Forward Thinking: Backward Design

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What we will do today

• Describe backwards design
• Unpack standards
• Define learning performance
• Discuss how starting from learning goals leads to alignment
• Show that students learn when learning goals, learning tasks and assessments align
What is backwards design?

Start with learning goals before you plan assessments and instruction

Use standards to identify key learning goals

What are Standards?

• Summarize the knowledge students should know.
• Examples include
  – Benchmarks for Science Literacy
  – National Science Education Standards
• Consist mostly of brief statements of propositional knowledge that students of different ages should know

Value of Standards

Standards Guide
• The development of curriculum materials
• The selection of resources
• Teachers in instructional priorities
• Teachers in planning lessons
• The developing assessments
  – Large scale and classroom based
• Setting performance levels
What does it mean to “understand” a scientific idea? How do we know if students understand?

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. (6 - 8 benchmark from Atlas of Scientific Understanding)

What does it mean? What do we expect students to be able to do?

• But what standards should you pick?
• Assumption: Learning is facilitated when new and existing knowledge is structured around the enduring or big ideas of the discipline.
• Pick Big Ideas

Criteria for “Big Ideas”

- Explanatory power within and across discipline and/or scales: The enduring idea helps one to understand a variety of different ideas within and/or between science disciplines.
- Powerful way of thinking about the world: The enduring idea provides insight into the development of the field, or has had key influence on the domain.
- Accessible to learners through their cognitive abilities (age-appropriateness) and experiences with phenomena and representations.
Criteria Big Ideas Continued

• Building blocks for future learning: The enduring idea is key for future development of other concepts and helps lay the foundation for continual learning.

• The enduring ideas will help the individual participate intellectually in making individual, social and political decisions regarding science and technology.

Some Big Ideas

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. (6 - 8 benchmark from Atlas of Scientific Understanding)

What are other big ideas?

Elaborating Standards

1. Identify Standards -- use criteria for big ideas
2. Consider students prior knowledge
   • Students prior knowledge
3. Interpreting the Standard
   • Decompose into related concepts
   • Clarify points
   • What other ideas are needed
   • Make links if needed to other standards
     • Examine Atlas to see links
4. Specifying learning performance
An example

Step 1: Identifying Standards

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. (from Science for All Americans)

What does this standard mean?

Step 2: Considering Student Prior Knowledge

• Necessary Prior Knowledge and experiences
  – Substances may move from place to place, but they never appear out of nowhere and never just disappear. (BPL, p. 119)
  – All matter is made up of atoms, which are far too small to see directly through a microscope. 4D:1A/6-8

• Possible non-normative ideas
  – Original substance is transformed into a completely new substance
  – A "new" substance appears because it has been moved from another place (smoke from wood)
  – continuous view of matter vs. particulate view of matter

Step 3: Interpretation

Without a particulate view of matter:

A substance is a material that has have distinct properties and is made of one material throughout. A chemical reaction is a process where new substances are made from old substances. An element is the smallest part of a substance that cannot be made into a simpler substance. 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). When scientists talk about “old” substances that interact in the chemical reaction, they call them reactants. When scientists talk about new substances that are produced by the chemical reaction, they call them products.
Look for links to other standards

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.

Our Interpretations

With the a particulate view of matter (+ 4D: 1)

A substance is made of the same type of atom or molecule all the way through. The old substances can be either atoms or molecules. A chemical reaction occurs when two or more substances interact and their atoms recombine and stick together in different ways to form new substances (atoms or new molecules). These new substances have different properties compared with the old substances. Atoms are not created or destroyed. Instead, we have a new arrangement or combination of the same atoms. This new arrangement of atoms (either atoms or in molecules) is the new substance.

Step 4: Creating Learning Performances

- What are Learning performances?
  - Learning performances define, in cognitive terms, the designers’ conception for what it means for learners to “understand” a particular scientific idea
  - Learning performances define how the knowledge is used in reasoning about scientific questions and phenomena

- Why Learning Performances
  - Know or understand is too vague

- Use terms that describe the performance you want students to learn and be able to do.
  - Identify, Define, Analyze and Interpret data, Explain, Design investigation, …
  - Not “know” or “understand”
A Range of Performances (simpler to more complex)

1. **Identify, describe, …**
   - Students identify the type system, open versus closed, for a process and describe that in a closed system no material (atoms and molecules) can enter or leave the system.

2. **Measuring**
   - Students measure important physical magnitudes such as volume, weight, density, and temperature using standard or nonstandard units.

3. **Representing data and interpreting representations.**
   - Students using tables and graphs to organize and display information both qualitatively and quantitatively.

4. **Predicting/Inferring.**
   - Predicting/inferring involves using knowledge of a principle or relationship to make an inference about something that has not been directly observed.

5. **Give an example of**
   - Student produce an example

6. **Posing questions.**
   - Students identify and ask questions about phenomena that can be answered through scientific investigations.

7. **Performances (continued)**
   - Designing and conducting investigations.
     - Designing investigation includes: identifying and specifying what variables need to be manipulated, measured (independent and dependent variables) and controlled; constructing hypotheses; specifying the relationship between variables; constructing/developing procedures that allow them to explore their hypotheses; and determining what observations will be made, how often the data will be collected, and what type of observations will be made.

8. **Constructing evidence-based explanations.**
   - Students use scientific theories, models and principles along with evidence to build explanations of phenomena; it also entails ruling out alternative hypotheses.

9. **Analyzing and interpreting data.**
   - Students make sense of data by answering the questions: “What does the data we collected mean?” “How does this data help me answer my question?” Interpreting and analyzing can include transforming the data and finding patterns in the data.

10. **Evaluating/Reflecting/Making an Argument.**
    - Students ask: Do these data support this claim? Are these data reliable? Evaluate measurement: Is the following an example of good or bad measurement?

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### Learning Performances

<table>
<thead>
<tr>
<th>Content Standard</th>
<th>Scientific Practice</th>
<th>Learning Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>When substances interact to form new substances, the elements comprising them combine in new ways. In each combination, the properties of the new combination may be very different from those of the old (AAAS, 1996, p. 47).</td>
<td>Technology/operations using evidence (NRC, 1999, A. 1/14, 3/5).</td>
<td>Students use scientific theories, models and principles along with evidence to build explanations of phenomena; it also entails ruling out alternative hypotheses.</td>
</tr>
<tr>
<td>Think critically and logically to make the relationship between the neutral equations (AAAS, 1996, A. 1/15, 5/6).</td>
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<td>Students use scientific theories, models and principles along with evidence to build explanations of phenomena; it also entails ruling out alternative hypotheses.</td>
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</tbody>
</table>
An example assessment:
Maya has two liquids, hexane and ethanol. She determines a number of measurements of the two liquids and then mixes them together. As she mixes the liquids, she observes a few bubbles. After mixing the liquids, they form two separate layers, layer A and layer B. Maya uses an eyedropper to take 8 cm$^3$ from each layer, and she determines a number of measurements of each.

<table>
<thead>
<tr>
<th></th>
<th>Volume</th>
<th>Mass</th>
<th>Density</th>
<th>Solubility in Water</th>
<th>Melting Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>hexane</td>
<td>25 cm$^3$</td>
<td>16.5 g</td>
<td>0.66 g/cm$^3$</td>
<td>No</td>
<td>-95 °C</td>
</tr>
<tr>
<td>ethanol</td>
<td>40 cm$^3$</td>
<td>31.6 g</td>
<td>0.79 g/cm$^3$</td>
<td>Yes</td>
<td>-114 °C</td>
</tr>
<tr>
<td>layer A</td>
<td>8 cm$^3$</td>
<td>6.3 g</td>
<td>0.79 g/cm$^3$</td>
<td>Yes</td>
<td>-114 °C</td>
</tr>
<tr>
<td>layer B</td>
<td>8 cm$^3$</td>
<td>5.3 g</td>
<td>0.66 g/cm$^3$</td>
<td>No</td>
<td>-95 °C</td>
</tr>
</tbody>
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Write a scientific explanation stating if a chemical reaction occurred when Maya mixed hexane and ethanol. Include your claim, evidence, and reasoning.

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Student Investigation: Did a chemical reaction occur?

<table>
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<tr>
<th>Properties</th>
<th>Density</th>
<th>Melting Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper Penny (Before Experiment)</td>
<td>8.96 g/cm$^3$</td>
<td>1084 °C</td>
</tr>
<tr>
<td>Vinegar (Acid)</td>
<td>not soluble</td>
<td>17 °C</td>
</tr>
<tr>
<td>Solid on Penny (After Experiment)</td>
<td>1.88 g/cm$^3$</td>
<td>115 °C</td>
</tr>
</tbody>
</table>
Do students learn??

An example assessment:
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Chemical Reaction (Student H)

Write a scientific explanation stating whether a chemical reaction occurred when mixed hexane and ethanol. Include your claim, evidence, and reasoning.

- Claim = 1
- Appropriate Evidence = 3
- Appropriate Evidence = 1
- Reasoning = 2
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>1</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Classrooms</td>
<td>32</td>
<td>4</td>
<td>2</td>
<td>3</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

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
Elaborating Standards

1. Considering students prior knowledge
   - Students prior knowledge
   - Possible non-normative ideas
2. Interpreting
   - Decompose into related concepts
   - Clarify ideas
   - What other ideas are needed
   - Examine Atlas to see links
3. Make links to other standards/benchmarks
4. Specifying learning performance

Big message: Start with learning goals!

Big Idea

Standards → Elaboration

Learning Performance ↔ Assessments

Instructional Tasks

Thanks to many

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- Center for Curriculum Materials in Science (CCMS) (NSF-ESI-0227657)
More Information

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- www.hice.org/IQWST

Join the IQWST Team