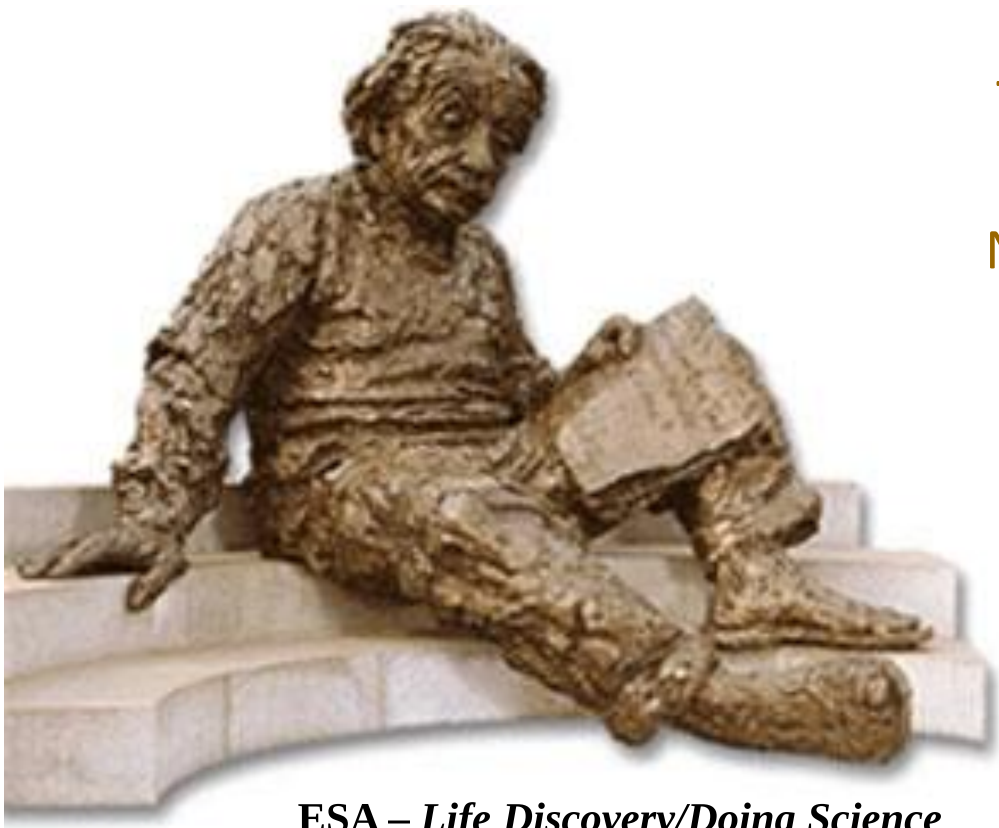
# The Changing National Landscape of STEM Education:

## Building Partnerships with Scientists & Educators



ESA – *Life Discovery/Doing Science*
*March 15, 2013*

THE NATIONAL ACADEMIES
National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council

**Jay Labov**

**National Academy of Sciences**
**National Research Council**
**Washington, DC**

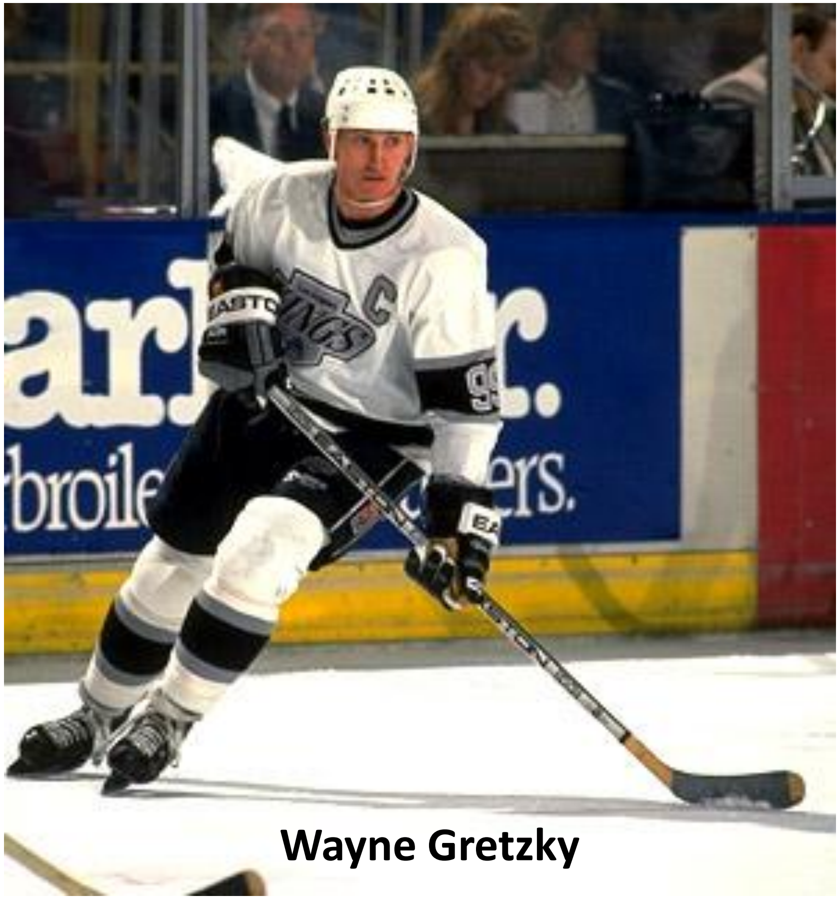
**jlabov@nas.edu**
**http://nas.edu**

# Premise 1:

Improving STEM Education is *Not* Rocket Science

It's a LOT harder!

# Premise 2:



Wayne Gretzky

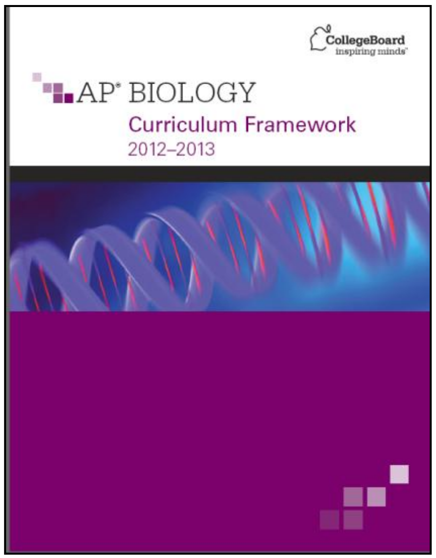
"A good hockey player plays where the puck is.

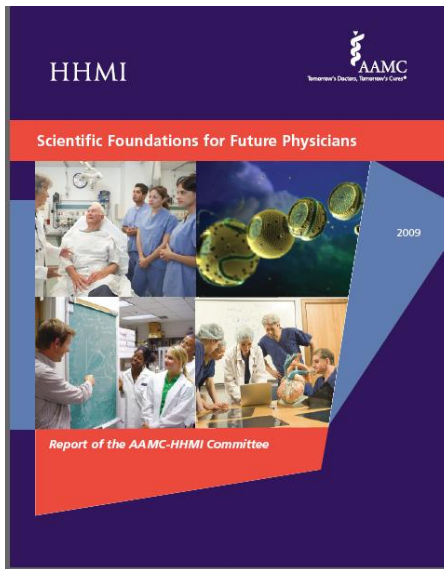
A great hockey player plays where the puck is going to be."

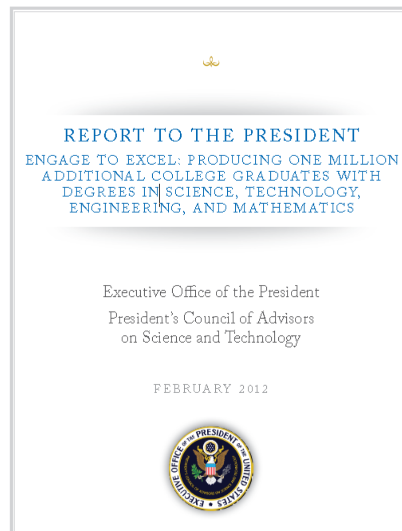
# Learning Goals for This Session:

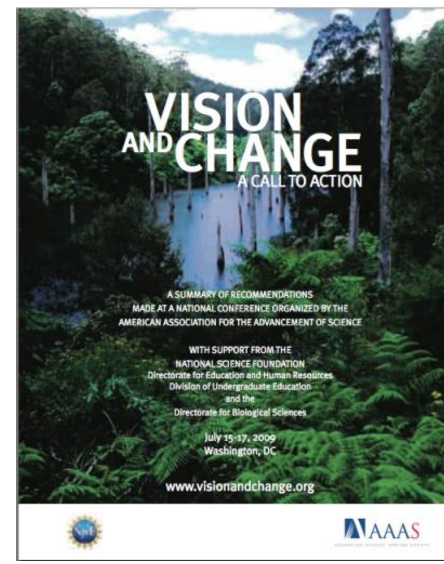
- Briefly review several recent national reports on the improvement of undergraduate education in STEM and how they might inform your discussions.
- Appreciate the growing influence of K-12 education on what you do and your role in influencing K-12 education to increase the number of college-educated STEM graduates.
- Explore opportunities for professional societies to engage with the improvement of STEM education at the K-12 and postsecondary levels.

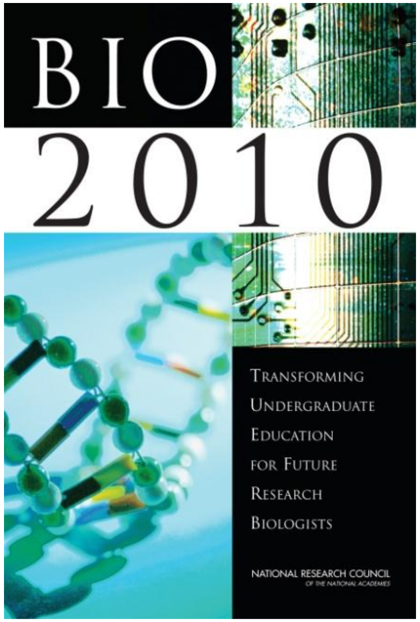
# Briefly review several recent national reports on the improvement of education in STEM and how they might inform your discussions.

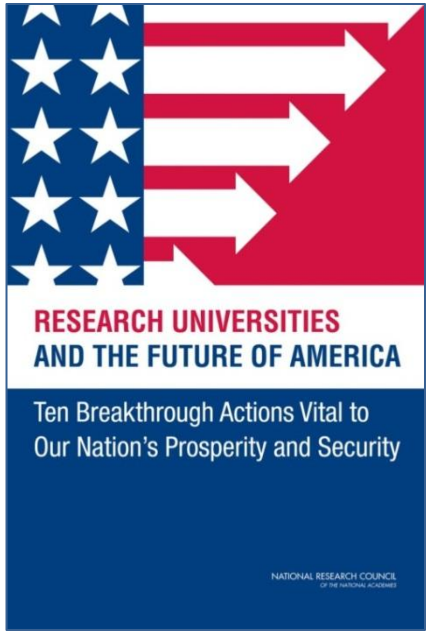


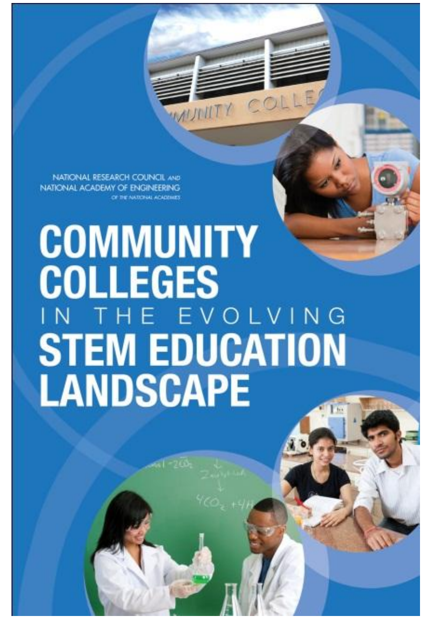



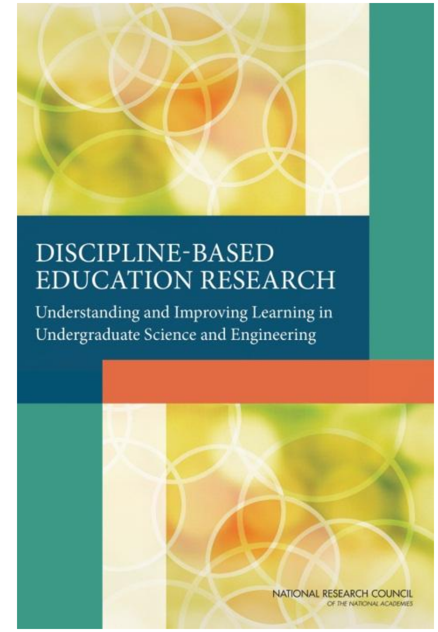



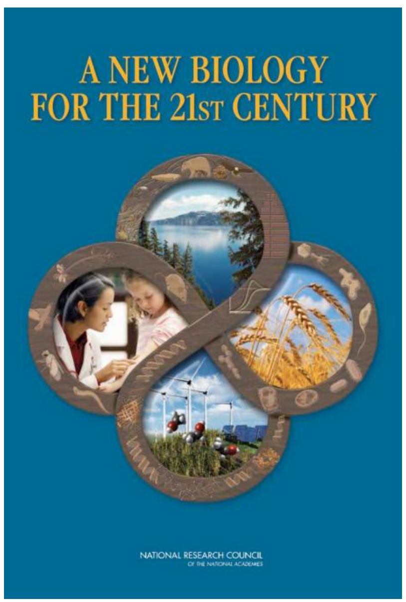



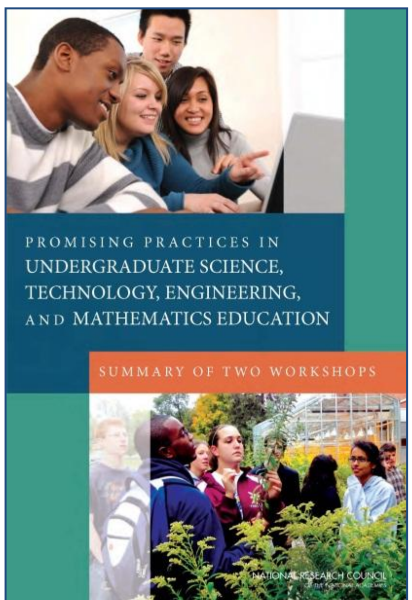


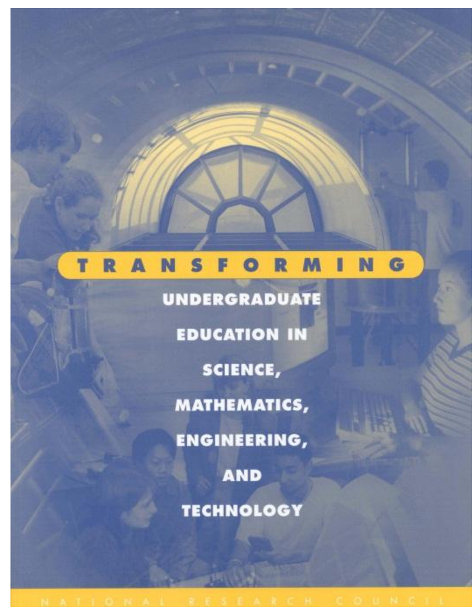



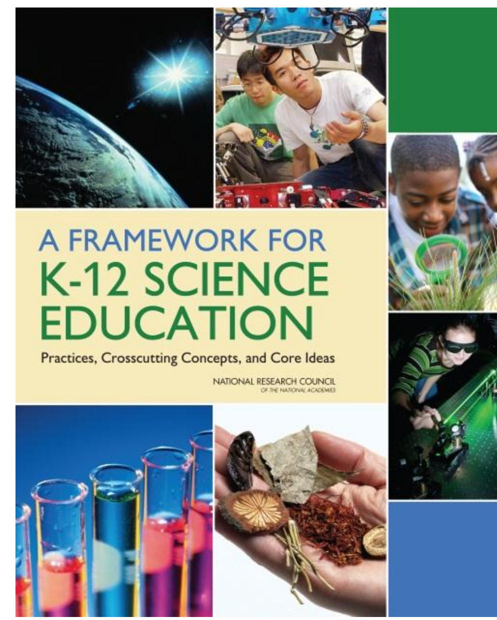



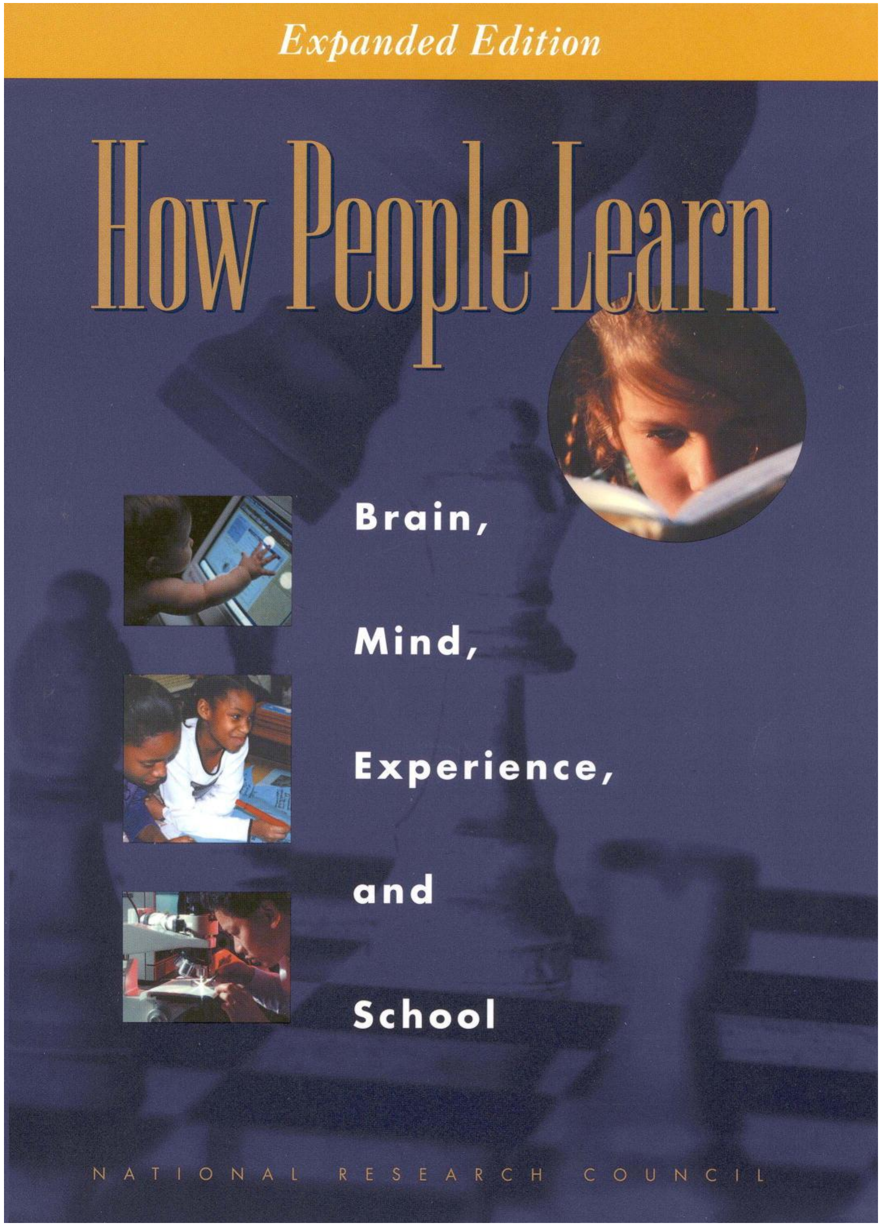



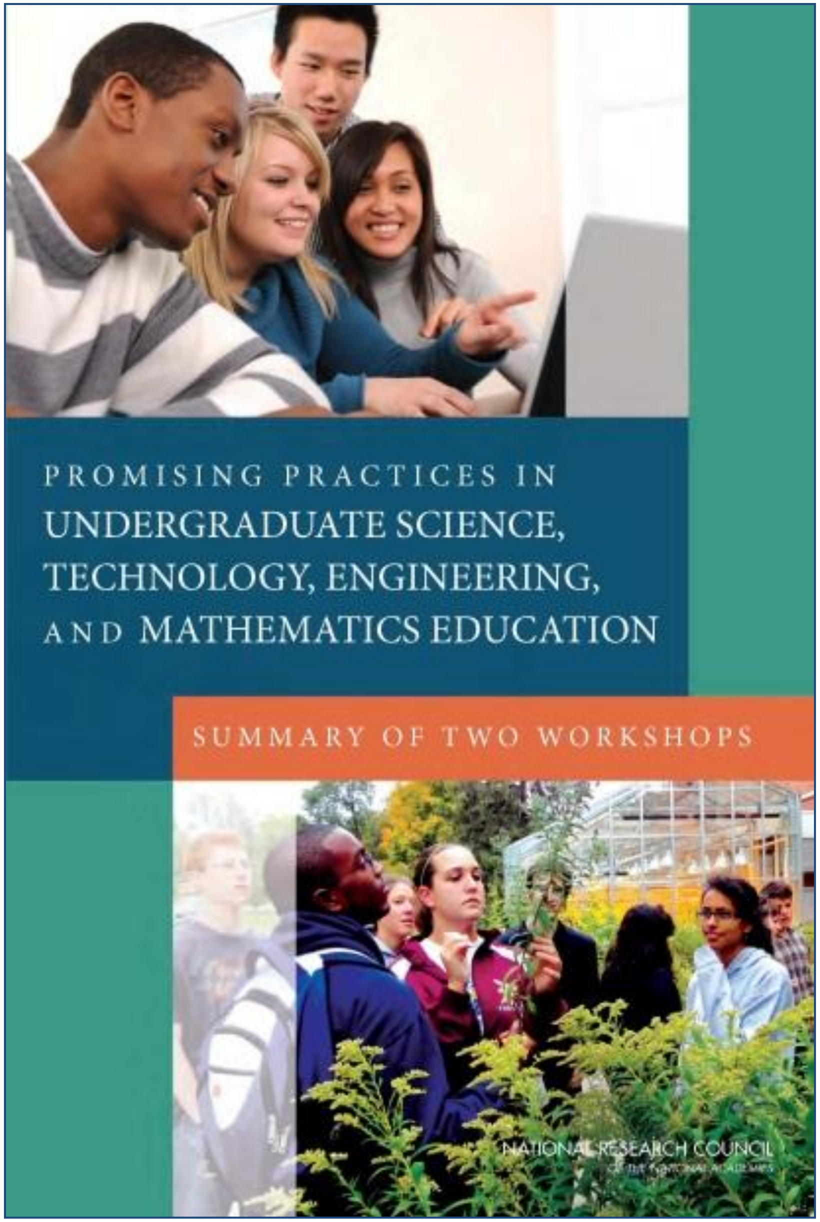



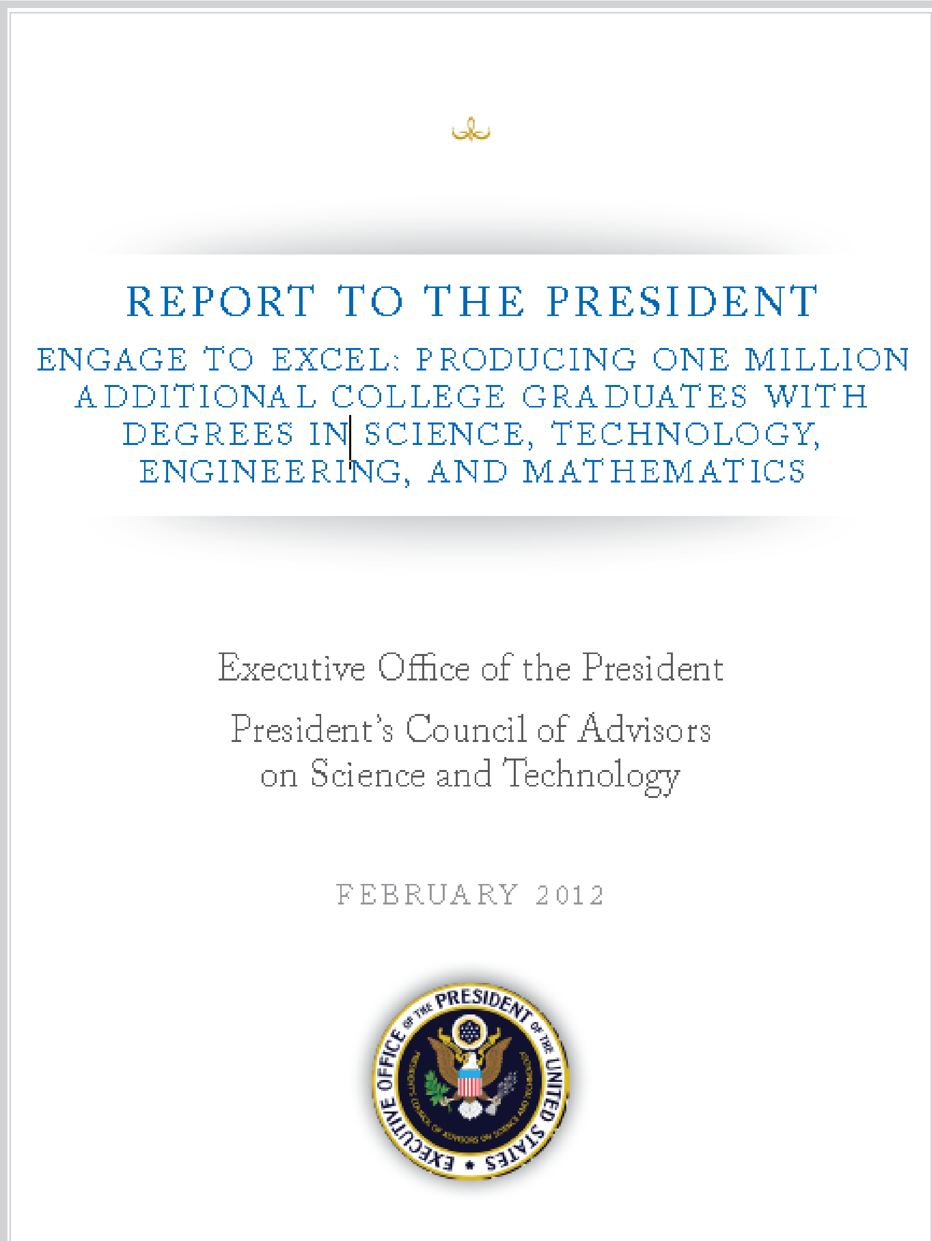

All freely downloadable at http://nap.edu




National Research Council 2000

National Research Council 2011



REPORT TO THE PRESIDENT

ENGAGE TO EXCEL: PRODUCING ONE MILLION ADDITIONAL COLLEGE GRADUATES WITH DEGREES IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

Executive Office of the President

President's Council of Advisors on Science and Technology

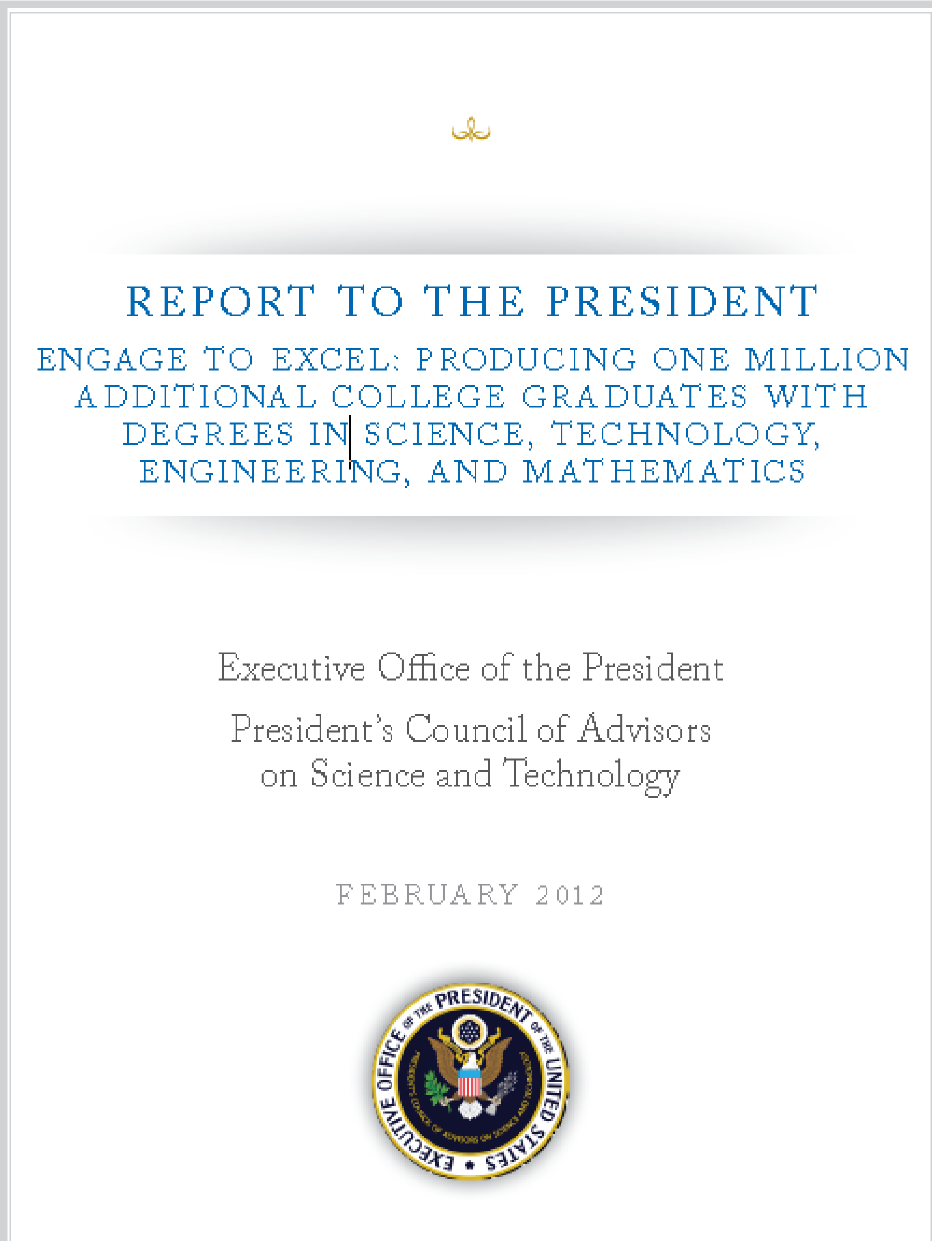
FEBRUARY 2012

**2012**

**CURRENTLY: ~ 300,000 bachelor and associate degrees in STEM fields annually in the U.S.**

**FUTURE NEEDS: 1 million more STEM professionals in the next decade than the U.S. will produce at the current rate if the country is to retain its historical preeminence in science and technology.**

**"To meet this goal, the United States will need to increase the number of students who receive undergraduate STEM degrees by about 34% annually over current rates."**



REPORT TO THE PRESIDENT

ENGAGE TO EXCEL: PRODUCING ONE MILLION ADDITIONAL COLLEGE GRADUATES WITH DEGREES IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

Executive Office of the President

President's Council of Advisors on Science and Technology

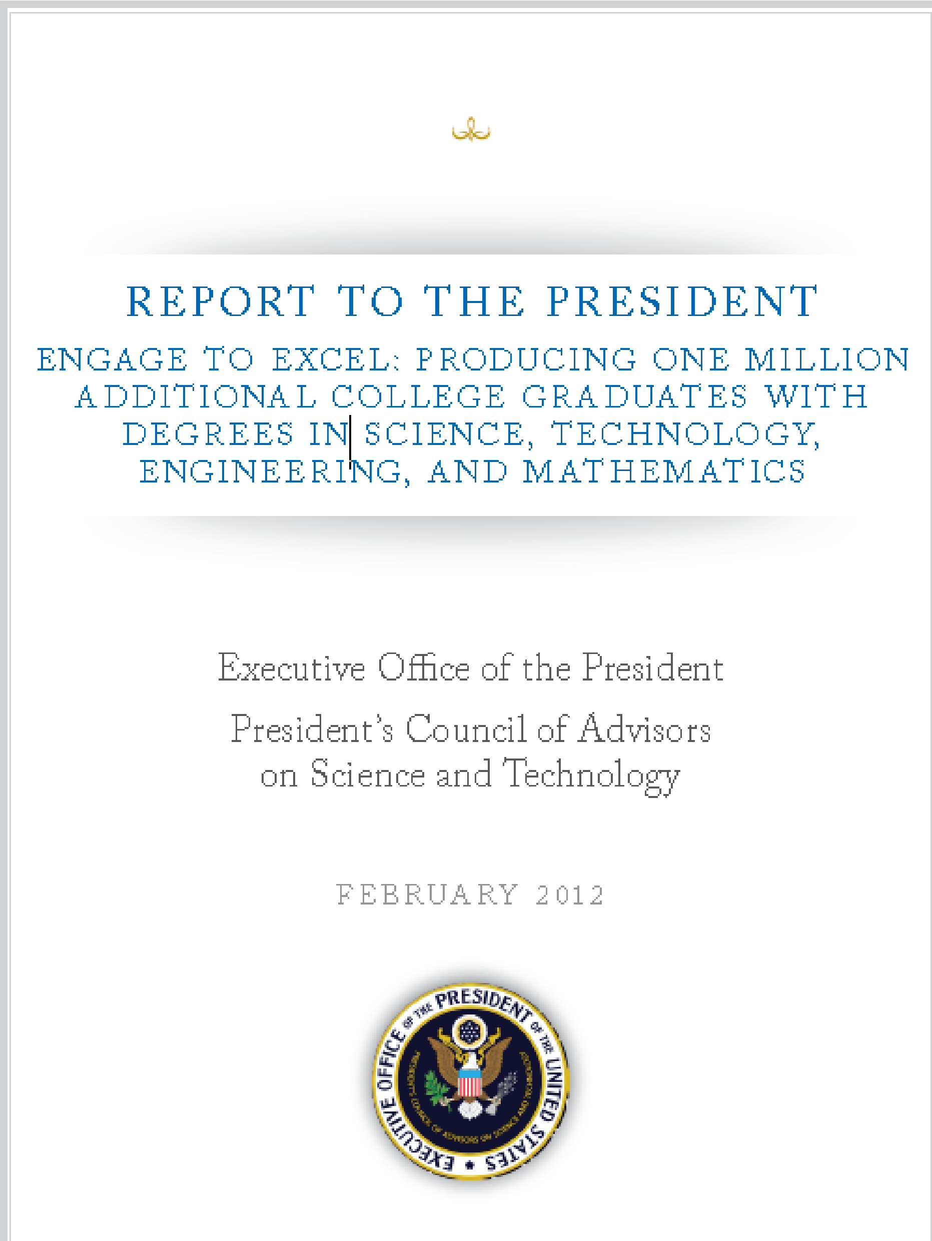
FEBRUARY 2012

**2012**

**Fewer than 40% of students who enter college intending to major in a STEM field complete a STEM degree.**

**Increasing retention of STEM majors from 40% to 50% would generate three-quarters of the 1 million additional STEM degrees over the next decade.**

**Many student who abandon STEM majors perform well in their introductory courses and would make valuable additions to the STEM workforce.**



REPORT TO THE PRESIDENT

ENGAGE TO EXCEL: PRODUCING ONE MILLION ADDITIONAL COLLEGE GRADUATES WITH DEGREES IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

Executive Office of the President

President's Council of Advisors on Science and Technology

FEBRUARY 2012

**2012**

**Retaining more students in STEM majors is the lowest-cost, fastest policy option to providing the STEM professionals … and will not require expanding the number or size of introductory courses, which are constrained by space and resources at many colleges and universities.**

# But retention for WHAT?

**What undergraduates will be experiencing during THEIR lifetimes…**

# STEM Education and Our Economic Future

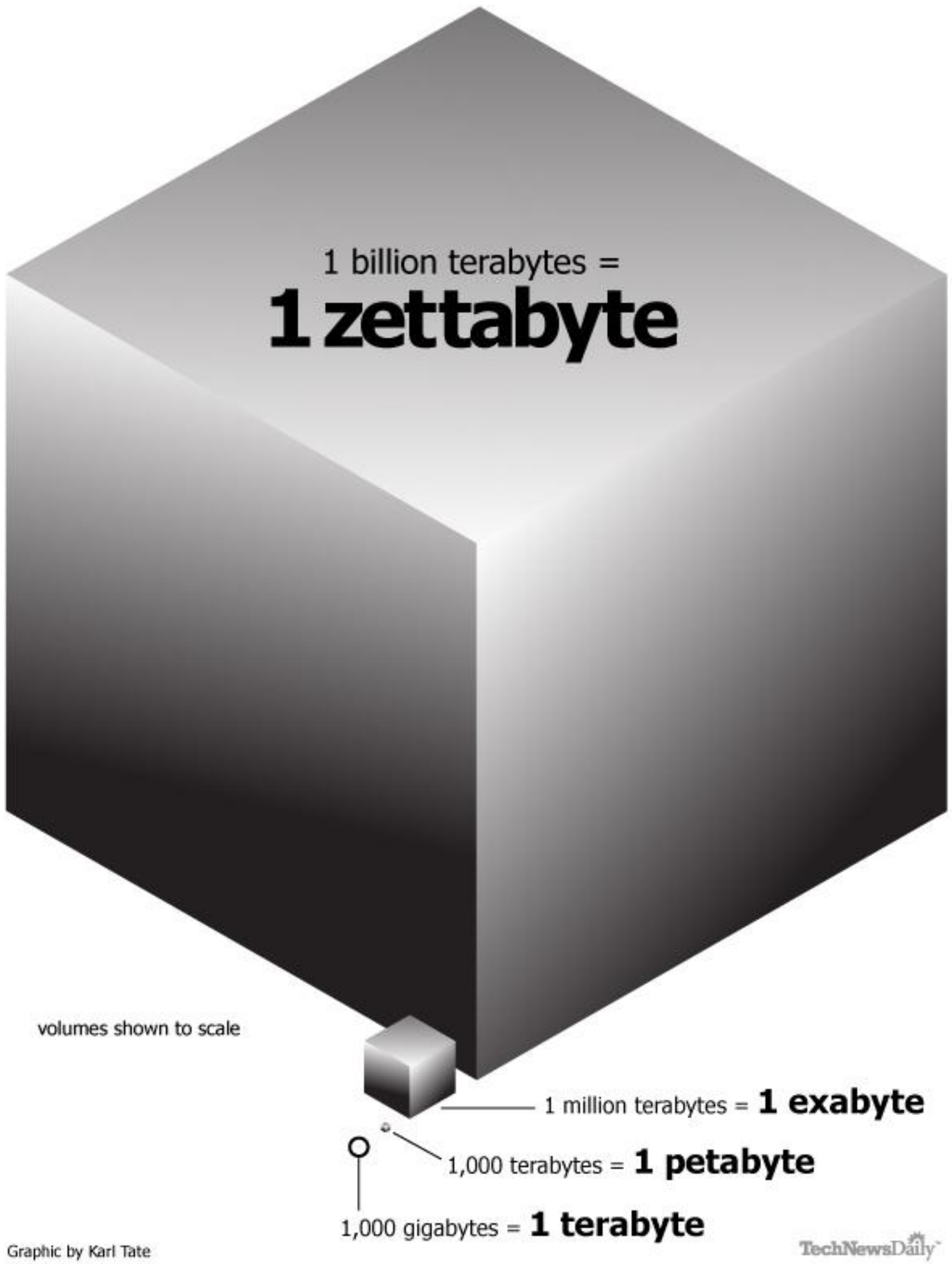
**"If I take the revenue in January and look again in December of that year, 90% of my December revenue comes from products which were not there in January."**

Craig Barrett, Chairman of Intel

"Rising Above the Gathering Storm" (NAS, NAE, and IOM, 2007)

**"The illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn."**

Alvin Toffler, American Writer and Futurist




# Humanity Passed the 1 Zettabye Mark in 2010 (1.8Zb in 2011).

1 Zb = $10^{21}$ bytes. That's enough data to fill 75 billion 16-gigabyte-sized iPads.

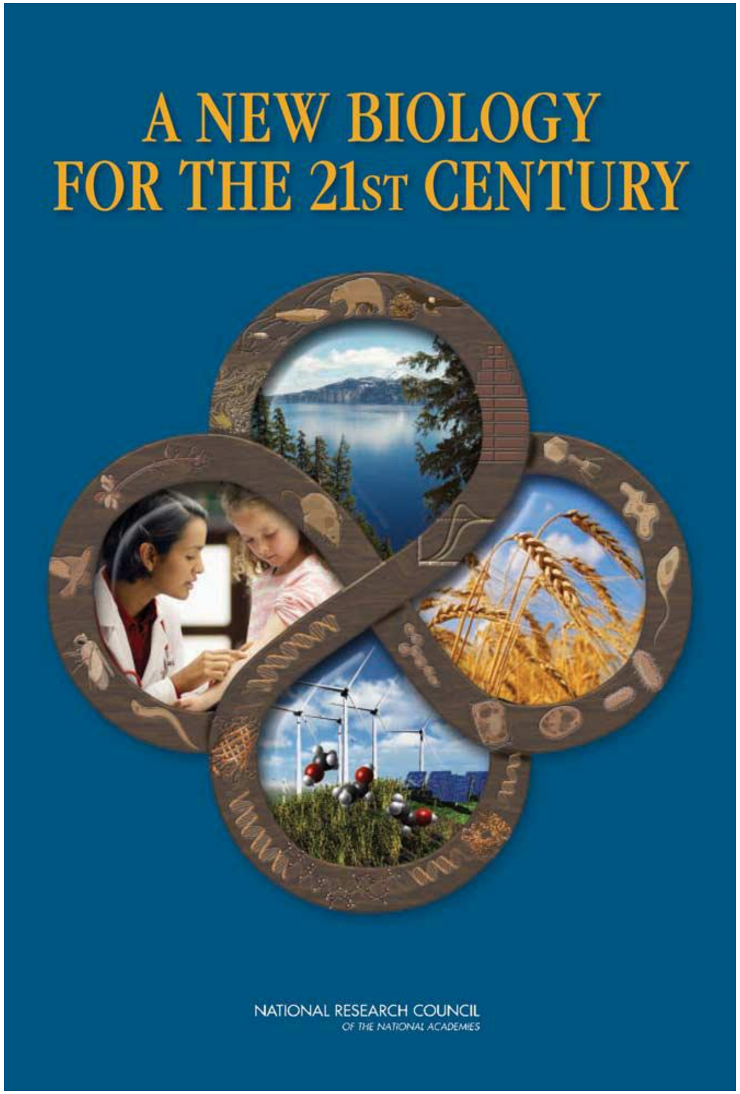

Source: http://www.marfdrat.net/wp-content/uploads/2011/02/zettabyte-100504-02.jpg

# A Shifting Job Market

| | 20th Century | 21st Century |
| --- | --- | --- |
| **Number of Jobs:** | 1 – 2 Jobs | 10 – 15 Jobs |
| **Job Requirement:** | Mastery of One Field | Critical Thinking Across Disciplines |
| **Teaching Model:** | Subject Matter Mastery | Integration of 21st Century Skills into Subject Matter Mastery |
| **Assessment Model:** | Subject Matter Mastery | Integration of 21st Century Skills into Subject Matter Mastery |

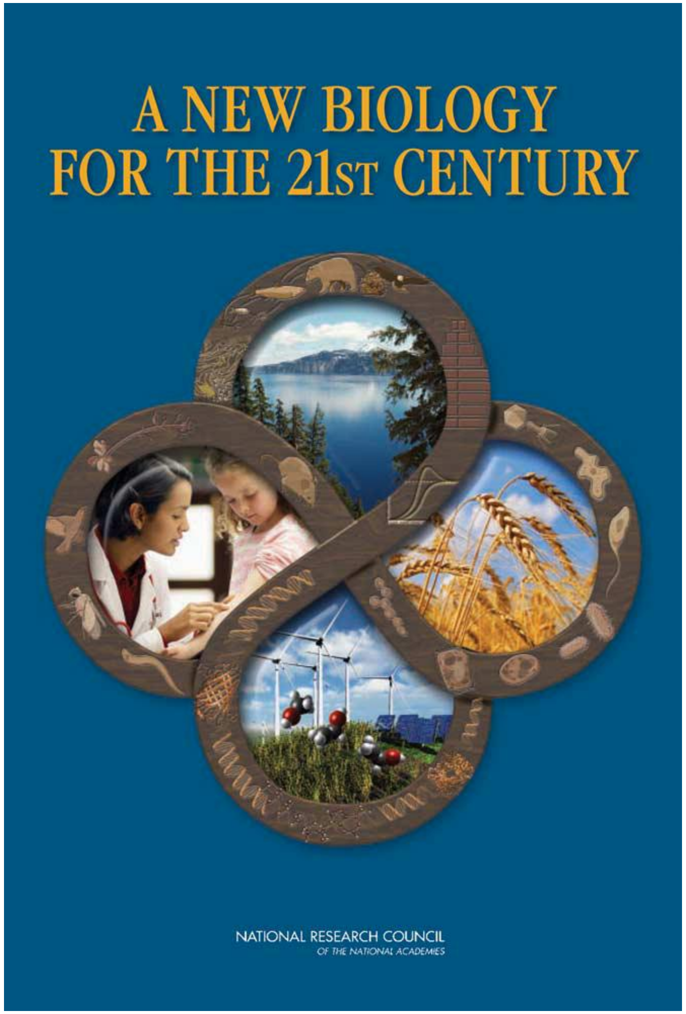
**Courtesy of Linda Froschauer**

# A New Biology for the 21st Century: Addressing & Affecting Urgent Problems



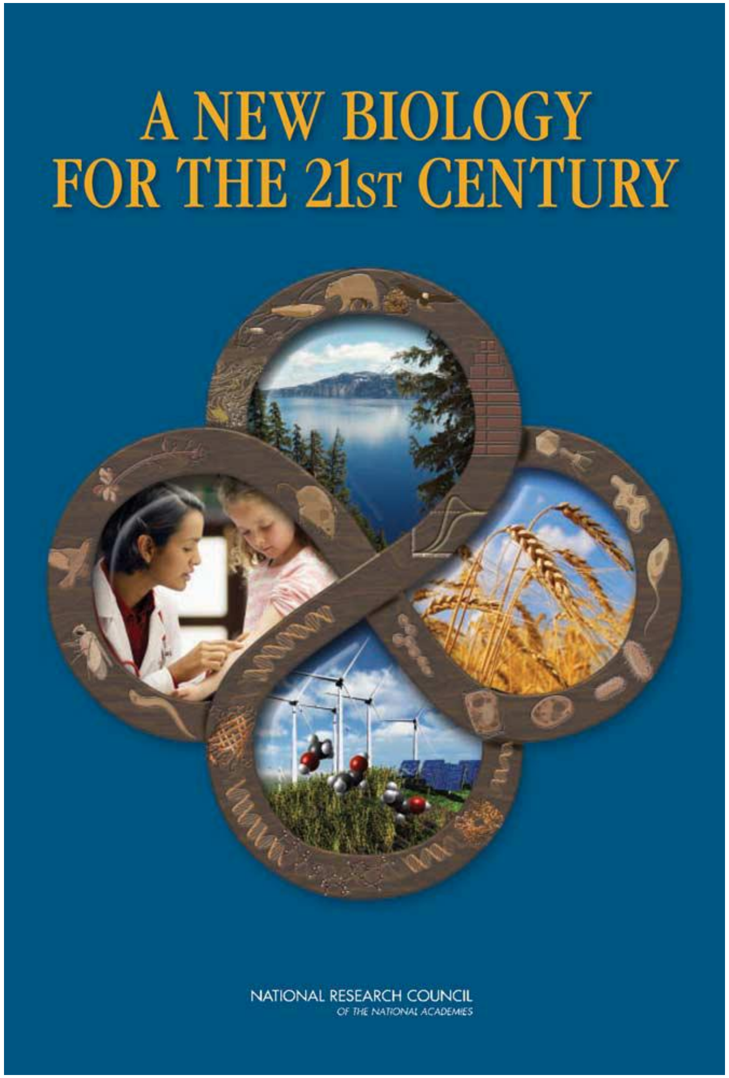

- FOOD: Nearly a billion undernourished in ’07; still increasing, especially where the food supply is already inadequate
- ENVIRONMENT: Human activities are stressing, altering and destroying ecosystems on which we rely
- ENERGY: Transportation fuels depend almost fully on limited non-renewable resources
- HEALTH: Healthcare decisions based on statistics; rely on costly technologies that may not benefit a given individual

# A New Biology for the 21$^{st}$ Century: 4 areas of interdisciplinary focus




- Food
  - Generate food plants to adapt and grow sustainably in changing environments
- Environment
  - Understand and sustain ecosystem function and biodiversity in the face of rapid change
- Energy
  - Expand sustainable alternatives to fossil fuels
- Health
  - Understand individual health

# A New Biology for the 21st Century: Why Now?




**A moment of unique opportunity –**

- **Integration of subdisciplines within biology**
- **Cross-discipline integration: life science research by physical, computational, earth scientists, engineers**
- **Technological advances enable biologists to collect data unprecedented in quantity and quality**
- **Past investments providing value beyond what was expected**

# A New Biology for the 21st Century: Implications for Education

- The New Biology Initiative provides an opportunity to attract students to science who want to solve real-world problems.
- The New Biologist is not a scientist who knows a little bit about all disciplines, but a scientist with deep knowledge in one discipline and a “working fluency” in several.
- Highly developed quantitative skills will be increasingly important.
- Development and implementation of genuinely interdisciplinary undergraduate courses and curricula will both prepare students for careers as New Biology researchers and educate a new generation of science teachers well-versed in New Biology approaches.
- Graduate training programs that include opportunities for interdisciplinary work are essential.
- Programs to support faculty in developing new curricula will have a multiplying effect.

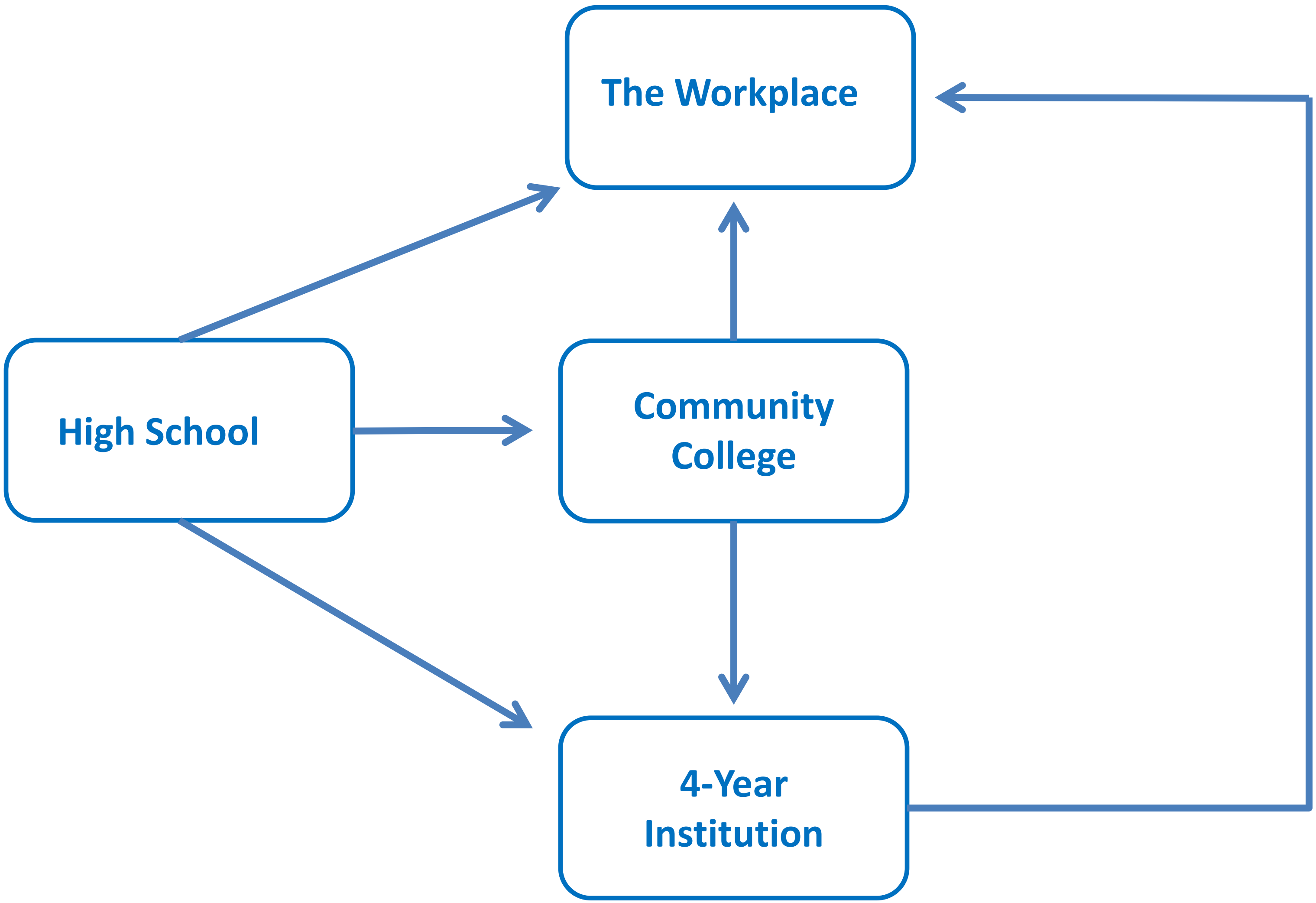
# AAMC/HHMI Committee Defines Scientific Competencies for Future Physicians


*Scientific Foundations for Future Physicians* recommends that medical and premedical education evolve from a static listing of courses to a dynamic set of competencies…This … will encourage the development of innovative and interdisciplinary science curricula, maintain scientific rigor, and allow premed students at the undergraduate level the flexibility to pursue a strong liberal arts education.

Association of American Medial Colleges & Howard Hughes Medical Institute

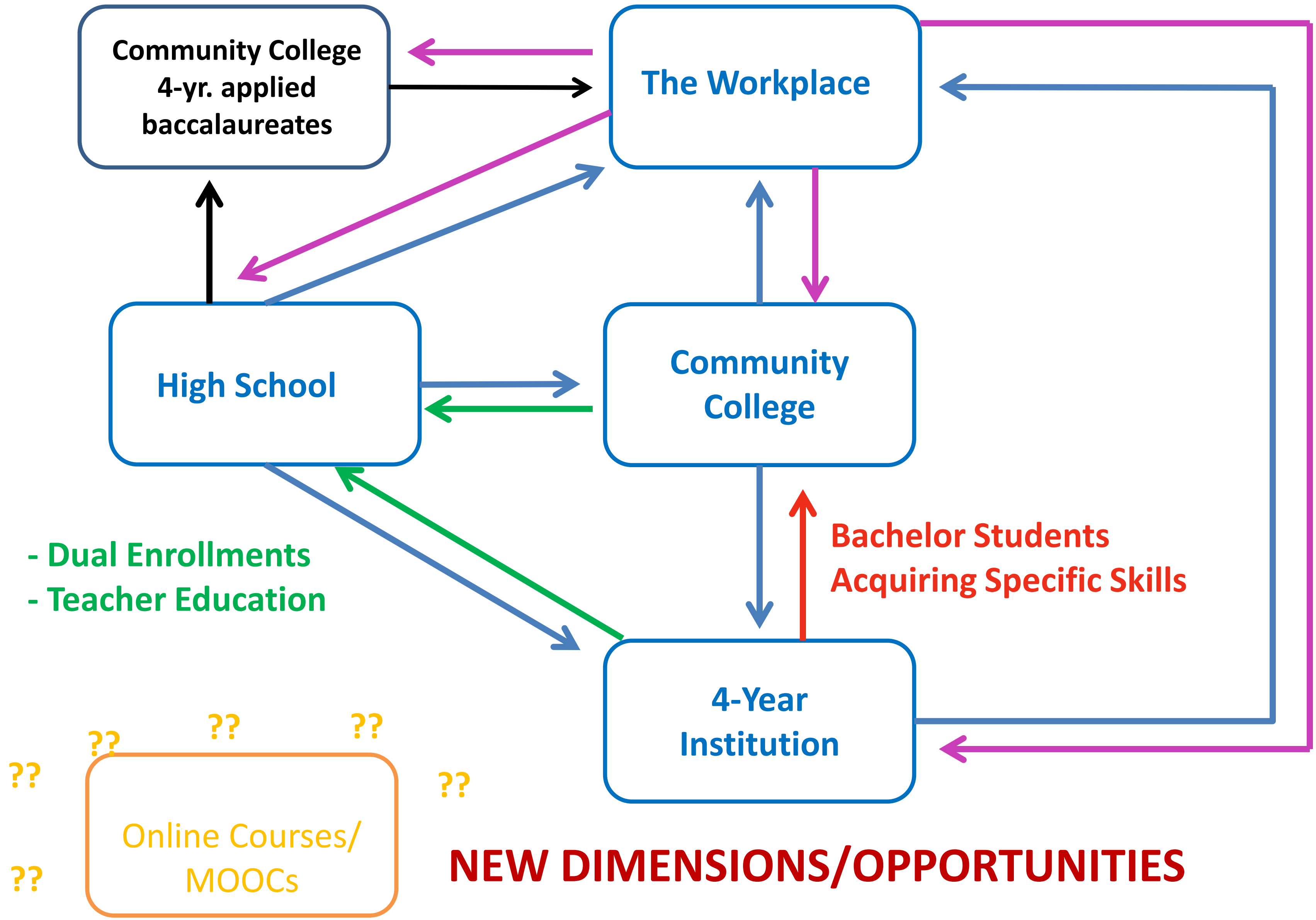
# The Evolving Dynamics Between Two- and Four-Year Colleges and Universities

# THE EMERGING HIGHER EDUCATION ECOSYSTEM




THE TRADITIONAL PIPELINE

# THE EMERGING HIGHER EDUCATION ECOSYSTEM

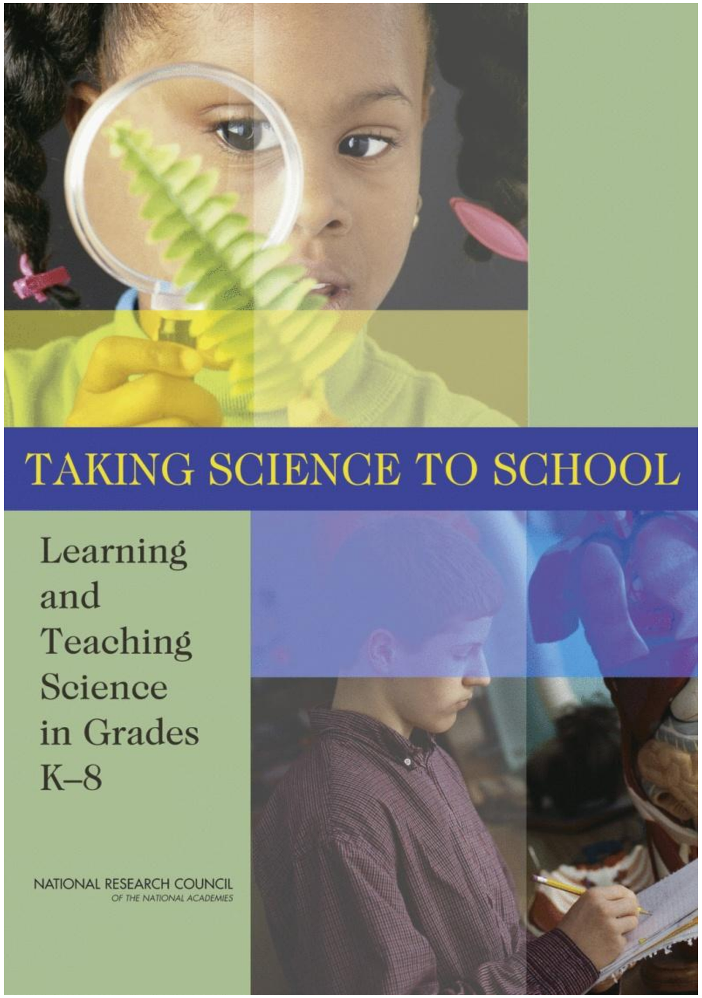



NEW DIMENSIONS/OPPORTUNITIES

# New Opportunities in College and K-12 to Improve STEM Teaching and Learning

# 4 Strands of Scientific Proficiency

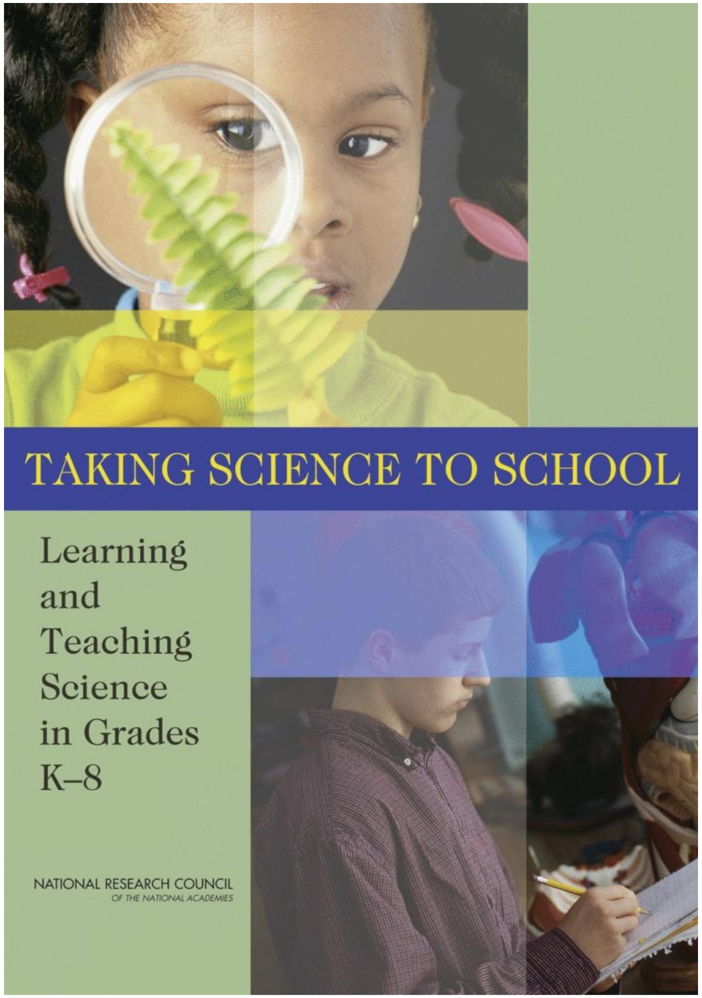
- Know, use and interpret scientific explanations of the natural world.
- Generate and evaluate scientific evidence and explanations.
- Understand the nature and development of scientific knowledge.
- Participate productively in scientific practices and discourse.




National Research Council (2007)

# 4 Strands of Scientific Proficiency

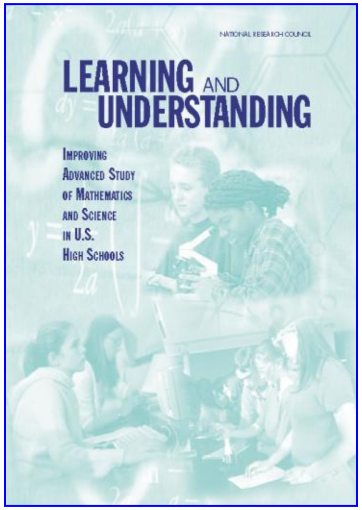
- Know, ~~use and interpret~~ scientific explanations of the natural world.
- ~~Generate and evaluate scientific evidence and explanations.~~
- ~~Understand the nature and development of scientific knowledge.~~
- ~~Participate productively in scientific practices and discourse.~~

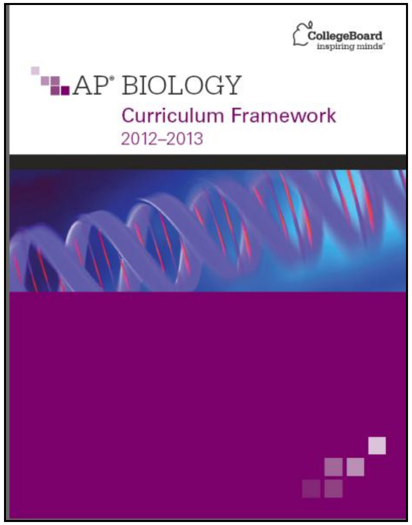



National Research Council (2007)

# AP Redesign

## Biology, Chemistry, Environmental Science, Physics (2012-16)




- Science Panels
  - Big Ideas / Unifying Themes
  - Enduring Understandings
  - Competencies
  - Evidence Models (Formative Assessments)

- Evidence of Learning
- The student can use representations and models to communicate scientific phenomena and solve scientific problems.
- The student can use mathematics appropriately
- The student can engage in scientific questioning
- The student can perform data analysis and evaluation of evidence
- The student can work with scientific explanations and theories
- The student is able to transfer knowledge across various scales, concepts, and representations in and across domains

http://books.nap.edu/openbook.php?record_id=10129&page=R1

# Big Ideas/ Unifying Themes of the New AP Biology Course

- The process of evolution drives the diversity and unity of life.
- Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis.
- Living systems store, retrieve, transmit and respond to information essential to life processes.
- Biological systems interact, and these systems and their interactions possess complex properties.

# The redesigned AP curriculum focuses on merging content with the 21st century skills needed for college and career

| | |
|---|---|
| **Content** | Transmission of information between neurons occurs across synapses. |
| **+ Skill** | The student can *create representations and models of natural* phenomena and systems |
| **Learning Objective** | The student is able to create a visual representation to describe how nervous systems transmit information. |

# Try a college-level biology question

*The creeping horizontal and subterranean stems of ferns are referred to as:*

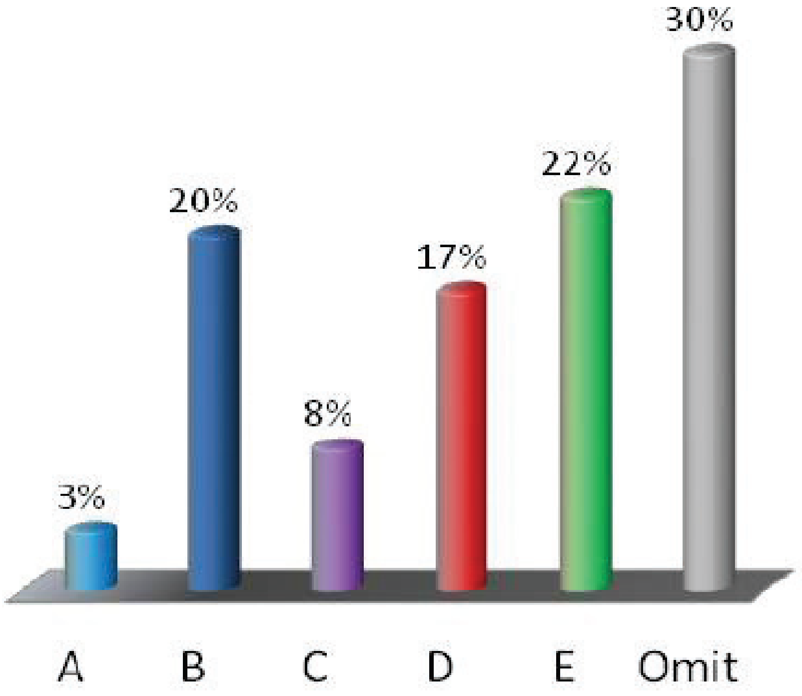
A. Prothalli

B. Fronds

C. Stipes

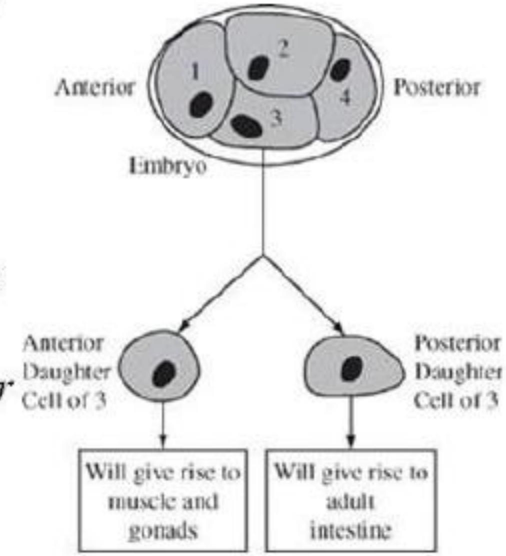
D. Roots

E. Rhizomes

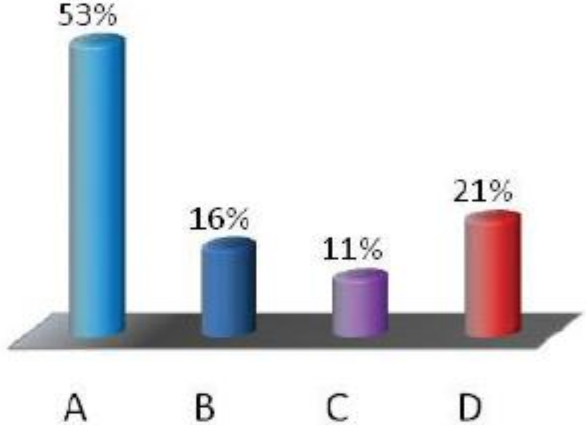


## Now try this college-level biology question:

*The diagram at right shows a developing worm embryo at the four-cell stage. Experiments have shown that when cell 3 divides, the anterior daughter cell gives rise to muscle and gonads and the posterior daughter cell gives rise to the intestine. However, if the cells of the embryo are separated from one another early during the four-cell stage, no intestine will form. Other experiments have shown that if cell 3 and cell 4 are recombined after the initial separation, the posterior daughter cell of cell 3 will once again give rise to normal intestine. Which of the following is the most plausible explanation for these findings?*




A. A cell surface protein on cell 4 signals cell 3 to induce formation of the worm's intestine.
B. The plasma membrane of cell 4 interacts with the plasma membrane of the posterior portion of cell 3, causing invaginations that become microvilli.
C. Cell 3 passes an electrical signal to cell 4, which induces differentiation in cell 4.
D. Cell 4 transfers genetic material to cell 3, which directs the development of intestinal cells.



# Similarities in Thinking:

## AP Biology Redesign (2011):

- The process of evolution drives the diversity and unity of life.
- Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis.
- Living systems store, retrieve, transmit and respond to information essential to life processes.
- Biological systems interact, and these systems and their interactions possess complex properties.

## Vision and Change (2011)

- The diversity of life evolved over time by processes of mutation, selection, and genetic change.
- Basic units of structure define the function of all living things.
- The growth and behavior of organisms are activated through the expression of genetic information in context.
- Biological systems grow and change by processes based upon chemical transformation pathways and are governed by the laws of thermodynamics.
- Living systems are interconnected and interacting.

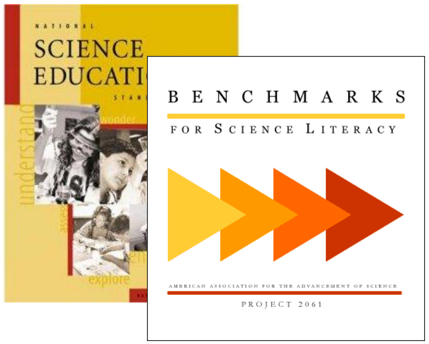
# NEXT GENERATION SCIENCE STANDARDS

Science and Engineering Practices

Disciplinary Core Ideas

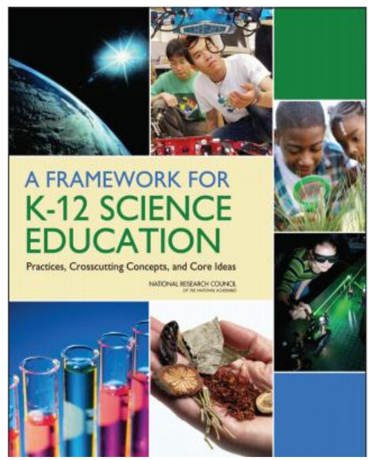
Crosscutting Concepts

# Building on the Past; Preparing for the Future



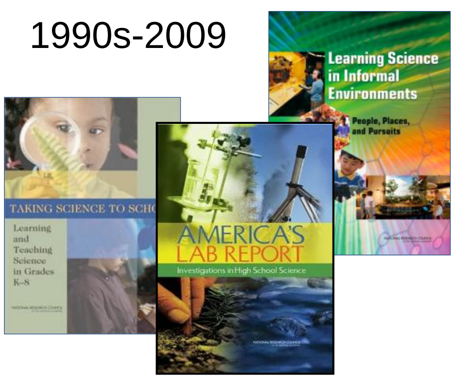

1990s

Phase I




1/2010 - 7/2011

1990s-2009




Phase II

NEXT GENERATION SCIENCE STANDARDS

7/2011 – **3/2013**

# Dimensions of the Framework

- Science and Engineering Practice
- Crosscutting Concepts
- Disciplinary Core Ideas

# Science and Engineering Practices

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics, information and computer technology, and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Framework 3-28 to 31

NEXT GENERATION SCIENCE STANDARDS

# Crosscutting Concepts

1. Patterns
2. Cause and effect
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter
6. Structure and function
7. Stability and change

*Framework 4-1*

# Possible Leverage Points for Professional and Disciplinary Societies


# The Role of Scientific Societies in STEM Faculty Workshops

## *A Report of the May 3, 2012 Meeting*

**Council of Scientific Society Presidents**
**American Chemical Society**
**Washington, D.C.**

*Supported by:*

National Science Foundation, Division of Undergraduate Education
Council of Scientific Society Presidents
American Association of Physics Teachers

National Science Foundation
WHERE DISCOVERIES BEGIN

THE COUNCIL OF SCIENTIFIC SOCIETY PRESIDENTS

American Association of Physics Teachers
Enhancing the understanding and appreciation of physics through teaching

# Roles of STEM Societies

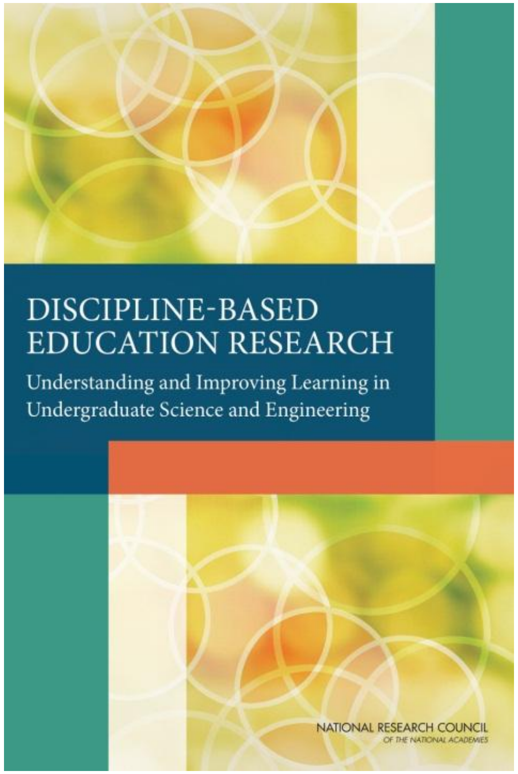
- Most beginning college and university faculty members feel more loyalty to their disciplines than to their home institutions.
- Disciplinary societies set the norms and expectations for professional work.
- Disciplinary societies can provide venues for STEM faculty professional development in teaching.

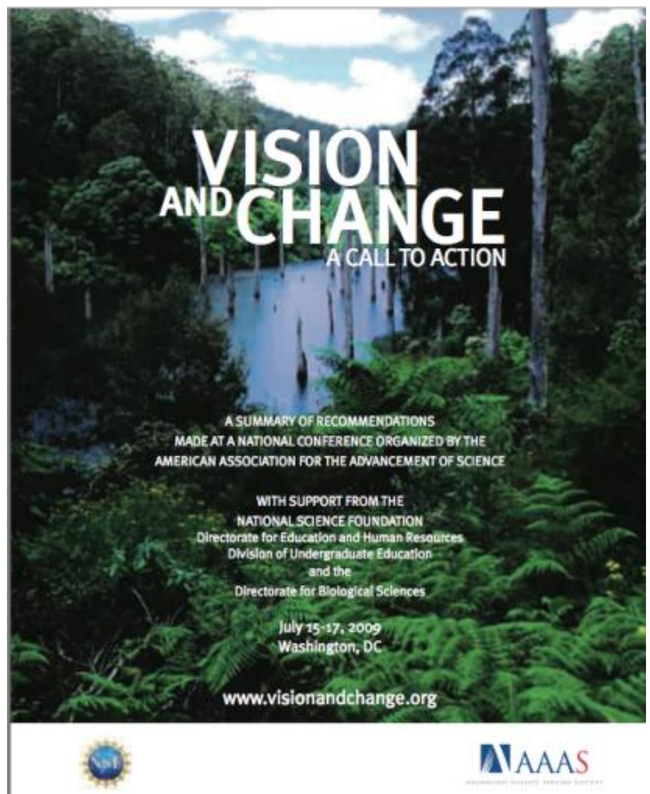
Modified from Hillborn (ed.). 2013

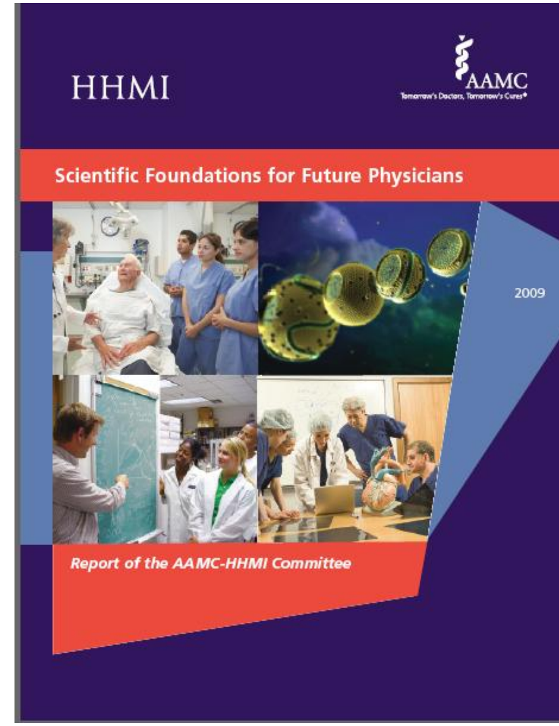
# Roles of STEM Societies

- Meetings can promote continued interaction among participants in STEM faculty workshops and educational leaders in the discipline.
- Forums for the community to articulate learning goals and objectives for educational programs.
- Through active collaboration, provide venues for the development and dissemination of nationally normed assessments of student learning and student attitudes across the STEM disciplines.

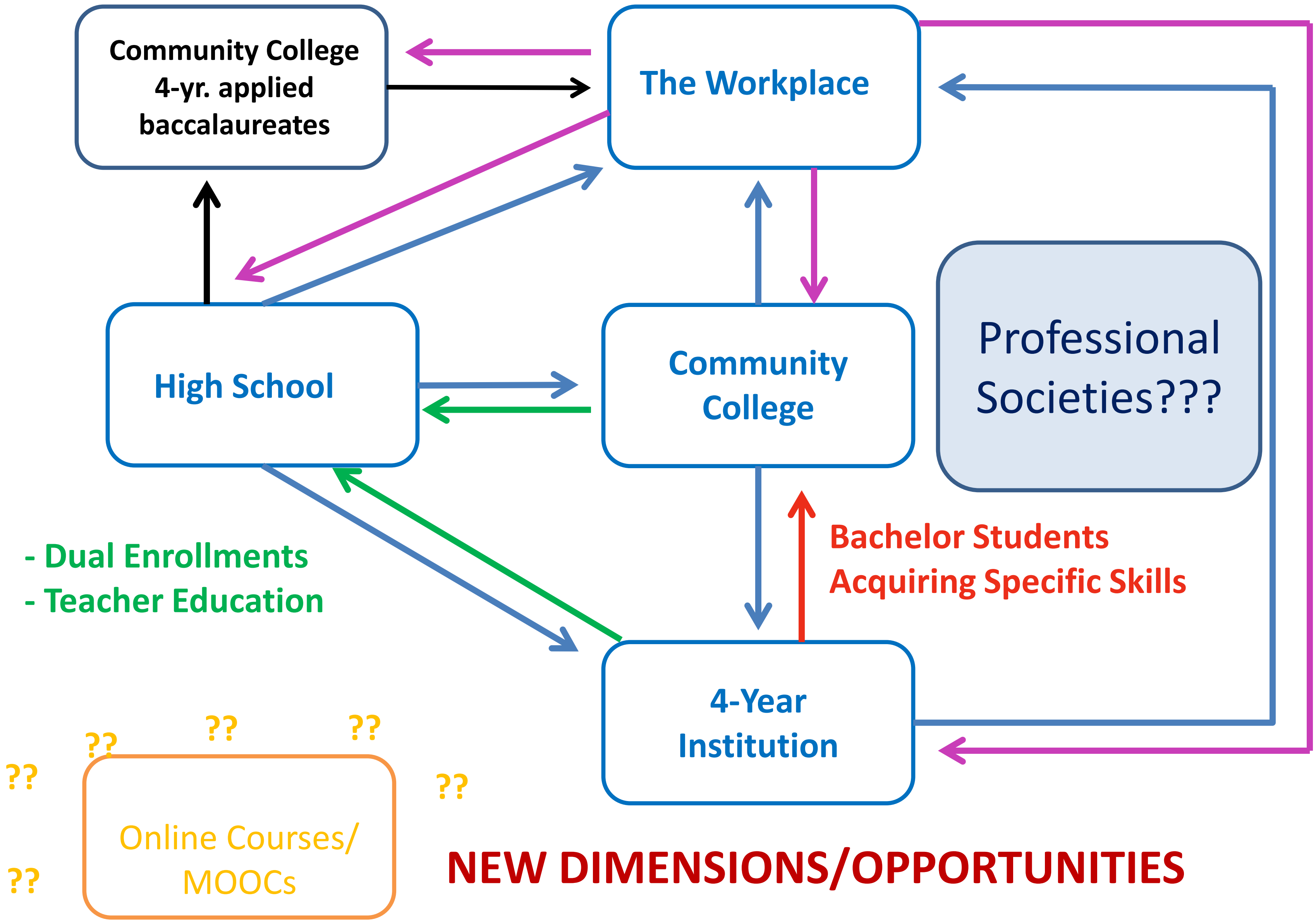
Modified from Hillborn (ed.). 2013


DISCIPLINE-BASED
EDUCATION RESEARCH
Understanding and Improving Learning in
Undergraduate Science and Engineering
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

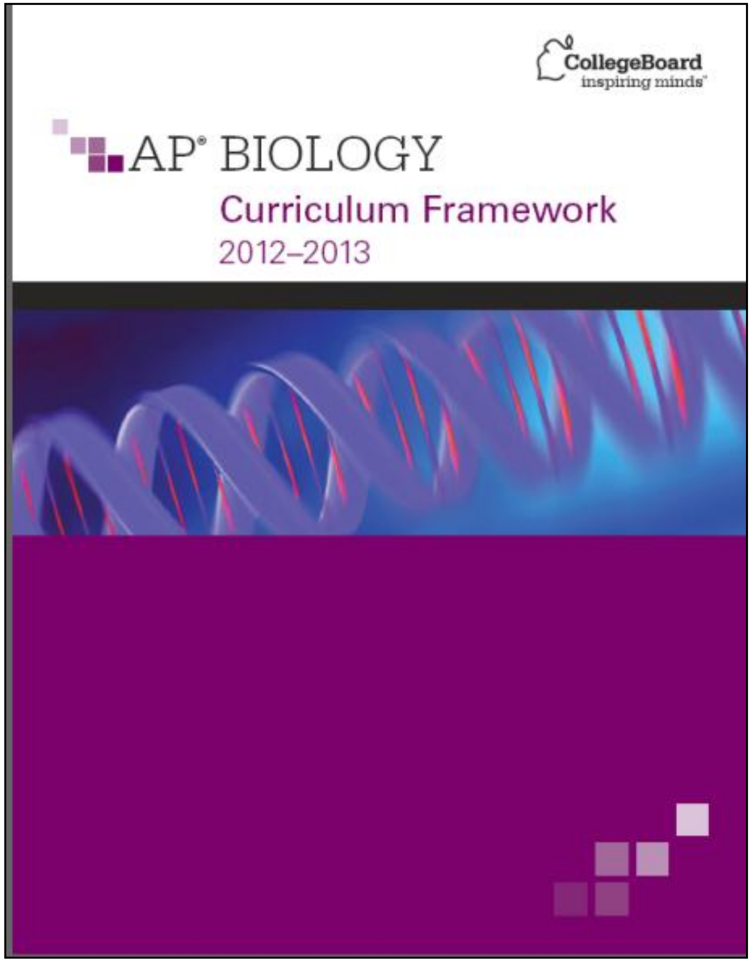

VISION AND CHANGE
A CALL TO ACTION
A SUMMARY OF RECOMMENDATIONS
MADE AT A NATIONAL CONFERENCE ORGANIZED BY THE
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
WITH SUPPORT FROM THE
NATIONAL SCIENCE FOUNDATION
Directorate for Education and Human Resources
Division of Undergraduate Education
and the
Directorate for Biological Sciences
July 15-17, 2009
Washington, DC
www.visionandchange.org
AAAS


HHMI
AAMC
Scientific Foundations for Future Physicians
2009
Report of the AAMC-HHMI Committee

# THE EMERGING HIGHER EDUCATION ECOSYSTEM



NEXT GENERATION SCIENCE STANDARDS


CollegeBoard inspiring minds

AP® BIOLOGY

Curriculum Framework

2012–2013

# Teacher Education

“Not long ago, a college chemistry professor grew angry with the way her daughter’s high school chemistry class was being taught. She made an appointment to meet with the teacher and marched with righteous indignation into the classroom—only to discover that the teacher was one of her former students.”

**National Research Council (1998)**

Education is the kindling of a flame, not the filling of a vessel

Socrates

# And Returning Full Circle:

"You miss 100% of the shots you never take."

Wayne Gretzky

**Support the Education Revolution!!!**

**(Mantra, National Academies Summer Institutes for Undergraduate Education)**