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LIVE INTERACTIVE LEARNING @ YOUR DESKTOP

Making the Transition to Scientific and Engineering Practices: Visiting the Potential of the Next Generation Science Standards

Presented by: Dr. Francis Eberle, Dr. Brian Reiser and Harold Pratt

October 25, 2011

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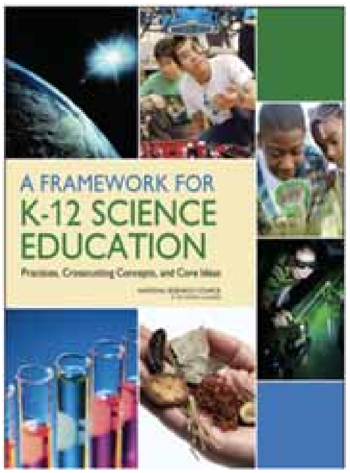
Framework and Standards



NEXT GENERATION SCIENCE STANDARDS

- Assessment
- Curricula
- Instruction
- Teacher development

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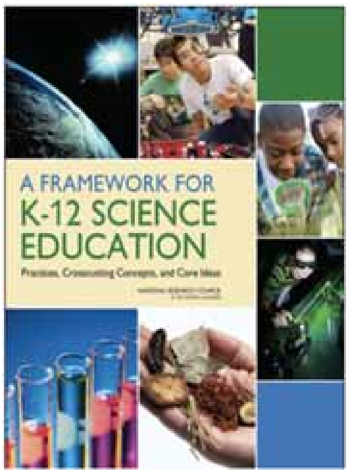
Framework and Standards



July 2011

NEXT GENERATION SCIENCE STANDARDS

Drafts released,
Final version Dec 2012

- Assessment
- Curricula
- Instruction
- Teacher developmen t

1. Scientific and Engineering Practices

- Asking questions and defining problems
- Developing and using models
- Planning and carrying our investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in arguments from evidence
- Obtaining, evaluating and communicating information

2. Crosscutting Concepts

- Patterns
- Cause and effect
- Scale proportion and quantity
- Systems and system models
- Energy and matter
- Structure and Function
- Stability and change

3. Disciplinary Core Ideas

- **Physical Science s**
- **Life Sciences**
- **Earth and Space Sciences**
- **Engineering, Technology , and the Applications of Science**

Let’s pause for questions from the audience

Overview

- Motivation for including practices in the framework
  - Research on learning core ideas
  - Building on importance of “scientific inquiry”
- How practices are included as part of standards
- Implications for assessment, curriculum materials, and classroom teaching

Scientific and Engineering Practices

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
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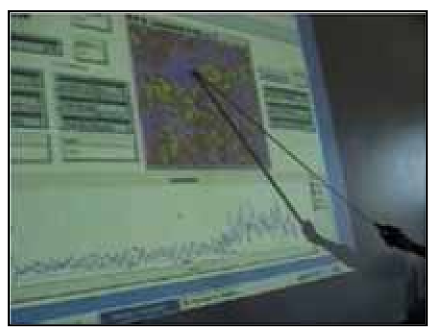

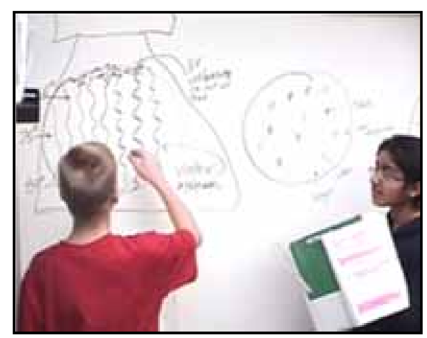

Do your students engage in the practice of scientific argumentation?

Do students compare alternative explanations and evaluate the evidence for each, and attempt to reach consensus?

Do students go beyond explaining the substance of an important scientific idea, and also justify why we believe that idea, with the evidence and the logical reasoning that supports it?

A. Readily, without prompting
B. When prompted, often
C. When prompted, sometimes
D. Rarely
E. Never

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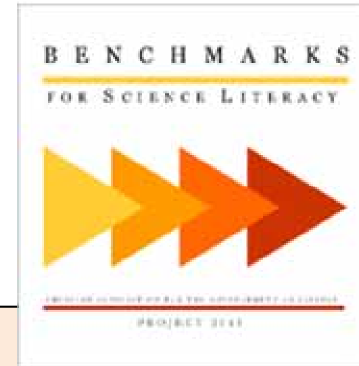
Limitations of current standards that the practices are designed to improve



Living Systems Chapter:

By the end of 8th grade, all students should know that:

•All living things are composed of cells, from just 1 to millions, whose details usually are visible only through a microscope. Different body tissues and organs are made up of different kinds of cells. The cells in similar tissues and organs in other animals are similar to those in human beings but differ somewhat from cells in plants. 5C/M1

•Cells continually divide to make more cells for growth and repair. Various organs and tissues function to serve the needs of cells for food, air, and waste removal. 5C/M2

•Within cells, many of the basic functions of organisms – such as extracting energy from food and getting rid of waste – are carried out. The way in which cells function is similar in all living things. 5C/M3

•About 2/3 of the weight of cells is accounted for by water, which gives cells many of their properties. 5C/M4

What do these standards mean?

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- *Describe how bone cells are different from muscle cells.*
- *Define “tissue,” “organ, and “organ system,” and give an example of each type of object.*
- *Name two functions that cells perform.*

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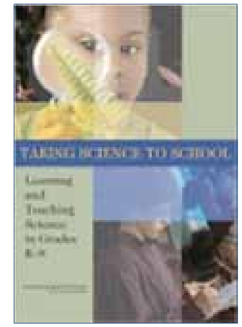
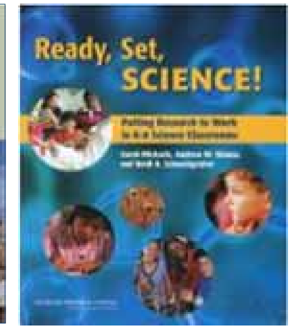
- *Describe how bone cells are different from muscle cells.*
- *Define “tissue,” “organ, and “organ system,” and give an example of each type of object.*
- *Name two functions that cells perform.*

- *OR… Explain why cells are needed for organs and organ systems to function.*
- *Develop an argument, from evidence, that both oxygen and food are needed for an animal’s energy needs.*
- *Develop a model that explains how matter and energy flow through body systems to get to cells.*

Recommendations from research on science learning

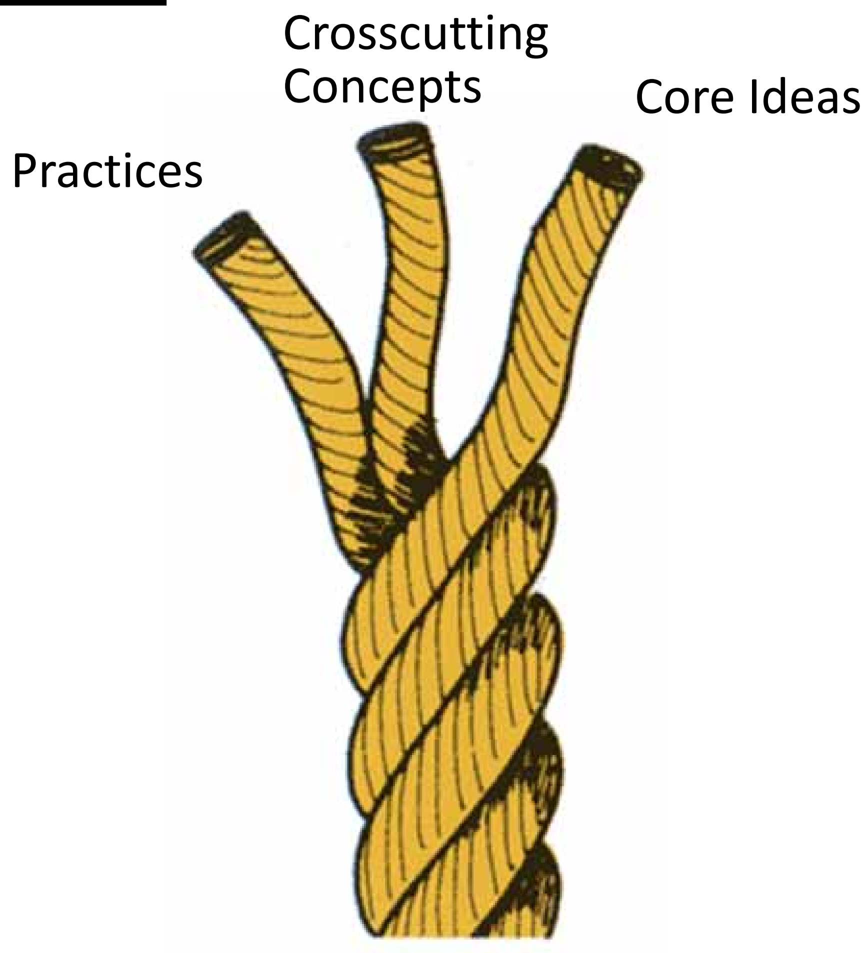




- Problem: too many disconnected topics, not treated in enough depth.
- "The next generation of standards and curricula … should be structured to identify *a few core ideas* in a discipline and elaborate how those ideas can be *cumulatively developed over grades K-8*." (Rec. 2)
- "Developers of curricula and standards should present science as a process of building theories and models using evidence, checking them for consistency and coherence, and testing them empirically." (Rec. 3)

(NRC, 2007)

Three dimensions of the framework



- The three dimensions need to be considered as an integrated system.
- Practices are the processes of building and using the core ideas to make sense of the natural and designed world

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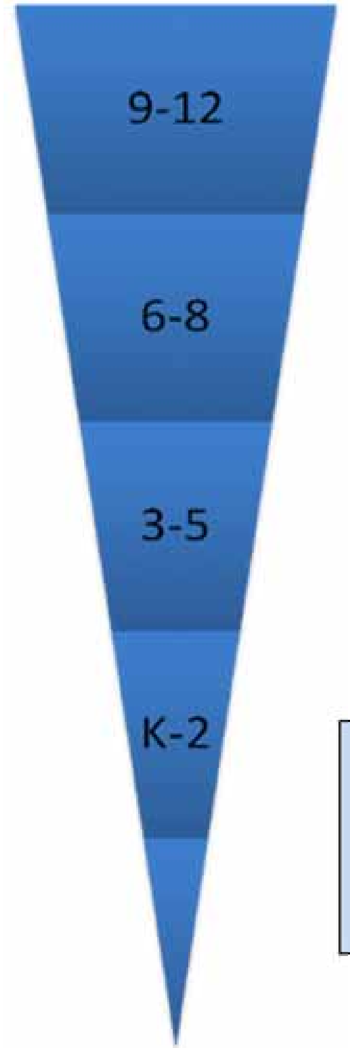
Core ideas: Coherent explanatory ideas at *each* grade level



Molecular model of biochemical reactions for matter and energy in food.

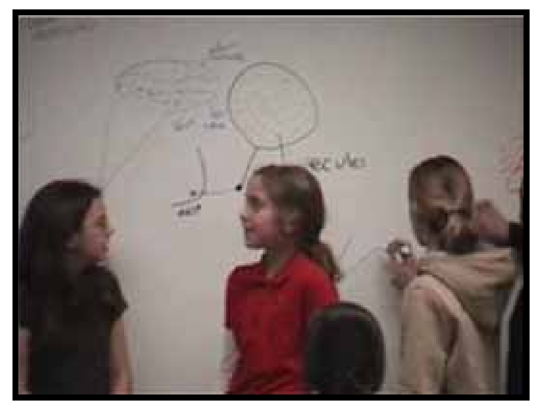
Chemical reactions model for matter and energy in food, drawing on particle model of matter and energy transfer model.

Simple food model: food consumed or produced is made of matter and provides energy for organisms.

K-2 General needs model: Organisms get what they need to survive from the environment.

Importance of practices in science learning

- Science is both a body of knowledge and the process that develops and refines that body of knowledge.
- Developing explanatory core ideas requires engaging in practices. Simply "consuming" information leads to declarative, isolated ideas.
- Learning complex explanatory ideas unfolds over time
  - students engage in tasks in which they need to synthesize and apply those ideas
  - students revisit core ideas in new contexts where they need to extend these ideas



Let's pause for questions from the audience

Evolution from Inquiry to Scientific Practices

- Focus not just on "investigation of hypotheses" but on building ideas -- making sense of findings, using results to develop models, argue competing explanations and reach consensus
- Includes collaboration and discourse elements of working together to develop scientific knowledge

1. Asking questions and defining problems
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Standards that integrate core ideas, cross-cutting ideas, & practices

- "Standards should include *performance expectations* that integrate the scientific and engineering practices with the crosscutting concepts and disciplinary core ideas. These expectations should require that students demonstrate knowledge-in-use and include criteria for identifying successful performance." (NRC 2011 Framework, Rec 5).

Creating performance expectations from core idea and practice

Practices: Developing explanations, argument from evidence

✖

Core idea: Matter and energy in organisms (grade 8): Plants, algae, and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. Animals obtain food from eating plants or eating other animals. Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth or to release energy. In most animals and plants oxygen reacts with carbon-containing molecules (sugars) to provide energy and produce waste carbon-dioxide…

⬇

Performance expectation: Students construct and defend an explanation for why the air a human breathes out contains a lower proportion of oxygen than the air he or she breathed in. The explanation needs to address where in the body the oxygen was used, how it was used, and how it was transported there.

Construct and defend an explanation for where the oxygen goes in the body, and why

"Oxygen is used by our body. We know this because when we burned the cashew, the water above it and the cashew changed because of a chemical reaction. The cashew turned tannish color to black, the water temperature changed from 23° to 68°. When we inhale oxygen, it travels through your epiglottis and trachea to the alveoli. Finally it gets into the blood stream, where it gets taken to other parts of the body. You use the oxygen to burn the food into energy. According to our scientific principles, you need oxygen to convert the chemical energy to other energies for our cells. Since we need oxygen to burn food to get energy, you need to inhale."

(Source: 7th grade, suburban district, Apr 2010)

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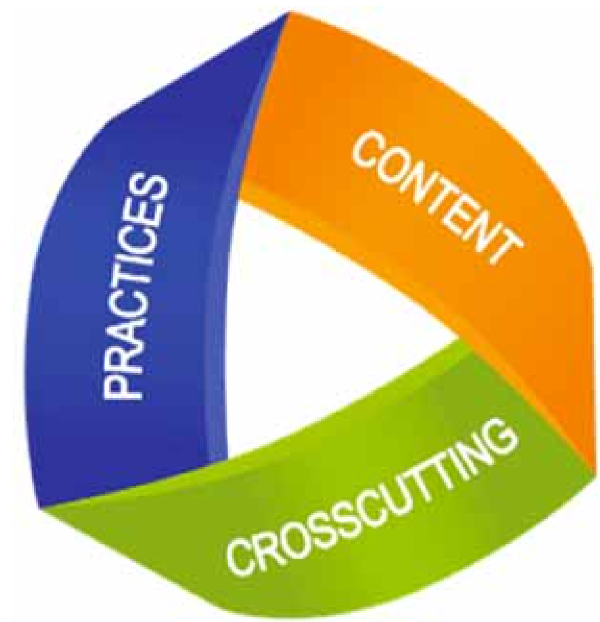
Implications for curriculum materials, teaching, and assessment

- Not separate treatment of "content" and "inquiry" (No Chapter 1 on "The Scientific Method").
- Science teaching needs to do more than present and assess scientific ideas – learners need to be involved in using scientific practices to *develop* and *apply* scientific ideas.



Organizing learning around the practice of building arguments and explanations

7th grade unit: *How can my body do the things it can do?*	
Steps in the investigation	The argument students build
1. What is our body made of?	Students discover the body is made of cells, observe single cells outside the body in yogurt & pond water; conclude cells are living. Q: Why do we have cells?
2. How does the body use food for materials and energy?	Trace food through digestive system. Evidence for physical and chemical processes in breakdown of food. Follow food into circulatory system. Evidence from activity blood glucose levels shows food in blood stream.
3. Where does the food go?	Discover glucose molecules end up at cells. Osmosis experiments show that glucose and water can move into cells. Yeast experiments show that glucose can provide materials and energy for cells to grow and reproduce.

(from an NSF-funded curriculum, 2011)

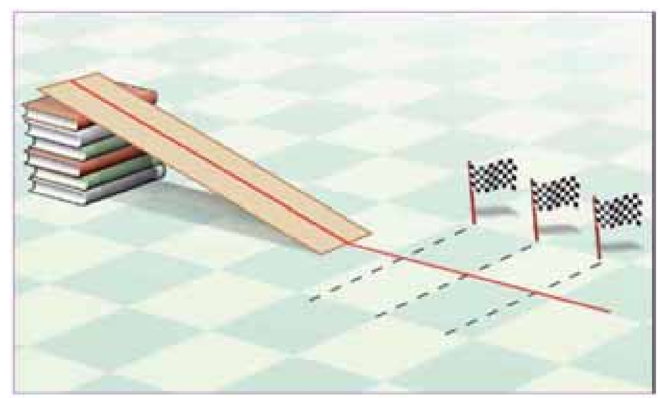
Organizing learning around explanations (cont.)

7th grade unit: *How can my body do the things it can do?*	
Steps in the investigation	The argument students build
4. Where is the O_2 used in the body?	Discover that O_2 increases along with heart-rate with increased activity. Q: What is the O_2 used to do? Analyze O_2 and CO_2 in exhaled vs. room air. Trace O_2 through body. Students explain that O_2 is absorbed by lungs, carried by blood to cells where a chemical reaction with O_2 and glucose releases energy.
5. What in your body needs the food	Synthesize conclusions from prior lessons to construct an explanation of *where* food is used in the body, supported by evidence and reasoning.

Curriculum materials example of engineering practices: Designing solutions

- "You will be the design engineer of a small vehicle. …It will have to go straight, far, and fast, and carry a load. As the design engineer, you will be using science knowledge to conduct investigations to determine how best to achieve the challenge. Then you will design and test a vehicle. You will modify your designs, and retest your vehicle to achieve the best possible performance. Like professional design engineers, you will report on your results and progress. To do the job well, you will need to learn about how forces affect motion." (from an NSF-funded curriculum, 2009)

- Core ideas: force and motion
- Practices: Asking questions, designing solutions, designing and conducting investigations, arguing for claims from evidence



Shifts in How Science Should Be Taught in Classrooms

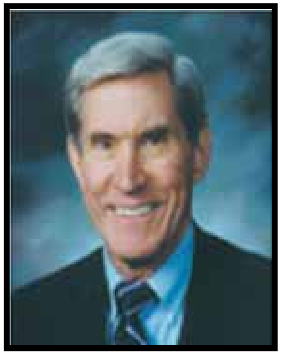
Standards will bring together scientific ideas (core ideas, cross cutting ideas) with scientific practices.

- Curriculum materials need to focus on limited number of core ideas, and favor depth and coherence over breadth of coverage.
- Assessments need to focus on *use* of knowledge through the practices – developing and applying scientific ideas to make sense of phenomena

Shifts in Science Teaching and Learning (cont.)

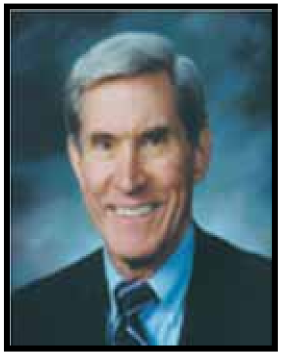
- Teaching needs to revisit core ideas in increasing depth, and sophistication across years. Focus of teaching needs to be on developing ideas and building connections:
  - Teaching needs to involve learners in practices that develop, use, and refine the scientific ideas.
  - Careful construction of a storyline – helping learners build sophisticated ideas from simpler explanations, using evidence.
  - Connections between scientific disciplines, using powerful ideas (nature of matter, energy) across life, physical, and environmental sciences

Let's pause for questions from the audience



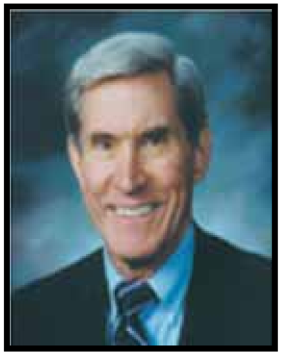
Scientific and Engineering Practices; What's New – What's Familiar?

- Science practices similar to NSES Inquiry Standards – but more specific
- Parallel practices in science and engineering - This does not imply teaching them together
- The integration of practices with the core ideas and cross cutting concepts
- Based on research on how students learn science since the NSES was published



Suggested Action

- Read Chapter 3 *Scientific and Engineering Practices* in the *Framework*. Download it free at www.nap.edu.
- Read Chapters 3 through 7 of *Taking Science to School.* Download it free at www.nap.edu
- For teachers in grades K-8 read *Ready, Set, Science*. Download it free at www.nap.edu.
- Review the discussion of argumentation and discourse in the first two NRC publications. These practices in the learning of science may be new to many science educators.



Suggested Action - continued

- Examine your instructional materials; how many practices are in one or two chapters or units.
- Find a familiar experiment and add the practice of argumentation to it.
- Read Rodger Bybee's article on the practices in the December issue in one of the NSTA journals.
- Locate a design activity and identify the engineering practices that it incorporates.

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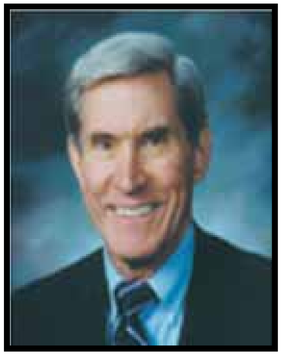
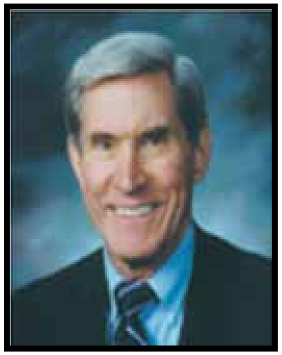


NSTA Resources

www.nsta.org/ngss

- Latest News and Updates
- Web Seminars (archived)
- NSTA Reader's Guide to Framework (coming soon!)
- NSTA Journal Series on Framework
- Updates from Achieve
- Calendar of Events



Let's pause for questions from the audience

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