Highly Interactive Classrooms Curricula Computing in Education

at the University of Michigan

Forward Thinking: Backward Design

Joseph Krajcik
The University of Michigan

National Science Teachers Convention
Baltimore, MD
November, 2006

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Forward Thinking: Learning Goals Driven 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?

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Start with learning goals before you plan assessments and instruction

Use standards to identify key learning goals

What are Standards?

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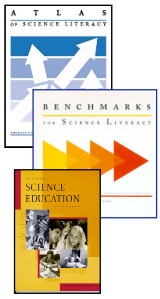
- Summarize the knowledge students should know.
- Examples include
  - Benchmarks for Science Literacy
  - National Science Education Standards
- Consist mostly of brief statements of propositional knowledge that students of different ages should know



Value of Standards

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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 is students understand?

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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?

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- 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"

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- 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
   - Possible non-normative ideas
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.

Performances (continued)

7. *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?

Learning Performances

Content Standard X Scientific Practice → Learning Performance

Content Standard	Practice	Learning Performance
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).	Develop…explanations… using evidence. (NRC, 1996, A: 1/4, 5-8) Think critically and logically to make the relationships between evidence and explanation. (NRC, 1996, A: 1/5, 5-8)	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.

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Moving on to assessments and tasks

Standards → Elaboration

↓

Learning Performance → Assessments

Learning Performance → Instructional Tasks

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.

	Volume	Mass	Density	Solubility in Water	Melting Point
hexane	25 cm^3	16.5 g	0.66 g/cm^3	No	-95 °C
ethanol	40 cm^3	31.6 g	0.79 g/cm^3	Yes	-114 °C
layer A	8 cm^3	6.3 g	0.79 g/cm^3	Yes	-114 °C
layer B	8 cm^3	5.3 g	0.66 g/cm^3	No	-95 °C

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

Student Investigation: Did a chemical reaction occur?

		Properties				
		Color	Hardness	Solubility in Water	Density	Melting Point
Before Experiment	Copper Penny	*Bronze*	*Very hard*	*Not soluble*	*8.96 g/cm^3*	*1084 °C*
	Vinegar (Acid)	no color	liquid	soluble	1.04 g/cm3	17 °C
After Experiment	Solid on Penny	*Green*	*Soft solid*	*Soluble*	*1.88 g/cm^3*	*115 °C*

Do students learn??

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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.

Chemical Reaction (Student H)

Write a **scientific explanation** that states whether a chemical reaction occurred when Carlos stirred and heated butanic acid and butanol.

A chemical reaction did occur. Evidence of this is that neither of the beginning substances share the same amount of density with either of the end substances. Also, the melting points changed from -7.9°C and -89.5°C to 91.5°C an 0.0°C. Another peice of evidence is that the mass changed from 10.18cm3 and 10.15cm3 to 2.00cm3 and 2.00cm3. The solubility also changed. Because the mass and volume decreased so much, I think that gas formed. This data is evidence of a chemical reaction because properties changed.

- Claim = 1
- Appropriate Evidence = 3
- Inappropriate Evidence = 1
- Reasoning = 2

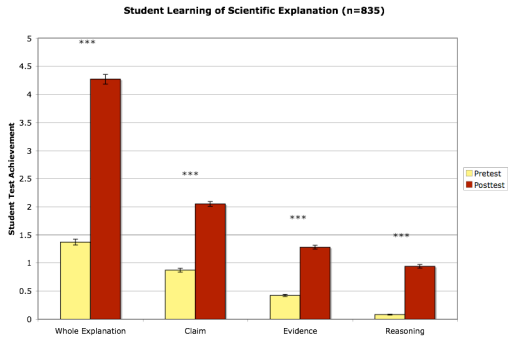
Participants

7th grade science teachers and students

Site	Urban A	Town B	Urban C	Suburb D	Total
Schools	8	1	1	1	11
Teachers	9	2	1	1	13
Classrooms	32	4	2	3	41
Students	1026	61	51	59	1197

- 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

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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

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   - 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
Learning Performance → Instructional Tasks

Thanks to many

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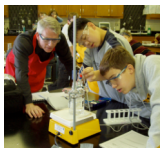

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More Information

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