Supporting students in scientific inquiry without sacrificing the science content

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November, 2006

What we will do today
• Work on constructing an explanation
• Look at the current state of science education
• Explore how to do inquiry without sacrificing content
• Define and explore some BIG IDEAS
• Unpack a content standard and an scientific inquiry standard
• Examine the use of explanations as an exemplar of scientific practices

Substance and Property Explanation Task
Examine the following data table:

<table>
<thead>
<tr>
<th>Density</th>
<th>Color</th>
<th>Mass</th>
<th>Melting Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid 1</td>
<td>0.93 g/cm³</td>
<td>no color</td>
<td>38 g</td>
</tr>
<tr>
<td>Liquid 2</td>
<td>0.79 g/cm³</td>
<td>no color</td>
<td>38 g</td>
</tr>
<tr>
<td>Liquid 3</td>
<td>13.6 g/cm³</td>
<td>silver</td>
<td>21 g</td>
</tr>
<tr>
<td>Liquid 4</td>
<td>0.93 g/cm³</td>
<td>no color</td>
<td>16 g</td>
</tr>
</tbody>
</table>

Write a scientific explanation that states whether any of the liquids are the same substance.
Were you just involved in doing some form of inquiry?

Science Education Today

- An exciting time
  - Emerging ideas in science
  - New ideas on how students learn
  - Emergence of standards
- A challenging time
  - US students continue to fall behind internationally
  - US students are not pursuing STEM degrees
  - Too much to teach
  - Learning through inquiry remains underused and challenged
  - No Child Left Behind
  - Dwindling resources

How will you support students in scientific inquiry without sacrificing the science content?
Focus on Learning Goals

- Need to focus on the most important ideas learners will need
- What is it that you want students to learn? What do you really value?

USE Standards

Claim: Learning is facilitated when new and existing knowledge is structured around the enduring or big ideas of the discipline. What big ideas should you pick?
**What are Big Ideas**

- Explanatory power within and across discipline
- Powerful way of thinking about the world
- Building blocks for further learning
- Necessary for intellectual participation in making individual, social and political decisions regarding science and technology.

**Subject Matter Big Ideas**

- **Energy**
- **Structure-Function**
- **Ecology/Interrelationships**
- **Particulate Theory Of Matter**
- **Conservation**
- **Plate Tectonics**
- **Force and Motion**
- **Diversity**

**Use and match Big Ideas with Standards**

- Big Idea: Particle nature of matter
- National Standards from Benchmarks 4D1: Atoms may stick together in well-defined molecules or may be packed together in large arrays. Different arrangements of atoms into groups compose all substances.
Unpacking Standards

1. Interpreting the Standard
   I. Decompose into related concepts
   II. Clarify the different concepts
   III. Consider what other concepts are needed
   IV. Make links if needed to other standards
2. Consider students prior knowledge
   I. Students prior knowledge
   II. Possible non-normative ideas

Scientific Inquiry Practices

• What are Scientific Inquiry Practices?
  • The multiple ways of knowing and doing that scientists use to study the natural world.

• Scientific practices include
  • Asking questions to guide investigations
  • Creating, revising and using models
  • Constructing and revising explanations
  • Using and giving priority to evidence
  • Designing and performing investigation

Essential Features of Classroom Inquiry and Their Variations

Learners
• Engage in scientifically oriented questions
• Give priority to evidence in responding to questions
• Formulate explanation from evidence
• Connect explanations to scientific knowledge
• Communicate and justify explanations

From the National Science Education Standards
Scientific Explanations

- Stressed in the science education standards
- Science is about explaining phenomena
- Change students’ image and understanding of science
- Foster deeper understanding of important science concepts

Student Difficulties with Explanations

Evidence
- Students have difficulty using appropriate evidence and connecting evidence to a claim
- Students typically discount data if the data contradicts their current theory

Reasoning
- Most explanations include claims with little backing

Explanations in Classroom Practice

- Although important, explanations are frequently left out of classroom practice
- Project 2061 review of middle school science materials found that most materials were unlikely to result in students developing understandings of key learning goals.
Unpacking the Inquiry Standard

- Our Framework for a Scientific Explanations
  - **Claim**: a conclusion about a problem
  - **Evidence**: scientific data that supports the claim
  - **Reasoning**: a justification that shows why the data counts as evidence to support the claim and includes appropriate scientific principles
  - Consider alternative explanations

Creating Learning Performances

- **What are Learning Performances?**
  - Describes what it means for learners to "understand" a scientific idea
  - Clarifies how the subject matter knowledge is used in reasoning about scientific questions and phenomena
- **Why Learning Performances?**
  - Know or understand is too vague
  - Use scientific inquiry practices to specify what students should do.

<table>
<thead>
<tr>
<th>Content Standard</th>
<th>Inquiry Practice</th>
<th>Learning Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>When substances interact to form new substances, the elements composing them combine in new ways. In such recombinations, the properties of the new substances may be very different from those of the old.</td>
<td>Develop an explanation, using evidence. (NRC, 1996, A: 1/4, 5-8)</td>
<td>LP 12 - Students construct scientific explanations stating a claim whether a chemical reaction occurred; evidence in the form of properties; and reasoning that a chemical reaction is a process in which old substances interact to form new substances with different properties than the old substances.</td>
</tr>
</tbody>
</table>
Content Standard plus Inquiry Standard

Learning Performance

Assessment Learning Task

Instructional Strategies

1. Make the inquiry framework explicit
2. Discuss the rationale behind inquiry practice
3. Model the inquiry practice
4. Provide multiple opportunities to perform the inquiry practice
5. Have students critique their work and the work of other students
6. Provide students with feedback

Substance and Property Explanation Task

Examine the following data table:

<table>
<thead>
<tr>
<th></th>
<th>Density</th>
<th>Color</th>
<th>Mass</th>
<th>Melting Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid 1</td>
<td>0.93 g/cm³</td>
<td>no color</td>
<td>38 g</td>
<td>-98 °C</td>
</tr>
<tr>
<td>Liquid 2</td>
<td>0.79 g/cm³</td>
<td>no color</td>
<td>38 g</td>
<td>-26 °C</td>
</tr>
<tr>
<td>Liquid 3</td>
<td>13.6 g/cm³</td>
<td>silver</td>
<td>21 g</td>
<td>-39 °C</td>
</tr>
<tr>
<td>Liquid 4</td>
<td>0.93 g/cm³</td>
<td>no color</td>
<td>16 g</td>
<td>-98 °C</td>
</tr>
</tbody>
</table>

Write a scientific explanation that states whether any of the liquids are the same substance.
Student Response for Substance Explanation

Write a scientific explanation that states whether any of the liquids are the same substance.

Liquid 1 and 4 are indeed the same substance. Looking at this data, the properties include: Density, Color, and Melting Point. Mass is not a property. Density, color, and M.P. are all the same for liquid 1 and 4. Since all of these properties are the same, liquid 1 and 4 are the same substance.

Were you involved in inquiry?

- Did you engage in working with big ideas?
- Did you construct a scientific explanation?
- Did you give priority to evidence?

Do students learn??
Participants

7th grade science teachers and students.

<table>
<thead>
<tr>
<th>Site</th>
<th>Urban A</th>
<th>Town B</th>
<th>Urban C</th>
<th>Suburb D</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schools</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Teachers</td>
<td>9</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Classrooms</td>
<td>32</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>41</td>
</tr>
<tr>
<td>Students</td>
<td>1026</td>
<td>61</td>
<td>51</td>
<td>59</td>
<td>1197</td>
</tr>
</tbody>
</table>

- Students completed identical pre- and posttest measures. Three open-ended items were explanations.
- Independent raters scored the items. Inter-rater reliability was 97% for claim, 95% for evidence, and 97% for reasoning.

Results: Student Learning

Student Learning of Scientific Explanation (n=935)

The Big Message
- To support students in scientific inquiry without sacrificing the science content
  - Focus on learning goals
  - Unpack the learning goals
  - Create learning performances
  - Develops aligned lessons and assessments
Thanks to many IQWST Development and Research Team Colleagues at Northwestern University, MSU & Project 2061 Many teachers with whom we work National Science Foundation - Investigating and Questioning our World through Science and Technology Project - Center for Curriculum Materials in Science

More Information

- Join the IQWST Team
- Slides will be posted at
  - http://www-personal.umich.edu/~krajcik/Papers.htm
- Contact me
  - krajcik@umich.edu
- See my web sites
  - www.hice.org/
  - www.hice.org/IQWST

Hyperlink Slides
Emergence of Standards

- Summarize the knowledge students should know
- Standards Guide
  - The development of materials
  - The selection of resources
  - Teachers instructional priorities
  - Teachers in planning lessons
  - The development of assessments
- Examples include
  - Benchmarks for Science Literacy
  - National Science Education Standards

Inquiry - the Preferred Method

“Inquiry into authentic questions generated from student experience is the central strategy for teaching science. Teachers focus inquiry predominantly on real phenomena, in classrooms, outdoors, or in laboratory settings, where students are given investigations or guided toward fashioning investigations that are demanding but within their capacities.”

New NanoScience Ideas

Stain-free pants

10 nm long (nano-whiskers)
Whiskers create an air cushion that keeps fabric dry but “whiskers” are so short the fabric still is soft to the touch.

Nanoscience will push us to use new phenomena in science education as we as push us in helping students understand the ideas!

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Essential Features of Classroom Inquiry and Their Variations

<table>
<thead>
<tr>
<th>Essential Feature</th>
<th>Variation</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner engages in evidence-directed thinking</td>
<td>Learner given data and asked to analyze</td>
<td>Learner directed to collect certain data</td>
</tr>
<tr>
<td>Learner gives priority to evidence</td>
<td>Learner given data and asked to analyze</td>
<td>Learner directed to collect certain data</td>
</tr>
<tr>
<td>Learner communicates explanations</td>
<td>Learner given data and asked to analyze</td>
<td>Learner directed to collect certain data</td>
</tr>
<tr>
<td>Learner formulates reasonable explanations</td>
<td>Learner given data and asked to analyze</td>
<td>Learner directed to collect certain data</td>
</tr>
</tbody>
</table>

Adapted from the National Science Education Standards.

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Learner gives priority to evidence in responding to questions

- Learner determines what constitutes evidence and collects it
- Learner directed to collect certain data
- Learner given data and asked to analyze
- Learner given data and told how to analyze

- Greater amount of student direction
- Lesser amount of student direction
Unpacking Standards

• Standard from SFAA: When substances interact to form new substances, the elements composing them combine in new ways. In such recombinations, the properties of the new combinations may be very different from those of the old (AAAS, 1990, p.47).

• Unpacked Standard: Substances have distinct properties and are made of one material throughout. (Prior knowledge of properties is necessary). A chemical reaction is a process where new substances are made from old substances. One type of chemical reaction is when two substances are mixed together and they interact to form new substance(s). The properties of the new substance(s) are different from the old substance(s).

Writing Assessments

Carlos wants to know if two liquids will react with each other. He uses an eyedropper to get a sample from the two liquids. He takes some measurements of the two samples. Then he puts the two liquids together and heats them. After stirring and heating the liquids, they form two separate layers — layer X and layer Y. Carlos uses an eyedropper to get a sample from each layer. He takes measurements of each sample. Here are his results:

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Melting Point</th>
<th>Volume</th>
<th>Solubility in water</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before stirring &amp; heating</td>
<td>Sample A</td>
<td>9.0 °C</td>
<td>2.00 cm³</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Sample B</td>
<td>80.5 °C</td>
<td>2.00 cm³</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Layer X</td>
<td>91.5 °C</td>
<td>2.00 cm³</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Layer Y</td>
<td>0.0 °C</td>
<td>2.00 cm³</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Write a scientific explanation that states whether a chemical reaction occurred.

Student Investigation: Did a chemical reaction occur?

<table>
<thead>
<tr>
<th>Properties</th>
<th>Density</th>
<th>Melting Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper Penny</td>
<td>Very hard</td>
<td>8.96 g/cm³</td>
</tr>
<tr>
<td>Vinegar (Acid)</td>
<td>No water</td>
<td>Liquid</td>
</tr>
<tr>
<td>Solid on Penny</td>
<td>Green</td>
<td>Soft solid</td>
</tr>
</tbody>
</table>
Ideas from Learning Theory

- Expert Knowledge Organization
- Contextualized
- Relate to Prior Knowledge
- Active Construction
- Community of Learners
- Cognitive Tools

NRC B5-B: 1A: A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample.