." And Jack and Jill said, "Hmm. I don't know. But I can feel it in the ground. I can hear it in the buildings. Something is not right." If you were Jack and Jill, what would you do?

Imagination and Brainstorming Time

[Students make suggestions] (THERE ARE NO WRONG ANSWERS! Whatever they say, you should reply: "That's a good idea," "They might do that," etc. After brainstorming, proceed with the experiments, then finish the story.)

We'll leave this "To be Continued . . ."

Experiment: "Earthquakes"

We've got lots of Legos. And the first part of the experiment is to build some sort of a Lego thing that falls over and makes as many individual pieces as possible. So it should have a bunch of things hanging out. Let's see where we could stick this that would be fun. I noticed in the other classes, if you make the base too weak, it just tips over really early. So the base has to be kind of strong so that the arms and legs and heads and stuff fall off and scatter all over the place.

I'll turn this on. *[Turns on shaking table at low speed.]* Wouldn't it be great to be right there *[indicating a part that's bouncing up and down]?* *[Structure starts to break apart, and Instructor speeds up the shaking.]* So when you put one together, you just bring it over here. *[Structure breaks up even more.]* And test it through different speed ranges. And this one ended up being seven pieces of stuff.



Putting lego structure on shaking table.

Now, if you want to, you can test it on our round-and-round guy. Just stick it on there somewhere *[puts a structure on the circular shaking device]*. And then this one only goes on and off, so you can't change the speed. *[Turns on the device and the structure starts to break apart.]* We ended up with a bunch of pieces there, and the top looks like it's never going to fall off. You can feel it with your hands, too, to see what it feels like *[students put their hands on the shaking table]*.

That one's pretty sturdy, and you can put your hands on it. This one *[indicating the smaller shaking table]* isn't very sturdy. If you want to feel this one, you just put your fingers on it lightly. *[Turns it on, and students feel it with their fingers.]* Just lightly. If you put your whole hand on it, you're going to stop it from vibrating. *[Instructor increases the speed so students can feel it.]*



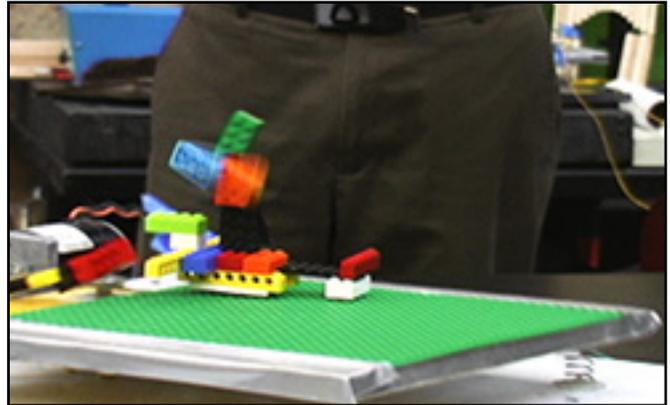
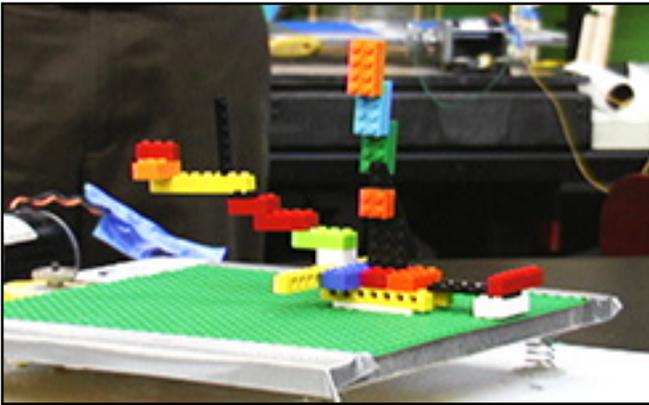
Feeling the vibrations of the shaking table.

[Assistant hands out containers of Legos.] You can work with someone or by yourself. And your first structure should be things that fall down well. The goal is to fail. *[Students build Lego structures. As each student finishes, they test their structure on one of the shaking tables. The Instructor counts the number of pieces left after they fall apart. After testing one, students go back and modify their design to see if they can make it break into more pieces.]*

[Then the students try to make a structure that will withstand the shaking.] And for the sturdy thing, the taller it is and sturdy, the more points you get. *[After each student tests their sturdy structure, the Instructor counts the number of layers of Legos remaining on it. The more layers, the stronger the structure. As time allows, students can test more structures.]*



Building structures from Legos.



Left: Structure about to be tested. Right: Structure shaking apart.



"Sturdy" structure before and after.

[At end of experiment] Take them apart as much as possible, so that the other kids have pieces to work with, rather than completed thingamajigs.

End of Story

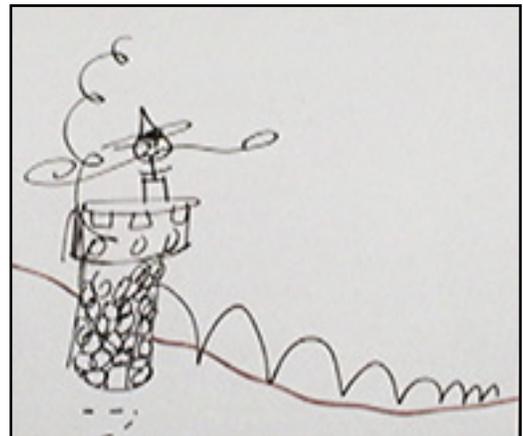
*** DO NOT * present this part of the lesson until after the experiments!**

So Evil Mister Fred is undermining the entire town. Of course, he was the one who made them build it up in the first place, just so he could knock it down. There's all kinds of people up in the buildings, and the buildings are starting to sway and move because of the shivering gopher that's down there. And Jack and Jill have to figure out what to do. And Jill said, "Huh! I don't think I know what to do." And Jack said, "Well, let's dig a hole under and see what's going on." So Jack and Jill got shovels and they dug down there, and lo and behold, they found caves going everywhere under their city. And Jill can talk to animals. So Jill, using gopher talk, yelled down the tunnel, "Helloooooo! Where are youuuuuu?" And the gopher says, "I'm not here. I'm all by myself, and you'll never find me."

And Jill said, "Huh! Jack, start running." So Jack started running through the tunnels one way, and Jill ran the other way. And Jack ran right into the gopher -- smack! -- right into his face. And the gopher said, "Huh! I'm going to eat you up!" And Jack said, "Oh, please don't eat me up. I'm just all skin and bones. Look at me. I'm just a stick figure. You should wait for Jill. She's a lot tastier than me."

And pretty soon, here came Jill around the back side and saw Jack talking to the gopher. And Jill grabbed the gopher's tail, which is like a whip, and yanked on it -- goozhh! Well, it turned out the gopher was kind of like a little baby. He was a coward. And he said, "Aaaaaahhhh!" And he started crying because Jill pulled on his tail. And Jack said, "What's wrong with you? You have no courage?" And the gopher said, "No, I don't. I dig holes. That's why I stay down here. No courage at all." And Jack said, "Well, you're going to knock down our whole town with your holes. That's not good." And the gopher said, "Well, what should I do?" And Jack and Jill said, "Well, fill the holes back up. You've got the super-duper hole-filler-up feet thing."

And so the gopher did what they said. He filled all the holes back up and made the city super sturdy. And then Jack and Jill said, "Now go find something useful to do." So the gopher said, "Okay." And he took off. And he's digging underground, and he found a nice spot right under Evil Mister Fred's castle, of course. And the gopher was under there digging around, and he hit a little spot where there was some pepper somebody had left in the ground. And he accidentally dug through the pepper. And of course, he sneezed. "A-choo! A-choo!" And he blew Evil Mister Fred's castle up into the air. And his castle is made out of what? *[Students: Rubber.]* Rubber. And the castle bounced all over the place -- boing, boing, boing, boing, boing, boing, boing, clear over the horizon. And they all lived happily every after, except Evil Mister Fred.



End of Lesson

If you have questions about this lesson, please ask them through the online [Teacher Support Forum](#) on our web site.