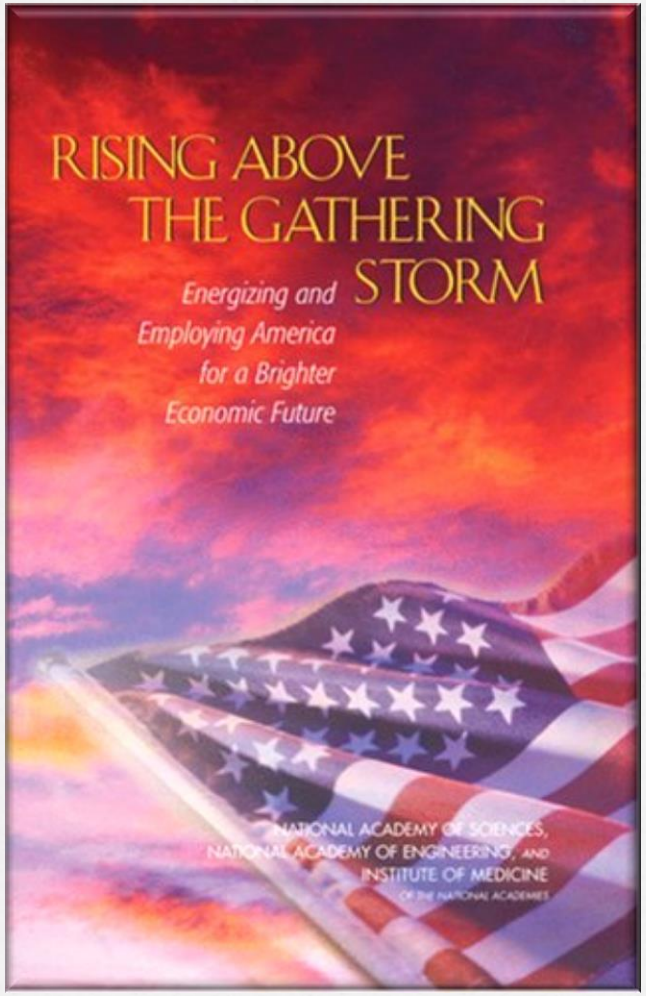
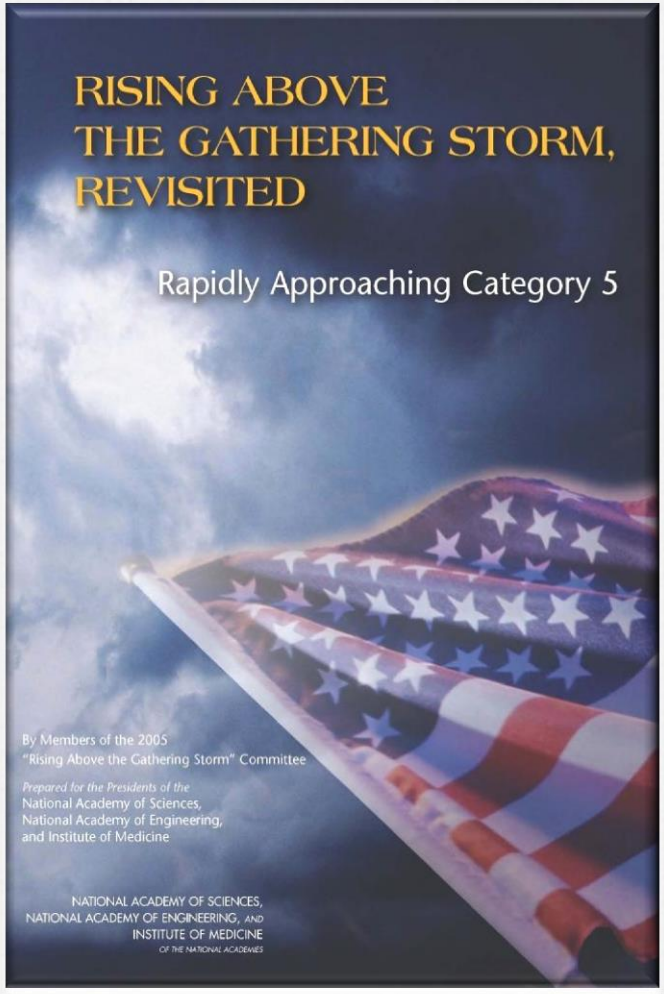
Shifting the Question in STEM Education Reform

from “What should students know?”

to “How should students know?”

A Wake-Up Call?





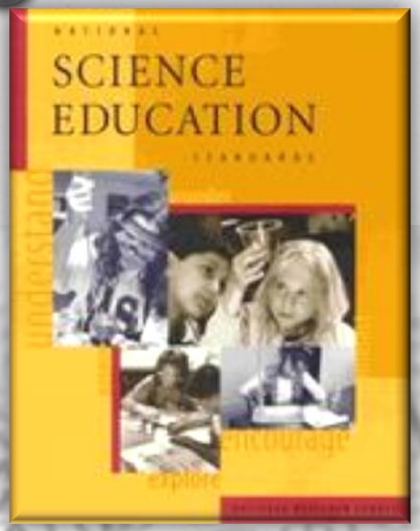
Groundhog Day?

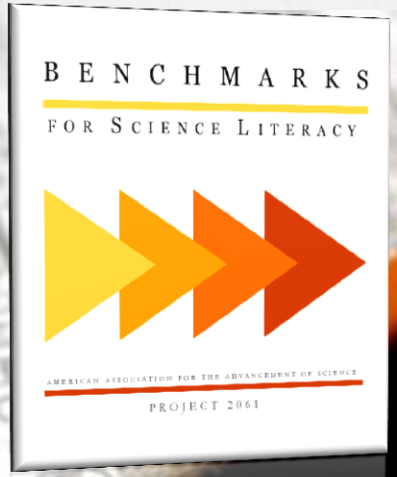
"Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world. This report is concerned with only one of the many causes and dimensions of the problem, but it is the one that undergirds American prosperity, security, and civility. We report to the American people that while we can take justifiable pride in what our schools and colleges have historically accomplished and contributed to the United States and the well-being of its people, the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people. What was unimaginable a generation ago has begun to occur-- others are matching and surpassing our educational attainments."

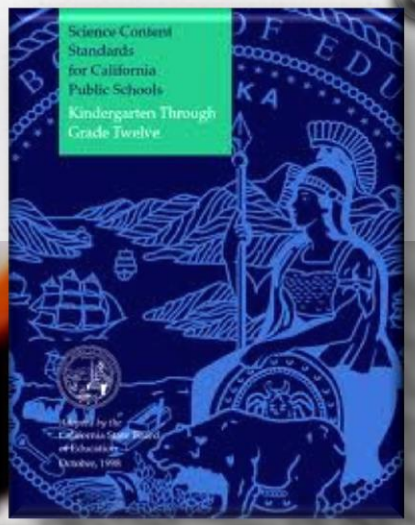
The National Commission on Excellence in Education (1983). *A Nation at Risk: The Imperative for Educational Reform.* Washington, D.C.

Standards

and No Child Left Untested



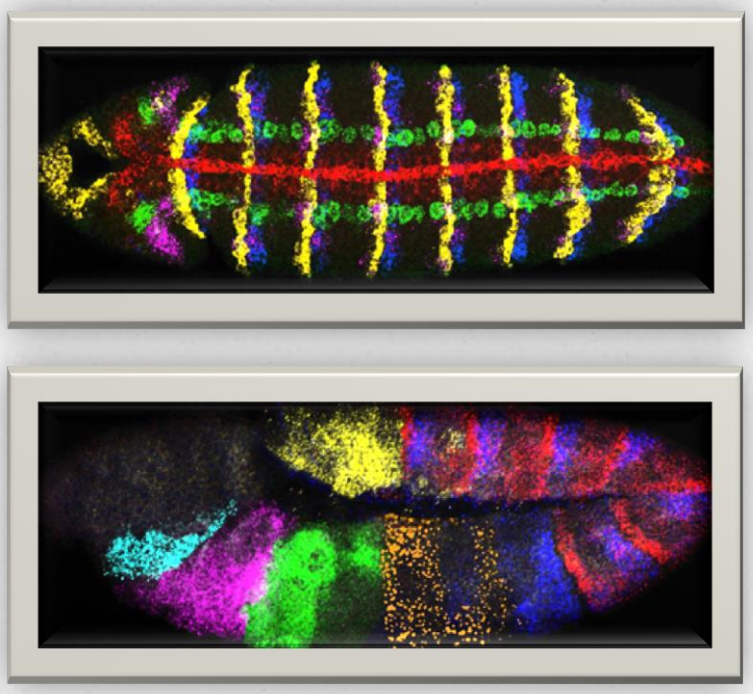




A single-minded focus on what students should know has pitfalls.

1. Loss of the big picture and the beauty of science.

"Consider, for example, the beginning of life for an animal like ourselves. Somehow a single fertilized egg cell is able to multiply to give rise first to a tiny embryo and then, through many cycles of cell growth and division, to an adult animal composed of thousands of billions of cells. This process requires that cells behave like tiny computers that store a memory of where they have been in the embryo, selectively expressing only those genes appropriate for their time and place in the giant 'cell cooperative' that is a multicellular organism...."



Multiplex labeling reveals gene expression in a Drosophila embryo.
Image credit: Dave Kosman, UCSD

"…Yet, a 700-page life science textbook for 12-year-olds selected by the state of California (with a glossary of 500 words) **never challenges students to consider the fascinating question of what cells must do to produce an embryo**, focusing instead on introducing them to many hundreds of dry "scientific" terms and a multitude of associations to memorize."

--Bruce Alberts, in *Science*, December 14, 2012.

2. Tradeoff of depth for coverage.

“Freshmen in my general chemistry classes claim to be bored by any discussion of quantum mechanics, kinetics, or electrochemistry because they already ‘know it from high school.’
What they *actually know* are some of the buzzwords but with no depth of understanding.”

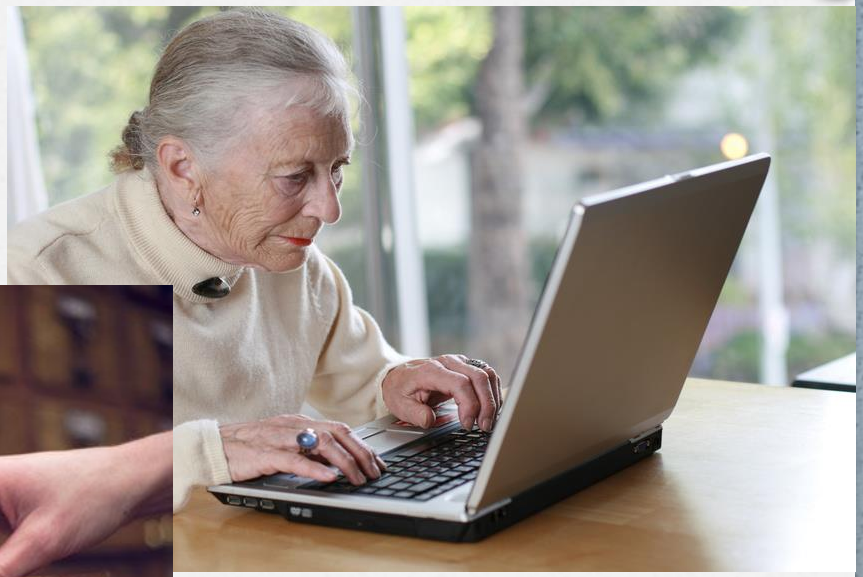
-Barbara Sawrey, in *Journal of Chemical Education*, February 1989.

"Hardly a minute after the test began, one student asked, '**How should I answer these questions? According to what you taught me or according to the way I usually think about these things?**'"

Eric Mazur, in *Science*, January 2, 2009.
Student's response to conceptual questions about Newton's third law

Students may learn "what" instructors want, without learning "how" instructors want.

3. Failure to understand how the Information Age has changed the knowledge landscape, and consequently, what it means to know.



Zelazny, Roger 1937-1995

SCIFI
ZEL

Nine princes in amber [1st ed.], by
Roger Zelazny. Garden City, NY,
Doubleday [1970]

188 p. ; 22 cm.

Cover art: Amelia S. Edwards.

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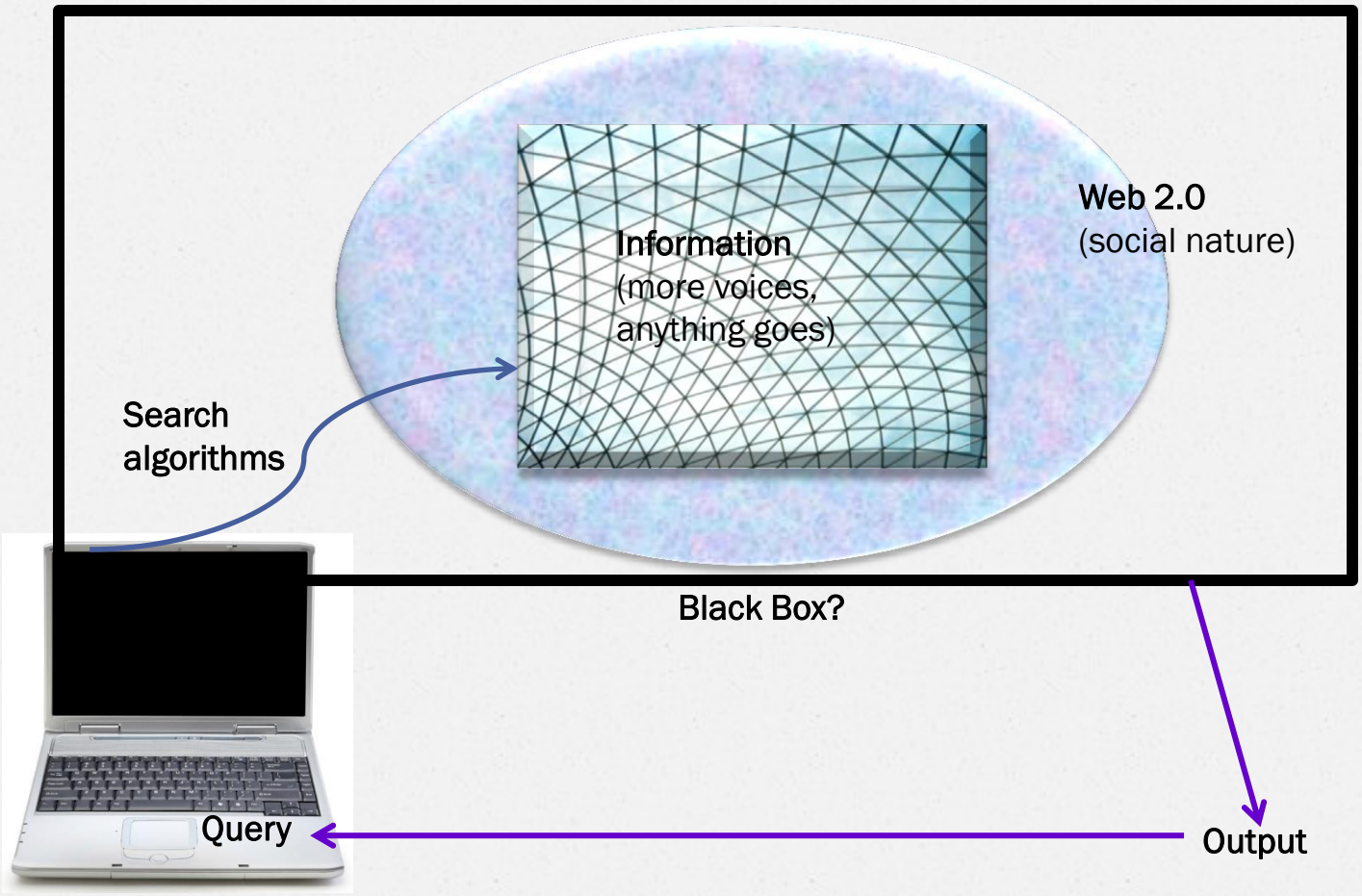
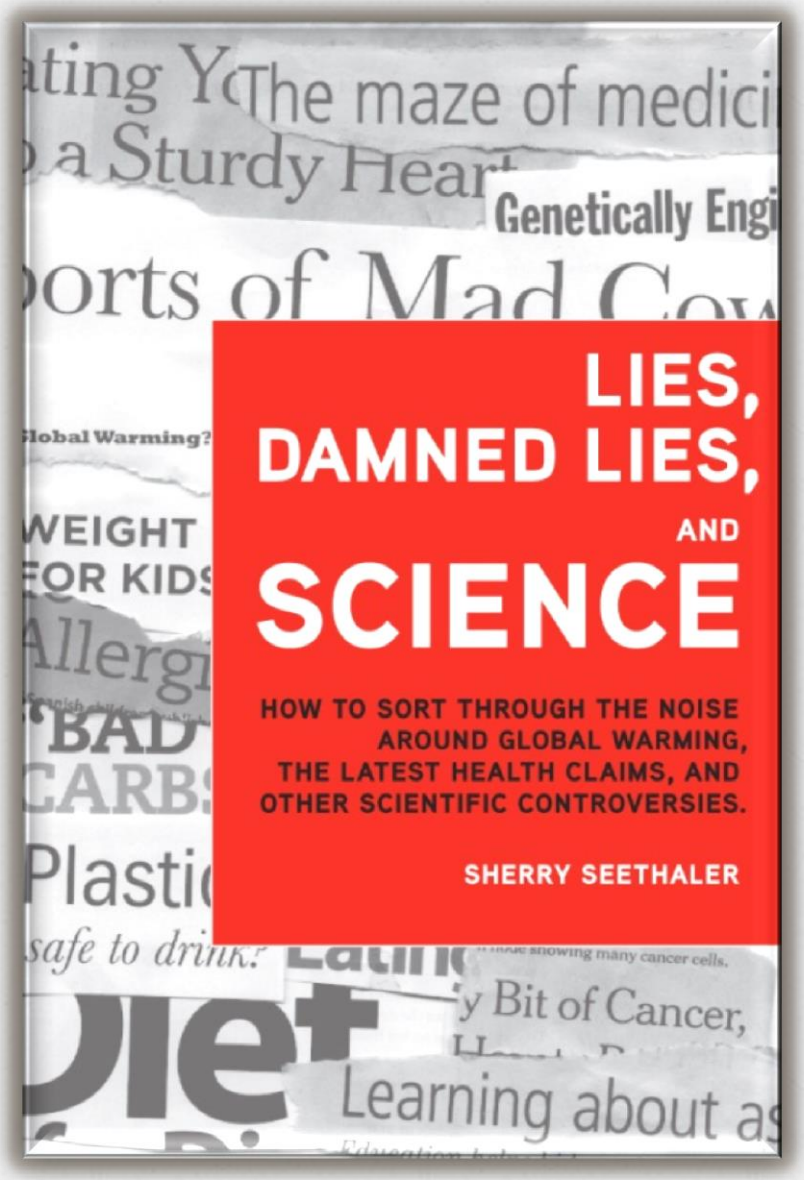
NOT AVAILABLE FOR INTERLIBRARY LOAN

1. Amber (Imaginary place)--Fiction.
I. Title


Information
(more voices,
anything goes)
Web 2.0
(social nature)
Search
algorithms
Black Box?
Query
Output

In the Information Age, one still needs to know things
(i.e. the "what to know"),
but I would argue it is now more important to develop
the right dispositions and habits of mind
(i.e. the "how to know").

Some aspects of "how to know" will be discipline and grade specific.



Examples of habits of mind useful for navigating claims in the media.

Metacognition

The most important habit of mind is the propensity to question one's own understanding and the ability to analyze and synthesize information to actively refine that understanding.

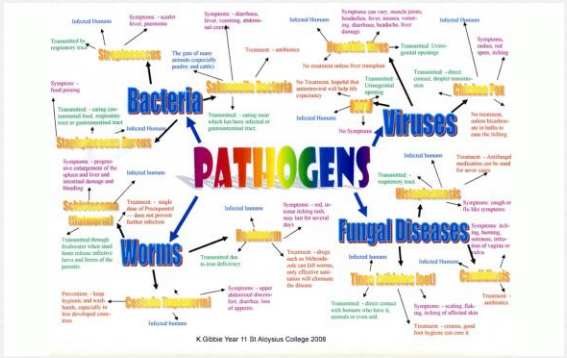
Innovation or Bandwagon?

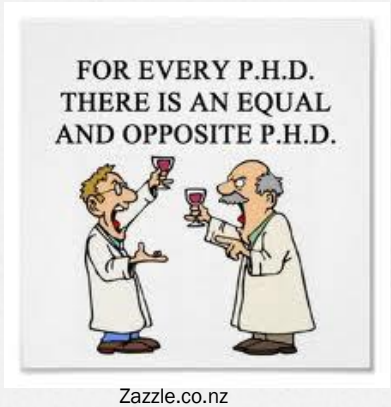
Three trends in education in the context of "How should people know?"

Collaborative learning
Clickers
MOOCs

Collaborative Learning

- Designed well, can help students become aware of misconceptions and develop self-questioning skills.
- Pressure to do more group work and assumption that more is better.
- Positive effect sizes are largest for “medium” amounts of group work.* Can have too much of a good thing.





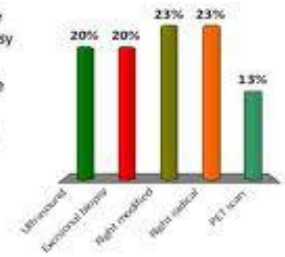
Zazzle.co.nz

*Springer, L., M. Stanne, and S. Donovan, “Effects of Small- Group Learning on Undergraduates in Science, Mathematics, Engineering and Technology: A Meta-Analysis,” *Review of Educational Research*, Vol. 69, No. 1, 1999, pp. 21–52.

Clickers

female underwent near-total thyroidectomy
pillary thyroid cancer 2 years ago. Her PCP
y identified a palpable mass along the right
eidomastoid muscle. Which of the following
ices is the **most appropriate** next step?

1. Ultrasound guided fine needle aspiration biopsy of the mass
2. Excisional biopsy of the mass
3. Right modified radical neck dissection
4. Right radical neck dissection
5. PET scan



- Carefully designed clicker questions can help students recognize their misconceptions and reflect on their own understanding.
- But this is feasible without the technology

MOOCs

Massive Open Online Courses

Editorials are either scathing or breathlessly enthusiastic.

Make education more accessible (e.g. stories from developing nations, autistic students.)

Flexible lesson length, instant feedback, interactions with diverse fellow students, potential for research on student learning.

Many of the technologies that preceded it generated similar predictions.
E.g. Closed circuit T.V., correspondence courses , Open University, Computer-based Learning, Great Courses on tape/CD/DVD…)

But perhaps the conversations resulting from the iterative refinement of MOOCs could shift the focus to “how students should know.”

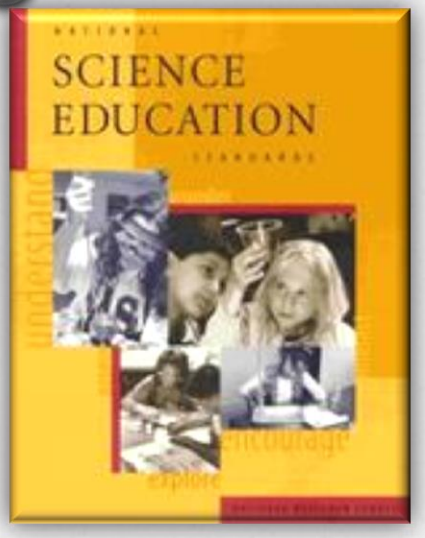
"Ultimately, reform is more about people than it is about policies, institutions, and processes."

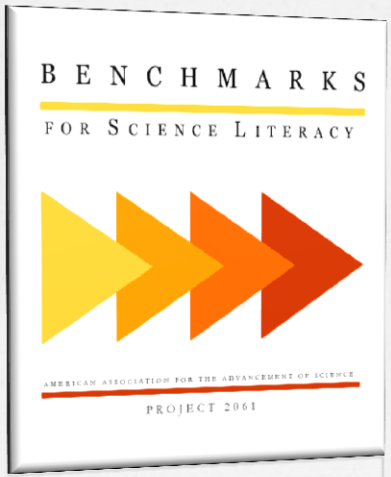
"Sensible professionals do not replace their strongly held views and behavior patterns in response to fiat or the latest vogue; instead, they respond to developing sentiment among respected colleagues, to incentives that reward serious efforts to explore new possibilities, and to the positive feedback that may come from trying out new ideas from time to time—all of which can take years."

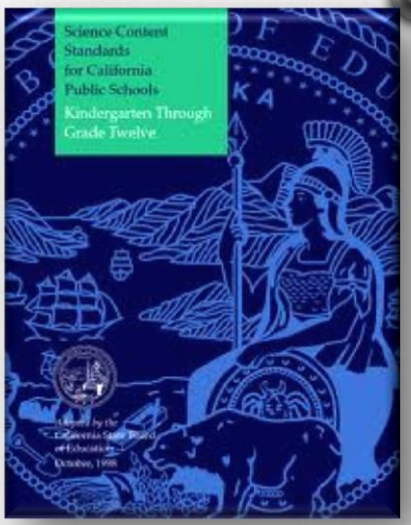
"Comprehensive reform does not imply going off in all directions at once. Rather, it demands that some steps occur before others, that some problems take precedence, and that resources be deployed strategically. Careful systemwide planning should precede action, and no aspect of planning is more crucial than setting priorities. Failure to set priorities can result in only a little change; setting the wrong priorities may leave the students worse off than before reform was undertaken."

Rutherford, F.J., & Ahlgren, A. (1989). Science for all Americans. New York: Oxford University Press.

Reconsidering the Standards







Teachers play a critical and central role in reform. Therefore teacher education is also pivotal.

All community college and university instructors are teacher educators.

Teachers learn how to teach STEM, not in their credential year, *but while they are STEM students*.

Cal Teach—Bridging the Divide

- 34-quarter units
- Four education courses with practica in local schools
- One lecture course on cultural aspects of teaching
- Three science education (or math education) courses, plus optional freshman seminar

Focused on science/math content, problem solving, sharing solution approaches. Discussions about learning emerge naturally from the content and are grounded in it.

Students are…

- Recognizing limitations in their own understanding
- Identifying misconceptions they hold
- Grasping the difference between memorizing and gaining a conceptual understanding
- Seeing the interconnectedness of different scientific disciplines
- Employing more active learning strategies, such as self-questioning, working in learner groups, seeking applications

Another reason for helping students explore how they learn in STEM classes.

- Why do we have seasons?
- What causes the phases of the moon?
- Where does the matter come from that enables a seedling to grow into a tree?

"I realized from these courses that learning science often involves disproving pre-conceived thoughts, or alternative conceptions, in order to learn a subject material effectively. Everyone comes into a science class with their own belief in how the world works, and it is important to address these conceptions rather than ignore it."—Cal Teach student

A resource: National Research Council (2012). *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*. Washington, D. C.: National Academies Press.


Knowledge is power.
-Sir Francis Bacon
The most important product of knowledge is ignorance.
-David Gross,
2004 Nobel Laureate in Physics
NASA Image