

# Key Ideas Research-Based “Data Design Patterns”

## 1. Data Puzzles

- *What is it?* Snippets of data, preselected by instructor, to demonstrate clearly an important scientific concept or process, via a found or created data visualization.
- *What are the students doing?*
  - Making sense of the data visualization and answering series of guided questions.
  - Working with the data visualization in terms of observations and descriptions of the data (e.g., describe patterns, relationships, and trends or compare and contrast data).
  - Interpreting the data within the data visualization (e.g., develop a potential explanation for each pattern, relationship, or trend or consider the consequences for humans of the phenomenon shown in the data).
- *How does it culminate?* Students experience an “Aha!” while interpreting concrete data in terms of processes previously learned in the abstract, so that they can make meaning of the data by drawing on the concept.

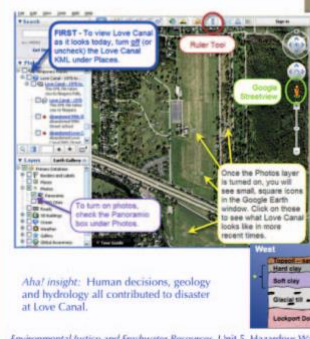
### Data Puzzle

**Sequence:**

- 1) Curriculum developer identifies snippet(s) of authentic data that embody an important and widely-taught scientific concept, and develops data visualization(s) that foreground the patterns or relationships emerging from that concept.
- 2) Students view static data visualization(s) and answer guiding questions about the system represented by the data (not just about how to decode the data).
- 3) *Culmination:* Students experience an “Aha! insight” as they apply a concept they had previously learned about in the abstract to a real world situation manifested in data.

**Hypothesized mechanism:**  
This type of activity allows students to use the connection between data and concept for clear-cut, unambiguous cases. Students practice geoscientists’ habits of mind (spatial and/or temporal reasoning, systems thinking, or quantitative reasoning), and coordinate information from the data with their knowledge of the Earth system. The Aha! insight may provide an affective reward.

**Example:**  
As pre-work, students view videos of Lois Gibbs, leader of Love Canal citizen activists, and create a timeline of events. In think-pair-share format, they combine their timelines, and discuss events most relevant to establishment of the Superfund program.



Working in Google Earth with aerial images and photographs, students compare and contrast Love Canal in 1978 with today.

Using ruler tool, student measure distance from landfill to 1978 houses and present day houses.

Students discuss how location of river and creek, and permeability of stratigraphic layers, influenced the spread of toxic materials.

**Aha! insight:** Human decisions, geology and hydrology all contributed to disaster at Love Canal.

Environmental Justice and Freshwater Resources, Unit 5, Hazardous Waste and Love Canal, Activity 5.2/5.3  
By Jill S. Schneiderman and Meg Stewart

FIGURE 2: The *Data Puzzle* design pattern was found in every one of the six modules examined. It is adaptable for a range of content areas and data types. Color for this figure is available in the online journal.

## 2. Nested Data Sets

- *What is it?* Students connect learner-generated data with professionally-collected data as they work with the same data type(s) across different spatial and/or temporal scales.
- *What are the students doing?*
  - Interpreting a local data set, drawing on local knowledge and personal observations to make sense of the local data (often learner-generated).
  - Accessing the same data type(s) covering a larger area, longer time span, and/or larger populations from professionally-collected data.


### Nested Data Sets

**Sequence:**


- 1) Students interpret a local data set. Ideally they collect this data themselves.
- 2) (optional) Students combine their data with similar data from other students to span a larger population or larger area.
- 3) *Culmination:* Leveraging experience with local data, students interpret professionally collected datasets of the same data type, to expand beyond their local situation to encompass the region, nation or globe.

**Hypothesized mechanism:**  
In interpreting their local data, students can draw on their life experience in the locality, and (in some cases) on their experiences collecting the data. Such experiences can provide insights about potential limitations of the data and potential causal processes or influencers in the system under study. When they move on to interpreting the regional, national or global datasets, students carry these understandings with them, and thus are more appropriately cautious in their treatment of the data and more insightful in their interpretation of its meaning.


**Example:**  
As pre-work, students take an online version of the “Six Americas” survey on “What’s your climate change personality?”



Survey categorizes respondents as alarmed, concerned, cautious, disengaged, doubtful, or dismissive with respect to climate change.



Still as pre-work, students categorize themselves and their community according to population characteristics that affect vulnerability to environmental hazards (e.g. age, education.)



**U.S. Adults, March 2012**

13%	Alarmed
26%	Concerned
23%	Cautious
15%	Disengaged
12%	Doubtful
10%	Dismissive

As students enter classroom, they find the six climate change personalities written on the board. They enter a tally mark next to their own type. Tallies are converted to percentages.

As full class, students compare and contrast class data with national data, hypothesizing about source of differences.

Climate of Change: Interactions and Feedbacks between Water, Air and Ice, Unit 6, Adapting to a Changing World, by Cindy Shellito, Becca Walker, and Cynthia Fadem

FIGURE 7: In the *Nested Data Sets* design pattern, students leverage insights obtained from local data to interpret data on a regional, national, or global scale. Color for this figure is available in the online journal.

- Describing patterns, relationships, and trends in the larger data set.
- How does it culminate? Students leverage their experience with and analysis of the local data to interpret the larger data set and make an inference, see a pattern, or explain a phenomenon at the larger scale.

### 3. Pooling Data to See the Big Picture

- What is it? Across the class, students work with different data sets, preselected by instructor to display a range of attributes, that all pertain to the same real-world phenomenon.
  - What are the students doing?
    - Exploring and interpreting individual data sets pertaining to a phenomenon (individually or in groups).
    - Sharing findings from individual data sets with the full group.
    - Comparing and contrasting data from different data sets.
  - How does it culminate? Students combine insights from multiple data sets to make an inference, see a pattern, or explain a phenomenon that is bigger than could have been accomplished by only looking at one data set.

**Pooling Data to See the Big Picture**

**Sequence:**

- 1) Individually or in small groups, students interpret different datasets pertaining to the same real world phenomena.
- 2) Students share insights from the different datasets.
- 3) Culminating step requires students to combine information so as to construct a broader or deeper view of the phenomenon than would be obtainable from only one dataset.

**Hypothesized mechanism:**

- Well-structured cooperative learning activities foster engagement and collaboration skills, and build an understanding that study of something as vast and heterogeneous as the Earth system must advance through collaboration.
- When humans compare and contrast instances that are related but not identical, they can leverage the powerful cognitive process of analogical reasoning to “extract the schema,” mapping out what the analogs have in common. Through repeated engagement around similarities and differences, students develop the habit of mind of seeing the world as themes with variations.

**Example:**

Everyone examines a submarine divergent margin as pre-work.

Small groups examine 3 separate on-land divergent margins (each with multiple data types).

Full class discussion compares and contrasts across field areas.

Table 1: Complete the Submarine Divergent Plate Boundaries column below before class.

Date Type	Submarine Divergent Plate Boundaries
Earthquake characteristics (area/depth)	
Volcanism characteristics ( erupted products, distance affected)	
Hazards to Humans (how are humans affected – at what scale?)	

Table 2: Group Activity (in class). When instructed, examine data provided for your:

Plate Boundaries/Summary of Data Provided	Mid-Atlantic Ridge: Iceland (Glimmered) Nov 2004	East African Rift: Dabbia Volcano, Afar Region Sept 2005
Earthquake Hazards (e.g. specific spatial patterns/depths)		

*Living on the Edge: Building Resilient Societies on Active Plate Margins, Unit 3, by Laurel Goodell, Peter Selkin, and Rachel Teasdale*

FIGURE 4: In *Pooling Data to See the Big Picture*, students combine insights from related data sets to construct deeper insights than they could get from any single data set. Color for this figure is available in the online journal.

### 4. Predict–Observe–Explain

- What is it? After gaining familiarity with a system through data and/or models, students are then asked to apply that knowledge to how the system could respond to new circumstances.
  - What are the students doing?
    - Making a prediction of how data will look under not-yet-observed conditions.
    - Explaining their reasoning behind their prediction.
    - Proposing how to test their prediction with further data.
  - How does it culminate? Students test their prediction with data, compare and contrast the predicted behavior with the actual

**Predict-Observe-Explain**

**Sequence:**

- 1) Based on either a conceptual model, physical model or computational model, students predict what data from the system under consideration would look like under not-yet-seen conditions.
- 2) Students examine additional data, looking for the presence or absence of predicted patterns.
- 3) Culmination: Students confront success or failure of their prediction.

**Hypothesized mechanism:**

Working out the predictions attunes students to the relationship between candidate causal processes and observable behaviors in the system under consideration. Then, when they explore the data, they have an idea what they are looking for; they have a specific search pattern in mind, and can draw on the human brain's strong pattern-recognition ability. They also see that reality is not as clean and simple as theory might predict.

**Example:**

Previous work familiarized students with a concept map that models how the flow of minerals is impacted by economic and societal factors, such as development of new mineral-using products.

Using concept map model, students predict how certain developments would have impacted price and production of Li and Ni, e.g.:

- 1992: EPA classifies Cd, used in Ni-Cd batteries, as a carcinogen
- 1998-2004: Three new Ni mines open in Australia
- 2007-2009: Global recession.

After making and justifying their predictions, students are given data on Ni and Li prices and production during time span of prediction.

Prompt is “Explain how the data ... support or refute your predictions.”

*Humans' Dependence on Mineral Resources, Unit 2, Activity Option 2.1, The Economics of Batteries, by Prajkti Bhattacharyya, by Branklud and Leah Joseph.*

FIGURE 6: The P-O-E design pattern is widely used with hands-on demonstrations in K–12 education, but in the InTeGrate modules, we found it used for data-based investigations. Color for this figure is available in the online journal.

data, and discuss how the observed patterns in the data support or refute their predictions.

## Other Design Patterns:

### 5. Deriving a New Data Type

- *What is it?* Students work with preselected, by the instructor, data sets or observations to build familiarity with what is being measured and then build their own derived data type step by step.
- *What are the students doing?*
  - Performing a series of calculations based on the measured data.
  - Converting units to develop a derived data type from the measured data.
- *How does it culminate?* Students leverage insights into how the new data type was derived, as well as interpret a data set of the derived data type to make an inference, see a pattern, and/or explain a phenomenon from the derived data.

### 6. Hypothesis Array

- *What is it?* Students are provided with text descriptions and/or sketches of several alternative working hypotheses that might depict a process or structure of the system they are unfamiliar with.
- *What are the students doing?*
  - Moving from a starting point of “I have no idea what I am looking for” to “I am looking for one of these patterns”
  - Practicing how to pay attention to different aspects of a data visualization by comparing and contrasting the candidate hypotheses with the data
- *How does it culminate?* Students use provided data to find evidence that supports or refutes the different provided hypotheses.

### 7. Make-a-Decision or Recommendation

- *What is it?* Students are provided data that are relevant to making a decision for a situation that requires a decision about a human action to be made in regard to Earth-human interaction.
- *What are the students doing?*
  - Working on observation, description, and/or interpretation of data with respect to the scenario.
  - Developing a recommendation, or making a decision for stakeholders, based off of their interpretation of the data.
- *How does it culminate?* Students must make their decision or provide a recommendation for stakeholders that is grounded in the data as well as explain and defend the reasoning behind their decision.

## References

Kastens, K. and Krumhansl, R. (2017). Identifying curriculum design patterns as a strategy for focusing geoscience education research: a proof of concept based on teaching and learning with geoscience data. *Journal of Geoscience Education*, 65(4), 373-392.

Kastens, K., Krumhansl, R., & Baker, I. (2015). THINKING BIG. *The Science Teacher*, 82(5), 25-31.