

Meaningful Research on Science Education: a Challenge for the International Science Community

Bruce Alberts

President, US National Academy of Sciences

Monterrey, Mexico: May 12, 2003

Talk outline

- The US National Academies: a focus on science education for all students
- The importance of incorporating more teacher wisdom into research and policy making.
- Energizing education research
- The critical role of science departments in our universities

U.S. National Academy of Sciences Charter (1863)

“The academy shall, whenever called upon by any department of the government, investigate, examine... and report upon any subject of science or art ,... but the Academy shall receive no compensation whatsoever for any services to the government of the United States”.



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TUESDAY, SEPTEMBER 21, 2001

Broader Stem Cell Research Backed

Key Science Group Differs With Bush

By Rick Weiss
Washington Post Staff Writer

Research on human embryonic stem cells deserves generous funding by the federal government and will not live up to its therapeutic potential if the work is restricted to a small number of cells from a limited number of embryos, according to a report to be released today by the National Academy of Sciences.

Moreover, scientists should be allowed to pursue research that involves the cloning of human embryos because cells derived from such embryos may prove to be especially useful for the treatment of many degenerative conditions, the report concludes.

The report by the academy, an independent organization chartered by Congress to advise the government on science issues, comes one month after President Bush announced his policy regarding federal funding of human embryo cell re-

THE DISTRICT'S LOST CHILDREN | Babies at Risk



A twin who died: A photo of Tyrina Perry, who died at 5 months in 1995, is held by her sister.

EPA to Urge Tighter Rules For Arsenic

Report Raises Agency Concern About Drinking Water Limits

By Eric Pianka
Washington Post Staff Writer

The Environmental Protection Agency has concluded that it must adopt a new standard for the amount of naturally occurring arsenic allowed in the nation's drinking water that is at least as tough as the one proposed by the Clinton administration, officials said yesterday.

EPA Administrator Christine Todd Whitman decided to recommend a stringent new limit after receiving a report from the National Academy of Sciences that found that the health risks posed by arsenic are much greater than previously assumed by the EPA, according to agency officials.

"This increases our concern about arsenic and what the level should be," an EPA official said last night.

The decision addresses one of the most controversial environmental decisions the Bush administration has made since coming into office. In March, the administration unveiled a Clinton administration regulation tightening the 50-year federal standard for arsenic levels in drinking water from 50 parts per billion to 10 parts per billion. The move touched off criticism from Democrats, environmentalists and moderate Republicans and prompted a House vote working to reverse the action.

Whitman charged at the time that the Clinton rule had been hastily crafted without adequate scientific study or consideration of the costs for small communities. She ordered further examination, by the academy and other bodies,

Published 1996
18,000 reviewers
250 pages

NATIONAL SCIENCE EDUCATION STANDARDS



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NATIONAL RESEARCH COUNCIL

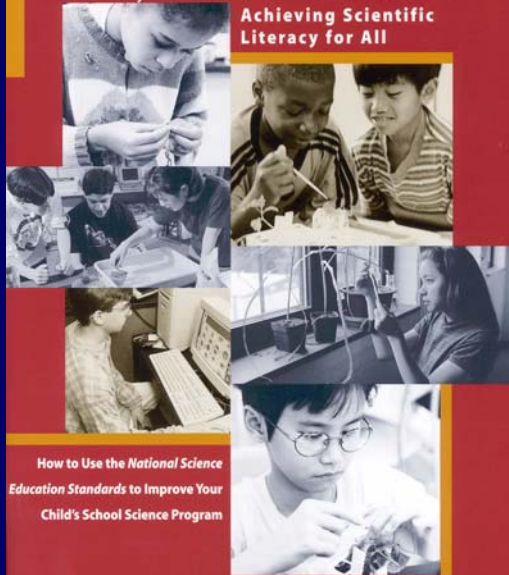
US National Science Education Standards

- Guiding Principles
 - Science is for all students
 - Learning science requires active engagement
 - School science should reflect professional science
 - Improving science requires system-wide reform

Booklet
for parents

Every Child a Scientist

Achieving Scientific
Literacy for All



How to Use the *National Science
Education Standards* to Improve Your
Child's School Science Program

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<http://www.si.edu/nsrc/>

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**Sally Shuler,
Director**

About the NSRC Contact Information Educational Resources LASER Initiative Leadership Development NSRC Newsletter (ScienceLink) Outreach Activities Publications Science and Technology for Children (STC) STC Discovery Deck Science and Technology Concepts for Middle Schools (STC/MS)	About the NSRC Overview Sponsoring Institutions Staff Directory Advisory Board Outreach Archives LASER Initiative Applications and Registration Forms Articles Background Information Calendar of Events Regional Sites  NSF Science and Mathematics Education Implementation and Dissemination Centers Description of Centers Science and Math Core Curricula Publications	News and Events April <i>California LASER K-8 Science Education Symposium, "Implementing Effective Science Education Programs: Challenges to Sustainability", April 16-17, 2002, Arnold and Mabel Beckman Center of the National Academy of Sciences and Engineering, Irvine, California.</i> May <i>Rhode Island College HELMSS-LASER Building Awareness Workshop and Dinner and Rhode Island College HELMSS-LASER Middle School Science Education Curriculum Showcase, May 8-9, 2002, East Bay Educational Collaborative, Warren, Rhode Island. [Registration Form]</i> June <i>South Carolina LASER K-8 Science Education Strategic Planning Institute: Helping School Districts Initiate and Implement Science Education Programs that Align with Science Standards, June 9-14, 2002, Florence-Darlington Technical College, Florence, South Carolina. [Application Form] [Application for South Carolina Districts Only]</i>
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The good news

- Inquiry based science education precisely fits the needs for workforce skills that have been widely expressed by business and industry

The skills needed to be successful competitors in the modern world economy

- A high capacity for abstract, conceptual thinking.
- The ability to apply that capacity for abstract thought to complex real-world problems—including problems that involve the use of scientific and technical knowledge—that are nonstandard, full of ambiguities, and have more than one right answer.
- The capacity to function effectively in an environment in which communication skills are vital – in work groups.

*Ray Marshall and Marc Tucker,
Thinking for a Living*

Or, as you heard last night:

Our front-line production employees need to be much more flexible: we want workers with an intrinsic curiosity, inquisitive attitudes and aptitudes, and a willingness to work in interdisciplinary teams.

Leopoldo Rodriguez
May 11, 2003

The bad news

Inertia

How can we exploit the knowledge and wisdom of teachers to improve education?

- Our best science teachers need to have much more influence on the education system.
- This influence is needed at every level: from school districts, to states, to the national government.
- How can we institutionalize such an influence, as needed to create a continuously improving education system?

NEW Teacher Advisory Council at the National Academies

- Designed to give a major voice for teachers in the work of the National Academies.
- Each member must be spending at least 50 percent time as a K-12 classroom teacher of math, science, or technology.
- First meetings held in 2002.
- **Can we also use this group to begin to create an effective national voice for teachers?**



Why we are all here

- Just as good science has commonly accepted norms that apply globally, good science education will have many features that apply to each nation.
- Therefore, we can help each other succeed by sharing the best of our curricula, and the lessons learned from our work.

Three central features of the new international effort to spread good science education to every nation

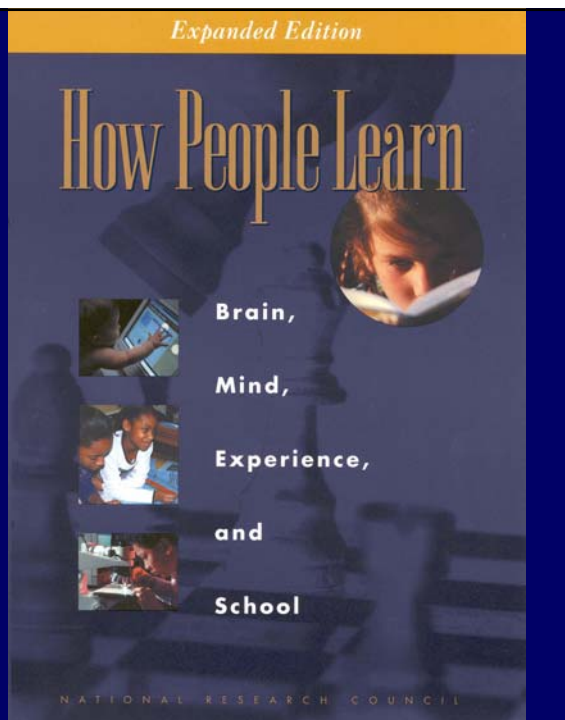
- An emphasis on connecting institutions representing a nation's best scientists to the effort to improve science education for children.
- A focus on providing all students with the rational problem-solving skills of a scientist, by engaging them actively in scientific inquiry.
- Encouraging scientifically based, education research that can guide the continuous improvement of our education systems.

A major mission of the National Academies **Making a science out of education**

- This means creating a much more effective **education research** enterprise, focusing on real classroom settings
- The goal is to use knowledge of what does and does not improve student learning, based on scientifically obtained evidence, to create a continuously improving education system at all levels

Now used as
a text for
teacher
preparation
courses

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How People Learn: some key points

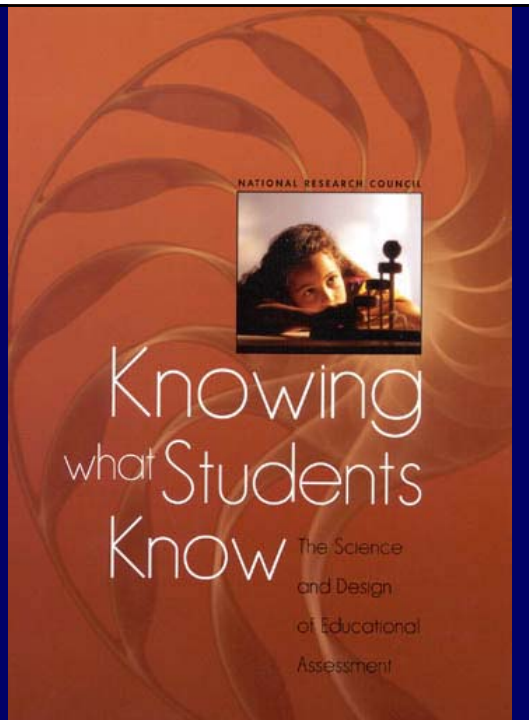
- Conceptual understanding is facilitated when new knowledge is structured around major concepts and principles
- Students' preconceptions must be engaged in order to construct new understandings
- Learners have different strategies, ability sets, and learning styles for gaining comprehension
- Learners' motivation affects what is learned

The importance of getting the tests right

- It is much easier to test for knowledge of science facts than it is to test for science understanding; inexpensive tests designed to hold teachers and schools "accountable" will trivialize science teaching and drive most students away from science.

Describes the opportunity for new types of computer-aided assessments

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But there are big gaps in our knowledge

To create a continuously improving education system, we badly need a more focused and effective system of education research

- Otherwise our nations' schools will continue to be driven by one simple "magic bullet" solution after another, as new leaders seek a quick fix.
- It is critical that, as in science, we improve education by accumulating a commonly accepted body of knowledge based on confirmable evidence.

What is good research in education?

Published 2002

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SCIENTIFIC RESEARCH IN
EDUCATION

NATIONAL RESEARCH COUNCIL

Scientific Research in Education (2002)

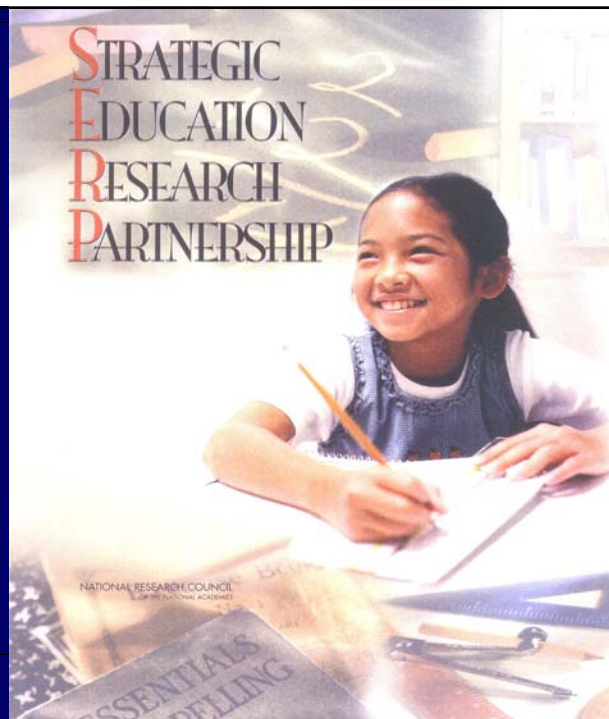
Designs for the Conduct of Scientific Research in Education:

- **What Is Happening?**
 - Estimates of population characteristics
 - Descriptions of localized educational settings
- **Is There a Systematic Effect?**
 - Causal relationships determined through **randomized field trials** when feasible
- **How or Why Is It Happening?**
 - Mechanisms and development of theories to drive further research

Published 2003

Recommends establishing a set of research field sites, in which many teachers and school system leaders interact closely with researchers.

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Urgently needed: more research on teaching science as inquiry in elementary and middle school classrooms



A meaningful field trial of inquiry based science education will require:

1. An extensive program of on-going teacher professional development
2. Monitoring of the actual classroom teaching by skilled investigators to assess delivery
3. A long term longitudinal study designed to determine the effect of the delivered curriculum on the students -- for example, on their career and educational outcomes

One important issue:

Conducting meaningful random field trials on some of the most important educational challenges – those focused on the acquisition of higher learning skills – will be expensive.

- Delivering a educational curriculum is very different than delivering a pill.
- In addition, we need to create a consensus about the validity of the output measures to be used for each trial, if the results are to be convincing for policymakers.

Can we work together to design an international research project to facilitate inquiry based science teaching?

- We would like research to guide us to the most effective strategies for implementation and teacher support.
- We need to accumulate convincing data on the effects of this kind of science education on long-term student outcomes.
- Findings that are consistent across different nations would have a powerful effect.

Any large-scale change at lower levels will require major changes in the introductory science courses at colleges and universities

In particular, we need:

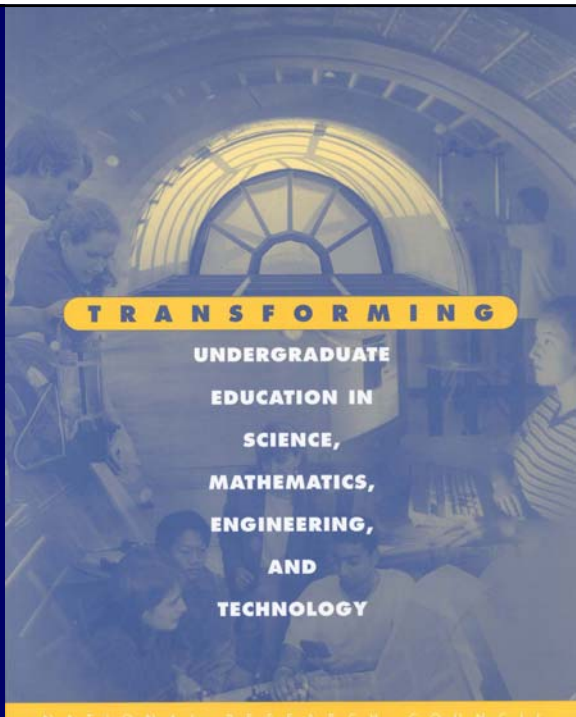
- 1). Inquiry-based teaching of science and its relation to society, for all students
- 2). Inquiry-based, non-cookbook laboratory experiences associated with introductory science courses.

A new vision for introductory college science courses

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Friday, Jan. 31, 2003 -- Updated Weekdays

Site Highlights

HEALTH INSURANCE: Is your family protected? The latest article from the National Academies Op-Ed Service may surprise you.

AFRICAN-AMERICAN HISTORY MONTH: Join Rodney Slater and other honored guests in a [Celebration of Advancement and Opportunities for African Americans in Public Service](#) on Monday, Feb 10.

BEYOND DISCOVERY SERIES: Read the newest

Top News

Government Should Continue Public Weather Forecasts

Jan. 30 -- The National Weather Service should continue to issue general forecasts and provide unrestricted access to observational data, even though private companies also produce weather forecasts, says a new National Academies report. The weather service should come up with a new process for deciding whether a particular forecast or weather product should be created by the Weather Service or the private sector.

[Press Release](#)
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The National Science Education Standards, 1996

1. Science as core subject in every year of school, starting in kindergarten.
2. Science for all.
3. Science as inquiry based learning, not word definitions.

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We are part of an international movement of science academies

- A focus on recruiting the best scientists in each nation to support science education for young people.
- A focus on teaching science as inquiry, rather than as fact memorization.
- A focus on using scientifically based research to create a continuously improving education system.

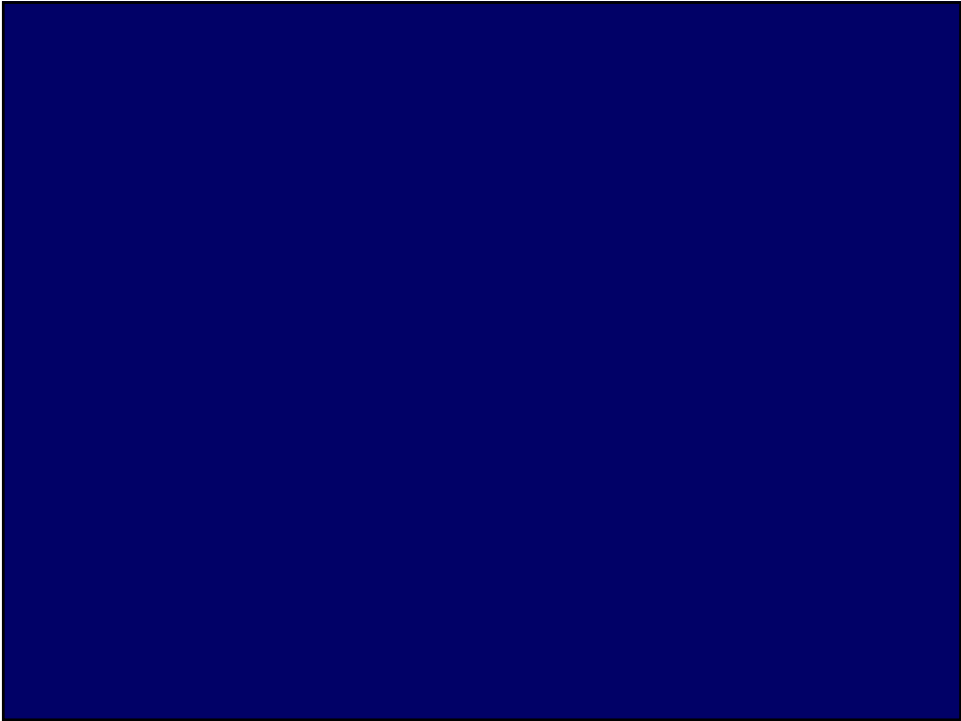


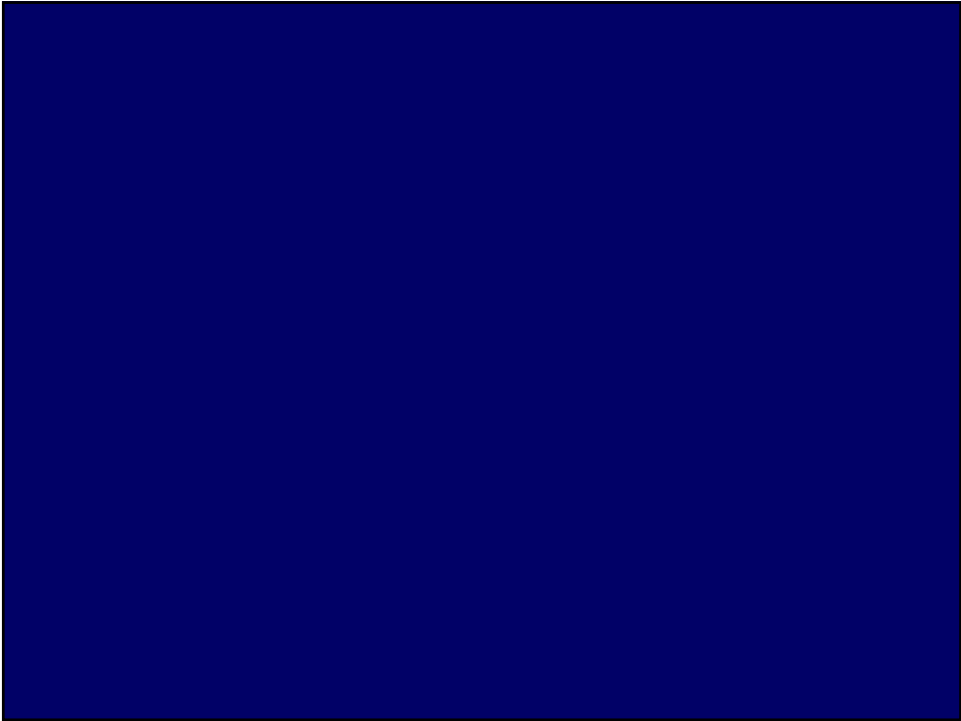
A challenge for science professors in colleges and universities

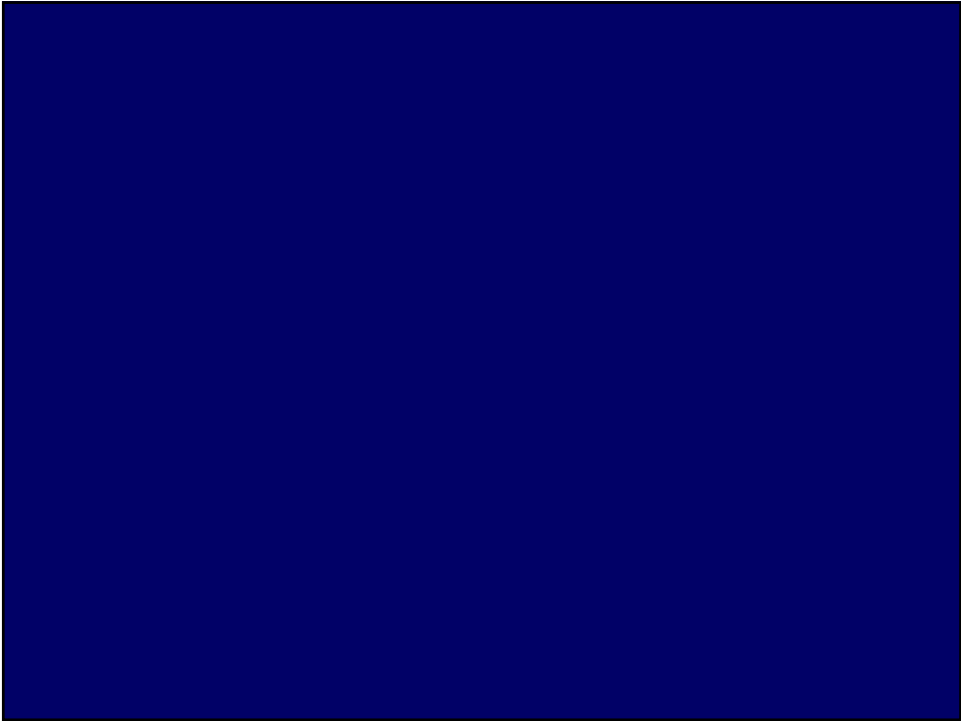
When we teach, how many of us have the primary aim of giving students enough exposure to scientific reasoning and scientific culture to enable them to appreciate science as a very special, evidence-based way of knowing about the natural world?

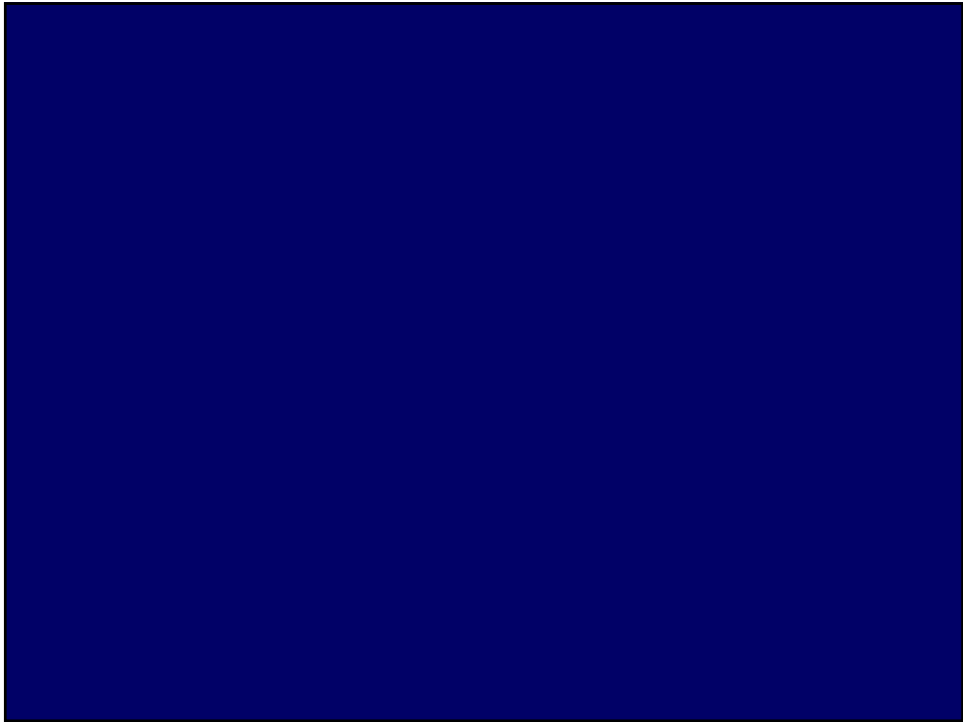
And yet, without this appreciation, we have no right to expect that our nations can continue to prosper in a world that is becoming evermore complicated due to the accelerating advances in science and technology.

The screenshot shows the homepage of www.nationalacademies.org. The header features the site's name and a navigation menu with links for 'Read 2500+ Reports Online', 'Current Projects', 'Publications', 'Directories', 'Search', 'Site Map', and 'Feedback'. A secondary navigation bar includes 'Report Outlines Priorities for Army Homeland Security Efforts'. The main content area is divided into several sections: a 'Quick Search' box, a 'Top News' section with a featured article on a 'Live Webcast Tomorrow on Food Safety' (dated April 23), and a 'Carbon Monoxide Emissions Controls Are Effective' article (dated April 23). A 'Site Highlights' sidebar on the right contains sections for 'SUBSCRIBE', 'INTERVIEWS', 'BEYOND DISCOVERY', and 'NEW ONLINE BOOKS'. The left sidebar lists various academies and research councils, along with a 'Special Collections' and 'Subject Index' menu.









The cover of the 'ELECTRIC CIRCUITS TEACHER'S GUIDE' features a green background. At the top, the title 'ELECTRIC CIRCUITS' is written in a bold, black, sans-serif font. Below it, 'TEACHER'S GUIDE' is written in a smaller, black, sans-serif font. On the left side, there is a vertical black and white illustration of a lightning bolt striking a tree. The central illustration shows two children, a boy and a girl, looking intently at a small electronic component on a table. The boy is on the left, and the girl is on the right, with her hair in a braid. At the bottom, the logo 'NSRC/STC' is displayed in a bold, black, sans-serif font. Below the logo, the text 'National Science Resources Center' and 'Science & Technology for Children' is written in a smaller font.

THE LIFE CYCLE OF BUTTERFLIES

TEACHER'S GUIDE



NSRC **STC**
National Science Resources Center Science & Technology for Children

EXPERIMENTS WITH PLANTS

TEACHER'S GUIDE



NSRC **STC**
National Science Resources Center Science & Technology for Children

An unfortunate fact :

For both medicine and education, each randomized field trial must be carefully designed and focused on one or more hypotheses derived from a large amount of prior research.

- We presently invest only about 0.1 percent of the total K-12 education budget on education research
- This level of investment is vastly inadequate to provide the intellectual basis for a system of randomized field trials that could make a real difference in our education system

Another unfortunate fact:

Conducting meaningful random field trials on some of the most important educational challenges – those focused on the acquisition of higher learning skills – will be very expensive.

- Delivering a educational curriculum is very different than delivering a pill
- In addition, we need to create a consensus about the validity of the output measures to be used for each trial, if the results are to have any traction



Values of Science

- Honesty
- Generosity
- Respect for evidence, with openness to all ideas and opinions irrespective of their source

The society of scientists is simple because it has a directing purpose: to explore the truth. Nevertheless, it has to solve the problem of every society, which is to find a compromise between the individual and the group. It must encourage the single scientist to be independent, and the body of scientists to be tolerant. From these basic conditions, which form the prime values, there follows step by step a range of values: dissent, freedom of thought and speech, justice, honor, human dignity and self respect.

Jacob Bronowski

Scientific Research in Education (2002)

Important summary:

“In estimating the effects of programs, we urge the expanded use of random assignment. We also urge that randomized field trials be supplemented with other methods, including in-depth qualitative approaches that can provide additional sources of evidence for supporting causal claims in complex educational settings.”

The Bottom Lines:

1. Science for all
2. Science as inquiry based learning, not word definitions
3. Science as core subject in every year of school, starting in kindergarten

But who will do this research?

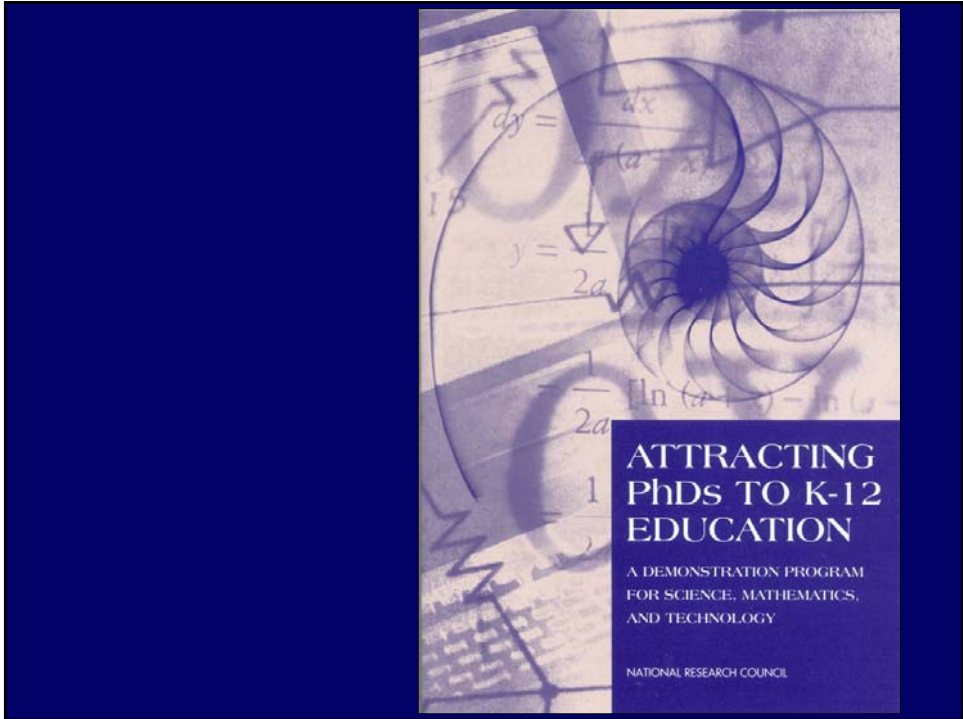
Postdoctoral students in US university departments of science & engineering

- There are approximately 40,000 of these postdocs in a holding pattern looking for more permanent positions today.
- Our survey of a sample suggests that about a third of these talented individuals would be willing to consider a career in secondary education under the right conditions.
- **BUT:** there is presently no obvious place for these talented individuals to go to be trained effectively for a productive career in either education or education research.

“While most descriptions of necessary skills for children do not list “learning to learn,” this should be the capstone skill upon which all others depend.

Memorized facts, which are the basis for most testing done in schools today, are of little use in the age in which information is doubling every two or three years. We have expert systems in computers and the Internet that can provide the facts we need when we need them. Our workforce needs to utilize facts to assist in developing solutions to problems.”

*Robert Galvin and Edward Bales,
Motorola, 1996*

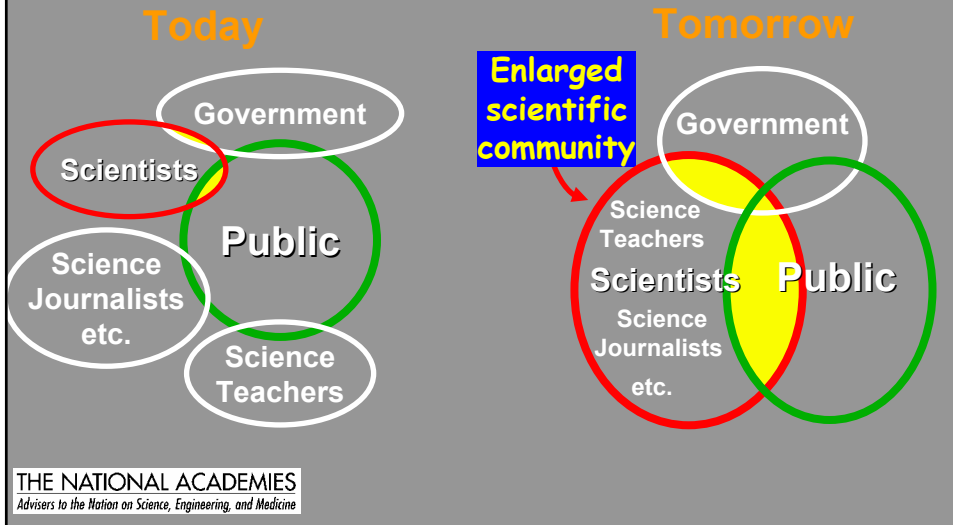


ATTRACTING PhDs TO K-12 EDUCATION

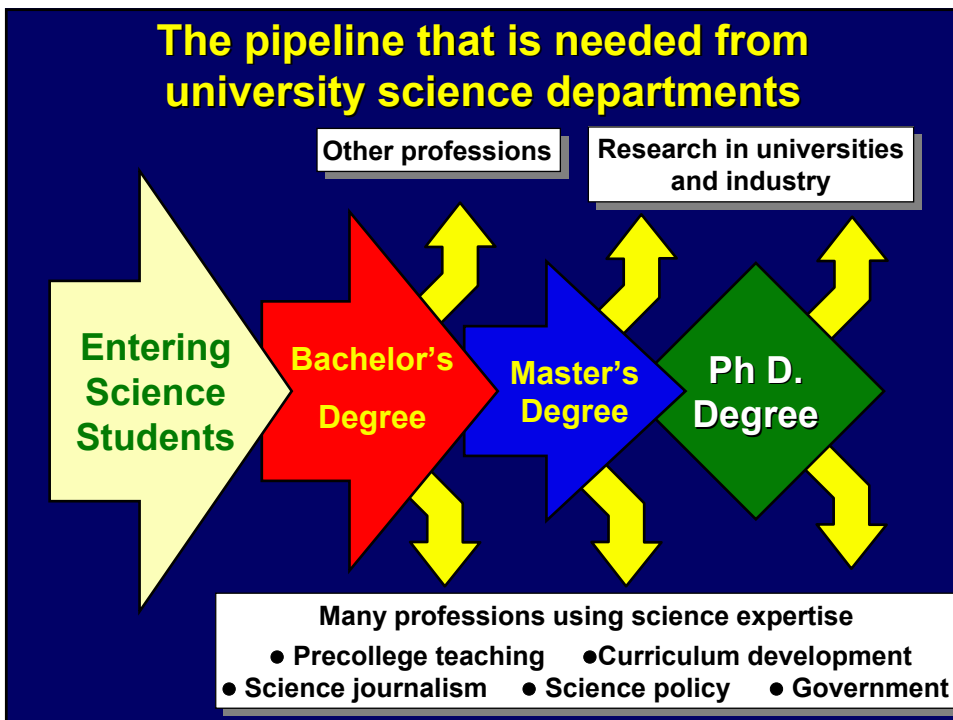
A DEMONSTRATION PROGRAM
FOR SCIENCE, MATHEMATICS,
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ENLARGING THE SCIENTIFIC COMMUNITY AND ITS CONNECTIONS



The pipeline that is needed from university science departments



Scientific Research in Education (2002)

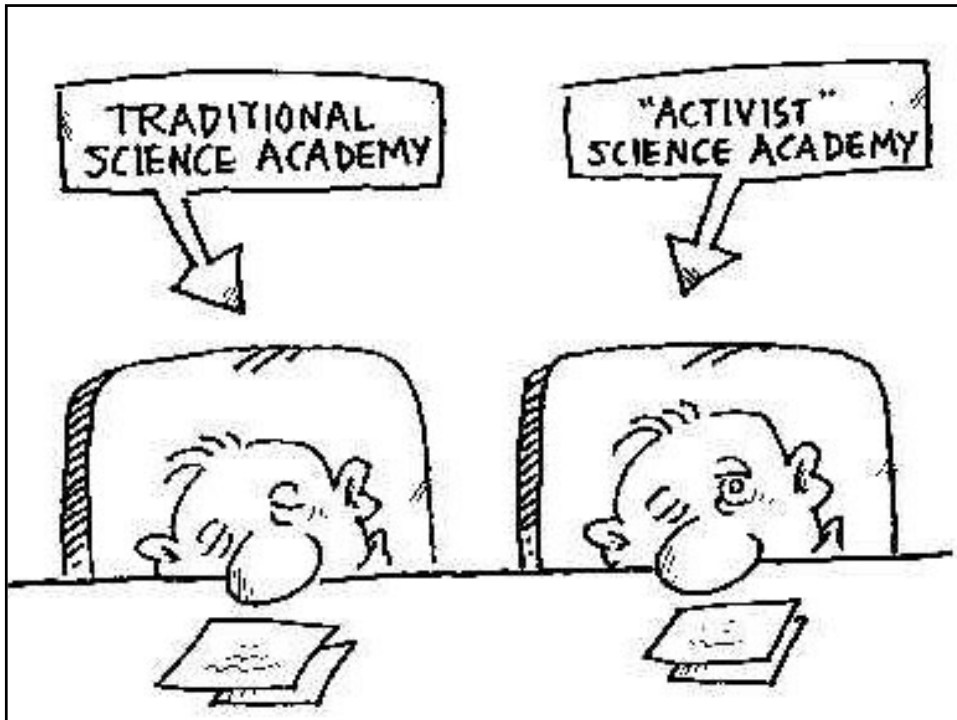
Summary at end of Chapter 5:

“In estimating the effects of programs, we urge the expanded use of random assignment. We also urge that randomized field trials be supplemented with other methods, including in-depth qualitative approaches that can provide additional sources of evidence for supporting causal claims in complex educational settings.”

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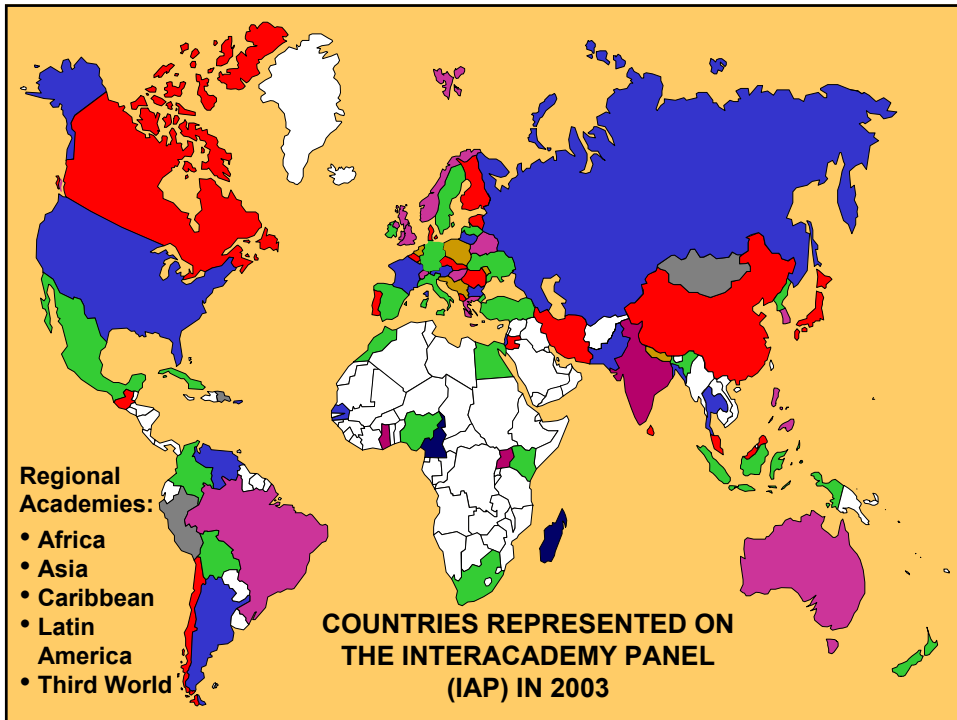
The advantage of “academy-type” organizations

- Permanent organizations governed by members.
- Merit-based selection of all new members based on peer evaluations; therefore represent the best of science and engineering.
- Self-renewing membership, free from political interference.



The formation of a mutual-help organization of the world's science academies

- Began with a 1993 meeting of 70 academies in New Delhi to give a voice for science at the 1994 Cairo UN meeting on population issues.
- Led to the formation of the InterAcademy Panel on International Issues (the IAP), now with its Secretariat in Trieste.

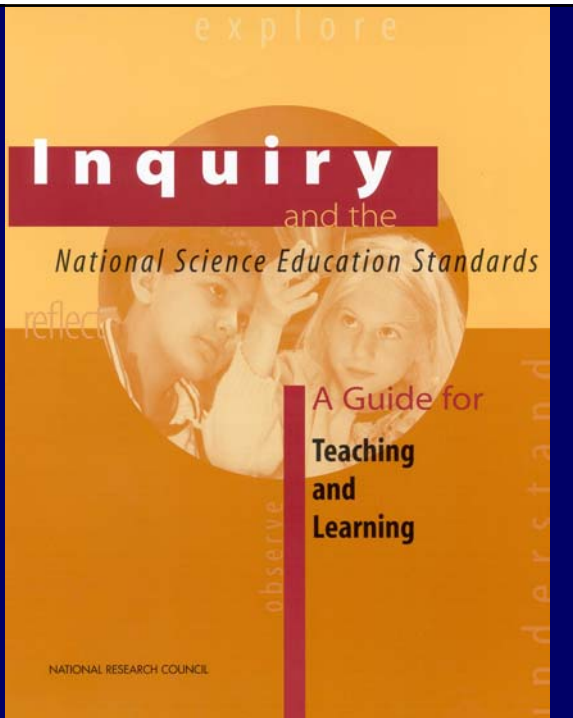


The support of science by the InterAcademy Panel

- Helping the academies in each nation develop a larger role in their own societies, including becoming a respected advisor to their own governments.
- Sharing information and resources to strengthen world science (e.g., electronic journals and other Web publications, programs and resources for science education, ages 5 to 25).

Supplement for teachers

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Inquiry in school science

1. Learners engage in question provided by teacher, materials, or other source.
2. Learners directed to collect certain data.
3. Learners guided in process of formulating evidence.
4. Learners coached in communicating their answers to the question in form of explanations.
5. Teacher guides class toward correct explanations.

One important fact :

For both medicine and education, each randomized field trial must be carefully designed and focused on hypotheses derived from a large amount of prior research.

- The US presently invests only about 0.1 percent of the total K-12 education budget on education research
- This level of investment is vastly inadequate to provide the intellectual basis for a system of randomized field trials that could make a real difference in our education system