SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

Supporting students in scientific inquiry without sacrificing the science content

Joseph Krajcik
University of Michigan

National Science Teacher Association
Baltimore, Maryland
November, 2006

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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:

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

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?

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

Science Education Today

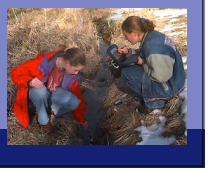
- An exciting time
  - Emerging ideas in science →
  - New ideas on how students learn →
  - Emergence of standards →
- A challenging time
  - US students continue to fall behind internationally
  - US students are not pursuing STEM degrees
  - Too much to teach
  - Learning through inquiry remains underused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

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

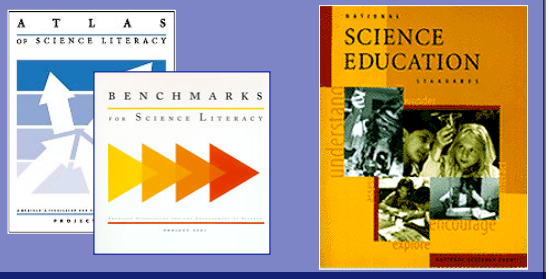
How will you support students in scientific inquiry without sacrificing the science content?

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?

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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.

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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.

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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.

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

Learning Performances

Content Standard × Inquiry Practice → Learning Performance

Content Standard	Inquiry Standard	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	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.

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

Content Standard plus Inquiry Standard

↓

Learning Performance

↙ ↘

← Assessment

Learning Task →

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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:

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

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 I and H are indeed the same substances. 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 I and H. Since all of these propeties are the same, I and H are the same substance.

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

Were you involved in inquiry?

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

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

Do students learn??

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

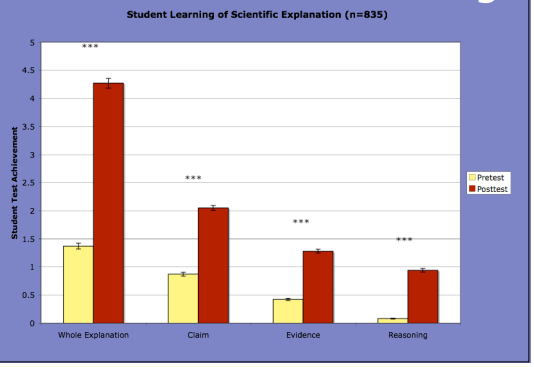
Participants

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



SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

Thanks to many

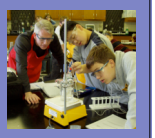
IQWST Development and Research Team

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



SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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

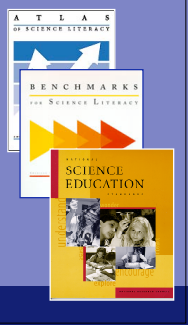
SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

Hyperlink Slides

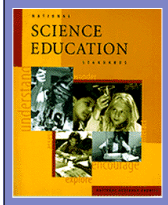
SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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

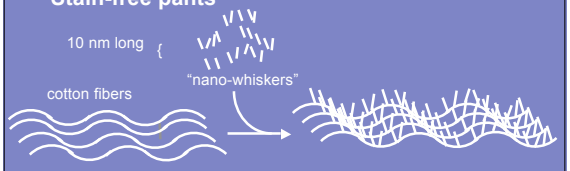


"Inquiry into authentic questions generated from student experience is the central strategy for teaching science. Teachers focus inquiry predominately on real phenomena, in classrooms, outdoors, or in laboratory settings, where students are given investigations or guided toward fashioning investigations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

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

New NanoScience Ideas

Stain-free pants



SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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!

Essential Features of Classroom Inquiry and Their Variations

Essential Feature	Variation			
Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Leaner sharpens or clarifies question provided by teacher, materials, or other sources	Learner engages in question provided by teacher, materials, or other sources
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
Learner formulates explanation from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanation from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence
Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections	
Learner Communicates and justifies explanations	Learner forms reasonable and logical arguments to communicate explanation	Learner coached in development of communications	Learner provided broad guidelines to sharpen communications	Learner given steps and procedures for communications

More----------Amount of Learner Self Direction----------Less

Less----------Amount of Direction from Teacher or Material----------More

Adapted from the National Science Education Standards

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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 stirs 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:

		Measurements			
		Melting Point	Volume	Solubility in water	Density
Before stirring & heating	Sample A	-7.9 °C	2.00 cm^3	Yes	0.96 g/cm^3
	Sample B	-89.5 °C	2.00 cm^3	Yes	0.81 g/cm^3
After stirring & heating	Layer X	-91.5 °C	2.00 cm^3	No	0.87 g/cm^3
	Layer y	0.0 °C	2.00 cm^3	Yes	1.00 g/cm^3

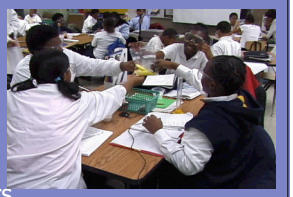
Write a **scientific explanation** that states whether a chemical reaction occurred.

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*

Ideas from Learning Theory

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



SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

- NRC B5-8: 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.