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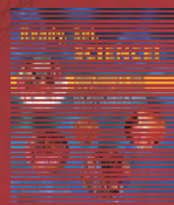
Role of Evidence in STEM Education Policy



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Innovation 2008 Conference

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Advisers to the Nation on Science, Engineering, and Medicine
National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council

Board on Science Education

Taking Science to School & America's Lab Report	*Ready, Set, Science!*
▪ **Formal research study** ▪ **For academically inclined readers** ▪ **Reviews research and evidence for findings**	▪ **Built on the findings of TSS** ▪ **For a practitioner audience** ▪ **Uses case studies to provide rich illustrations** ▪ **Provides in-depth description of instruction**
 	

New Vision

- Reframing how we think about science and proficiency in it
- Rethinking children's competence
- Drawing from research on learning

What Is Science?

Definition of Science -- The use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process.

- Doing science involves:
  - Building theories and models
  - Collecting and analyzing data from observations or experiments
  - Constructing arguments
  - Using specialized ways of talking, writing and representing phenomena

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Scientific "Method"

- There is no single scientific method
- Science involves a broad range of methods beyond controlled experiments including observation, modeling and historical reconstruction
- Different science disciplines approach investigations differently (physics, biology, earth sciences, astronomy, etc.)

Strands of Scientific Proficiency

1. Understanding scientific explanations
2. Generating scientific evidence
3. Reflecting on scientific knowledge
4. Participating productively in science

➔ Not separate goals — intertwined strands during effective learning and teaching.

Children's Competence

- Children starting school are surprisingly competent. They already have substantial knowledge of the natural world.
- They are ***not*** concrete and simplistic thinkers and can use a wide range of reasoning processes that form the underpinnings of scientific thinking
- Instruction must build on these foundations

Constraints on Children's Reasoning

- Conceptual knowledge – children are universal novices
- Nature of the task
- Awareness of their own thinking (metacognition)

Three Core Principles of Learning

1. The need to engage students' prior understandings
2. The essential role of factual knowledge and conceptual frameworks in understanding
3. The importance of self-monitoring (metacognition)

Prior Understandings

- Understanding is constructed on a foundation of existing understanding and experiences.
- Prior understanding can support further learning
- Prior understanding can also lead to the development of conceptions that act as barriers to learning

Learning Progressions

- Developing rich, conceptual knowledge takes time and requires instructional support.
- Need to focus on a few key concepts (core ideas) and explore them in depth over time.
- Many existing curricula, standards and assessments in the US contain too many disconnected topics given equal priority.

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Key Scientific Practices

- Talk and argument
- Modeling and representation
- Learning from investigations

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Challenges: Tensions with Current Practice

- Science argument is rare in classrooms but central to science; teaching focuses on recall rather than on model-based reasoning
- Classroom norms (teacher and textbooks provide answers) in tension with building scientific models from evidence
- Curricula and standards “mile wide, inch deep” (TIMSS)
- Variation in standards works against coherent learning progression; marketplace realities lead to modularity.

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Challenges: Tensions with Promising Practices

- Improving teachers’ capacity to teach science effectively is critical to advancing goals.
- Need major changes in undergraduate science education, including a range of effective laboratory experiences for future teachers and comprehensive teacher support systems.
- The organization and structure of most schools impedes teachers’ and administrators’ ongoing learning about science instruction and implementation of quality laboratory experiences.

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Taking Science to School on-line

http://www.nap.edu/catalog.php?record_id=11625

Ready, Set, Science! on-line

http://www.nap.edu/catalog.php?record_id=11882

America’s Lab Report on-line

http://www.nap.edu/openbook.php?isbn=0309096715

BOSE Website

http://www7.nationalacademies.org/bose/

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Goals of Lab Experience

- Mastery of subject matter.
- Developing scientific reasoning.
- Understanding the complexity and ambiguity of empirical work.
- Developing practical skills.
- Understanding of the nature of science.
- Interest in science and science learning.
- Developing teamwork abilities.

Design Principles

1) Clear learning outcomes in mind.
2) Thoughtfully sequenced into the flow of classroom science instruction.
3) Integrate learning of science content with learning about the processes of science.
4) Incorporate ongoing student reflection and discussion.

Example: Core Ideas in a Learning Progression for Evolution

- Biodiversity
- Structure/function
- Interrelationships in ecosystems
- Individual variation
- Change over time
- Geological processes

Reframing Science and Proficiency in Science

Strands in Action I

Biodiversity in a City Schoolyard (Chp. 2)

- 5th Grade predominately low-income urban school, northwestern Mass.
- The class decides to investigate the plants and animals around their school.

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Strand 1: Developing/Using Scientific Explanations

- Students begin studying their school yard by identifying the trees, shrubs and flowers. Over time and through investigations and discussion they realize that certain plants are found in certain areas. They begin to develop an understanding of habitat.

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Strand 2: Generating Scientific Evidence

- Students begin by mapping the plants they identify. They later divide into groups and carry out investigations of particular plants and animals, such as trees, weeds or squirrels.

- They encounter problems in how to study the plants or animals and develop strategies for measuring and recording observations and summarizing results. They decide they need to map observations more carefully and begin to develop methods of sampling.

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Strand 3:Reflecting on Scientific Knowledge

otice that the trees on one side of the school than on the other. They hypothesize that de may be older, but they realize that the gathered about the age of the trees is eads them to reflect on the quality and other evidence they have gathered and to interpretation of the evidence.

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Strand 4: Participating productively in science practices

- The students participate in monthly "biodiversity" conferences where they share the results of their ongoing investigations.

- They learn how to summarize and present their data, how to develop and present an argument based on empirical evidence, and how to ask appropriate questions, e.g., about interpretations or limitations of the evidence.

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Rethinking Children's Competence

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Children's Knowledge of the Natural World

- Some areas of knowledge may provide more robust foundations to build on than others.
  - Physical mechanics
  - Biology
  - Matter and substance
  - Naïve psychology (theory of mind)

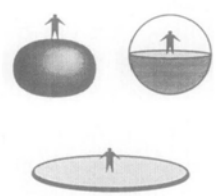
- These appear very early and appear to have some universal characteristics across cultures throughout the world.

- Earth science and cosmology – not early and universal

Children's Reasoning

- Young children can think in sophisticated, abstract ways. For example, they:
  - Distinguish living from non-living
  - Identify causes of events
  - Know that people's beliefs are not an exact representation of the external world
- Practice and instructional support are key
  - Children can learn how to control variables
  - They can learn how to evaluate evidence objectively

Drawing from Research on Learning



Prior understanding and "misconceptions" in science

- Children's understandings of the world sometimes diverge from accepted scientific explanations. These are often described as "misconceptions" to be overcome.
- But students' prior knowledge also offers leverage points that can be built on to advance students' science learning.
- Emphasis on eradicating misconceptions can cause us to overlook the productive knowledge they bring

Concepts and Frameworks in Science

- Proficiency in science is more than knowing facts. It is ***not*** a simple accumulation of information.
- Factual knowledge must be placed in a conceptual framework to be well understood.
- Students need to learn how ideas are related to each other, and their implications and applications in the discipline.

Conceptual Change in Science

- Some kinds of conceptual change occur naturally, some require intentional effort.
- For many ideas in science, students are unlikely to arrive at an understanding of them without explicit instruction (for example, understanding atomic-molecular theory or genetics).
- Major changes in conceptual frameworks are often difficult and are facilitated by instruction – they take time!

Supporting Metacognition

- Metacognition – people's knowledge about themselves as learners, or "information processors"
- Focus on helping students develop the ability to take control of their own learning
- Support students' ability to reflect on the status of their own knowledge

Example: Metacognition

In the past I thought the book on the table had only 1 force, and that force was gravity. I couldn't see that something that wasn't living could push back… This year I began to think about the book on the table differently. Last year I was thinking on the macroscopic level and not on the microscopic level. Last year I was looking at living beings as the important focus and now I am looking at molecules as being the important focus. When I finally got my thoughts worked out, I could see things from a different perspective. I found out that I had no trouble thinking about two balanced forces instead of just gravity working on the book. It took me a whole YEAR to figure this concept out!!! Now I know it was worth THE YEAR to figure it out because now I can see balanced forces everywhere!

Implications for Education

Learning Progressions

- Developing rich, conceptual knowledge takes time and requires instructional support.
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Key Scientific Practices

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Talk and Argument

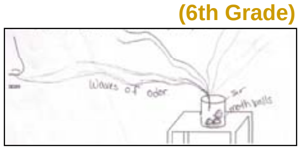
Teacher Move	*Example*
Re-voicing	"So let me see if I've got your thinking right. You're saying _________?" (with space for student to follow up)
Asking students to restate someone else's reasoning	"Can you repeat what he just said in your own words?"
Asking students to apply their own reasoning to someone else's reasoning	"Do you agree or disagree and why?"
Prompting students for further participation	"Would someone like to add on?"
Asking students to explain their reasoning?	"Why do you think that?" "What evidence helped you arrive at that answer?"
Using wait time	"Take your time…. We'll wait."

Modeling and Representation

- Engage students in creating and using representations to communicate scientific ideas

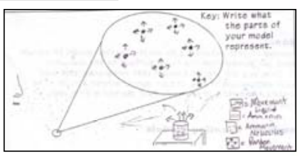
- Engage students in developing, using, evaluating, and revising models

Developing More Sophisticated Models (6th Grade)



Original Model: Smell as "waves of odor"

Revised Model: Smell as particles moving through space



Learning from Investigations

- Students learn science by actively engaging in the practices of science including generating questions, gathering and analyzing data, and debating the evidence.
- Unguided inquiry alone is not effective. Students need multiple supports to learn from investigations and understand scientific ideas.
- All major aspects of inquiry, including posing questions, managing the process, making sense of the data and discussing the results may require guidance.

Example: Project-based Inquiry

IQWST: Investigating and Questioning Our World Through Science and Technology (an NSF middle school curriculum series)

• Driving question (6th grade Bio):

"How do we stop a biological invasion?"

•Task: Assist Great Lakes Fishery Commission in designing plan to stop the sea lamprey invasion.

•Form/function; food webs; predator/prey; interdependence of species in ecosystems

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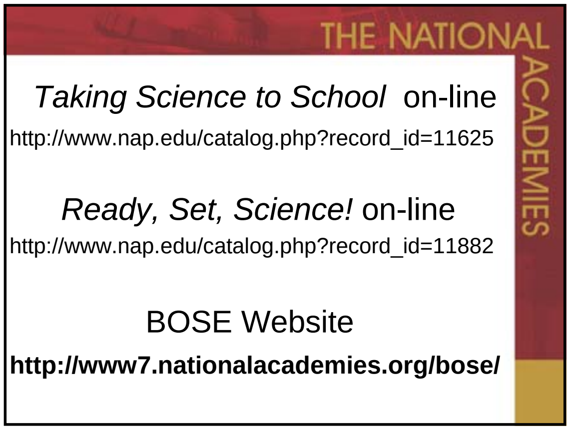
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