Why changing the way we teach introductory science courses is crucial to our nation's future

Rising Above the Gathering Storm: Developing Regional Innovation Environments

Madison, WI
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Bruce Alberts,
University of California, San Francisco (UCSF)
Editor-in-Chief, Science magazine

Full-time job as president of the National Academy of Sciences

THE NATIONAL ACADEMIES

National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council

My education in Washington, DC
1993 to 2005

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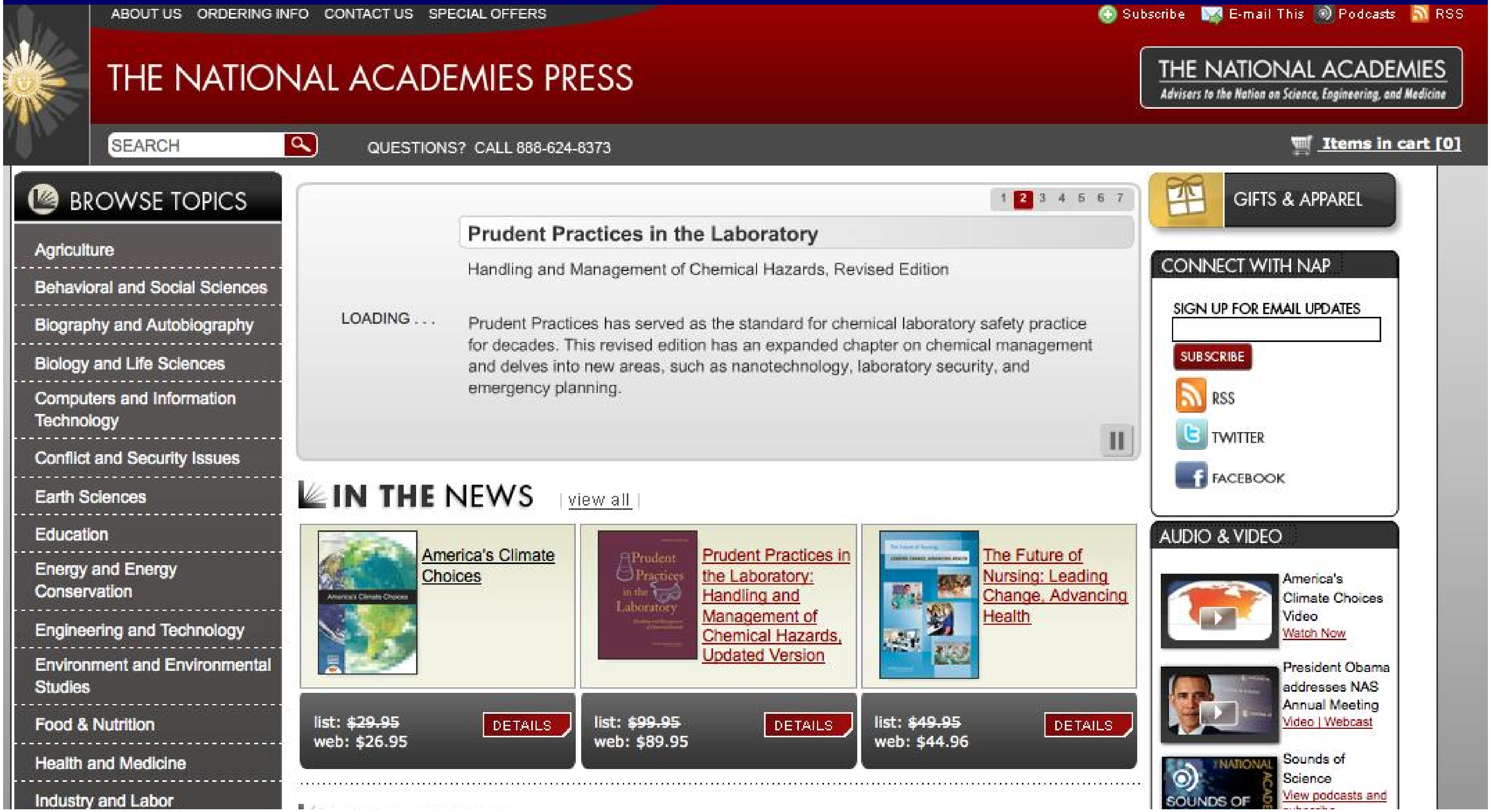


What I learned in 12 years in Washington

It is critically important that science, and scientists, achieve a much higher degree of influence, throughout both their nations and the world.

In particular, we need much more of the creativity, rationality, openness, and tolerance that are inherent to science --- what Indian Prime Minister Nehru called a **"scientific temper"** -- for both the US and all other nations

My favorite quote

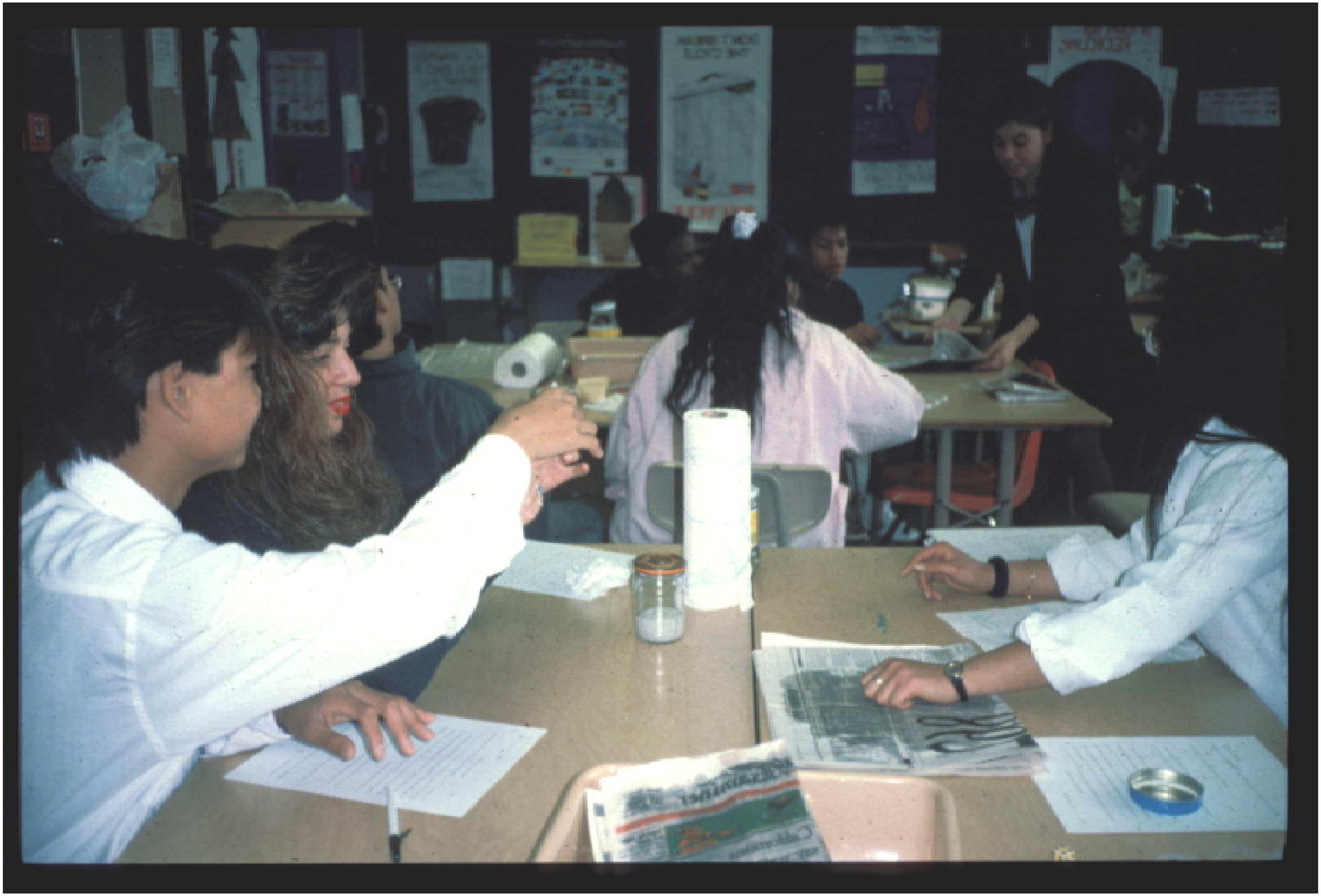
The society of scientists is simple because it has a directing purpose: to explore the truth. Nevertheless, it has to solve the problem of every society, which is to find a compromise between the individual and the group. It must encourage the single scientist to be independent, and the body of scientists 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.

Science has humanized our values. Men have asked for freedom, justice and respect precisely as the scientific spirit has spread among them.

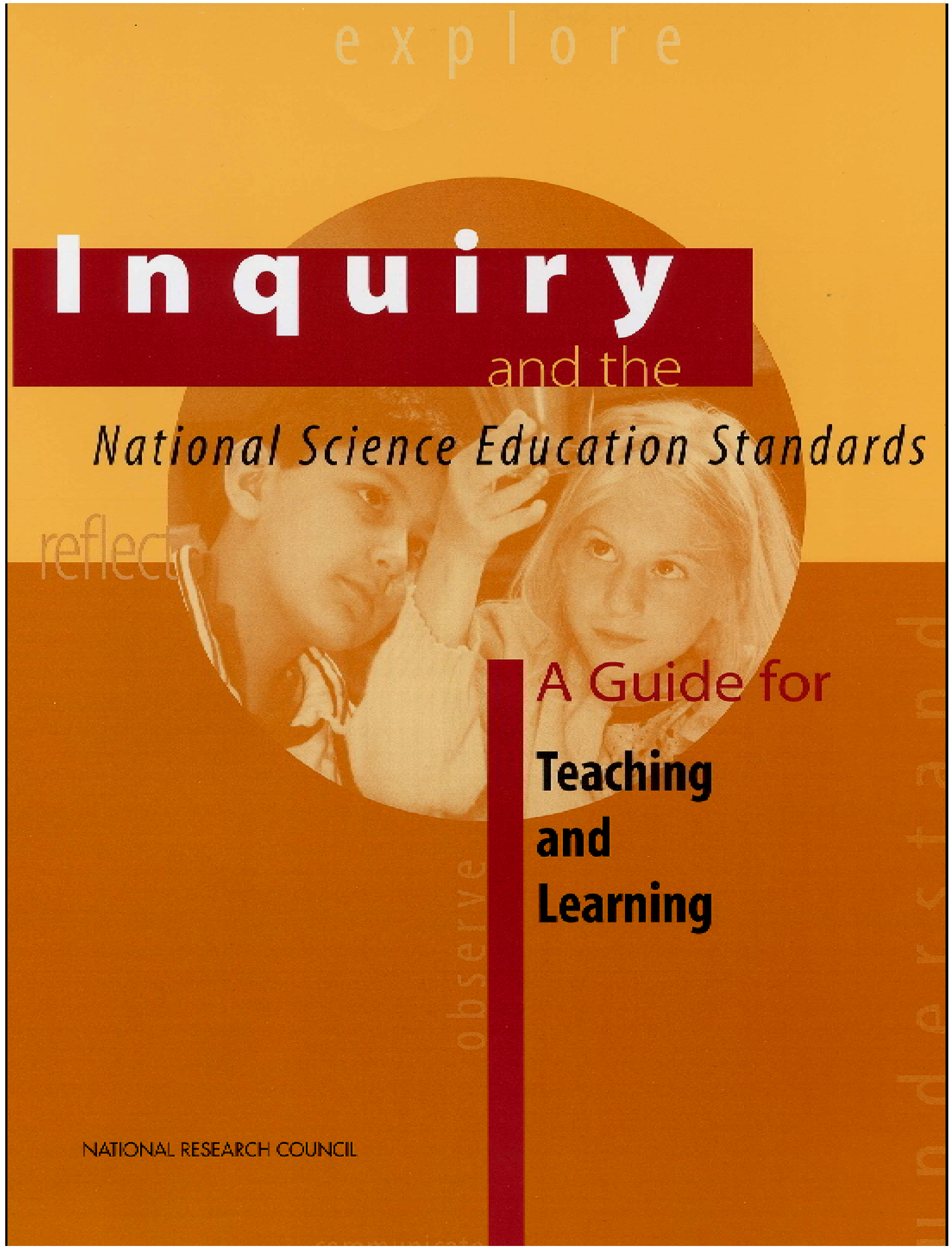
Jacob Bronowski,
Science and Human Values, 1956

To generate a <u>scientific temper</u> for a nation, we need good science education for all

What science should look like in school



An emphasis on active inquiry



What 5 year olds can do

1) Put on clean white socks and walk around school yard.
2) In class, collect all black specks stuck to socks and try to classify them: which are seeds and which are dirt?
3) Start by examining each speck with a 3 dollar, plastic "microscope".
4) End by planting both those specks believed to be dirt and those believed to be seeds, thereby testing their own idea that the regularly shaped ones are seeds

The Vision

Imagine an education that includes solving hundreds of such challenges over the course of the 13 years of schooling that lead to high school graduation – challenges that increase in difficulty as the children age.

I believe that children who are prepared for life in this way would be **great problem solvers** in the workplace, with the abilities and the can-do attitude that are needed to be competitive in the global economy.

Even more important, they will also be **more rational human beings** – people who are able to make wise judgments for their family, their community, and their nation.

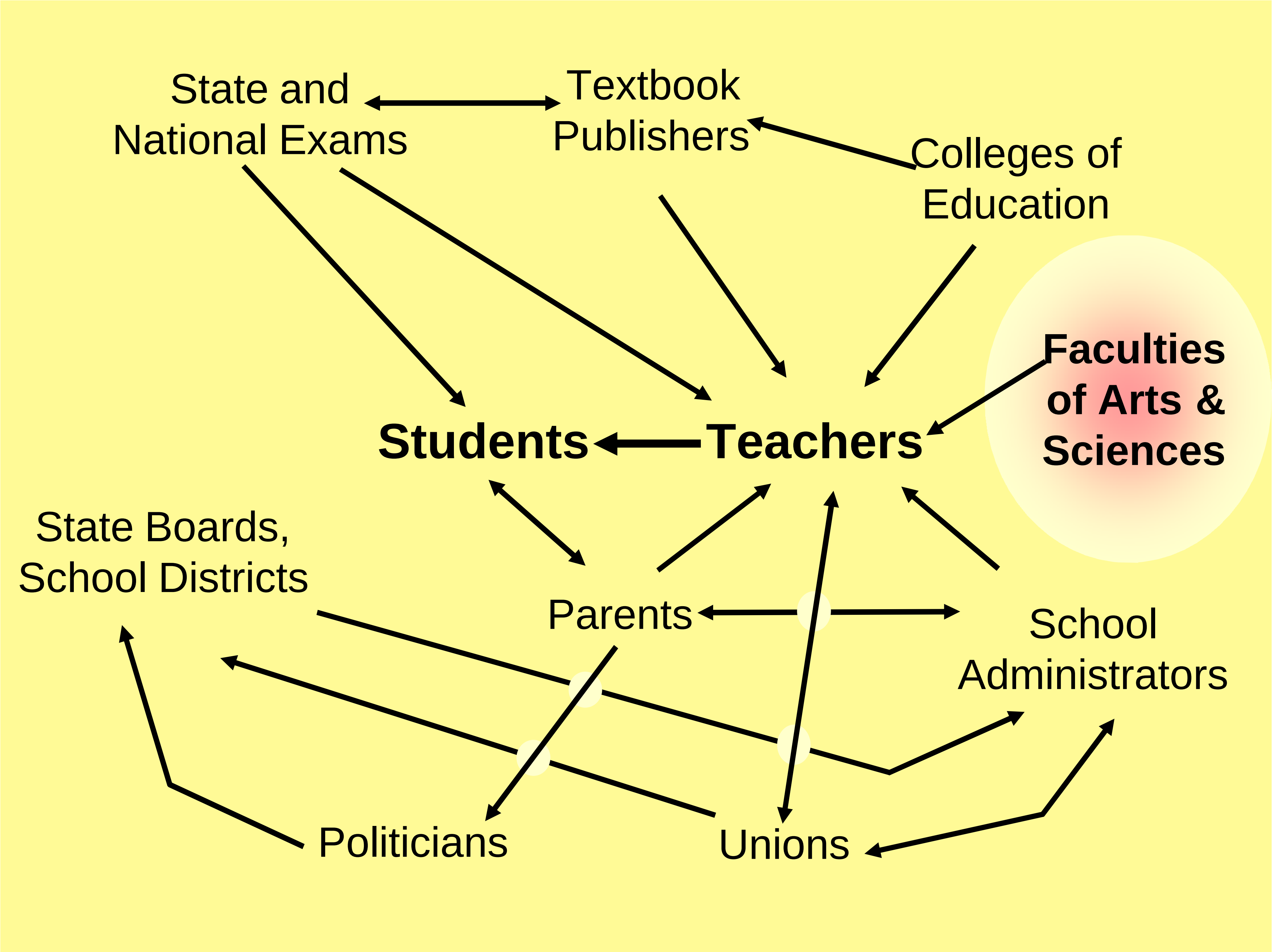
This vision for science education precisely fits the needs for workforce skills that have been widely expressed by US business and industry

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, 2002

To remove a major barrier to progress, science education at the college level must change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It is not enough to acquire knowledge about what scientists have discovered about the world:

Students must also learn to generate and evaluate scientific evidence and explanations,

to understand the nature and development of scientific knowledge,

and to participate productively in scientific practices and discourse.

An important barrier to progress

The traditional lecture format allows a single professor to "batch process" many hundreds of students through an introductory science class.

Can we create much better alternatives without a great increase in cost?

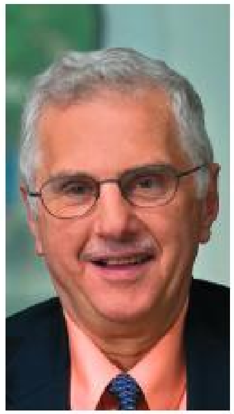
Learning to use "clickers" at a summer workshop for teams of Biology 1 teachers at University of Wisconsin

(Jo Handelsman and Bill Wood, co-organizers)

How can *Science* magazine help to promote the needed revolution in science education?

My current obsession

Using science and *Science* to create more coherence in the field of education



Bruce Alberts is Editor-in-Chief of *Science*.

EDITORIAL

Redefining Science Education

THERE IS A MAJOR MISMATCH BETWEEN OPPORTUNITY AND ACTION IN MOST EDUCATION SYSTEMS today. It revolves around what is meant by "science education," a term that is incorrectly defined in current usage. Rather than learning how to think scientifically, students are generally being told about science and asked to remember facts. This disturbing situation must be corrected if science education is to have any hope of taking its proper place as an essential part of the education of students everywhere.

Scientists may tend to blame others for the problem, but—strange as it may seem—we have done more than anyone else to create it. Any objective analysis of a typical introductory science course taught today in colleges and universities around the world, whether it be biology, chemistry, physics, or earth sciences, would probably conclude that its purpose is to prepare students to "know, use, and interpret scientific explanations of the natural world" (strongly emphasizing the "know"). This is but one of four goals recommended for science education by the distinguished committee of scientists and science education experts convened by the U.S. National Academies that produced *Taking Science to School: Learning and Teaching Science in Grades K-8*. And yet college courses set the model for the teaching of science in earlier years.

The three other goals of equal merit and importance are to prepare students to generate and evaluate scientific evidence and explanations, to understand the nature and development of scientific knowledge, and to participate productively in scientific practices and discourse (summarized in the Academies' *Ready, Set, Science!*). Scientists would generally agree that all four types of science understanding are critical not only to a good science education but also to the basic education of everyone in the modern world. Why then do most science professors teach only the first one?

As the scientist and educator John A. Moore emphasized in his pro-

How Science magazine can help

24 monthly winners of contest for best free science education websites

ESSAY

WINNER OF *SCIENCE* PRIZE FOR ONLINE RESOURCES IN EDUCATION

Making Genetics Easy to Understand

An integrated pair of Web sites for students and teachers supports genetics and genomics education worldwide.

Louisa A. Stark* and Kevin Pompei

The Human Genome Project and the subsequent explosion of genomic information are transforming our knowledge of how organisms function and how genes and the environment interact. These insights have led to advances in personalized medicine, stem cell treatments, and genetic testing. Students, teachers, and the public must be prepared to make informed decisions about participation in genomics research, genome-related health care, use of genetically modified agricultural products, and public funding for stem cell research. Education has been identified as a crosscutting element that is critical to achieving the potential of genomics research (1).

To address this need for genomic literacy, we have developed two related Web sites. Learn.Genetics (see figure, right, from http://learn.genetics.utah.edu/) provides educational materials that currently cover 15 topic areas ranging from DNA to epigenetics. Classroom activities designed to support and extend these materials, as well as other resources for educators, are available on Teach.Genetics (http://teach.genetics.utah.edu/).

graduate school use the site to better understand content their instructors present, to assist in completing assignments, and to explore science independently. Higher-education faculty use the materials for courses ranging from introductory biology to professional preparation in education and nursing.

Animations presenting science concepts in an accessible and engaging way attract members of the general public, which leads to "viral" dissemination through link-sharing Web sites and blogs. Although this type of dissemination is unpredictable, both our "Mouse party" and "Cell size and scale" (see figure below) interactive animations have spread this way, engendering discussions about science in over 30 languages around the world. "The new science of addiction: Genetics and the brain" module has received the most unanticipated use; it has been incorporated into police officer training and addiction treatment in several countries.

We use a participatory design approach to developing our materials, involving teachers and scientists along with the science educators, instructional designers, science writers, teacher professional developers, scientists, multimedia designers, Web developers, and evaluators that comprise our team. Our method emerged from extensive work with teachers in professional development programs and capitalized on teachers' real-world expertise in successful teaching approaches, knowledge of engaging topics and materials, knowledge of the gaps in available online materials, and familiarity with the state science education standards guiding curricula. It also draws on scientists' depth of expertise in their fields. Involving the center's entire team

Learn.Genetics. The site provides educational materials on 15 topic areas, ranging from DNA to epigenetics.

http://www.sciencemag.org/site/special/spore

Learn Genetics / Teach Genetics	http://learn.genetics.utah.edu/ http://teach.genetics.utah.edu/
On the Cutting Edge	http://serc.carleton.edu/NAGTWorkshops/index.html
BioEd Online	http://www.bioedonline.org http://www.k8science.org
The Chem Collective	http://www.chemcollective.org/find.php
The Habitable Planet	www.learner.org/courses/envsci
Neuroscience for Kids!	http://faculty.washington.edu/chudler/neurok.html
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The Sloan Digital Sky Survey	http://cas.sdss.org/dr7/en/
Immunopaedia	www.immunopaedia.org
Physics Teaching Technology Resource	http://paer.rutgers.edu/pt3
Ask A Biologist	http://askabiologist.asu.edu/
Understanding Science / Understanding Evolution	http://undsci.berkeley.edu http://evolution.berkeley.edu/
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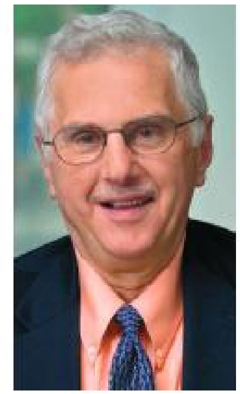
2011 contest for best **inquiry lab modules** for introductory college science

EDITORIAL



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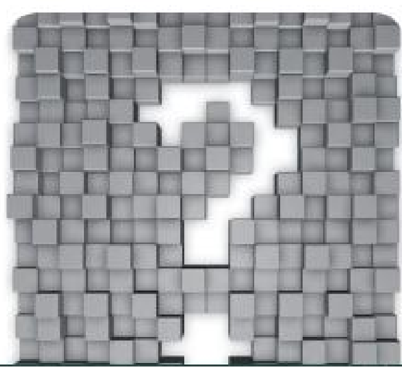
A New College *Science* Prize

TO START THE NEW YEAR, *SCIENCE* IS PLEASED TO ANNOUNCE THE "*SCIENCE* PRIZE FOR Inquiry-Based Instruction" to highlight outstanding "modules" for teaching introductory college science courses that can readily spread to other settings and schools. Therefore, a unit can neither be unusually expensive nor require highly specialized expertise. To be eligible, a module must provide a coherent piece of coursework in a field such as biology, chemistry, physics, or earth sciences and require 8 to 50 hours of student effort. It should also be free-standing: that is, suitable for teaching as a discrete unit, independent of other modules in the course. How do inquiry-based science modules differ from other science lessons, and why does *Science* care enough about them to create a special prize?

Inquiry-based classes focus on activating students' natural curiosity in exploring how the world works, differing from traditional lectures that focus on transmitting facts and principles derived from what scientists have discovered. Inquiry-based teaching is often associated with hands-on activities. But not all hands-on activities involve inquiry. Consider the laboratory work that traditionally accompanies an introductory college science course. As a science major, I spent three afternoons a week in such laboratories throughout my first 2 college years. Most of us who later became scientists recall these laboratories as tedious "cooking classes," where we learned to follow directions. True, we encountered various pieces of scientific apparatus, such as measuring devices for weights and liquids, and we learned how to keep a laboratory notebook. But we gained neither any real understanding of the nature of science nor experience in generating and evaluating scientific evidence



My next education editorial:

- To remove a major barrier to progress at the precollege level, we need a **specially trained scientist** in each major school district to connect that district's schools to the wealth of available resources.

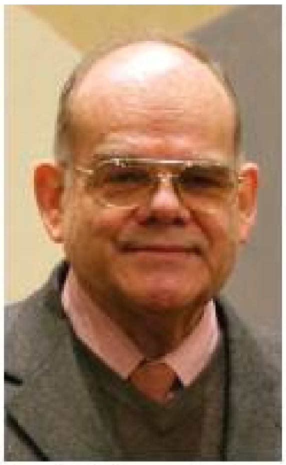
Specific challenge: can we create a training / certification process to convert PhD scientists into science curriculum specialists that school districts would want to hire?

1) School districts need such an inside person with “science in his/her soul” to connect them to the enormous outside resources that exist to aid school science, including **coordinating** the inputs from the local scientific and engineering community.

2) Many talented science graduate students and postdocs would be interested in such a career, if **a productive new pathway** for entry could be developed and promoted.

A final note: Scientists are cooperating to catalyze a worldwide effort

EDITORIAL



Jorge E. Allende is vice president for research at the University of Chile, coordinator of the IAP Science Education Program, and a former president of the Chilean Academy of Sciences.

Academies Active in Education

SUSTAINABLE SOCIOECONOMIC AND CULTURAL DEVELOPMENT REQUIRES NATIONS WITH A citizenry that understands science, shares its values, and uses scientific critical thinking. This can best be attained through science education that is based on inquiry, an approach that reproduces in the classroom the learning process of scientists: formulating questions, doing experiments, collecting and comparing data, reaching conclusions, and extrapolating these findings to more general situations. The Program for International Student Assessment, an international organization of industrialized nations, measures the extent to which 15-year-olds can identify scientific issues, explain phenomena scientifically, and use scientific evidence to draw conclusions. The results, made public earlier this year (http://nces.ed.gov/surveys/pisa), reveal that all developing countries and many industrial ones, including the United States, are failing to prepare their children adequately for life in the modern world. Leading scientists of each nation, acting through their national science academies, are working together to change this state of affairs.

In 1985, the U.S. National Academy of Sciences and the Smithsonian Institution established the National Science Resources Center, an organization that has helped to spread inquiry-based science education to nearly 20% of U.S. school districts. About 10 years later, across the Atlantic, the French Academy of Sciences engaged France's Ministry of Education with its "La