Re-conceptualizing the Scientific Inquiry Geoscience Education Literature in Context of the K-12 Next Generation Science Standards (NGSS) Practices

Nancy A. Price - Department of Geology - Portland State University

- Asking Questions & Defining Problems
- Developing & Using Models
- Planning & Carrying Out an Investigation
- Analyzing & Interpreting Data
- Using Mathematics & Computational Thinking
- Constructing Explanations & Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating, & Communicating Information
Driving Questions for the Literature Review:

1. How can we re-conceptualize the past literature on “scientific inquiry” in the face of the new terminology of the NGSS?

   Developing & Executing Methods:
   • Conceptual Framework from which to consider the Practices?
   • Defining (comprehensive) search terms.
   • What parameters with which to evaluate existing literature?

2. Which Practices are well studied/understudied in the Earth & Space Sciences literature?

   Example Practice: Developing & Using Models

   Execution of Methods: Emergent Themes for the Earth & Space Sciences:
   • Articulating “aspects of inquiry“ that are characteristic of each Practice in the Earth & Space Sciences
   • Definition of Practice Pairs as “inquiry paths” in the Earth & Space Sciences
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Intellectual Framework:
- Holistic view of the process of science as encompassing epistemic, cognitive, and social dimensions

Contributions from the Literature:
- How social aspects of science have influenced the progression science
- Contexts from which to learn and interact with science
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- “Activities of science” as pedagogy.
- Inquiry methods lead to a greater depth understanding

**Contributions from the Literature:**
- Pedagogical strategies (“best practices” for inquiry)
- Professional development that promote inquiry
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**Intellectual Framework:**
- Science practice as a set of epistemic activities
- Practices as skills/competencies on which students can be assessed

**Contributions from the Literature:**
- Definition of practices as used by scientists
- Isolated activities (skills) vs. practice as a set of epistemic activities
1. How can we re-conceptualize the past literature on “scientific inquiry” in the face of the new terminology of the NGSS?

- *Defining (comprehensive) search terms.*

<table>
<thead>
<tr>
<th>Practice: Developing and Using Models</th>
<th>Search Terms</th>
<th>Topics Encountered in the Search</th>
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<tbody>
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<td>Developing and Using Models</td>
<td>Models*; Developing Models; Using Models; Modeling; Model-Based; Model-Based Conceptual Change; Conceptual Model; Scientific Models; Causal Models; Systems Model</td>
<td>mental models; misconceptions/alternative conceptions/preconceptions; conceptual change; analogical thinking; visualization; spatial thinking; student conceptions of deep time; systems thinking; model-based learning; gesturing; concept mapping; Sun-Moon-Earth system; watershed models; computational models; virtual environments; Google Earth/GIS as an educational tool; constructivist learning</td>
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*Note: Search terms as outlined above were combined with “Geosciences”; “Geology”, & “Earth Sciences”*

- Started with terminology of the Next Generation Science Standards, then added search terms based on the nature of results.

- For each search, results were reviewed for ~15-20 pages (depending on the relevancy of the results) and continued until little-to-no novel/relevant results.
1. How can we re-conceptualize the past literature on “scientific inquiry” in the face of the new terminology of the NGSS?
   - *What parameters with which to evaluate existing literature?*

### A. Type of Article

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<th>Instructional Treatment Research Study</th>
<th>Reflective Study of Classroom Products/Student Work</th>
<th>Survey Study</th>
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### B. Grade Level

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<th>Elementary</th>
<th>Middle School circa 11 yr, 5/6 grade</th>
<th>High School</th>
<th>K-12</th>
<th>Intro College/University</th>
<th>Pre-service/In-service Teacher Education</th>
<th>N/A or not stated</th>
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A. Type of Article
B. Grade Level
C. Practice

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- Relevant, but not directly connected to a Practice
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A. **Type of Article**

B. **Grade Level**

C. **Practice**

D. **Learning Target**

- Asking Questions & Defining Problems
- Developing & Using Models
  - Planning & Carrying Out an Investigation
  - Analyzing & Interpreting Data
  - Using Mathematics & Computational Thinking
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- Relevant, but not directly connected to a Practice

A. Develop/Use a model to represent an event or object
B. Compare models to find similarities and/or differences
C. Develop/Use a model to represent differences in amounts, scales
D. Develop/Use a model to represent an abstract/unobservable concept
E. Develop/Use a model to describe phenomena
F. Develop/Use a model to make a prediction
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   **Example Practice:** Developing & Using Models

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**Example Practice: Developing & Using Models**

- Papers resulting from search terms for “Developing & Using Models” (N= 73)

- Some papers fit into multiple categories (e.g. Literature Review & Outline of a Framework)

**Topics Encountered in the Search**
- Mental models;
- Misconceptions/alternative conceptions/preconceptions;
- Conceptual change; analogical thinking; visualization; spatial thinking; student conceptions of deep time; systems thinking; model-based learning; gesturing; concept mapping; Sun-Moon-Earth system; watershed models; computational models; virtual environments; Google Earth/GIS as an educational tool; constructivist learning
Example Practice: Developing & Using Models

- Elementary & Middle School are well represented, but there is much to learn from studies of 2/4yr colleges/universities.

- How well do teachers understand models?

- Overlap between Paper Type & Grade Level for Developing & Using Models?
  - Elementary Levels and Cognitive = Sun, Moon, Earth System
Example Practice: Developing & Using Models

Execution of Methods: Emergent Themes for the Earth & Space Sciences:

• Definition of Practice Pairs as “inquiry paths” in the Earth & Space Sciences
FIGURE 5
Science practice model.

FIGURE 6
Science practice model annotated for owl pellets.

<table>
<thead>
<tr>
<th>Steps</th>
<th>Specifics of practice</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Made a food web model.</td>
</tr>
<tr>
<td>2</td>
<td>We got our owl pellets and he gave us questions.</td>
</tr>
<tr>
<td>3</td>
<td>We then planned out how we were going to make all the measurements and then carried it out.</td>
</tr>
<tr>
<td>4</td>
<td>Used mathematical thinking to make measurements.</td>
</tr>
<tr>
<td>5</td>
<td>Dissected the owl pellet, found bones, and other information.</td>
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(From Nyman & St. Clair, 2016; after Harwood, 2004- J of Col. Sci. Teaching)
A Geometric Teaching Model emphasizes the nonlinear nature of science. For example, the candle burning inquiry, the step “investigating the known” was not the process of stopping, evaluating the science practice that is currently being done in the lab and to think about their learning and doing process, that is, to evaluate what exactly they are doing in the lab and to think about their science practice model.

The next step in developing the NGSS’s science practices (Figure 5).

We used the NGSS science practice model to annotate the owl pellet inquiry (Figure 6), where the crossing lines and returning to the cross bridge class between science content and doing laboratories; we will report on the results of a study using the NGSS science practices model tasks they were undertaking. Clearly, using the NGSS science practices model was happening helped students see the connections between the scientific content and the practical tasks.

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Conducting an observational investigation in the Earth & Space Sciences.

**FIGURE 5**
Science practice model.

**Execution of Methods: Emergent Themes for the Earth & Space Sciences:**
- Definition of Practice Pairs as “inquiry paths” in the Earth & Space Sciences
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Visualization, Models as a way of communicating a concept.

Visualization, using computers to communicate information at different scales.

Visualization, studying patterns in data.

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Science practice model.

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- Sun-Moon-Earth System
- regional to micro- scales
- systems thinking
- change over time
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<th>Practice: Aspects Unique to the Nature of Science of the Geosciences</th>
<th>Aspects Unique to the Geosciences as Science Practice</th>
<th>Aspects Relevant for Teaching Geoscience Topics</th>
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<tr>
<td>Developing and Using Models - Geoscientists investigate concepts that span a wide range of spatial and temporal scales that are commonly understood and discussed using models. - Geologists used models to make sense of abstract and/or unobservable objects and phenomena.</td>
<td>- Analog models are used as physical representations of the Earth that are used in making predictions and investigating ideas. - Geoscientists represent Earth systems as models that are used as a common framework guiding all aspects of inquiry. - Representations of causal relationships in systems models are predictions that can be tested.</td>
<td>- Analogies and Analog models can be used as tools for building knowledge of abstract/unobservable geoscience concepts by explicitly mapping the ways that the two examples are related. - Model revision is important for students to move from representation to incorporation of causal mechanism. - Analog models allow students to manipulate the spatial and temporal scales of the model to study Earth processes</td>
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Questions, Comments, Feedback?
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