Celebrating Science: Earthquakes Rock Our World

Grade: *5-8*

Description:

Earthquakes have been rocking our world for the last several billion years, and yet the study of seismology has only really started making advances in the last 50 years, with the theory of plate tectonics. We still can't predict earthquakes, but we know a lot more about how and why they happen. By participating in this Passports exploration, students will understand that earthquakes occur along plate boundaries, that there are three different types of boundaries, and that these boundaries govern the location and type of earthquake that occurs. They will also learn that while there are three different types of earthquakes they all generate waves and that these waves have properties that enabled us to learn about earth's interior.

Preparation for the Excursion

To ensure the most meaningful learning experience for your students, it is recommended that students engage in activities prior to the excursion. The additional resources and activities offer opportunities for curricular connections and integration within your larger unit of study. The excursion is intended to complement a comprehensive unit.

Challenge Questions:

- What patterns do you notice in the earthquakes around the world? Can you think of a reason why these patterns might exist?
- Some people think that there are patterns between when earthquakes happen and the time of day, or with different types of weather. Prove whether this is true or not.
- Which plate boundaries cause which earthquakes?
- What are similarities and differences among the three different types of earthquakes?

Responses/Prompts:

- Patterns: Earthquakes happen in specific bands around the world. These bands are plate boundaries. This is because earthquakes are caused by motion along plate boundaries. Thin lines of earthquakes occur at divergent and transform boundaries, while thick zones of earthquakes can be observed at convergent boundaries. The shallowest earthquakes are at divergent plate boundaries and the deepest are at convergent plate boundaries. The earthquakes at convergent boundaries get deeper as they move inland. This is because divergent boundaries are usually in the ocean, and the oceanic crust is only 6-8 km thick. Transform boundary earthquakes occur along narrow zones, along vertical faults. Subduction zones are a type of convergent plate boundary. They pull oceanic crust deep below earth's surface down as deep as 700km. The plate subducts at an angle, the earthquakes occur all along the plate's surface and so when they are projected onto the surface the earthquakes appear in a wide band.

- Prompts: Where do you see the earthquakes happening? Everywhere? (no, along plate boundaries) Can you tell what types of plate boundaries there are by the earthquakes? (yes, see description above) What type of crust is needed for there to be earthquakes? (cold, if the crust is too hot the crust will flow instead of break) Where is there more crust? (at subduction zones) Use a map of global earthquakes as a visual aide.

- Earthquakes do not occur at a particular time of day or in a particular type of weather.
  - Prompt: Students can look up historical earthquakes on the internet and can then record the time of day and year that the earthquakes happened. They can then make a histogram with the number of earthquakes that happen at each time of day and time of year. They could also do more research online and look at newspapers from the day of the earthquake to find out what the weather was like that day.
  - http://www.earthquakecountry.info/roots/socal.html is a useful website with some information about times of historical earthquakes
  - http://www.earthquakecountry.info/roots/measuring.html is a useful website for "earthquake weather" Your students will have difficulty finding the exact weather on the day of the historical earthquakes, however, you can have them compare the time of year, for example, would the same weather occur in January as in July? How about the amount of rain in Seattle compared to Southern California – they are both regions with earthquakes?
- Divergent plate boundaries cause normal earthquakes. Convergent plate boundaries cause reverse earthquakes. Transform plate boundaries cause strike-slip earthquakes.
  - Prompt: Do divergent plates move towards each other, away from each other, or slide past each other? (away) convergent? (towards) transform? (slide past) Does land across a normal fault move away from each other, towards each other or past each other? (away) reverse? (towards) strike-slip? (slides past) Use the fault block models and the plate boundary maps to help model the motion.
- There are three types of earthquakes: normal, reverse and strike-slip. Strike-slip earthquakes tend to be the shallowest and usually don't happen below 20 km. The deepest earthquakes are reverse earthquakes, these happen in subduction zones and can happen at depths down to 700 km in some locations. Normal earthquakes cause crustal extension – more land. Reverse earthquakes cause crustal shortening – less land. Strike-slip earthquakes don't effect the amount of land. Land moves up and down in normal and reverse events and back and forth for strike-slip events. Almost all earthquakes are located along plate boundaries, others are located at hot spots, and a very few happen in the middle of plates. All earthquakes are caused by movement of ground on one side of the fault relative to land on the other side. All earthquakes generate waves. These waves differ in size depending on the earthquake, but each earthquake will have P-waves, S-waves and Surface waves. The bigger the earthquake, the longer the fault.

- Prompts: Do all earthquakes make waves? (yes) Do all earthquakes happen in the ocean? (no) on land? (no) Do all earthquakes happen in the same place? (no) Do different types of plate boundaries cause different types of earthquakes? (yes) Are some earthquakes bigger than others? (yes)

Lesson at a glance:
Students will learn that the earth is made up of pieces called plates. These pieces move around and cause earthquakes at their boundaries. Students will learn about these boundaries and the types of earthquakes that each boundary causes. Students will examine patterns among different earthquakes and their locations and times.

Lesson Outcomes:

The students will:
- Model the interaction between different types of plate boundaries
- Assemble the earth's plates into a current world map
- Determine the different types of boundaries at each plate boundary
- Discover correlation between plate boundaries and earthquake epicenters
- Examine patterns in earthquake locations and times
- Simulate motion across the three different types of earthquake faults

Activities:

MilkyWay Tectonics

Materials:
Mini Milky Way bars for each student
One larger Milky Way bar for the teacher (easier for the students to see)
Napkins

Background:
Students should already have been introduced to the names of the different types of plate boundaries. An in depth background isn't necessary, but they should have heard of the different types of boundaries and seen a map with Earth's plates and the plate boundaries.

Activity:
- Give each student a wrapped mini-Milky Way
- Explain that they are going to be modeling the different ways plates interact with each other
- Tell the students that they will be able to eat the Milky Way at the end of the lesson, but first they need to follow the directions
- Divergent Plate Boundaries: Plates that share a divergent boundary are pulling away from each other. Using the larger candy bar, the teacher should model pulling the Milky Way apart. Don't pull so that the candy bar splits into two, only pull so that the chocolate breaks and you can see the caramel and nougat inside

the bar. Emphasize to the students that they aren't breaking the candy bar into two pieces. Have students take out their Milky Way and gently pull apart. The chocolate is like the brittle lithosphere. Students can see that the chocolate breaks. This breaking is where the plate boundary forms and where most of the earthquakes occur. Underneath the broken chocolate the students should be able to see the caramel stretching and getting thinner (the material that will be used to form new crust, replacing the older crust that just moved away). This shows that there isn't empty space left behind when the plates pull away from each other. It also shows that there is thinning of the earth where plates are moving away from each other. When done with this boundary, have the students push the Milky Way back together so that it looks as close as possible to what it looked like when they first took it out of the package.

- Convergent Plate Boundaries: Plates that share a convergent boundary are being pushed towards each other. Again, using the larger candy bar, the teacher should model pushing the two "plates" of the candy bar together (use the boundary already created by the diverging plates – this is a good example for the students to see that the boundary forms in the region of weaker crust). Two possible outcomes will occur. Either the broken chocolate will push up against each other and form "mountains", or one piece of chocolate will get pushed underneath the other. These are both examples of what happens when two plates come together. The mountains will form when two continental plates collide, and subduction (one plate going underneath the other) will happen when one (or both) of the plates are made of oceanic crust and it goes underneath the other plate. The good thing about having a whole class of students do this is that some of the class will get mountain building while others will get subduction. After showing how to make the collision, allow the students to model a convergent boundary with their Milky Ways. When done with this boundary, have the students move the Milky Way back to its original state (or as close as possible).
- Transform Plate Boundaries: Plates that share a transform boundary are sliding past each other. Using the larger candy bar, the teacher should model sliding the two "plates" of the candy bar past each other. There should be minimal deformation of the candy bar at this point, no new material should be visible, and no new material was formed. The "plates" can move either to the right or left of each other, as both types of boundaries exist. Allow students to model transform plate boundaries with their Milky Ways.
- Enjoy the Milky Ways, yum!

Plate Puzzle

Materials:
Puzzle Pieces (one set per student) [master copy included, 2 pages]
Answer Key [master copy included, 1 page]
Scissors
Colored pencils or crayons
Markers (3 different colors)
Glue or tape
Piece of Construction Paper (1 per student)
Soccer ball
World Map
Internet Access

Background:
None needed.

Activity:

- Explain to the students that just like a puzzle, the earth is made out of pieces. Hold up the soccer ball and show to the class. Just like the soccer ball is made out of different sized and shaped pieces, so is the earth. The only difference is that Earth's pieces are not regularly sized or shaped like the pentagons and hexagons of a soccer ball. Point out the arrows on the different pieces and explain that they indicate the direction of plate motion.
- Hand out materials to students. Hold up the two sheets with the plate pieces on them. Tell the students that these are the pieces that make up the earth. The pieces are called plates (the larger pieces have their names written on them). The gray parts of the pieces are land and the white parts are ocean.
- Give the students a minute to look at the different pieces. Ask the students if they can find a plate piece that is mostly ocean and has hardly any land on it. (Pacific Plate, Nazca Plate, Cocos Plate, Antarctic Plate, Philippine Plate, Caribbean Plate) What about plate pieces that are mostly land. (Arabian Plate, Indian Plate, Eurasian Plate) Which plates have a combination of land and ocean? (African Plate, South American Plate, North American Plate, Australian Plate) Have the students look at the pieces and ask if the edges of the pieces match with the edge of the continents. (They don't)
- Explain to the students that they are going to cut out the pieces and assemble them to make a map of the way the earth looks today. First they are going to color in each plate a different color. Two things to note: 1) point out that the plates include both continent and ocean and that they should be colored as one; 2) even though the Eurasian Plate appears to be two pieces it is really just one. It is split only because the map is a flat representation of a round earth. Both pieces should be colored in the same color. Use the colored pencils or crayons.
- Color before cutting!

- After the students have colored and cut out the plate pieces have them place the pieces onto the construction paper arranged as the world looks today. Students then glue the pieces to the construction paper.
- Have students use the arrows to help them determine whether the plate boundary is divergent, convergent, or transform. Use the markers to draw the divergent plate boundaries in blue, convergent boundaries in red and the transform plate boundaries in green. The transform boundaries are harder to see, so you should point them out in advance: part of the boundary between the Pacific Plate and the North American Plate from the CA/Mexico boarder up to San Francisco, part of the plate boundary through New Zealand, and the boundary between the Nazca and Antarctic Plates. Other boundaries are messy and/or not well defined. The students should mark these with dotted/dashed black lines. These lines separate the Eurasian and African plate boundary, the South American and Antarctic plate boundary, the Australian and Pacific plate boundary, the Australian and Indian plate boundary, and the Saudi Arabia and the Indian plate boundary.

Plotting Earthquake Epicenters

Materials:
Internet – to get list of earthquake locations
Map of the world with latitude/longitude grid [master copy included, 1 page]
Plate Boundary map from the previous lesson

Background:
Students should be familiar with the location of plate boundaries. This isn't required to do the activity, but helps students correlate earthquake locations with plate boundaries.

Activity:

- Prior to doing this activity you will need to go to http://neic.usgs.gov/neis/qed/ and download/print a list of recent global earthquakes. Photocopy this list, one for each student. You will also need to make a photocopy of the world map with the latitude/longitude grid. Also copy the world map onto an overhead transparency.
- Hand out both the map and list of earthquakes. Using the overhead transparency, model for the students how to use the latitude and longitude of an earthquake to plot it on the world map. Have the students plot the point with you. For the younger students you can project the map onto a white board or black board instead of a screen and you can have the students come up to the front of the room and practice plotting the earthquake epicenters. While the students model it on the board, have the rest of the class plot it on their own maps.
- The students will then plot the rest of the points onto their maps independently.
- Compare the maps of earthquake epicenters with the plate boundary map. Have the students make a list (this can be done independently or as a class) of the similarities and differences between the two maps. Have students think about how the earthquakes appear on the map at different types of plate boundaries.

Graphing earthquake frequency with time of day

Materials:
Internet – list of earthquakes and their time of day and time of year, downloaded from the internet, do this for two different years.
Graph paper

Background:
Students should have already completed the activities listed previously in this lesson. This implies an understanding of the correlation between plate boundaries and earthquake locations. In this activity students will be looking for other types of correlations with earthquakes.

Activity:

- Prior to the lesson, you need to go to http://earthquake.usgs.gov/regional/world/historical.php (this link should be used for the students plotting by month) and http://neic.usgs.gov/neis/qed/ (this link should be used for the students plotting by time of day) and download/print a list of the earthquakes that happened in the last two years. If there are enough computers with internet access you can have the students do this themselves.
- Divide the class into groups of four. Half the class is going to graph the number of earthquakes that happen each month, the other half is going to graph the number of earthquakes that happen each hour of the day (ex: from 9am to 10am, 10am to 11am, etc.). Half of the group plotting by month will do it for 2005, and the other half will do it for 2004.
- Students will go through the list of earthquakes and make a tally of the number of earthquakes that happen each month (or the number of earthquakes that happen each hour). This will be slightly harder for the students who are graphing by time of day because they will have to search through all the earthquakes, while the students who are graphing the earthquakes by month will already have the list of earthquakes sorted for them.
- They will then graph the data from their tally. Label the X-axis "Time" (either hour by hour, or month by month), and the Y-axis "Number of Earthquakes". The title of the graph should be "When Earthquakes Happen". The graph should be in the form of a bar graph. Depending on the ability of your students, you can determine how much of this information you will give them and how much information they need to figure out for themselves. Students will need to label whether they are graphing year one or year two.
- Which month has the most earthquakes? How many earthquakes does it have? Which month has the least earthquakes? How many earthquakes does it have? What is the difference between the number of earthquakes in the highest frequency month and the lowest frequency month? What fraction out of the total number of earthquakes is this? What percent? What is the average number of earthquakes per month? How many more earthquakes happen in the most common month than average? What fraction of the total number of earthquakes

is this? What percent? How many less earthquakes happen in the least common month than average? What fraction of the total number of earthquakes is this? What percent? [do these same questions for time of day]

- Have the students meet in pairs to compare the different data from year one and year two. Do the same months (hours) have the most earthquakes? How about the least number of earthquakes? How do the averages from the two years compare?
- Have the whole groups of four meet together to share what they found from answering these questions.
- Ask the students if they think earthquakes are more likely to happen at one time than another. Discuss whether the difference between the most, least and average number of earthquakes is really significant. This is a good example to show students that scientific data is messy, and that just because the number of earthquakes isn't exactly the same in each group, that doesn't mean that it's significant. This also shows that the more data they have the more accurate they can make predictions.
- Have students go back into their pairs and have them combine the data from their tallies, and make one graph with the two years of data. Have them recalculate the answers to the questions above. How different are their answers? Do they think there is a correlation between time of year and when earthquakes happen? How about between time of day and when earthquakes happen?

Fault Block Models

Materials:
Scissors
Crayons or pencils
Fault Block Paper (one per student) [master copy included, 1 page]
Tape
Blank piece of paper (one page)

Background:
No background necessary, but should do the other lessons first.

Activity:

- The teacher should make an example of the model before the students do so that they can see what they are working towards.
- Explain to students that the different types of plate boundaries cause different types of earthquakes to happen. Today they are going to make a model where they can demonstrate the difference between these earthquake types. Show the students your model so they know what they are going to build.
- Have students color in the fault block paper. Layer one should be colored in brown, layer two should be colored in yellow and layer three should be colored in orange. The top should have a blue river, a black road and green for the grass.
- Students should then cut out the blocks along the bold black lines along the edges.
- Students should then fold along the remaining bold black edges and tape the sides together to make a three-dimensional model.
- For the younger students, the cutting and taping should ideally be done in small groups, with a parent volunteer if possible.
- Lead the students in modeling the different types of earthquakes: normal, reverse and strike-slip. For example: have the students match up the two Ns to show what the earth looks like after a normal earthquake; have the students match up the two Rs to show what the earth looks like after a reverse earthquake; have the students match up the two LLs to show what the earth looks like after a left-lateral strike-slip fault; have the students match up the RLs to show what the earth looks like after a right-lateral strike-slip fault.
- Call out the different types of earthquake faults and have the student demonstrate them using their models.
- Give the students blank pieces of paper and have them draw what they see after modeling each earthquake
- Ask the students which types of earthquakes are likely to occur at a divergent plate boundary? Which earthquakes are going to occur at a convergent plate boundary? Which earthquakes are going to occur at a transform plate boundary? Have them add these labels to their drawings of their fault block motions. How do they know which type of earthquake occurs with which type of plate boundary? It's the same type of motion.