CREATE for STEM Institute

MICHIGAN STATE UNIVERSITY

Learning Goals and Assessments in IQWST

Joseph Krajcik

Michigan State University

Workshop on Developing Assessments to Meet the Goals of the 2012 Framework for K-12 Science Education

September 13, 2012

The IQWST Project

A collaboration to improve the teaching and learning of science at the middle school level by developing the next generation of curriculum materials.

- Interdisciplinary Team
  - Joe Krajcik: MSU
  - LeeAnn Sutherland: University of Michigan
  - Brian Reiser: Northwestern University
  - David Fortus: Weizmann Institute of Science

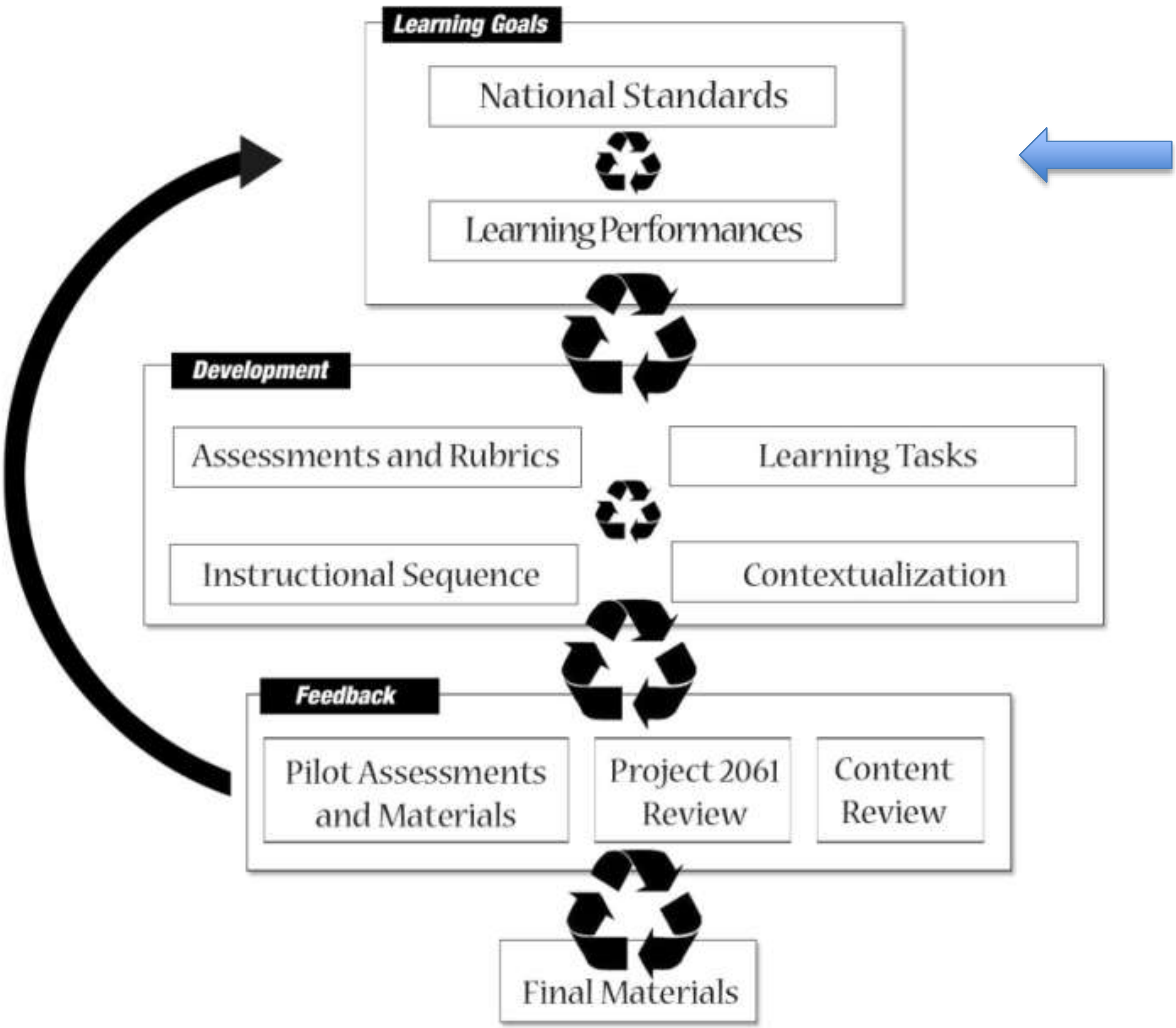
The IQWST Project

- *Overview: Design & Development Model*
  - Coherent curriculum: Understanding of scientific content and practices builds across the school year (6th grade) and across middle school (6-8th grades)
    - Inter and Intra unit coherence
  - Focus on big ideas and practices of science
  - Apply Learning-goals driven design
  - Use what we know about learning (PBS model)
  - Engage students in complex tasks
  - Promote scientific literacy
  - Utilize Iterative Design Model

What we will do

- See how the IQWST team developed learning goals
- See how we used learning performance to develop assessments
- Share some examples

LEARNING-GOALS-DRIVEN DESIGN MODEL



Clarifying and Specifying Learning Goals

In IQWST we asked: What does it mean to “understand” a scientific idea? How do we know if students understand?

- *All matter is made up of atoms, which are far too small to see directly through a microscope. The atoms of any element are alike but are different from atoms of other elements. 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.* (6 - 8 benchmark from Atlas of Scientific Understanding)
- What does it mean? What do we expect students to be able to do?

Clarifying and Specifying Learning Goals

Step 1: Identify the big idea/Standards

- use criteria for big ideas

Step 2: Consider students prior knowledge

- Identify students' prior knowledge
- Consider possible non-normative ideas

Step 3: Interpreting the Standard (unpacking)

- Decompose into related concepts
  - Break it down into smaller ideas
- Clarify points

Step 4: Make links if needed to other standards

- What other ideas are needed
- Examine Atlas to see links

Step 5: Develop Learning Performances

- Blend of of scientific practices and big ideas

An example – clarify and specify learning goals
Step 1: Identifying Standards

Use criteria for big ideas

a) explanatory power within the discipline, b) help learners understand a variety of ideas about the discipline, c) provide ideas/models to explain a range of phenomena d) allow learners to intellectually make individual, social, and political decisions regarding science and technology

An example: All matter is made up of atoms, which are far too small to see directly through a microscope. The atoms of any element are alike but are different from atoms of other elements. 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. (6 - 8 benchmark from Atlas of Scientific Understanding)

- What does this standard mean?

Step 2: Consider Student Prior Knowledge

a) Necessary Prior Knowledge and experiences

- Matter can be classified as objects and non-objects.
- Substances may move from place to place, but they never appear out of nowhere and never just disappear. (BPL, p. 119)

b) Possible non-normative ideas

- Continuous view of matter vs. particulate view of matter

Step 3: Interpretation -- Break it down into smaller components …….

- *All matter is made up of atoms, which are far too small to see directly through a microscope. The atoms of any element are alike but are different from atoms of other elements. 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.*

Step 3: Interpretation -- Break it down in smaller components …….

Idea a: All matter is made up of atoms.

Idea b: These atoms are extremely small—far too small to see directly through a microscope.

Idea c: The atoms of any element are alike but are different from atoms of other elements.

Idea d: Atoms may stick together in well-defined molecules or be packed together in large arrays.

Interpretation -- Clarify each of the ideas

- **Idea a: All matter is made up of atoms.**
- This idea has two aspects: (1) that matter is particulate, rather than continuous, and (2) that the particles (atoms) *are* the matter, rather than the commonly held incorrect idea that particles (atoms) *are contained* in matter.
- Students need to understand "matter" as anything that takes up space and has mass/weight. They may find this difficult to grasp with respect to air or other gases, because they are not able to "feel" their weight.
- An "atom" refers to the smallest particle of an element which gives the element its identity. Any particle smaller than the atom can no longer be identified as the element because the particles smaller than the atom are found in all elements, and therefore the presence and/or absence of these subatomic particles provide an identity of each atom. The treatment of subatomic particles also goes beyond this idea. Large collections of atoms give elements their physical properties. Students are *not* expected to know that, while a single atom has the chemical properties of the element, it takes several atoms to give the element its physical properties. Discussion of atomic chemical properties goes beyond this idea.

Step 4: Look for links to other standards

- *BSL 4D/M3: Atoms and molecules are perpetually in motion. In solids, the atoms are closely locked in position and can only vibrate. In liquids, the atoms or molecules have higher energy, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions. Increased temperature means greater average energy of motion, so most substances expand when heated.*

Creating Learning Performances

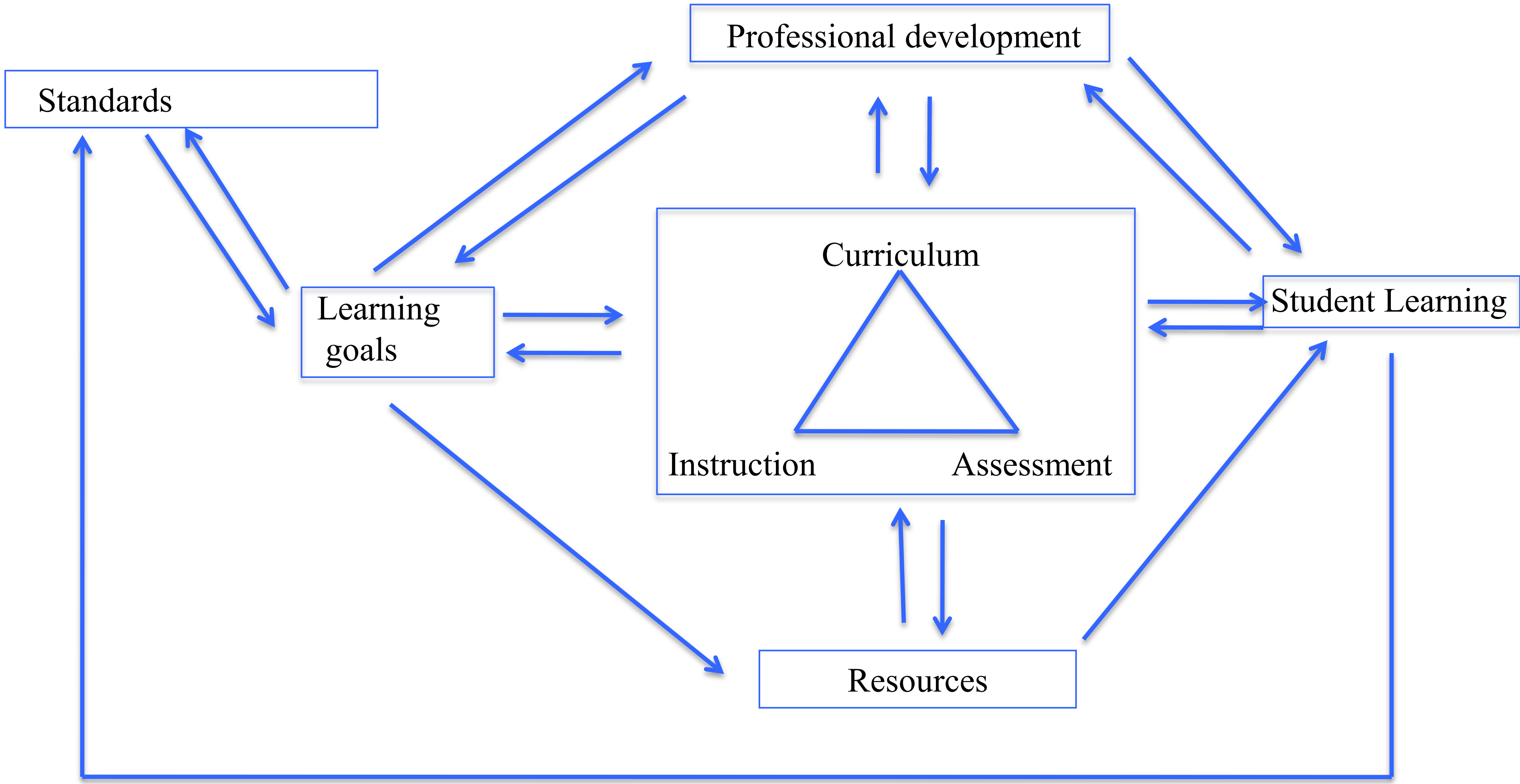
- What are Learning performances?
  - Learning performances define, in cognitive terms, the designers' conception for what it means for learners to "understand" a particular scientific idea
  - Learning performances define how the knowledge is used in reasoning about scientific questions and phenomena
- Why Learning Performances?
  - "Know" or "understand" is too vague
  - Performances requires learners to *use the ideas*.
- Use terms that describe the performance you want students to learn and be able to do.
  - Various Scientific Practices: Analyze and Interpret data, Construct a Scientific Explanation, Construct a Model, Design an investigation …
  - Not "know" or "understand"
  - Could use other cognitive verbs: Describe, compare and contrast, measure, etc.

Developing Learning Performances

Content Standard X Scientific Practice → Learning Performance

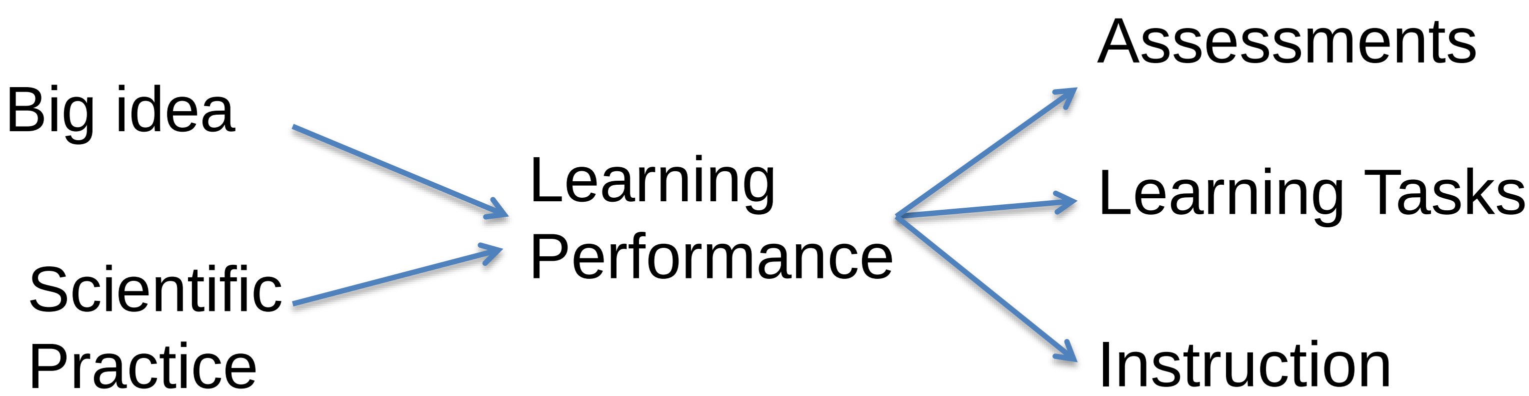
Content Standard	Practice	Learning Performance
All matter is made up of atoms, which are far too small to see directly through a microscope. The atoms of any element are alike but are different from atoms of other elements. *And from BSL 4D/M3: Atoms and molecules are perpetually in motion. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions.*	Models are often used to think about processes that happen… too quickly, or on too small a scale to observe directly… (AAAS, 1993, 11B: 1, 6-8)	Students create models and use the models to explain that a gas is made of tiny particles that are in constant motion.

Value of Learning goals



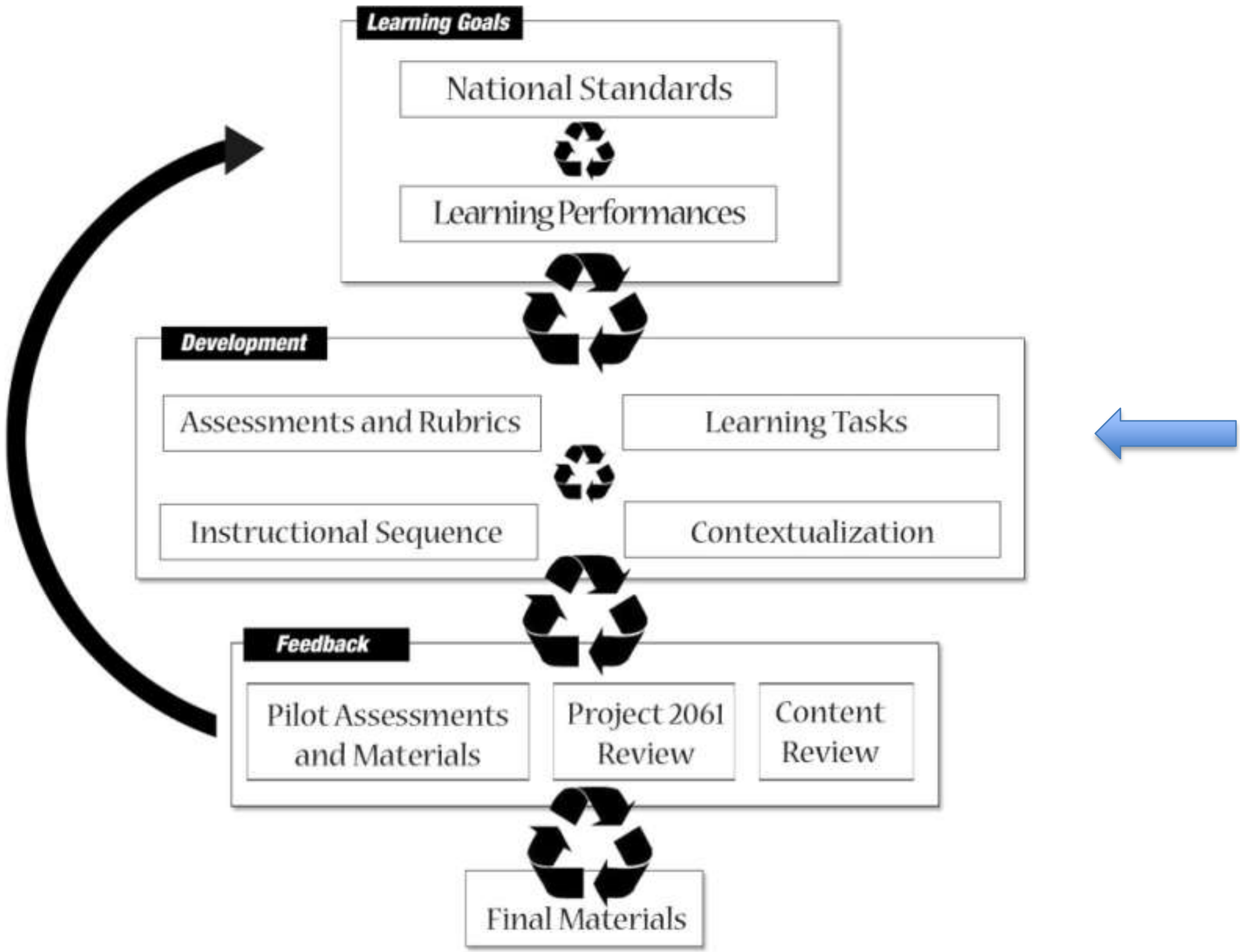
Modified from Systems for State Science Assessments NRC, 2005

Relationship of Learning Performances to Assessment Development and Instruction



Highly specified learning goals

LEARNING-GOALS-DRIVEN DESIGN MODEL



Multiple Means to Assess Learning

Students construct models of the particle nature of matter to explain phenomena

- Embedded assessments
- Pre- Posttest comparison

Creating Assessments

- Identify and clarify Standard/big idea

All matter is made up of atoms, which are far too small to see directly through a microscope. The atoms of any element are alike but are different from atoms of other elements.

And from BSL 4D/M3: Atoms and molecules are perpetually in motion. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions.

- Develop learning performance

Students create models and use the models to explain that a gas is made of tiny particles that are in constant motion.

- Create assessment

Shayna had a small bottle of Bromine gas. The bottle was closed with a cork. She tied a string to the cork, and then placed the bottle inside a larger bottle. She sealed the large bottle shut. (See Figure 1.) Next, Shayna opened the small bottle by pulling the string connected to the cork. Figure 2 shows what happened after the cork of the small bottle was opened. First, draw a model that shows what is happening in this experiment. Second, explain in writing what is happening in your model.

- Develop Rubrics

- See Rubrics

Assessment Example

Shayna had a small bottle of Bromine gas. The bottle was closed with a cork. She tied a string to the cork, and then placed the bottle inside a larger bottle. She sealed the large bottle shut. (See Figure 1.) Next, Shayna opened the small bottle by pulling the string connected to the cork. Figure 2 shows what happened after the cork of the small bottle was opened.

First, draw a model that shows what is happening in this experiment. Second, explain in writing what is happening in your model.

Review Assessment Item

- Is the knowledge needed to correctly respond to the task?
- Is the knowledge enough by itself to correctly respond to the task or is additional knowledge needed?
- Is the assessment task and context likely to be comprehensible to students?

(George Deboer, Project 2061)

Example: Student Pre and Posttest

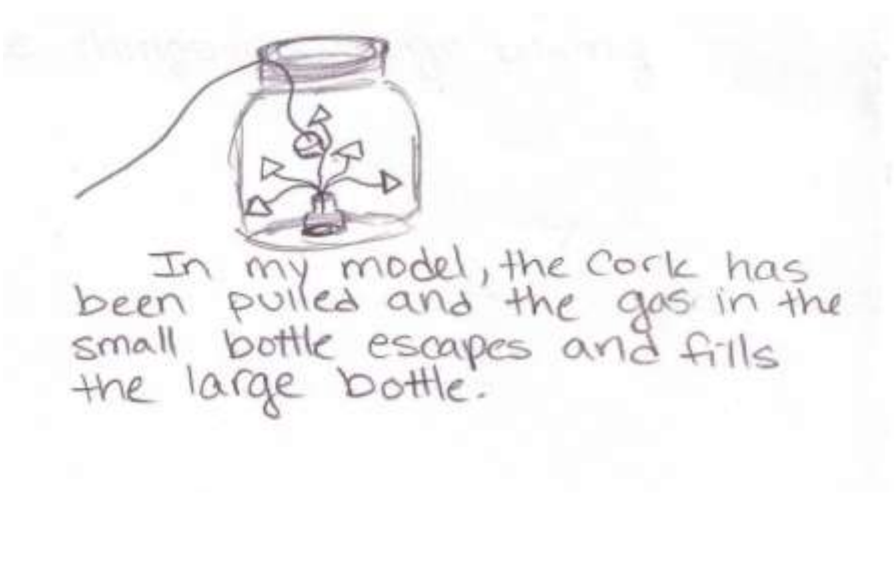
Shayna had a small bottle of Bromine gas. The bottle was closed with a cork. She tied a string to the cork, and then placed the bottle inside a larger bottle. She sealed the large bottle shut. (See Figure 1.) Next, Shayna opened the small bottle by pulling the string connected to the cork. Figure 2 shows what happened after the cork of the small bottle w opened.

First, draw a model that shows what is happening in this experiment. Second, explain in writing what is happening in your model.

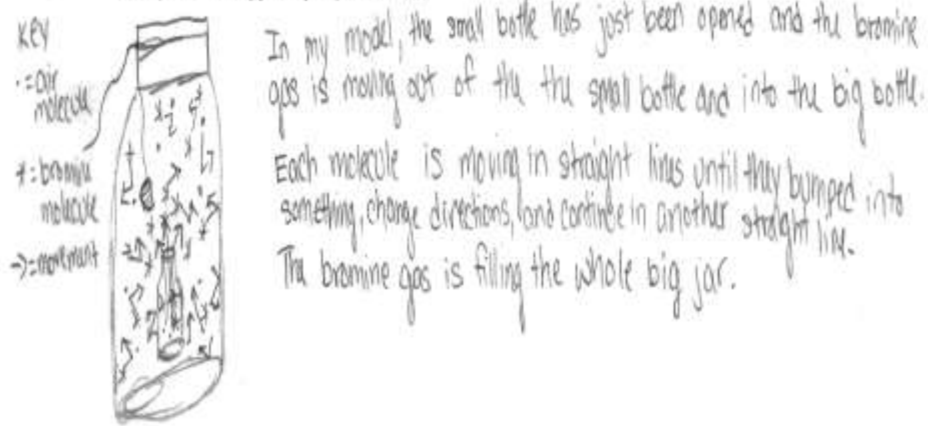
Figure 1

Figure 2

Pretest



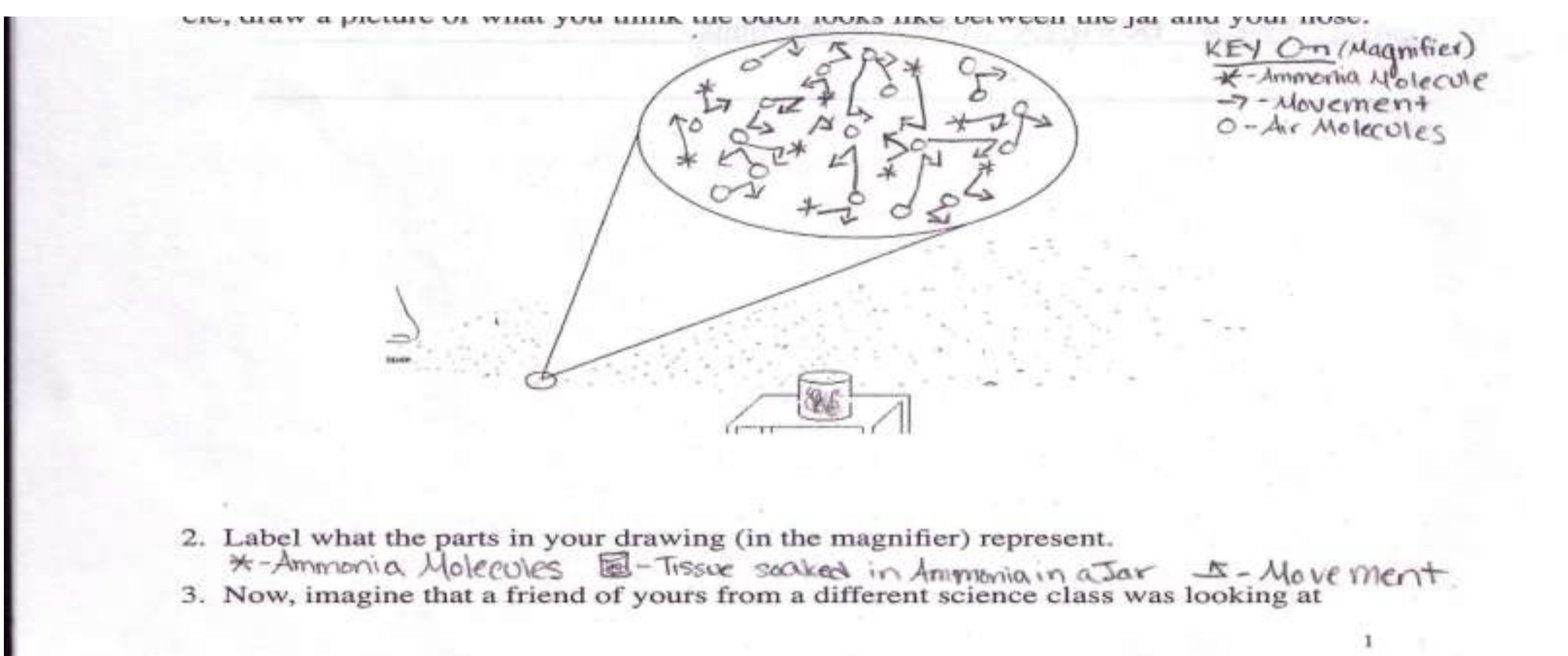
Posttest


First, draw a model that shows what is happening in this experiment. Second, explain in writing what is happening in your model.

Embedded Assessment: *Modeling Smell*

Your teacher opened a jar that contained a substance that had an odor. Imagine you had a very powerful microscope that allowed to see the odor up really, really close. What would you see?

- Lesson 15: student models
  - 75% of students create a particle model, 25% a mixed model
  - 68% of students include odor particles that are moving in straight lines until they collide into each other; 32% include both odor and air



Example 2: Learning Performances

Content Standard × 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.

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.

Chemical Reaction (Student

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 10.18cm^3 and 10.15cm^3 to 2.00cm^3 and 2.00cm^3. 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

Creating Learning Performances

Content Standard × Scientific Practice → Learning Performance

Content Standard	Practice	Learning Performance
A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample (NRC, 1996, B:1A/ 5-8).	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)	Students construct a scientific explanation that includes a claim about whether two items are the same substance or different substances, evidence in the form of density, melting point (boiling point), solubility, color and hardness of the substances, and reasoning that different substances have different properties.

Writing Assessments

Learning Performance

Students construct a scientific explanation that includes a claim about whether two items are the same substance or different substances, evidence in the form of density, melting point (boiling point), solubility, color and hardness of the substances, and reasoning that different substances have different properties.

↓

Assessment Task

Examine the following data table:

	Density	Color	Mass	Melting Point
Liquid 1	0.93 g/cm^3	no color	38 g	-98 ℃
Liquid 2	0.79 g/cm^3	no color	38 g	26 ℃
Liquid 3	13.6 g/cm^3	silver	21 g	-39 ℃
Liquid 4	0.93 g/cm^3	no color	16 g	-98 ℃

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

Explanation Exemplar

Write a **scientific explanation** that states whether any of the liquids are the same substance. Liquid 1 and 4 are the same substance. They both have a density of .93 g/cm^3, have no color, and start to melt at -98°C. For substances to be the same, they must have the same properties. Since Liquids 1 and 4 have the same properties, they are the same substance. The other 2 Liquids are different substances because they have different properties.

Relationship of Learning Performances to Assessment Development and Instruction

Highly specified learning goals

Learning Performances bring together scientific ideas with scientific practices.

Articulate learning in terms scientific content and practice

Guide the development of assessments that blend scientific content and practices

Thanks to many

IQWST Development and Research Team

Colleagues at University of Michigan, Northwestern University, the Weizmann Institute of Science, Boston College – LeeAnn Sutherland, Brian Reiser, David Fortus, Kate McNeill

Many grad students and post doctoral fellow

Many teachers with whom we worked

National Science Foundation

- **Investigating and Questioning our World through Science and Technology (IQWST) (NSF-ESI-0101780 & NSF-ESI-0439352)**