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.

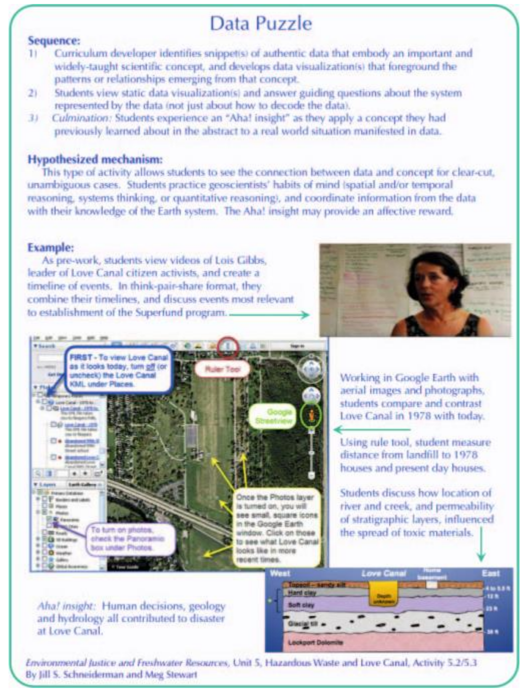

FIGURE 2: The *Data Puzzle* design pattern was found in every one of the six modules examined. It is adaptable for a range of content areas and data types. Color for this figure is available in the online journal.

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.

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.

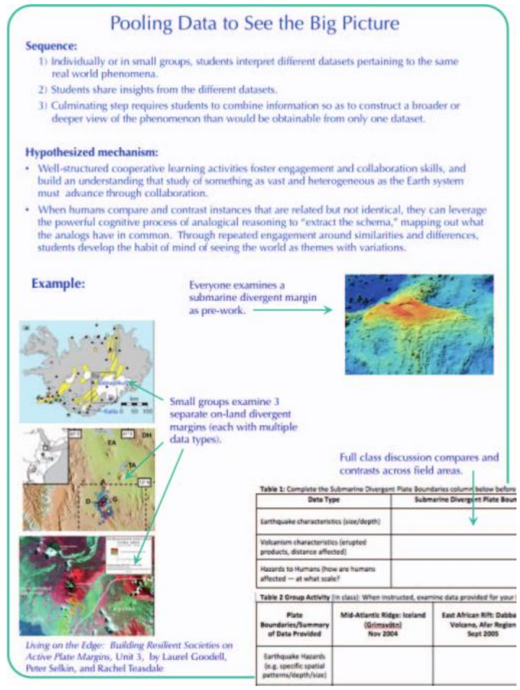

FIGURE 4: In *Pooling Data to See the Big Picture*, students combine insights from related data sets to construct deeper insights than they could get from any single data set. Color for this figure is available in the online journal.

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

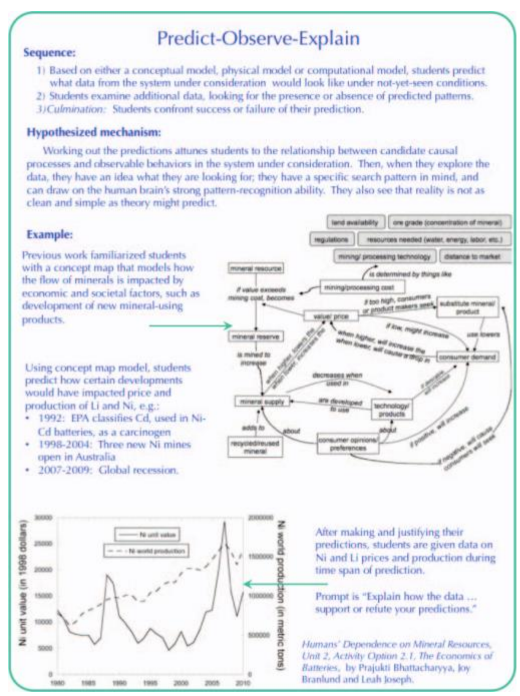

FIGURE 6: The *P-O-E* design pattern is widely used with hands-on demonstrations in K–12 education, but in the InTeGrate modules, we found it used for data-based investigations. Color for this figure is available in the online journal.

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.