NGSS Practices in Action

Breakout B: MS/HS Earth/Space Science

Presented by: Ann Rivet

November 15, 2014
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Introducing today’s presenter...

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Teachers College Columbia University
Earth Science and Science Practices

Professor Ann Rivet
Teachers College Columbia University

NSTA Virtual Conference
November 15, 2014
Who Am I?

• Associate Professor of Science Education at Teachers College Columbia University
• Background in science: physics and earth science
• Focus on the design of learning environments that support students in understanding the Earth
• Connections between curriculum, instruction and assessment
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Caveat
• Not part of the Framework development team
Overview

• Key themes and modes of inquiry in Earth science

• Examples of connecting NGSS learning performances, modes of inquiry, and range of science practices through instruction

• Discussion
Practices and the *Framework*

1. Ask questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Developing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information
Merging Practices and DCIs

Questions for the day:

• What does the merging of science practices with the core ideas of Earth Science look like?

• What are the most productive ways to develop them across the curriculum?
Why Focus on Earth Science?

• Unique among science disciplines

1. Interactions of four central Earth subsystems – atmosphere, hydrosphere, geosphere, and biosphere
   • Energy moves and matter cycles within and among these subsystems

2. Understanding the different processes that cause the Earth to change over time (how it “works”) requires knowledge of the multiple systems’ interconnections and feedbacks

3. Earth is part of a broader system—the solar system—which is itself a small part of one of the many galaxies in the universe

4. Rapidly increasing relevance of Earth science to many aspects of human society
Poll: Challenges to Teaching Earth Science

- In your opinion, which do you think is the biggest challenge to teaching Earth Science?

<table>
<thead>
<tr>
<th>Response</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>There is too much content to cover</td>
<td></td>
</tr>
<tr>
<td>The range of ideas is very wide</td>
<td></td>
</tr>
<tr>
<td>Students tend not to have prior instruction</td>
<td></td>
</tr>
<tr>
<td>The Earth is too big</td>
<td></td>
</tr>
<tr>
<td>Difficult to bring students outside</td>
<td></td>
</tr>
<tr>
<td>It is hard to run experiments</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>All of the above</td>
<td></td>
</tr>
</tbody>
</table>
A Central Challenge

- The Earth is 18 orders of magnitude larger than a classroom

Classroom (exaggerated)

Earth
Ways to Address Challenge

• 3 ways to engage students with Earth phenomena
  1. Bring samples of the Earth into the classroom (realia)
  2. Bring students out of the classroom to observe the Earth
  3. Use representations
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Shifts in Learning Earth Science

• Prior standards focused on sub-processes and systems
  • Lots of facts, rather isolated and disconnected
  • Missing a holistic perspective on why it is important to learn about aspects of the Earth, and how and why these aspects interact and work together
  • Implicit assumption that because the Earth is all around us, it is inherently interesting to learn about
Shifts in Learning Earth Science

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• NGSS places emphasis on interactions between key global systems, the role of energy and water across systems, and the impact of these interactions on the environment (both physical and biological)
  • Emphasizes multiple connections to the physical and life sciences
  • Foregrounds the notion of change, as a concept and a lens to view the consequences of Earth processes
Modes of Earth Science Inquiry

- Earth Science is a science of both what and how we know about the Earth
  - Need to understand the ways that we study and learn
- Six different ways that Earth scientists engage in scientific inquiry of large-scale Earth processes and phenomena
  - Classic “experiment”
  - Changes over time
  - Variations across space
  - Comparisons with modern processes
  - Physical models
  - Computational models
- Each mode allows for different kinds of questions, and different understandings to be explored and developed

1. Classic “Experiment”

- In a laboratory
- Control one or few variables
- Allow process to run
- Collect quantitative data
- Examine different outcomes as a function of controlled variable

Flume photo; [http://www.iihr.uiowa.edu/facilities/rsflume/index.html](http://www.iihr.uiowa.edu/facilities/rsflume/index.html)

Graph from: NY State Earth Science Reference Tables
Classic “Experiment”: Classroom Example

- Classroom example: Weathering rocks
  1. Students weigh samples of different rock types and place in unbreakable containers with water
  2. Shake vigorously for same amount of time
  3. Calculate the percentage of each sample that was “weathered”
  4. Graph changes in sample size to rock type, compare relative weathering rates
2. Changes Over Time

- Human timescale with instrumental record
- Longer timescales with natural timekeepers

![Tree rings](http://www.terradaily.com/images/tree-rings-bg.jpg)

![Carbon dioxide in atmosphere at Mauna Loa](http://astro.wsu.edu/worthey/earth/html/im-atmosphere/co2-keeling.gif)

- Tree coring: [bsi.montana.edu/programs/treeringlab](http://bsi.montana.edu/programs/treeringlab)
Changes Over Time: Logic

1. Sequence constrains causality
2. Rate constrains power
3. Patterns: increasing, decreasing, accelerating

The Cretaceous-Tertiary Boundary

Forams: http://www.nmnh.si.edu/paleo/images/k_t_core.jpg
Iridium: http://teachersnetwork.org/everywhere/Vaillancourt/extinction2.html
Changes Over Time: Classroom Example

Water Quality Investigation

• Visual images and water quality tests (pH, DO, turbidity)
• Analyze through tables, graphs, and comparison of images and archival data
• Triangulate interpretations across multiple data sources
3. Variations Across Space

- Spatial gradient
- Co-occurrence
Variations Across Space: Classroom Example

<table>
<thead>
<tr>
<th>Amount of precipitation</th>
<th>Mean population density</th>
<th>Description of locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>All values</td>
<td>31.6</td>
<td>-</td>
</tr>
<tr>
<td>Greater than 300 cm/year</td>
<td>47.4</td>
<td>Near the Equator – Indonesia, West Africa, Brazil, and Central America</td>
</tr>
<tr>
<td>Less than 10 cm/yr</td>
<td>9.6</td>
<td>Sahara Desert in Africa, Andes Mountains in South America, Himalaya Mountains in Asia.</td>
</tr>
</tbody>
</table>

Question: Where is all the water?
- Use GIS tool for looking at patterns of data across the Earth.
4. Comparisons with Modern (Active) Processes

- “The present is the key to the past”
Comparisons with Modern Processes: Classroom Example

• Fossilized Footprint Activity
  1. Students measure and graph ratios of their foot length: leg length, and leg length: stride length
  2. Compare those ratios to those of fossil footprints (both dinosaurs and early hominids)
5. Physical Models

- Develop and iteratively refine physical model
- Nuances of process: sequence geometry, trends, patterns
- Compare model behavior with observations from the Earth
Physical Models: Classroom Examples

- Stream tables
- Moon phases
Physical Models: Classroom Examples

- Stream tables
- Moon phases
6. Computational Models

- Begin with a conceptual model
- Express hypothesis as computational relationships
- Incorporate computational relationships into digital model
- Compare model output with data from real Earth
- “Data assimilation” to improve model

[Image of El Niño conditions and maps showing probability forecast for precipitation in October-November-December 2002 made in September 2002.]

http://www.pmel.noaa.gov/tao/elnino/gif/ElNino.gif

http://iri.columbia.edu/climate/forecast/
Computational Models: Classroom Example

EdGCM
Educational Global Climate Model
Modes of Inquiry

• Wide range of ways that Earth scientists study the Earth
  • Reflected in NGSS
  • Need for integration into the curriculum

• These six modes of inquiry can serve as opportunities for students to learn Earth Science disciplinary core ideas, cross-cutting themes, and practices across their K-12 learning experiences

• Up next: How modes of inquiry are related to science practices in Earth Science learning
Questions?
Relating Modes of Inquiry to NGSS

Questions for the day:

- What does the merging of science practices with the core ideas of Earth Science look like?
- What are the most productive ways to develop them across the curriculum?

Add one more...

- How does this perspective on modes of Earth Science inquiry relate to science practices?
DCI ESS1: Earth’s Place in the Universe

• Describes the universe as a whole, on a grand scale of space and time
  • Includes overall structure, composition and history of the universe; the forces and processes by which the solar system operates, and Earth’s planetary history

• 3 component ideas
  • The universe and its stars
  • Earth and the solar system
  • The history of planet Earth
Learning Performance

- **HS-ESS1-5**: Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks

[Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust increasing with distance away from a central ancient core (a result of past plate interactions).]
Investigation: Discovering Plate Boundaries

• Discovering plate boundaries: http://plateboundary.rice.edu/home.html

• Objectives: Synthesize evidence from Earth data to describe and explain the nature of tectonic plates
Investigation: Discovering Plate Boundaries
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Investigation: Discovering Plate Boundaries
Activity: Your Turn to Analyze

Using the data shown, which area of oceanic crust is older?
A. Purple star location
B. Orange heart location
C. Both locations are the same age

Think about your evidence.
Activity: Your Turn to Analyze

- Using the data shown, which area of oceanic crust is older?
  
  A. Purple star location
  
  B. Orange heart location

Think about your evidence.
Science Practices and Modes of Inquiry

• Earth Science mode of inquiry: variation across space
  • Co-occurrence across spatial gradients

• Science practices:
  • Asking questions
  • Using models
  • Analyzing and interpreting data
  • Computational thinking
  • Developing explanations
  • Arguing from evidence
  • Communicating information
DCI ESS2: Earth’s Systems

• The array of interrelated processes that create Earth’s current conditions and their continual change over time
  • Earth’s large-scale structure and composition; describes its subsystems and how they are interrelated; mechanisms that drive Earth’s internal motions; the vital role that water plays in all of the planet’s systems and surface processes

• 5 component ideas
  • Earth materials and systems
  • Plate tectonics and large-scale system interactions
  • The roles of water in Earth’s surface properties
  • Weather and climate
  • Biogeology
• MS-ESS2-2. **Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.** [Clarification Statement: Emphasis is on how processes change Earth’s surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]
Investigation: Evolution of Stream Systems

• Modification of Stream Table Inquiry: http://www.exploratorium.edu/ifi/docs/Stream_Table.pdf

• Objectives: to explore and describe the processes by which stream systems change over time, and the conditions that lead to those changes
Investigation: Evolution of Stream Systems

- Broader context of landforms and how they are shaped
- Identify and investigate variables (slope, materials, water speed, etc.) that affect stream shape and resulting landforms (meanders, alluvial fans, oxbow lake, etc.)
Investigation: Evolution of Stream Systems

- Compare resulting model with satellite images for data analysis and interpretation
Investigation: Evolution of Stream Systems

• Compare resulting model with satellite images for data analysis and interpretation
Activity: Your Turn To Analyze

• How is what is happening in the stream table (left) similar to what is happening at the mouth of the Connecticut River (right)? Select all that apply.

A. Both show erosion and deposition
B. In both, the sediment is making mud
C. Both show the formation of an alluvial fan
D. Both show islands being formed
E. Both show a deep canyon
Science Practices and Modes of Inquiry

• Earth Science mode of inquiry: *physical models*
  - Compare model behavior with data from the real Earth

• Science practices:
  - Asking questions
  - Developing and using models
  - Designing and carrying out investigations
  - Analyzing and interpreting data
  - Developing explanations
  - Arguing from evidence
  - Communicating information
DCI ESS3: Earth and Human Activity

- Addresses directly the interactions between the planet and human society
  - How Earth’s processes affect people through natural resources and natural hazards
  - Ways in which humanity in turn affects Earth’s processes

- 4 component ideas
  - Natural resources
  - Natural hazards
  - Human impacts on Earth systems
  - Global climate change
Learning Performance

- **HS-ESS3-5.** Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]
Investigation: Factors of Climate Change


- Objectives: Understand relationships between factors that influence climate in particular locations, then examine climate models to make predictions about the nature and rate of future changes
Investigation: Factors of Climate Change
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Investigation: Factors of Climate Change
Science Practices and Modes of Inquiry

• Earth Science mode of inquiry: *computational models*
  • Compare model behavior with data from the real Earth

• Science practices:
  • Asking questions
  • Developing and using models
  • **Analyzing and interpreting data**
  • Using computational thinking
  • Developing explanations
  • Arguing from evidence
  • Communicating information
Questions?
Common Challenges

• Mis-perception that content knowledge comes before practices
  • Blending of practices and DCIs to promote integrated understanding

• Focus on the activity rather than the meaning of the activity
  • Important supports for reflection, connections, and relating to the big ideas

• Narrow focus on only single performance of single practice
  • All modes of inquiry engage most all of the practices
  • Understanding allows ability to demonstrate all of the practices
Assessment

• Two-fold goal: Robust understandings of Earth science concepts demonstrated through participation in practices, and fluency with engaging with practices across a range of Earth science core ideas
  • Through modes of inquiry, both formal and informal assessment opportunities

• Ask students to explain their process
  • *How did they get to that interpretation?*

• Ask students to provide a rationale for their decisions
  • *Why did you choose to use that kind of model?*
  • *Why did you average?*
  • *Why did you select this evidence to support your claim?*

• Ask students about other considerations during inquiry
  • *What could be sources of error in your investigation?*
  • *What could be a counter-argument to your claim?*
Conclusions

• These practices, modes of inquiry, and Earth science understandings build across multiple experiences over many years

• These types of experiences take time in the classroom, but not more time

• Focus on teaching the core idea through the practice, not the learning performance

• Lots of different applications across the Earth science (and other sciences) curriculum
Thank You!

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Thanks to today’s presenter!

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