Plate Tectonics: Plate Boundaries, Earthquakes, and Volcanoes

Developed by Dave Curry – Newtown, PA – 8th Grade Science (2023-2024)

Guiding Questions

- How are the locations of plate boundaries, earthquakes, and volcanoes explained by the motion of Earth's tectonic plates?
- Are the locations of earthquakes random or is there a pattern to their locations?
- Are the locations of volcanoes random or is there a pattern to their locations?

Placement in Curriculum

This was an excellent activity to start a plate tectonics unit, even before discussing any content-specific topics involving earthquakes, volcanoes, or plate tectonics.

Learning Objectives

Students will be able to:

- describe the general pattern of earthquakes and volcanoes.
- describe the basic locations of plate boundaries and compare them using earthquake and volcano locations (like the stitches on a softball).
- explain why earthquakes, volcanoes, and plate boundaries are not random, but connected in a complex, global dynamic system.
- describe that there are locations on Earth where earthquakes and volcanoes are expected to occur with some regularity, due to the slow, fingernail-like speed of Earth's tectonic plates.

Standards Alignment

Performance Expectations:

- *MS-ESS3-2.* Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Science & Engineering Practices:

- Analyzing and Interpreting Data: Analyze and interpret data to determine similarities and differences in findings.

Disciplinary Core Ideas:

- ESS3.B: Natural Hazards: Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.

Crosscutting Concepts:

- Patterns: Graphs, charts, and images can be used to identify patterns in data.

Advice for Educators

This serves as my starting point for the plate tectonics unit. Even before delving into Alfred Wegener's Theory of Continental Drift and associated evidence, it can be helpful to have students visualize the global locations of earthquakes and volcanoes, which are not random. Alfred Wegener did not have access to this data, as the seafloor had yet to be mapped and earthquake and volcano distribution was not well established. Alfred Wegener continental drift instruction will follow this BIO lesson. It's a great thematic lesson of how sometimes new ideas are disputed and challenged when they threaten the existing conventional paradigm. So true in education too!

Materials

- Computer and LCD Projector to display artwork and dataset
- Observation & Discussion Slide Deck: PowerPoint; pdf
- Featured Artwork: *The Eruption of Vesuvius*
- Featured Data: Volcano Locations
- Sticky notes/easel/dry erase boards for recording questions
- Long strips of cardstock paper approximately 10 inches long by 2 inches across so you can have 5 squares of 2 in. x 2 in. (Template). Dimensions and shape can be changed based on your circumstances/resources/space.
- String and clothespins or tape
- Scissors, markers, colored pencils, erasers
- Rulers
- Paper clips
- Scratch paper
- 11" x 17" vellum tracing paper
- Base Map Template
- Handouts:
  - Fencepost Survey Questions
  - Optional: Data Visualization Choices Worksheet
  - Design Tools Guide
  - Additional Mapped Datasets
    - Earthquakes 6.5 or greater between 2001-2015 Animation (YouTube)
    - Population Density
    - Earthquakes 6.5 or greater between 2001 - 2015
    - Plate Boundaries-Colorized
  - Earthquakes of the 20th Century Cut-Outs
    - Letter (8.5"x11")
    - Tabloid (11"x17")
  - Data Sketches Student Worksheets

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STEP 1 – Observation and Discussion

Overview: Students will collectively observe and discuss artwork that features a scientific phenomenon.

Lesson time: ~45 minutes depending on elements included

Goal: The goal is to create a safe and supportive environment for students to practice making careful observations, thinking critically about the content and features of visual representations, and providing evidence to support their insights and interpretations.

Ground Rules: During the activity, students are invited to silently observe a piece of artwork and then a mapped visual representation of data, offering a comfortable amount of time to collect their thoughts and consider different elements of the artwork and data without influence from others. During the discussion that follows, strategic facilitation techniques are used to solicit and equitably validate ideas from as many students as possible; support students in citing evidence to support their thinking; and leverage students observations to build collective understanding, connect to students' experiences and prior knowledge, and introduce vocabulary related to scientific phenomena. The goal is to encourage students to notice, wonder, express uncertainty, and/or offer unique/diverging perspectives by removing the pressure or incentive to arrive at a "right" answer (or anxieties related to sharing the "wrong" one). The facilitation techniques are also intended to provide low-risk opportunities for students to practice supporting their inferences with evidence.

Part 1 – Art

1. Share norms for the discussion and briefly introduce the process to the students using the **Observation & Discussion Slide Deck**.
2. Optional: Distribute or share a digital copy of the **Featured Artwork**.
3. Project the **Featured Artwork** so that it's visible to the entire class.
4. Invite students to observe the image silently for 1-2 min.
5. Have students journal or write down initial ideas during this time.
6. Tell students: "*Let's take a moment to look at this picture together*."
7. Invite as many students as possible to share their ideas about what the image shows, using the following prompts/facilitation sequence (10-15 minutes)
    a. Invite Student Ideas: *What's going on in this image*?
    b. Gesture: As each student is speaking, use your hand, mouse, or pointer to gesture to parts of the image that they are referencing so that the whole class can see.
    c. Paraphrase: Repeat the student's observations using different language, taking advantage of opportunities to introduce appropriate vocabulary and without validating/invalidating their ideas.
    d. Ask for Evidence: *What do you see that makes you say* _____ ?
    e. Invite More Ideas: *What more can we find*?
8. Thank the class for participating in the experience and for sharing their observations.
9. (Optional) Have students share in pairs any additional thoughts or observations (5 minutes): "*Now that we have all looked together, I know there are still more ideas. Turn to a person sitting next to you and share more or share something you didn't share with the larger group.*"

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Part 2 – Data

1. Tell students that now you are going to use the same approach and observe a mapped dataset. **It is important you do these observation sessions back-to-back. The observation and discussion with the art image may be more accessible to many students and encourages those that do not usually speak up or that are uncomfortable with science/data to participate. The art image may be more engaging and personally relevant, getting the students primed in the approach of observing and talking.*
2. Optional: Share digital copies of the selected data-only visualization so that students can view on their own devices during the silent observation time. Have the students put these devices away and focus on the projected image after the observation time.
3. Project the **Featured Data** WITHOUT the legend. Ask for 1 minute of silent observation time and 2-3 minutes of journaling time. Use the map: **Volcano Locations – WITHOUT Title and Legend**.
4. (If this happens on the next day) Review the norms for discussion again.
5. Invite as many students as possible to share their ideas about the visual patterns they see in the data visualization, using the following facilitation sequence and prompts (~5 minutes)
    a. Invite Student Ideas: *What's going on in this image*?
    b. Gesture: As each student is speaking, use your hand, mouse, or pointer to gesture to parts of the visualization that they are referencing so that the whole class can see.
    c. Paraphrase: Repeat the student's observations using different language, taking advantage of opportunities to introduce appropriate vocabulary related to the phenomenon, visualization, and/or data (e.g., scale, hemisphere, latitude/longitude, trend, variability) and without validating/invalidating their ideas.
    d. Ask for Evidence: *What do you see that makes you say* _____ ?
    e. Invite More Ideas: *What more can we find*?
6. Project the **Featured Data** WITH the title & legend now, so that it's visible to the entire class.
7. Invite students to look again at the data visualization that now includes a legend, providing ~1 minute to silently and independently observe.
8. Invite as many students as possible to share their ideas about the visual patterns they see in the data visualization, using the following facilitation sequence and prompts (~5 minutes)
    a. Invite Student Ideas: *Now that you see this addition, how has your thinking changed?*
    b. Gesture: As each student is speaking, use your hand, mouse, or pointer to gesture to parts of the visualization that they are referencing so that the whole class can see.
    c. Paraphrase: Repeat the student's observations using different language, taking advantage of opportunities to introduce appropriate vocabulary related to the phenomenon, visualization, and/or data (e.g., scale, hemisphere, latitude/longitude, trend, variability) and without validating/invalidating their ideas.
    d. Ask for Evidence: *What do you see that makes you say* _____ *?*

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e. Probe for more: *What do you think [visual feature you observed] might mean?*

f. Invite More Ideas: *What more can we find?*

g. If students are having difficulty providing new observations, try asking:

   i. *What do you wonder?*

   ii. *What jumps out at you? What do you see first?*

   iii. *Does anything in this visualization seem unusual or unexpected to you?*

   iv. *What's interesting to you? What is familiar to you?*

   v. *If you could talk to the scientists who made this, is there anything you'd want to ask them?*

9. Thank the class for participating in the experience and for sharing their observations.
10. (Optional) Have students share in pairs any additional thoughts or observations. Ask them to think about additional questions they have which you will record in the next section (~5 minutes)
11. Tell students: "*Now that we have all looked together, I know there are still more ideas. Turn to a person sitting next to you and share more or share something you didn't share with the larger group. Think about additional questions you might have. We will discuss these questions next as a class."*
12. Develop a list of questions that were generated and ask for more questions. It is at this point that you, the teacher, can interject questions that would facilitate the investigation/learning of content if the students have not yet brought it up. Ask: *What are you curious about? What questions do we have? I'm curious why the patterns are…?*
13. Create a digital (e.g., Google Docs) parking lot with a question list or use sticky notes and tell students you will revisit these questions later in the program. Another option is for the teacher to aggregate the questions into 5-10 questions for a Driving Question Board that can be displayed in the classroom during this unit.

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STEP 2 – Bridging Approach: Fencepost Activity

Overview: Students will use their individual answers as data points and reflect on how the data looks in aggregate as a class and will consider how best to represent their data/answer choices.

Lesson time: 30 minutes

Goal: The goal is to spur students to think critically about data at local and global levels and to understand how data can be collected, compiled, analyzed, and represented.

Part 1 – In-Class Activity

1. Give each student the **Design Tools Guide** handout.

2. Provide context about data collection/sources and symbology. Tell students: "*Data like we just saw in the Mapped Data exercise comes from a variety of sources – individuals can collect data at a local level or one point in time and then combine those observations/data to show data over time or over a larger spatial area. We can also collect data with satellites which provide large areas of remotely sensed observations and can even provide global pictures of data/science phenomena. People use symbols to convey information in a simple and effective way. Symbols are an important part of maps and can represent a range of different types of data. Symbols are described in a legend – a box or other place on the map where there is a key that says what each color of symbol means. Let's look at different ways we can represent data.*"

3. Review the **Design Tools Guide** with students - ask the students to reflect on the previous activity comparing maps about which design tools were used/chosen and why.

4. Give each student a strip of paper that is divided into 5 numbered squares (You can use the **Template** provided).

5. Hand out the **Fencepost Survey Questions**.

6. Read through each question and discuss with the class which design tool would be best, and then determine which color, symbol, shading, etc. would work for that question. This could also be done initially in pairs and then discussed/decided on as a whole class. Tell the students that they can't use each design tool more than once in the survey. **Note: This can be a little time-consuming, but it's a great way to give students a chance to think carefully about design tools, and to take ownership over the data.**

7. Have the students answer the questions on their strip using the colors/symbols that correspond to their answer choice. Instruct the students to work their way through the questionnaire and respond to the first question in the first block and so on. For some questions, students can color, draw or collage with images from the magazines. For other questions, a written word or phrase is ideal.

8. After all students have finished their responses, line all the students' work side by side as a "fence post" (tape them on a wall or attach to a string) so that you can see trends across the class. Alternatively, you can spread them out onto a table so the strips can be moved around.

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9. Invite the students to silently observe the ‘fence posts’ for 1 minute.

10. Invite discussion or written responses on the following:

    a. What patterns do you notice?

    b. What do the patterns tell us about our collected data?

    c. Do you think the patterns would be different in other locations/with other ages/more people?

(Optional) Part 2 – At-Home Activity: Earthquakes of the 20th Century Globe Cut-Outs

Have students create 3D maps of 20th century earthquake locations using one of the **Earthquakes of the 20th Century Cut-Outs**. Though the time it takes to cut out and assemble these maps can be extensive, it is also worth it for helping students visualize and understand the Earth and plate boundaries in three dimensions.

(Optional) Part 3 – Independent Homework: Data Visualization Choices

Have students complete the **Data Visualization Choices Worksheet** as homework over two nights.

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STEP 3 – Data Sketches: Making Data Visual

Overview: This exercise borrows from the Design Thinking Process in a way that gets students engaged in collaboration, hands-on creation, and critical thinking. Through the active process of sketching, students are asked to grapple with what they're learning and reconstruct it in a way that makes sense to them.

Students will work to put what they are learning into action by creating their own representations of data from a set of mapped data. Students will work independently and collaboratively during this process.

Students will practice spatially processing maps that aren't the same scale and may contain distortions, using design tools to represent a set of data across a map; and layering maps to discover what inferences can be made. While the drawing of the map is a key component, it is equally crucial that the students collaborate within their group and have teacher-guided discussions to help support them through what may be a new learning experience.

Lesson time:

- Part 1 - 50 minutes: It's okay to start in class, but students may take it home to finish for HW if they insist on 'perfection'
- Part 2 - 50 minutes

Goal: The goal of this activity is to build skills in understanding the language of data. By carefully representing data in a new way, observation skills are honed, the basic framework of mapped data is learned and understanding of subject matter strengthened.

Lesson Objective(s): Students will

- read and understand a set of mapped data
- follow directions to use the data to create their own map
- develop and agree on design components for their mapped data visualizations
- select their drawing tools
- support each other to learn how to use the template, interpret data, develop conclusions, and give feedback
- create a written and visual example of what they are learning

Part 1 – Plan & Sketch

Have students sit in groups of three.

1. Give each student a printed copy of the original mapped data (with legend) from the Observation and Discussion with Data session along with the **Design Tools Guide** handout.
   Note: By now the students should be familiar with both the original map and the design tools. It is important to keep referring to the design tools so students become familiar with using them.

2. Explain: "*Remember how we looked at the different mapped data representations and how we used the Design Tools to come up with our own symbols to answer the questions in the Fencepost Activity? Today we are going to discuss mapped data further and practice using these tools ourselves by creating our very own map legends with symbols, colors, marks…"*

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3. First, let's remind ourselves about our map from earlier in this lesson. Invite discussion about the following questions regarding the printed map you have handed out (10 minutes)*:*

    - What design tools were used to draw the data on this map?
    - What is included in the legend?
    - Why do you think they chose this particular design tool for this set of data?
    - While some tools are better for representing sets of data, there is no right or wrong tool. Are there different design tools we could use to represent this data? *Look through the handout and discuss what some good choices might be for this topic.*

4. Give each group two **Additional Mapped Datasets** related to the topic so that each student has a different map to work with. You can have students choose or you can assign datasets to different students based on ability or interest. Just make sure that someone from each group is assigned to the original **Featured Data**.

5. Invite students to silently observe their maps for a few minutes and have them spend a little time making sure they understand what the dataset is trying to show. (5 min.)

6. Ask the students to decide within their group how they might represent the data in each of the three maps in a different way than it is currently while using three distinct design tools (i.e., color, symbols, scale) from their **Design Tools Guide** for the three maps. Have students work on developing new legends for each map using scrap paper, pencils, and markers (10 minutes)

7. Ask each student to choose one of the maps. Hand out **Data Sketches Student Worksheet 1** and the **Base Map Template**.

8. Have students paperclip a sheet of tracing paper over the map template and follow the prompts on worksheet 1 (*please show an example of what they are being asked to do*). This worksheet will guide them through beginning their map. *The map template provided to be used as a guide under the tracing paper is important because it forces each student to create a map that is on the same scale as the others so that these maps can be easily layered together in the second part of this exercise. The order of steps on the worksheet is important to follow because it allows the student to create the legend prior to getting involved in the task of drawing. You, as the teacher, can walk through each step one at a time, if needed, or have the students follow the instructions independently. (10 minutes)*

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9. "Sketch" - the final task of this worksheet asks for the student to use their new legend as a guide to sketching out their mapped data in a new way. Students are also asked to note important features. *Students may begin by tracing the outline of the countries and, although it is not necessary and sometimes time-consuming, it is a way that they can begin to process the map spatially. For that reason, the timing of this component is variable and left up to the teacher. Students should have a minimum of 20 minutes to respond or the teacher may choose to break here and allow the students to complete their mapped "work of art" at home overnight and wrap up the next day with Part 2. (20 minutes – 2 hours)*

Part 2 – Analyze & Discuss

1. Looking at the maps they have sketched, ask students to write a one or two sentence summary of what their sketched data represents and then complete **Data Sketches Student Worksheet 2**.
2. Have the students share their answers with their group. (5 min.)
3. Group work Round 1 - Patterns, Correlations, Hypotheses: The group works together to layer two maps at a time and look carefully at the paired maps, noting any patterns and correlations they can find and hypothesizing about what the correlations mean and giving each other feedback. (15 minutes)

   Suggested sentence starters:

   - *We notice that there is a correlation between ___ and ____ …*
   - *There seems to be a pattern in…*
   - *One possible hypothesis that could explain this correlation / pattern is… This makes sense because…*
   - *This could tell us about… by…*
4. Have students report out as a group to the rest of the class about possible patterns, correlations, hypotheses. (10 minutes)

Wrap Up/Synthesis

1. Group work Round 2 - Evaluating Design Choices. Students discuss the design tools they used and evaluate how well those choices worked in terms of helping their analysis of the data. (10 minutes)

   Suggested sentence starters:

   - *One design tool we used was… It helped us notice…*
   - *When we used…. as a design tool, it made it more difficult to notice…*
   - *Using …. as a design tool was interesting because…*
   - *If we could do it again, we would do… differently. This is because…*

2. Have students report out as a group to the rest of the class about their design choices. (5 minutes)

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STEP 4 – Guided Discussion

1. Revisit the questions generated (parking lot/sticky notes) in Step 1.
2. Review if the answers were found during the rest of the activities or if more sleuthing and research needs to be done. This can also be a great jumping off point for other related lessons and activities related to your content.
3. Discuss with the class the following questions:
   a. What questions did we answer?
   b. What questions remain?
   c. How can we find the answers to the remaining questions?
   d. What skills/tools have we learned that can help us answer them?
   e. What research can we do? What additional data do we need?

Assessment

Assessment during this unit was participation based, where students received full credit for completing all activities. Following the BIO unit, students engaged in traditional learning activities and completed formative and summative electronic Canvas assessments.

Assessment can also be individualized based on your classroom/students. You can use these general questions for ideas.

- Did student complete all activities?
- Did student participate actively in discussion?
- Did student show understanding of content?
- Did student show critical thinking?

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