Better Assessment Through Four Essential Questions

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Powerpoint available at www.cosmic.umb.edu
Two Stories

• Information challenge
  – $50 vs $10
  – What is the height of Eiffel Tower?
  – What is both a mammal and a virus?

• Special needs students and test modification
  – “You’re doing it all wrong.”
  – “Seal the envelope”
  – “What kind of questions am I asking?”
Where is the knowledge we have lost in information...

T.S. Eliot
Open book vs Closed book tests

• Open book \(\rightarrow\) open internet
  – Instant access to internet at anytime and anyplace

• How do tests change when they are open internet tests?

• Which questions can we eliminate?

• Which questions should we eliminate?
Four Essential Questions

• What does it mean?
• How do we know?
• Why do we believe it’s science?
• Why should we care?
The Promise

• We can teach better
• We can assess better
• We can help students perform better

• IF (and only if) we don’t simply study these questions in isolation, but simultaneously adopt all four essential questions.
  – What does it mean?
  – How do we know?
  – Why do we believe it’s science?
  – Why should I care?
The Essential Questions

• What does it mean?
  » Newton’s 2\textsuperscript{nd} Law: $F = ma$
  » Energy is conserved
  » The Earth goes around the Sun
  » The atom has a nucleus
  » Mitochondria are the power house of the cell
  » H\textsubscript{2}O is a polar molecule (angle of 105)

• Textbooks and classrooms are dominated by this question.
What does it mean?

• In *Active Chemistry*
  – Chemistry explains a macroscopic phenomena (what you observe) with a description of what happens at a nanoscopic level (atoms and molecules) using symbolic structures as a way to communicate.
    • Macro
    • Nano
    • Symbolic
What does it mean?

Boyle’s Law

– Macro
  • How did the pressure changes affect the volume of gas in the syringe?

– Nano
  • Draw and label a picture of the gas particles in the syringe at points A and B on the graph shown.

– Symbolic
  • The graph is one way to represent the observations that you made symbolically. An equation for that graph is another representation of the relationship. Write the mathematical equation that describes this relationship.
What does it mean?

• Simple recall
  – What is the chemical symbol for calcium?
  – What is the acceleration due to gravity?
  – Which gas is required for photosynthesis?

• Comprehension questions:
  – What are the products when HCl reacts with NaOH?
  – How far will a ball fall on Earth in 3 seconds?
  – Why is light required for photosynthesis?
Artifacts of Science

• A conversation with a principal
  – Order of the planets
    • Mercury, Venus, Earth, Mars ...

• It’s not science - It’s an artifact of science
• “Science is a way of thinking much more than it is a body of knowledge.” - Carl Sagan

The science questions:
What does it mean to say that Venus is closer to the Sun?
How do we know that Venus is closer to the Sun?
The Four Essential Questions

• What does it mean?

• How do we know?
  » Newton’s 2nd Law: $F = ma$
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  » Mitochondria are the power house of the cell
  » $H_2O$ is a polar molecule (angle of 105)
The Four Essential Questions

• What does it mean?

• How do we know?
  » Newton’s 2nd Law:  \( F = ma \)
  » Energy is conserved
  » The Earth goes around the Sun
    • 80% know this
    • 49% know how long it takes
  » The atom has a nucleus
  » Mitochondria are the power house of the cell
  » \( \text{H}_2\text{O} \) is a polar molecule (angle of 105)
How do we know?

• We accept carefully controlled experiments as evidence of our understanding
• We accept careful observations as evidence of our understanding

• “How do we know” unacceptable responses:
  – It is in the book
  – The teacher told us
Goals of Laboratory Experiences

• Enhancing mastery of subject matter
• Developing scientific reasoning
• Understanding the complexity and ambiguity of empirical work
• Understanding the nature of science

The student who knows about experimental evidence has a deeper understanding of subject matter.
Positivism

• Is there only one truth?
• Does experimental evidence provide the one and only interpretation of nature?
• Can experimental evidence be interpreted in only one way?

• The 3rd Essential Question:
  – Why do we believe?
I need your help

• Believe
  – accept something as true
  – have trust
  – have religious faith

• How would you phrase the question
  – “Why do we believe?” where

• It captures the meanings that I will outline

• It is not misinterpreted to imply religious faith
Why do we believe?

- The Nature of Science
  - Seat belts in the laboratory and seat belts in cars.
  - Mixing liquids today and mixing them tomorrow.
  - Cell structure in San Francisco and cell structure in Auckland.

- The spectra of the Sun
Why do we believe?

- **Active Chemistry**
  - Why do you believe that this experiment in the school laboratory works in the outside world?
  - Can you provide examples of this principle being used in the outside world?
  - In industry, they use hundreds of gallons of these chemicals. Why do we think that the result will be the same as our use of 20 ml?
    - We have not tested?
    - Why do we believe?
Why do we “not” believe

• We believe some things and don’t believe others.
  – People magazine
  – Woman giving birth
  – Umbrella

• We have constructed filter systems after many years
• This filter system is rarely articulated
• We may not be able to communicate it
  – Polanyi -tacit knowledge
Why do we believe?

• **Active Physics**

  1. Does this content fit with other content in science?
  2. Does this content fit with the big ideas of science?
  3. Does this content meet the requirements of science?
Why do we believe?

1. Does this content fit with other content in science?
   - Each discipline has a set of traditional topics that helps us organize the discipline
     - Physics
     - Movement of the line during fly fishing – yes
     - Cezanne’s influence on Picasso - no
Why do we believe?

- *Active Physics*
  1. Does this content fit with other content in science?
  2. Does this content fit with the big ideas of science?
  3. Does this content meet the requirements of science?
2. Does this content fit with the big ideas of science? (Also referred to as organizing principles of science.)

- Benchmarks for Scientific Literacy
  - systems, models, constancy & change, and scale
- National Science Education Standards
  - evidence, models, evolution and equilibrium, and form and function
- Framework for K-12 Science Education
  - Crosscutting concepts (patterns, cause & effect, scale, systems, energy & matter, structure & function, stability & change

- Science instruction should regularly remind students of these unifying concepts and processes since they help scientists (and students) better organize new knowledge.
Why do we believe?

• *Active Physics*

  1. Does this content fit with other content in science?
  2. Does this content fit with the big ideas of science?
  3. Does this content meet the requirements of science?
Why do we believe?

3. Does this content meet the requirements of science?
   – We have certain expectations and requirements that all scientific knowledge must meet.
     • In all science, experimental evidence must be consistent with models and theories.
     • The notion that good, clear explanations should be no more complex than necessary – Occam’s razor
     • We expect that good theories will have predictive power. A few simple rules should be able to explain a large variety of phenomena – the ad hoc theory is frowned upon.
Science vs Pseudo-science

- Fields in physics vs auras
- Predicting the future in science vs astrologers
- Falsifiability
4 Q Assessment Model
The Essential Questions

• What does it mean?
• How do we know?
• Why do we believe? (When do we NOT believe?)

  » Newton’s 2\textsuperscript{nd} Law:  \( F = ma \)
  » Energy is conserved
  » The Earth goes around the Sun
  » The atom has a nucleus
  » Mitochondria are the power house of the cell
  » \( \text{H}_2\text{O} \) is a polar molecule (angle of 104°)
Why do we believe?

• Active Physics –
  – Newton’s 2\textsuperscript{nd} Law and rear end collision
1. Does this content fit with other content in science?
   • Force and motion
2. Does this content fit with the big ideas of science?
   • Systems
3. Does this content meet the requirements of science?
   • Optimal prediction and explanation: Is the use of headrests also consistent with Newton’s 1\textsuperscript{st} law?
The Essential Questions

• What does it mean?
• How do we know?
• Why should I believe?

• Why should I care?
  » Newton’s 2\textsuperscript{nd} Law: \( F = ma \)
  » Energy is conserved
  » The Earth goes around the Sun
  » The atom has a nucleus
  » Mitochondria are the power house of the cell
  » \( H_2O \) is a polar molecule (angle of 105)
Why should I care?

• Motivated students have higher achievement
• Relevance to their lives now.

Why are we learning this?
  – This is chapter 14.
  – One day this will be useful
    • Not about “now” and therefore not about me
    • Not even true!
\[ x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \]
Relevance

- Cosine 24

- When you have to teach your child
- When you need a loan
Why should I care?

“Education is not a preparation for life; education is life itself.”

John Dewey
Why should I care?

• If we want students to learn about science content, we have to respect them and their age appropriate perspective.
• We have to find ways to help them understand how the content is relevant to them and the society they live in.
  – Physics of sports,
  – Chemistry of cooking,
  – Earth science of global warming
  – Biological implications of prescription and non-prescription drug use.
• Science content into a larger context by adopting project-based learning.
Four Essential Questions

• Post them in the front of the room.
• Unintended consequence
  – Please help me to be engaged.
Four Essential Questions

• Discussed in class
• Assigned as homework
• Given as test questions

• ALL students – they are not an enhancement of the content for a select few.
# Four Essential Questions

**Special Needs support**

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| What does it mean when Newton’s 2
  nd law states that acceleration and mass are inversely proportional? (25 words)  | What part of your investigation shows you that stronger forces cause larger accelerations? (25 words)  |
| **Why do we believe?**  | **Why should I care?**  |
| Provide an example where Newton’s 2
  nd law can explain a phenomenon outside the classroom. (25 words)  | As a prospective sportscaster, you can make sports more interesting by referring to Newton’s 2
  nd law. Give a sports example of Newton’s 2
  nd law. (25 words)  |
**Four Essential Questions**

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Four Essential Questions
Special Needs support

• What does it mean?

• How do we know?

• Why do we believe?

• Why should I care?
What are our goals as science teachers?

• Higher student achievement
• Engaged students
• Appreciation (love?) of science in the world
• Critical thinking

• Five years later: what is science?
  – e.g. Chemistry responses
What do we value?

• Big ideas of science
• Inquiry
• Science as a way of knowing
Which Four Questions?

• What does it mean?
• How do we know?
• Why do we believe?
• Why should I care?

• What did you say?
• Should we write this down?
• Do we have to know this?
• Will this be on the test?
Shavelson & Li

- Declarative knowledge (knowing that)
- Procedural knowledge (knowing how)
- Schematic knowledge (knowing why)
- Strategic knowledge (knowing when and where to apply knowledge)

- What does it mean?
- How do we know?
- Why do we believe?
- Why should we care?
NAEP 2009-2019

- Identifying scientific principles
- Using scientific principles
- Using scientific inquiry
- Using technology

• What does it mean?
• How do we know?
• Why do we believe?
• Why should we care?
Taking Science to School

• These four strands describe the proficiencies that students need to develop when learning science including:
  – Knowing, using, and interpreting scientific explanations of the natural world
  – Generating and evaluating scientific evidence and explanations
  – Understanding the nature and development of scientific knowledge; and
  – Participating productively in scientific practices and discourse.

• What does it mean?

• How do we know?

• Why do we believe?

• Why should we care?
A Framework for K-12 Science Education

- Content Knowledge
- Procedural Knowledge
  - Also called “concepts of evidence”
- Epistemic Knowledge
  - knowledge of the constructs and values that are intrinsic to science
- Core Ideas: Relate to the interests and life experiences of students or can be connected to societal or personal concerns that require scientific or technical knowledge

• What does it mean?
• How do we know?
• Why do we believe?
• Why should we care?
One chorus
Where is the knowledge we have lost in information...

T.S. Eliot

We can insure, through our teaching, that we value knowledge over information
Where is the knowledge we have lost in information...
Where is the wisdom we have lost in knowledge?

T.S. Eliot
Please check out our website: www.cosmic.umb.edu for a copy of the power point.

Or email with questions: arthur.eisenkraft@umb.edu