Geoscience Data Puzzles: Developing Students’ Ability to Make Meaning from Data

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Elements of a learning progression from primary school to undergraduate

Student-collected data  Professionally-collected data

Day in the Life of the Hudson  Aboard *Joides Resolution*, Leg 107
Elements of a Learning Progression ….

Embodied, experiential grasp of the natural setting and data collection methods

Metadata

(from School in the Forest powerpoint, http://www.blackrockforest.org/docs/about-the-forest/schoolintheforest/)

(from Using a Digital Library to Enhance Earth Science Education, Rajul Pandya, Holly Devaul, and Mary Marlino)
Elements of a Learning Progression ….

Dozens of data points

Air temperature at noon (from Clement, 2002)

Megabytes

Observed Precipit. Anomaly QND 2002
Shaded ONLY for "ABOVE-Normal" & "BELOW-Normal"
[CAMS OPI data, courtesy of NCEP/CPC]
Elements of a Learning Progression ….

Interpret one data set at a time

Multiple data sets with interactions; varying data types

Air temperature at noon

(from Clement, 2002)
Looking up values

What was the salinity at noon on April 16?

Seeing and interpreting patterns

Atmospheric CO₂ at Mauna Loa Observatory

Anthropogenic input

Seasonal photosynthetic activity
Elements of a Learning Progression ….

Common sense lines of reasoning

Spatial, temporal, statistical reasoning. Multi-step chains of reasoning

(Wainwright, 2002)
Learning Progression

- Student-collected data
- Embodied, experiential sense of circumstances
- Dozens to hundreds of data points
- Interpret one data set at a time
- “Common sense” lines of reasoning
- Single step causal chains

- Professionally-collected data
- Sense of circumstances from metadata
- Megabytes
- Multiple data sets and their interactions
- Temporal, spatial, quantitative and other lines of reasoning
- Multi-step lines of reasoning
Many students have not had very much contact with real data in High School.
Many laboratory activities use physical models rather than actual Earth or Earth data.
Teachers themselves did not learn via data...

- Krajick et al (1998): “although middle school teachers may have considerable content knowledge, they are less likely to have had experience dealing with real data…”

- Bowen and Roth (2005): “despite considerable preparation, and for many, bachelor of science degrees, pre-service teachers do not enact the ('authentic') practices that scientists routinely do when asked to interpret data or graphs.”
Lamont-Doherty Earth Science Data Puzzles

- Use carefully-selected snippets of real Earth data
- High insight to effort ratio for students
- Low barrier to entry for teachers
- Require knowledge integration
- Require critical thinking
- Offer an “aha” moment

http://www.njtpa.org/About/Guide/default.aspx
The fog comes on little cat feet.

It sits looking over harbor and city on silent haunches and then moves on.

---- Carl Sandburg

Poetry: An example of a complex, multi-layered, non-linear, metaphorical, pattern-rich representation system

Low barrier to entry
High insight to effort
Example of a Data Puzzle

The Hudson River Data Puzzle

Section one of the puzzle incorporates student-collected data.

- Students read the river mile map and plot the data onto the map.

- Students consider Earth processes to explain
  - variations in salinity
  - variations in direction of flow
Example of a Data Puzzle

The Hudson River Data Puzzle

Section two of the puzzle incorporates data collected by a local Environmental Center.

• Students read and describe the rainfall and salinity charts.

• Students consider a relationship between the two Earth processes.

• Students formulate an hypotheses to explain the relationship between rain and river salinity.
Example of a Data Puzzle

5. The “Salt Front” is the location where the river salinity is 100 ppm. 100 ppm salinity falls within acceptable drinking water standards. The United States Geological Survey records the location of “the salt front” in river miles each day (see table). This data is a guide for communities that use the river as a source for drinking water.
   a. Using a blue color pencil, plot the “salt front” data for August/September in one continuous line on the graph paper provided. Describe the salt front location for August/September.
   b. Plot the March/April salt front data on the same graph using a red color pencil. Label your graph. Describe the salt front location for March/April.
   c. Compare and contrast the salt front location for the two time intervals plotted.
   d. Using the data from your graph, and your map, list two communities along the Hudson River where the salinity of the water was low enough to have been good to drink throughout all of August and September.

6. Thinking of the processes you explored in Question 4 and the data of Question 5, what might cause the differences between the March/April and August/September salt front locations?

<table>
<thead>
<tr>
<th>Dates</th>
<th>RM</th>
<th>Dates</th>
<th>RM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar 1</td>
<td>62</td>
<td>Aug 1</td>
<td>62</td>
</tr>
<tr>
<td>Mar 5</td>
<td>56</td>
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<td>66</td>
</tr>
<tr>
<td>Mar 9</td>
<td>47</td>
<td>Aug 9</td>
<td>68</td>
</tr>
<tr>
<td>Mar 13</td>
<td>55</td>
<td>Aug 13</td>
<td>68</td>
</tr>
<tr>
<td>Mar 17</td>
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</tr>
<tr>
<td>Mar 25</td>
<td>68</td>
<td>Aug 25</td>
<td>69</td>
</tr>
<tr>
<td>Mar 29</td>
<td>58</td>
<td>Aug 29</td>
<td>69</td>
</tr>
<tr>
<td>Apr 1</td>
<td>28</td>
<td>Sept 1</td>
<td>70</td>
</tr>
<tr>
<td>Apr 5</td>
<td>12</td>
<td>Sept 5</td>
<td>69</td>
</tr>
<tr>
<td>Apr 9</td>
<td>0</td>
<td>Sept 9</td>
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</tr>
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<td>30</td>
<td>Sept 13</td>
<td>70</td>
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<tr>
<td>Apr 17</td>
<td>38</td>
<td>Sept 17</td>
<td>73</td>
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<tr>
<td>Apr 21</td>
<td>60</td>
<td>Sept 21</td>
<td>67</td>
</tr>
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<td>Apr 25</td>
<td>58</td>
<td>Sept 25</td>
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<tr>
<td>Apr 29</td>
<td>38</td>
<td>Sept 29</td>
<td>71</td>
</tr>
</tbody>
</table>

The Hudson River Data Puzzle

Section three of the puzzle incorporates professionally collected data from the USGS

- Students plot points from the salt front - two months of spring and two of fall
- Students describe their graph
- Students interpret their graph
**Answer Key**

(4) We have talked about the tides. The graph pictured here displays data collected in April of a recent year by instruments at the Beczak Environmental Center in Yonkers (located at river mile 18). Notice the rise and fall of salinity levels twice a day 4/15 and 4/16. Salinity in the river fluctuates rhythmically with the tidal cycle. Trace your pencil along the rise and fall of salinity. Predict what the salinity will be like for 4/17 and 4/18 by completing the salinity line on the graph with your pencil.

*I predict that the salinity will continue to increase and decrease twice a day with the flood and ebb tides, see graph.*

**Critical Thinking**

(T) Students recognize that the graph is recording a periodic phenomenon, something that repeats at regular intervals of time, and that the time interval between repetitions is about half a day. (C) They connect that twice-a-day repeat time with their knowledge of tidal cycles.

(T) Students make a prediction about the future behavior of a system: to do so, they use:
- their observation that the system is behaving in a regular, repeatable way
- their understanding that there is a mechanism (tides) behind the observed regularity that would be expected to continue into the future.
Evidence + Reasoning → Claim

Data

Critical thinking or Meaning-making

- Temporal reasoning
- Spatial reasoning
- Concept-based reasoning
- Quantitative reasoning

Answer to the Question
Temporal Reasoning

Students make inferences from observations about the timing, rates and sequence of Earth events and processes.
Quantitative Reasoning

Students make use of numerical information to gain insight into, or reason about, Earth processes.

<table>
<thead>
<tr>
<th>River Mile</th>
<th>Salinity in ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>26000</td>
</tr>
<tr>
<td>2</td>
<td>16000</td>
</tr>
<tr>
<td>7</td>
<td>13300</td>
</tr>
<tr>
<td>14</td>
<td>9800</td>
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<td>84.5</td>
<td>35</td>
</tr>
<tr>
<td>127</td>
<td>30</td>
</tr>
</tbody>
</table>

Salinity Data from Hudson River Snapshot Day
Collected October 12th
Spatial Reasoning

Students make inferences from observations about the location, orientation, shape, configuration or trajectory of objects or phenomena.

4. Scientists use the present climates in which these trees live to help them understand past climates. The range maps above show the areas of North America where the three tree types represented in the sediment core are found today.

a) Which tree is found in the coldest locations?

b) Which tree is found in the warmest locations?
8. Why do you think the sediments before 14,000 years ago had no pine, spruce, or oak pollen?
Pedagogical Content Knowledge (PCK) Guide

<table>
<thead>
<tr>
<th>Answer Key</th>
<th>Critical Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) The table on the next page contains surface salinity readings collected by school groups during the annual Hudson River Snapshot Day. The Salinity is recorded in parts per million (ppm). Ocean water is ~35,000 ppm while distilled water is 0 ppm. Write the salinity readings from the different river miles onto the map. Answers on map below.</td>
<td>(S) Students reorganize information from a tabular arrangement into a spatial arrangement. (Q) Students use units of parts per million, a ratio measure of concentration. In helping students to understand these units, a comparison to the more familiar percent (parts per hundred) may be helpful.</td>
</tr>
</tbody>
</table>

Teachers can use the step-by-step reasoning:

- to plan scaffolding for their students,
- to diagnose student difficulties,
- to target specific thinking skills in their lesson planning,
- to learn from.
Puzzle Topics

• Where did the water go?
• Is the Hudson River too salty to drink? (Margie Turrin)
• How much heat is released by a seafloor hydrothermal vent? (Rosemarie Sanders)
• How do we know what climate was like in the past? (David McGee)
• What does an earthquake feel like?
• “Weather” or not to proceed with the trip? (Deanna Bollinger)
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