**Plate Tectonics**

**Building Insights through Observation Lesson Plan**

Developed Mid-November-December 2023

**General Earth Science Lesson Information:**

First day of lesson: (Estimated) Monday, October 23, 2023 (Continued Nov 1)

Overview:

Part 1 – Pbservation and Discussion (Artwork and Data)
Part 2 – Local to Global
Part 3 – Data Sketches

**Big Idea:**

Earthquake and volcano locations are explained by the theory of plate tectonics, the idea that Earth's crust is divided into a series of plates that are in slow, constant motion due to convectional forces within and below the mantle.

**Additional info:**

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!

**Topic:** Plate Tectonics: Specifically, Earthquake/Volcano locations on Earth

**Student Learning Objectives:**

- Students will be able to describe the general pattern of earthquakes and volcanoes.
- Students will be able to describe the basic locations of plate boundaries and compare them using earthquake and volcano locations (like the stitches on a softball).
- Students will be able to explain why earthquakes, volcanoes, and plate boundaries are not random, but connected in a complex, global dynamic system.
- Students will be able to 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.

**NGSS Standards addressed:** MS-ESS2-Earth Systems, MS-ESS2B Plate Tectonics and large scale systems, MS-ESS1C-History of Planet Earth, MS-History of Earth, MS-ESS3B - Natural Hazards

## Part 1: Observation and Discussion (One Class Period)

**Part A: Observation and Discussion with Artwork**
**Part B: Observation and Discussion with Data**

**Age group:** Middle School, Honors and Academic inclusion level students

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

**Lesson time:** ~45 minutes depending on elements included

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.

**Materials Needed:**

- Teacher selected artwork featuring scientific phenomenon
    - Projected so that visible to whole class
    - *Optional: Printed or digital copies of the artwork for each student*

- Teacher selected data visualization (2-D map recommended)
    - Projected so that visible to whole class
    - *Optional: Printed or digital copies of the dataset for each student*
- Pointer/Method of directing students' attention to features (**laser pointer**, yard stick, mouse/cursor)
- VTS Reference Card
- Sticky notes or digital space (e.g., Google Docs) for students to record and keep track of questions about the data

**Activity: Observation and Discussion w/ Art (link to complete slide set)**

*Optional: Distribute or share a digital copy of the selected artwork image.*
Project the selected artwork so that it's visible to the entire class.

***Chosen Image:*** *Pierre-Jacques Volaire, French, 1729–c. 1790-1800. The Eruption of Vesuvius, 1771. Oil paint on canvas. Purchased by the Art Institute of Chicago in 1978.*

**Silent Observation** (1-2 minutes): Invite students to observe the image. Provide ~1 minute to look at the image silently and independently. Optional: allow an extra minute to have students journal or write down initial ideas.

- ***Teacher:* "Let's take a moment to look at this picture together."**

**Facilitated Discussion** (10 minutes): Invite as many students as possible to share their ideas about what the image shows, using the following prompts/facilitation sequence.

- ***Invite Student Ideas: "What's going on in this image?"***
- **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.
- **Paraphrase**: Repeat the student's observations using different language, taking advantage of opportunities to introduce appropriate vocabulary and without validating/invalidating their ideas.
- ***Ask for Evidence: "What do you see that makes you say _____ ?"***
- ***Invite More Ideas: "What more can we find?"***

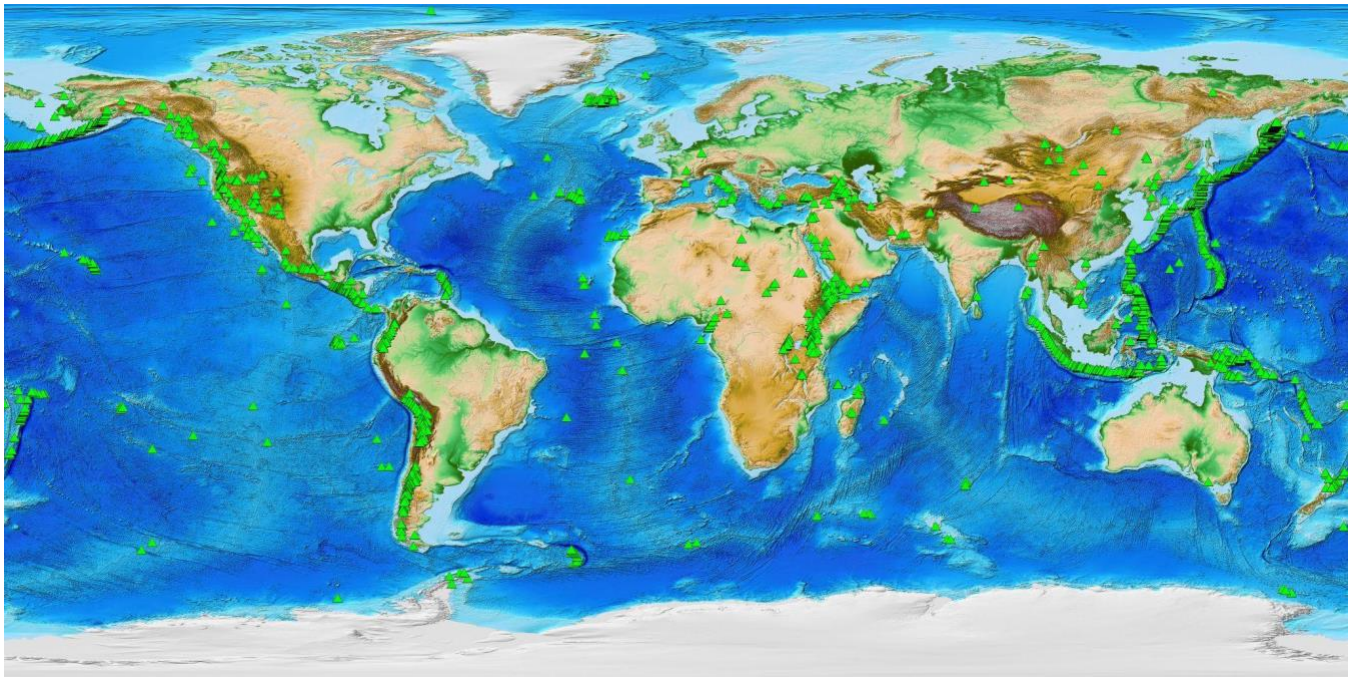
**Conclusion** (1 minute): Thank the class for participating in the experience and for sharing their observations.

**Optional Pair-Share activity** (5 minutes): allow time after the facilitated group discussion for students to share in pairs any additional thoughts or observations.
*Teacher: 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.*

## Observation and Discussion with Data

- Tell students that now you are going to use the same approach and observe a mapped dataset. *It is important you do these Observation and Discussion sessions back to back. 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 also be more engaging and personally relevant, getting the students primed in the approach of observing and talking.

- ***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.*
- Project the selected **data-only** visualization (no legend) visualization so that it's visible to the entire class.



*Chosen Data Visualization (Global Volcanism Program, Volcano Eruption Locations up to 2010, no legend))*

- **Silent Observation** (1-2 minutes): Invite students to observe the data visualization without legend. Provide ~1 minute to look at the visualization silently and independently. Optional: allow an extra minute to have students journal or write down initial ideas.

  ***Teacher:*** ***"Let's take a moment to look at this image together."***

- Facilitated Discussion Part 1 (5 minutes): Invite as many students as possible to share their ideas about what the visual patterns they see in the data visualization, using the following facilitation sequence and prompts.

  ***Invite Student Ideas: "What's going on in this image?"***

  **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.

  **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

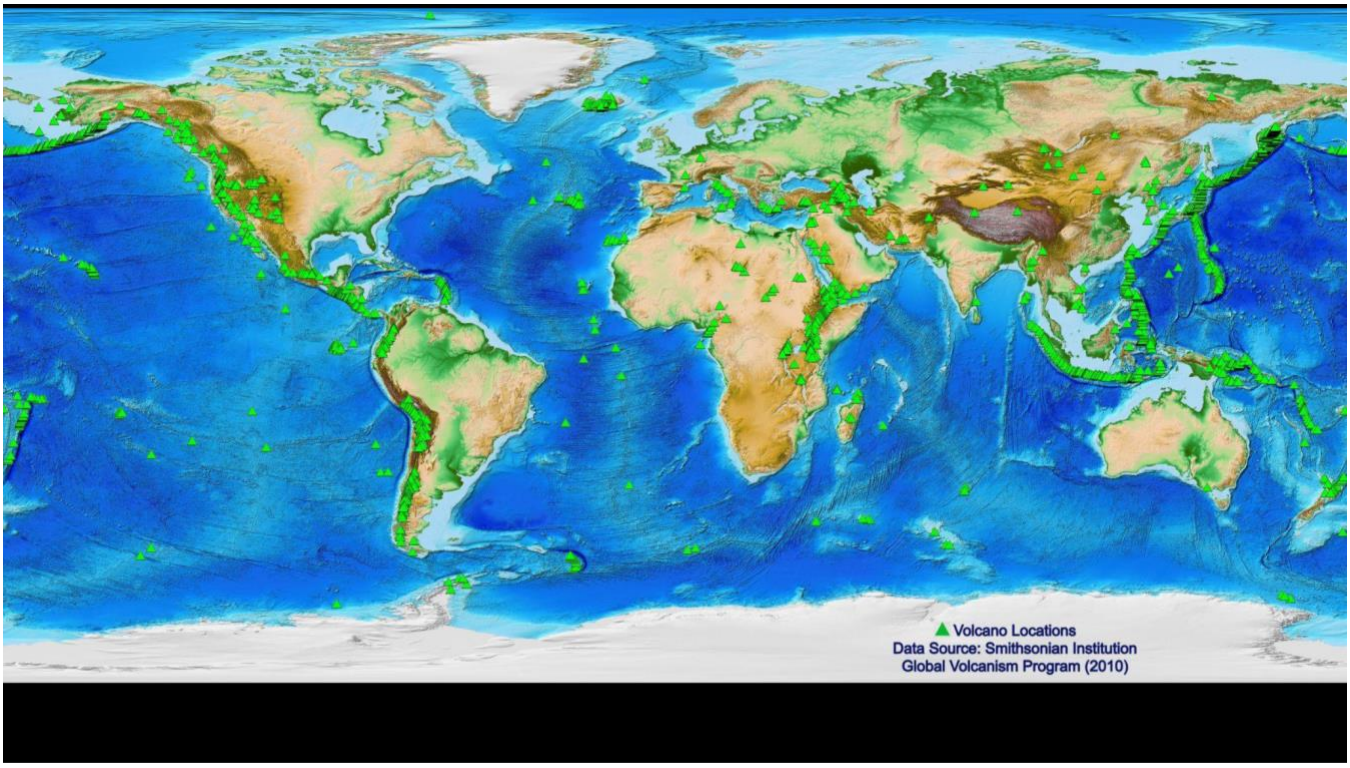
(e.g., scale, hemisphere, latitude/longitude, trend, variability) and without validating/invalidating their ideas.

***Ask for Evidence: "What do you see that makes you say _____ ?"***

***Invite More Ideas: "What more can we find?"***

**Complete Data Visualization with Legend - Observation and Discussion:**

- Project the selected **complete** data visualization (with legend) so that it's visible to the entire class.




*Actual SOSx Data Visualization* ***with Legend***

- **Silent Observation** (1 minute): Invite students to look again at the data visualization that now includes a legend, providing ~1 minute to silently and independently observe.
- **Facilitated Discussion** Part 2 (15-20 minutes):

***Invite Student Ideas: "Now that you see this addition, how has your thinking changed?"***

**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.

**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.

***Ask for Evidence:*** *"What do you see that makes you say _____ ? "*
***Probe for more:*** *"What do you think [visual feature you observed] might mean?"*

***Invite More Ideas: "What more can we find?"***

If students are having difficulty providing new observations, try asking:
***What do you wonder?***
***What jumps out at you? What do you see first?***
***Does anything in this visualization seem unusual or unexpected to you?***
***What's interesting to you? What is familiar to you?***
***If you could talk to the scientists who made this, is there anything you'd want to ask them?***

- **Conclusion** (1 minute): Thank the class for participating in the experience and for sharing their observations.
- Optional Pair-Share activity (5 minutes): allow time after the facilitated group discussion for students to share in pairs any additional thoughts or observations. You could use this time to have them think about additional questions they have which you will record in the next section.

***Teacher: 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.***

**Solicit & Record Questions About the Data & Phenomena** (5 minutes): After students have reflected on the dataset, 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 XXXX.***

**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.

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## Part 2: Fencepost Activity, Local to Global

### Building Insights Through Observation - Making Local to Global Data Connections – Fence Post Activity

**Age group:** middle school
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
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.
This activity asks students to respond personally to a series of environmental, science, and data related questions and then compare and discuss responses. The goal is to harness the power of individuals to illustrate connections within a classroom, as well as to broader communities and systems. Students respond to a questionnaire creatively through collage, drawing, designing, writing, and coloring. The end results are collaged together into a classroom piece and used as a focus of discussion of connections and observations. The activity can be adapted or modified to suit the needs of your classroom and the resources that are available. This example is for severe weather, hurricanes.

**Materials needed:**

- 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 (dimensions and shape can be changed based on your circumstances/resources/space). The strip is divided into different blocks for the total number of questions that are asked in the questionnaire.
- Markers, pencils, old magazines, scissors, glue, crayons, and anything else you think will spur the students' creativity.
- String and clothespin for hanging the strips next to each other like a fencepost.
- Set of questions related to the environmental/science topic under study. Some can be multiple choice and some can be open ended.
- Design Tools Guide

**Activity:**

1. Give each student the Design Tools Guide handout
2. Provide context about data collection/sources and symbology. Suggested text:
   "Data like we just saw in the Science on a Sphere 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 - you can 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 squares numbered 1 through 5. Hand out the survey questions.
5. Read through each question and discuss with the class what symbol they think would be best for each answer choice (this could also be done initially in pairs and then discussed/decided on as a whole class).
6. 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.
7. 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. Explore the results with the class through the script provided.

**Student Worksheet: Local to Global** NAME_____

Data comes from a variety of sources – individuals can collect data at a local level or one point in time and then combine those observations or data points to show information and how it changes 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. (Guide to forming Survey Questions)

We are going to answer a series of questions and then combine the data to see patterns on a larger scale.

**First, answer the questions below.**
Questions (*These will change based on the content topic chosen by the teacher; symbology shown are just suggestions and should be decided by the class together*)

**1. Which natural disaster would you LEAST like to experience? Draw that symbol**

- Hurricane
- Earthquake —----> 
- Volcano

**2. When do you think students should start to learn about preparing for natural disasters?**
  - elementary
  - middle
  - high school

**3. In the event of a natural disaster in an area, should most disaster relief should come from the state vs the federal government?**

- State government (Draw a Keystone)
  Equal parts? Draw a balance… think about making this a scale
- Federal government (Draw a US Flag)

**4.** Nearly every year has at least a magnitude 7.5 or greater earthquake somewhere in the world.
Let's examine the most SIGNIFICANT recent one for the **month** you were born.

**Divide the box for question 4 into 4 equal quadrant squares. In the back of the classroom are two ranked charts. Also posted here and here (two links in Canvas)**

1) **Using the first Link (Largest EQs), Scroll backwards from 2023 to the MOST RECENT INCIDENCE you find of the MONTH you were born and record the Largest Earthquake of that year in the top two quadrants. Record the magnitude, location, and number of deaths in the boxes from that earthquake.**

2) **Using the second Link (Deadliest EQs)Scroll backwards from 2023 to the MOST RECENT INCIDENCE you find of the MONTH you were born and record the Deadliest Earthquake that you find in the bottom two quadrants. Record the magnitude, location, and number of deaths in the boxes from that earthquake.**

| | |
|---|---|
| **Largest** EQ<br>Of<br>[WRITE MONTH/DAY<br>And YEAR] | Write Magnitude,<br>Location and<br>Number of Deaths |
| **Deadliest** EQ<br>Of<br>[WRITE MONTH/DAY<br>And YEAR] | Write Magnitude,<br>Location and<br>Number of Deaths |

**5. Volcanic landscapes often have very fertile soil that can grow crops that struggle to grow anywhere else. Would you be willing to pay more for your Starbucks Coffee/Frappuccino if the price was higher due to volcanic risks where it was sourced?**

Yes: Draw a picture of a dollar bill
No: Draw a picture of a penny or nickel

Now we are going to look at all our data together as a class. Take 1 minute of silent reflection/ observation of our 'fence posts' then answer the questions below.

1. What patterns do you notice?

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

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

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**Part 2B: At-home activity: Earthquakes of the 20th Century Globe cut-outs.**

Letter size (8.5x11) cutouts:
https://sos.noaa.gov/media/downloads/paper-globe-cutouts/Earthquakes%201901-2000%208.5x11x2.pdf

11x17 Cutouts:
https://sos.noaa.gov/media/downloads/paper-globe-cutouts/Earthquakes%201901-2000%2011x17.pdf

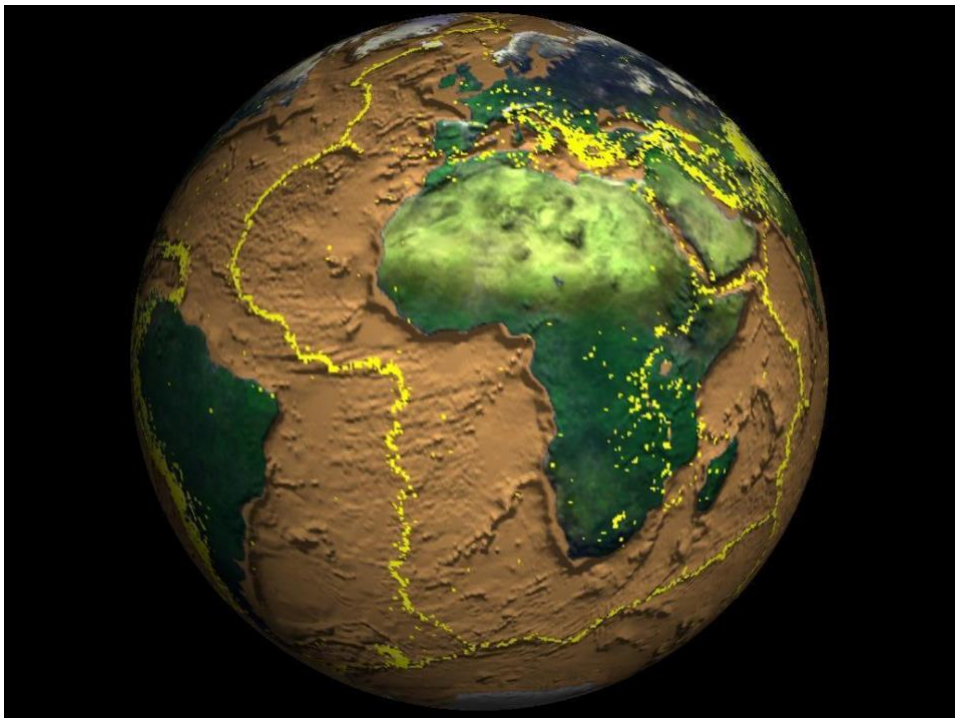
**Rationale:**

Though I agree with the other cohort members and NNC staff that the time it takes to cut these out is *extensive*, I think that in *this* case the time spent **at home** by students would be worth it.

As long as significant class time is not spent doing or explaining this, I would like to keep it in. The plate boundary visualization is just too hard to see on a flat screen, even with 3D touch-rotation. For plate

boundaries and earthquake locations, the 3D effect is valuable (I used to have kids put together the dodecahedron earthquake globe)

I frequently describe the Earth to students as an cracked eggshell or a baseball with the seam wrapping around it. How we get students to visualize and understand this three-dimensional representation of Earth is critical. You might be able to get away with skipping this activity with weather and climate but I don't think leaving it out is a wise decision when studying plate boundaries. I would like to leave it in.



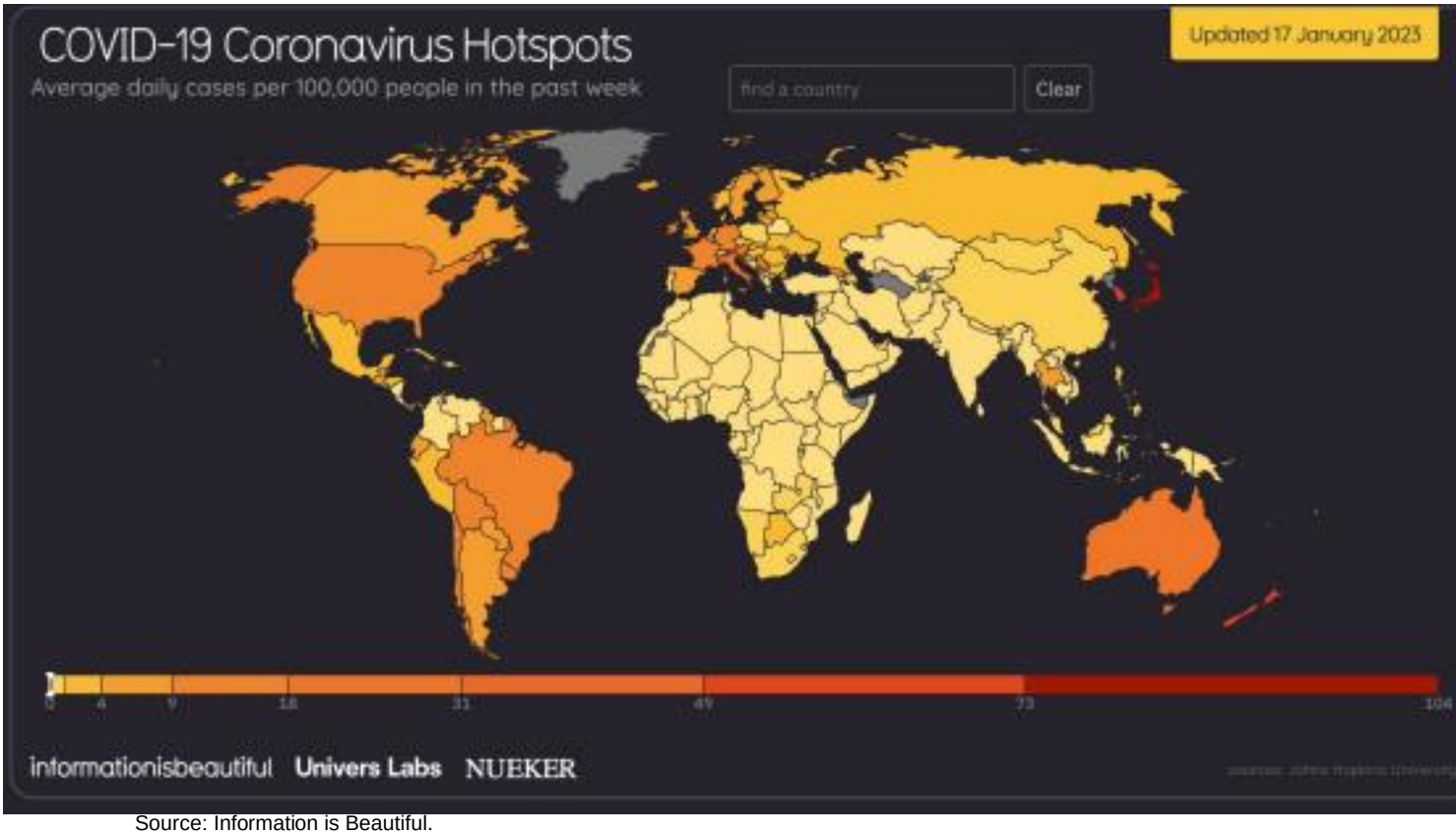
## Part 3: Independent Homework: Data Visualization Choices (Two nights HW)

**Data Visualization Choices Change Understanding of Data**

There are many decisions to be made about the way that data are visualized. A person, sometimes a whole team of people, make very purposeful choices when creating visualizations of data. Sometimes when a choice is made to show something, other important information must be left behind. If a data visualization were to show *everything* from a dataset, it would be overwhelming and nearly impossible for a reader to understand. This activity is meant to get you thinking about how different decisions about how data are visualized change the way that we understand data. There is no one or right way to visualize a dataset. On page 4, check out some of the possible ways you can represent data with different design tools.

While comparing the three data visualizations answer the following questions.

**Figure 1:** COVID-19 Coronavirus Hotspots: Average daily cases per 100,000 people in the past week.




Source: Information is Beautiful.

1. What is the title of the graph?

2. What do you think a "hotspot" means?

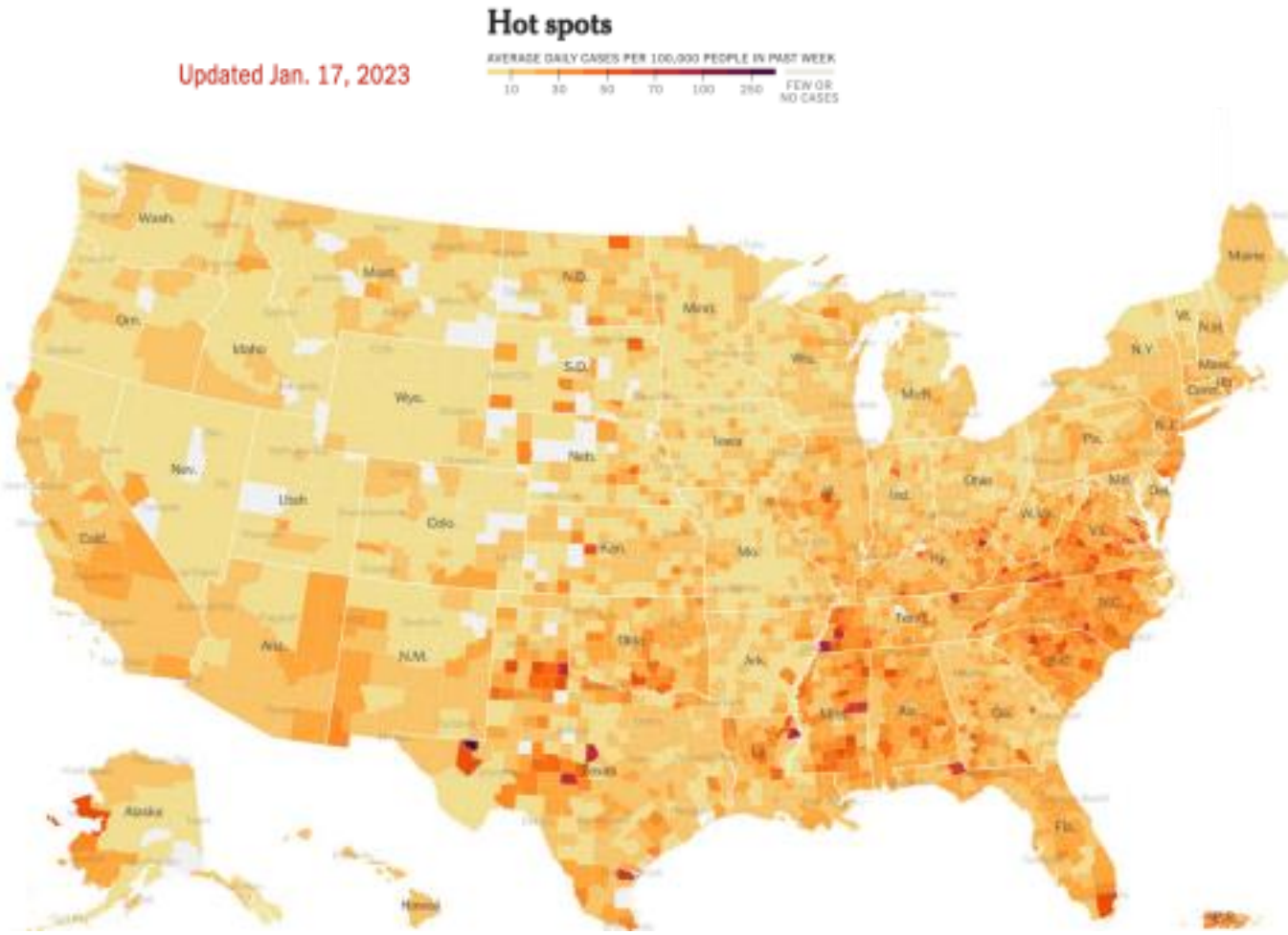
3. What country has the darkest colors? What does that mean? or, what part(s) of the world has the darkest colors? What does that mean?

4. What country has the lightest colors? What does that mean? or, what part(s) of the world has the lightest colors? What does that mean?

5. What design choices were made? Which design tools were used to represent the data? (Take a look at the "Design Tools for Representing Data" on page 5.)

6. How does Figure 1 help your understanding of COVID-19 cases?

**Figure 2:** The hot spots map shows the share of population with a new reported case over the last week. Source: New York Times.




7. What is this graph showing? (source, data, date, etc) How is it different from Figure 1?

8. What states or areas have the darkest colors? What does that

mean? 9. What states or areas have the lightest colors? What

does that mean?

10. What design choices were made? Which design tools were used to represent the data? (Take a look at the “Design Tools for Representing Data” on page 5.)

11. How does Figure 2 help your understanding of COVID-19 cases?

**Figure 3:** 28-Day COVID-19 Cases. Source: Center for Systems Science and Engineering (CSSE) at John Hopkins University (JHU).

12. What is this graph showing? (source, data, date, etc) How is it different from Figure 1? 13.

Where in the world are there more COVID-19 cases? How do you know?

14. What design choices were made? Which design tools were used to represent the data? (Take a look at the “Design Tools for Representing Data” below)

15. How does Figure 3 change your understanding of COVID-19 cases?

16. When and for what purpose would you use Figure 1?

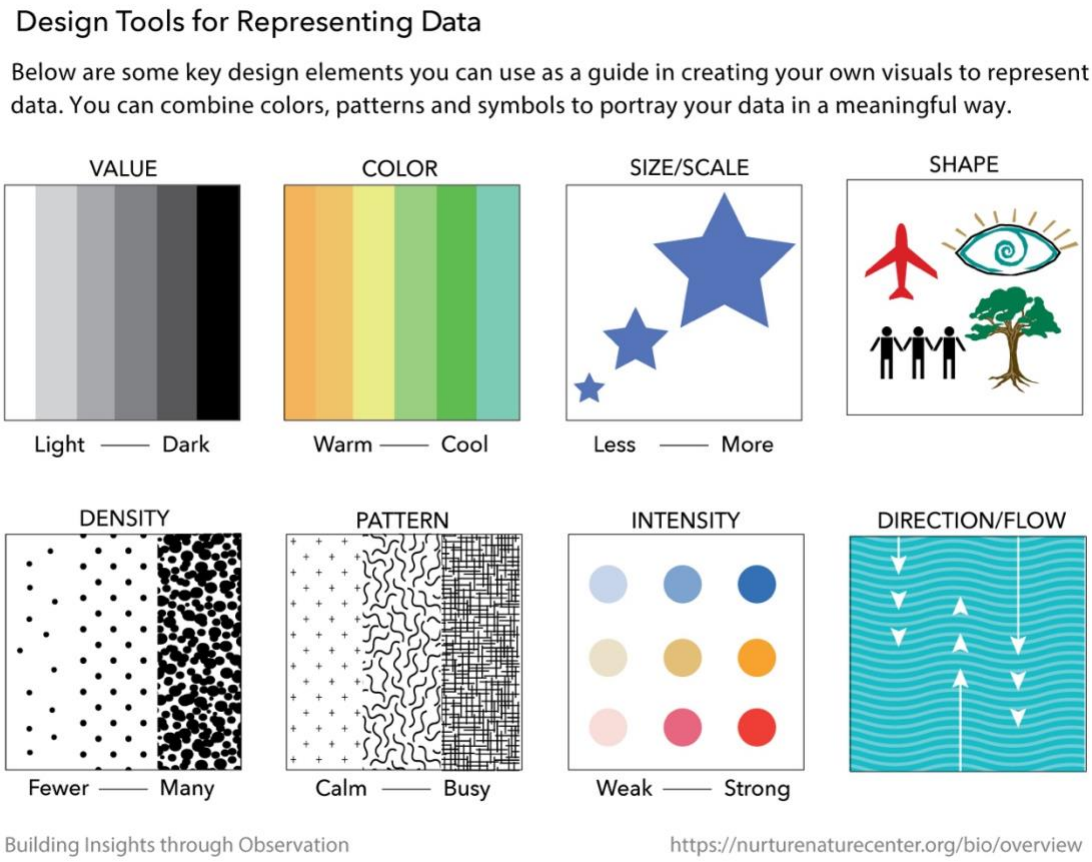
Figure 2?

Figure 3?

17. Between Figures 1-3, which is your favorite? Why?

18. Can you describe other ways that design choices in a data visualization might change your understanding of the information?

**Figure 4**: Design Tools for Representing Data. Source: Nurture Nature Center, Building Insights Through Observation

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## Part 4: Data Sketches Activity (2 Days)

**Links to Data Sketch Maps:**
Volcano Locations
Earthquakes 2001-2015 (Animation)
Population Density
Earthquakes 2005-2015
Plate Boundaries

**Building Insights through Observation - Data Sketches: Making Data Visual**
**Hands-on Exercise**

Age group: middle school

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

*This exercise borrows from the Design Thinking Process in a way that gets students engaged in group 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.*

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.

In the "Data Sketches" activity, 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 (3 at a table) 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.
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

Materials needed:

- Teacher's selection of 3 mapped representations of data (this can be screen displays or printed, static images that relate to the lesson topic. This includes the original dataset with legend used in the VTS - SOS section, along with 2 other related datasets.)
- Handouts:
  - Data Sketches worksheets (1 and 2)
  - Design Tools reference sheet
  - Map Template
- 11" x 17" vellum tracing paper
- scratch or note paper

- colored pencils and regular pencil
- markers (thin line)
- paper clips
- eraser
- ruler

ACTIVITY

**Part 1**

1. Give each student a printed copy of the original mapped data (with legend) from the Observation and Discussion Session along with the "Design Tools" 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 card 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…

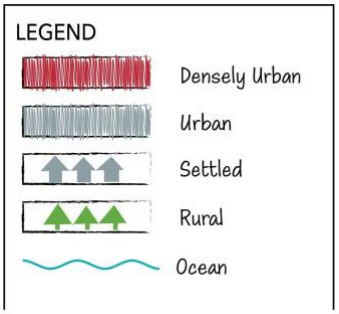
3. First, let's remind ourselves about our map from earlier in this lesson. *Invite discussion about the following questions regarding the printed map you have handed out* (**10 minutes**)*:*

   1. What design tools were used to draw the data on this map?
   2. What is included in the legend?
   3. Why do you think they chose this particular design tool for this set of data?
   4. 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 card 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 table of three students has a total of three maps to work with. Include the source of the data on each map. See links above for set of maps for this activity.

5. Invite students to silently observe their maps for a few minutes. (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 (ie. color, symbols, scale) from their Design Tools sheet 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 the Data Sketches Student Worksheet 1 and the 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)*

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**

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 answer the three following prompts (worksheet 2).
   (10 minutes)

   **My sketch represents**_____.

   a. **I see**…

   b. **I wonder**…

   c**. This data is interesting because…**

2. Have the students share their answers with their group. (5 min.)

3. The group then 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)

4. Have students report out as a group to the rest of the class about their maps. Why did you choose that design tool? Was there anything interesting you discovered when you mapped the data? What correlations were you able to find when you layered your maps? What do these maps tell us about _____ (topic)? *Remember that in this exercise, the teacher can guide the discussion, correct the course, and introduce information about the topic as the lesson unfolds. (20 minutes or until your lesson is over).*

Return to the questions students had throughout the process that were saved in the "Parking Lot".

How many of these questions can we now answer? What do we need to research?