The Changing National STEM Education Landscape:

Connecting (and Reconnecting) the Dots

THE NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE

Washington, DC

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SUNY-Industry Conference and Showcase: Engineering for Social Good
Stony Brook University, June 5, 2018

The National Academies of SCIENCES · ENGINEERING · MEDICINE

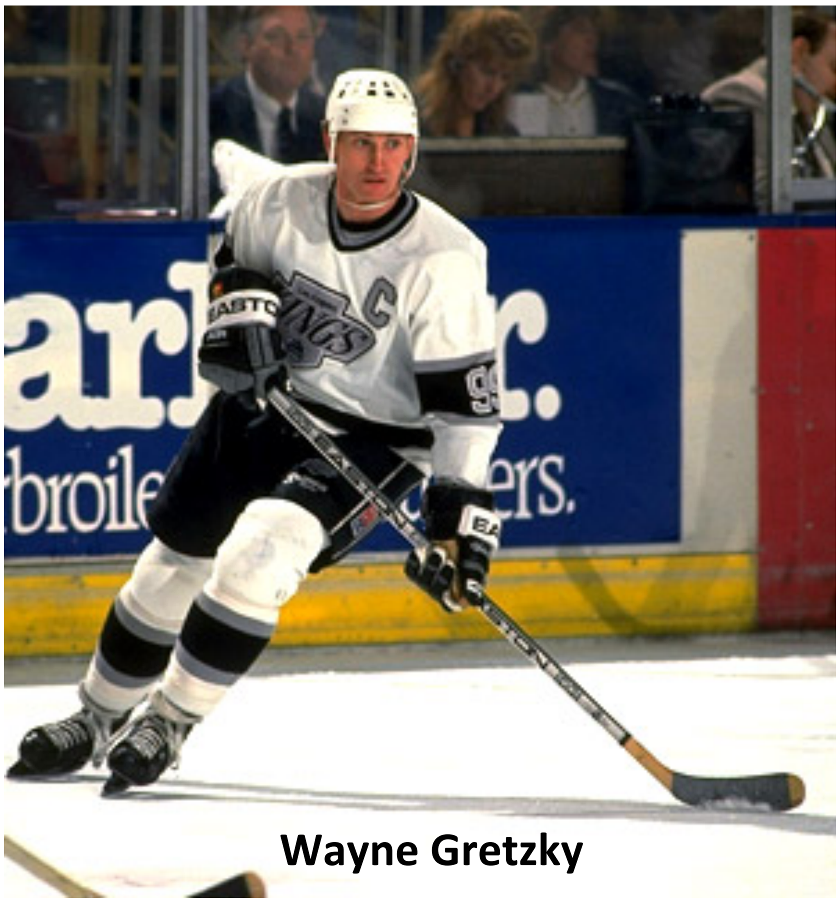
https://www.youtube.com/watch?v=UezY5NJ0FlA&feature=youtu.be </iframe>

Premise 1:

Improving STEM Education is *Not* Rocket Science

It’s a LOT harder!

Premise 2:



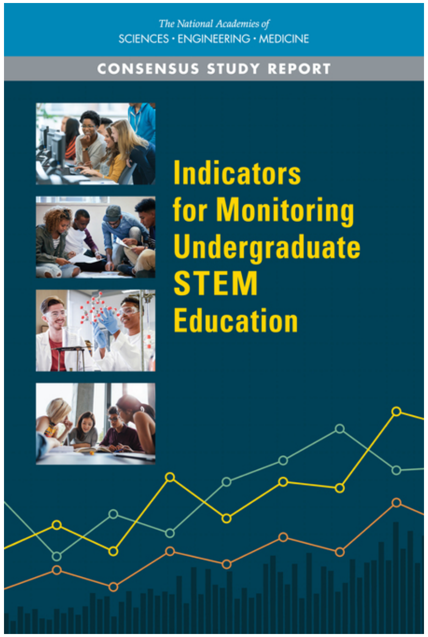
"A good hockey player plays where the puck is.

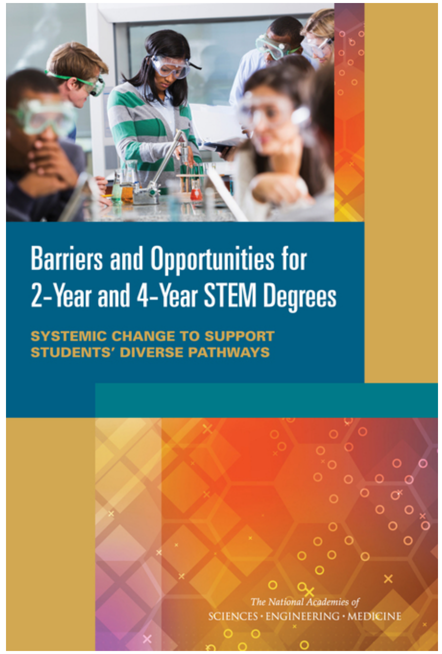
A great hockey player plays where the puck is going to be."

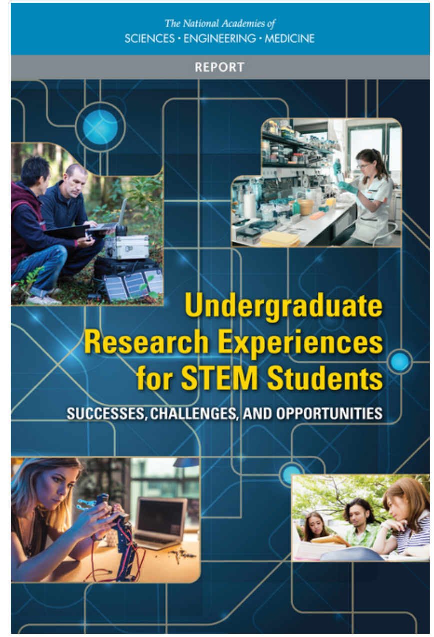
Learning Goals for This Session:

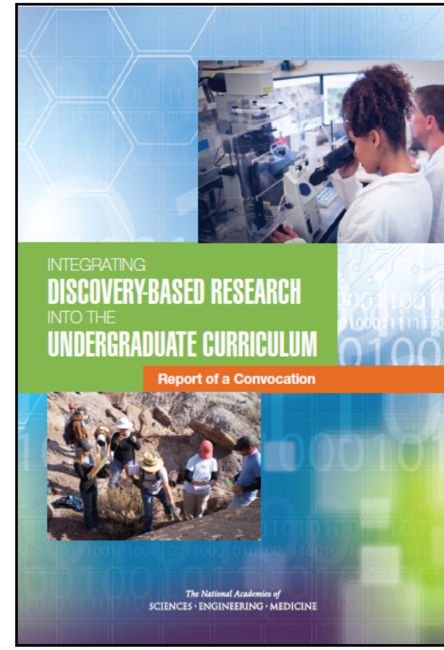
- Briefly review several recent national reports on the improvement of undergraduate education in STEM and how they might inform your discussions about effective teaching and education partnerships in the SUNY system.
- Examine the changing relationships among several components of the undergraduate STEM "education ecosystem."
- 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 and a STEM-educated citizenry.

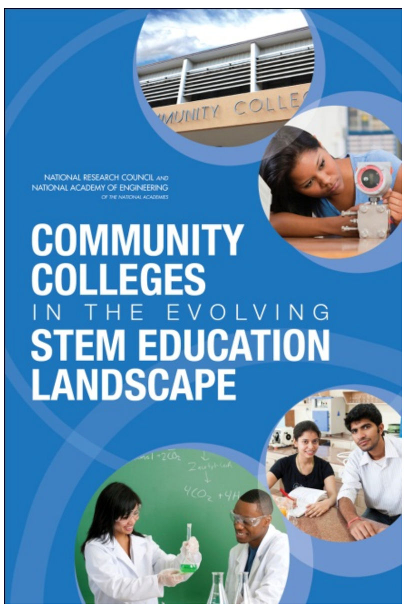
Access, Equity, Opportunity, Diversity, and Representation

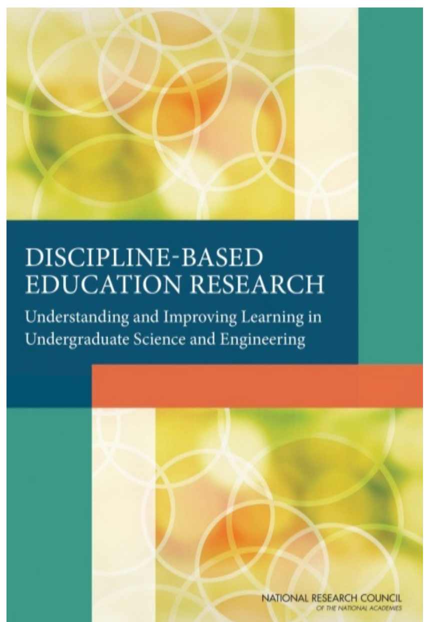


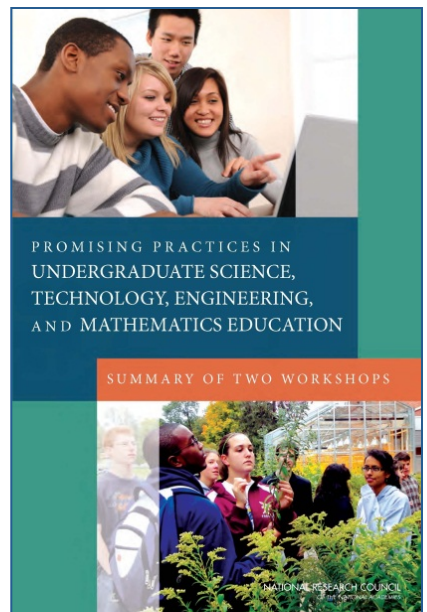


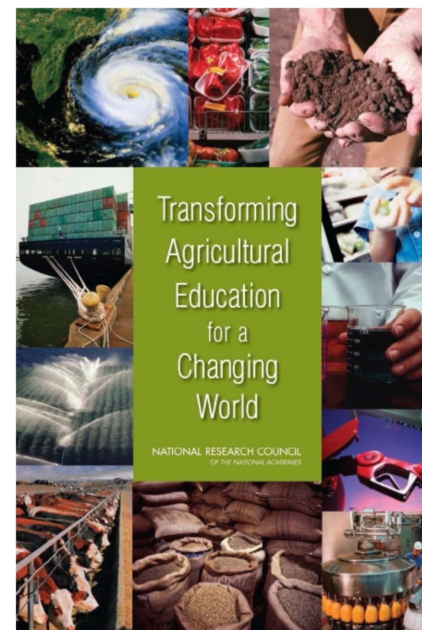




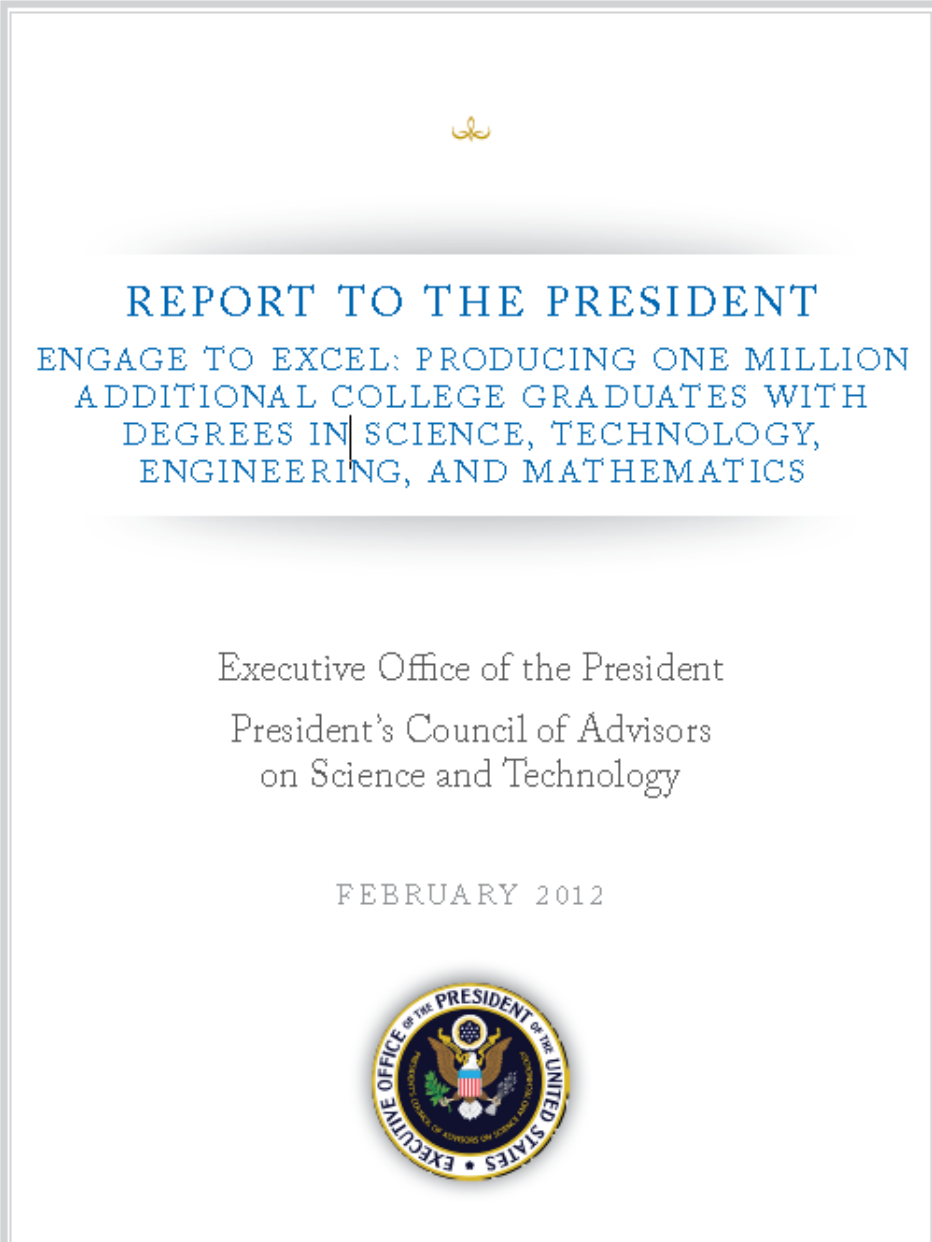








All freely downloadable at http://nap.edu


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

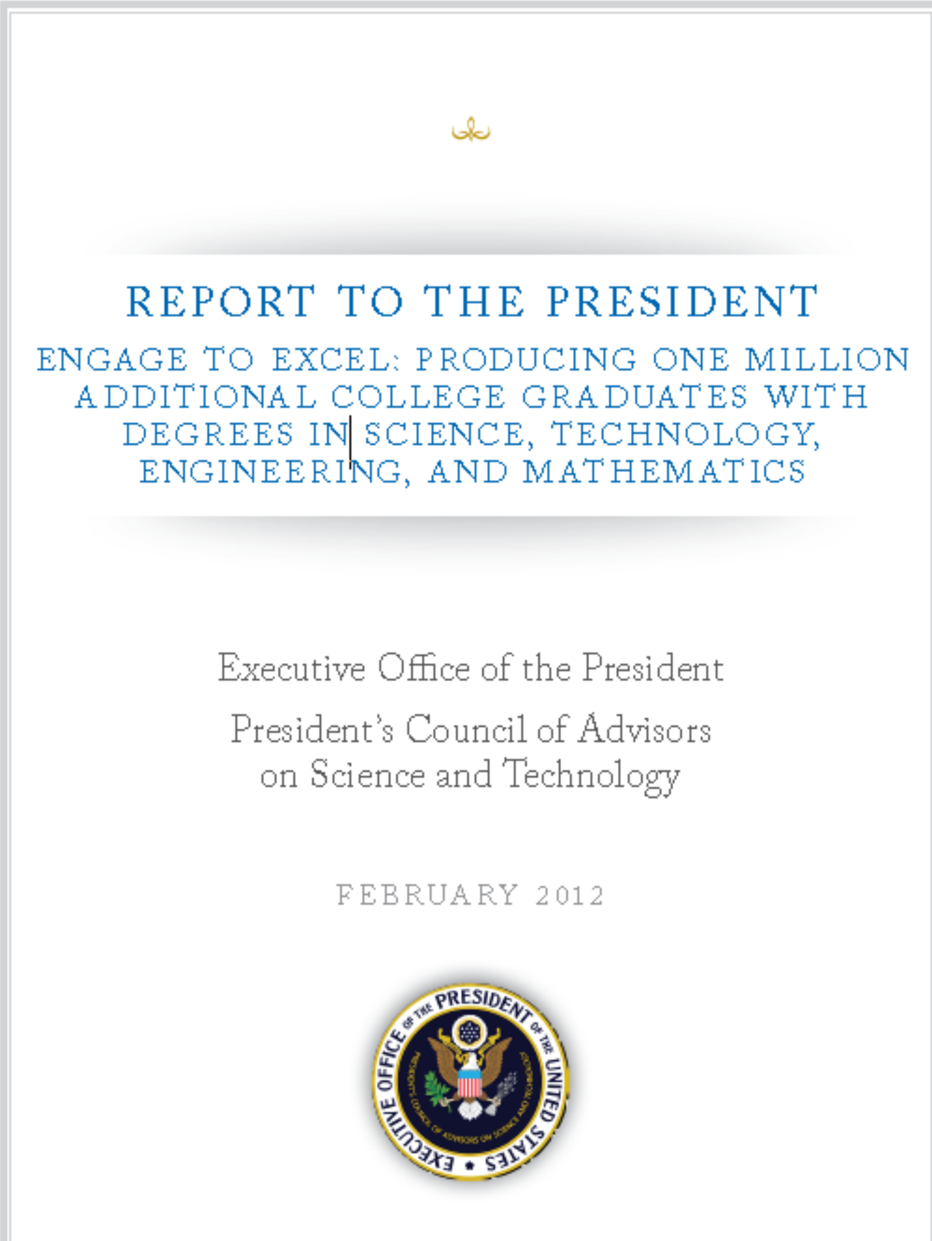
FEBRUARY 2012

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

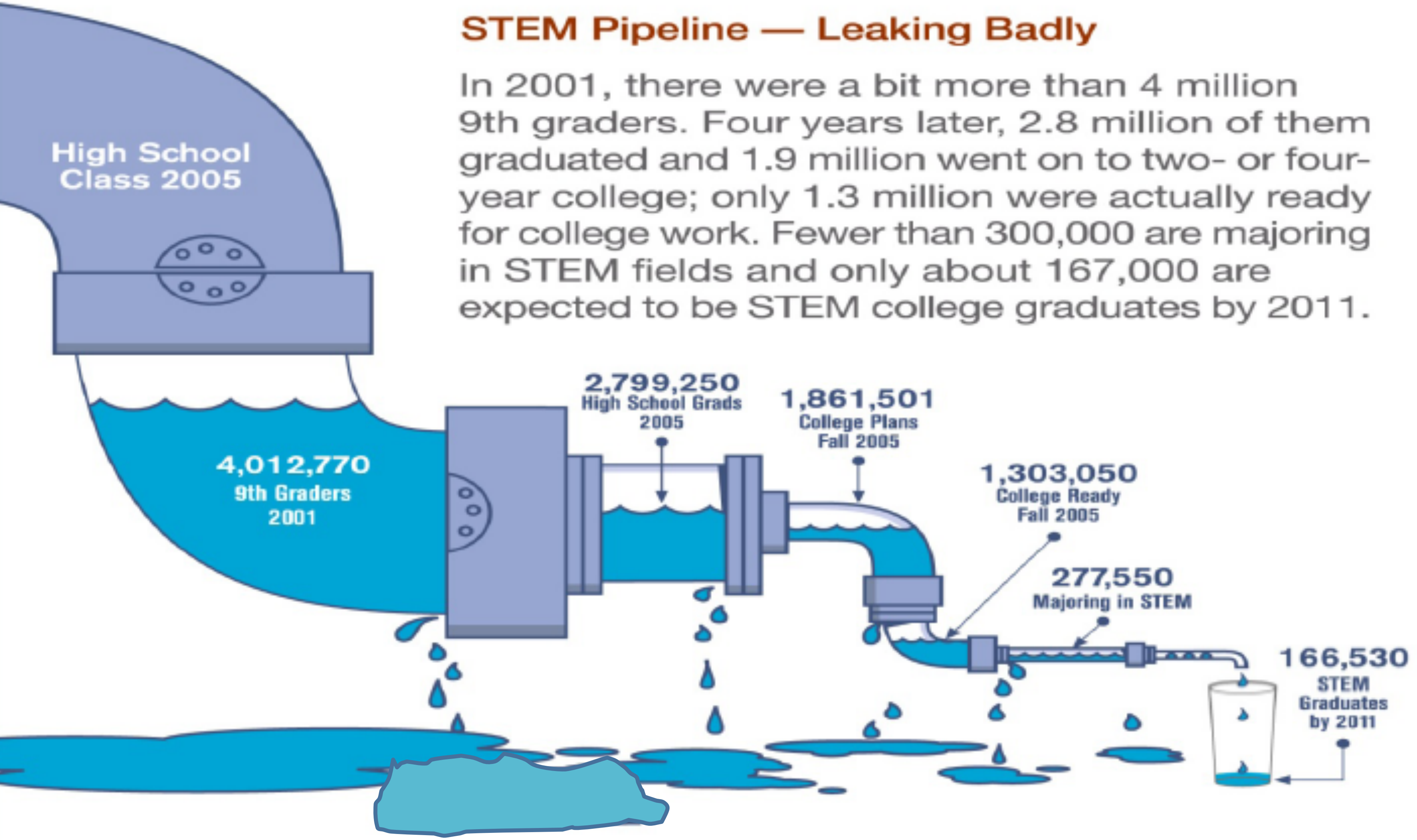
Increasing retention of STEM majors from 40% to 50% would generate three-quarters of the 1 million additional STEM degrees over the next decade.

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

The Problem: A Leaky Pipeline

STEM Pipeline — Leaking Badly

In 2001, there were a bit more than 4 million 9th graders. Four years later, 2.8 million of them graduated and 1.9 million went on to two- or four-year college; only 1.3 million were actually ready for college work. Fewer than 300,000 are majoring in STEM fields and only about 167,000 are expected to be STEM college graduates by 2011.



Source: NCES Digest of Education Statistics; Science & Engineering Indicators 2008

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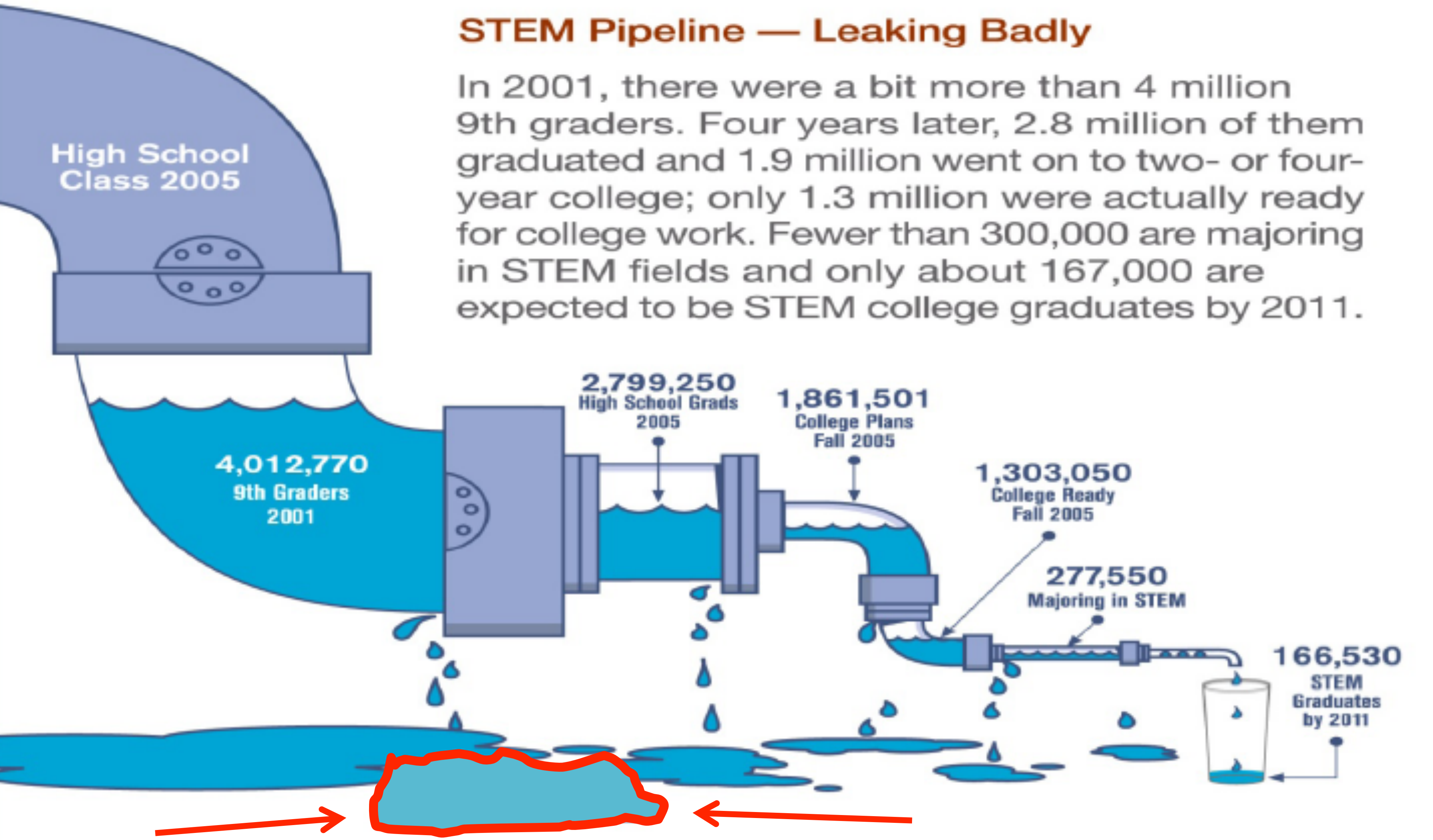

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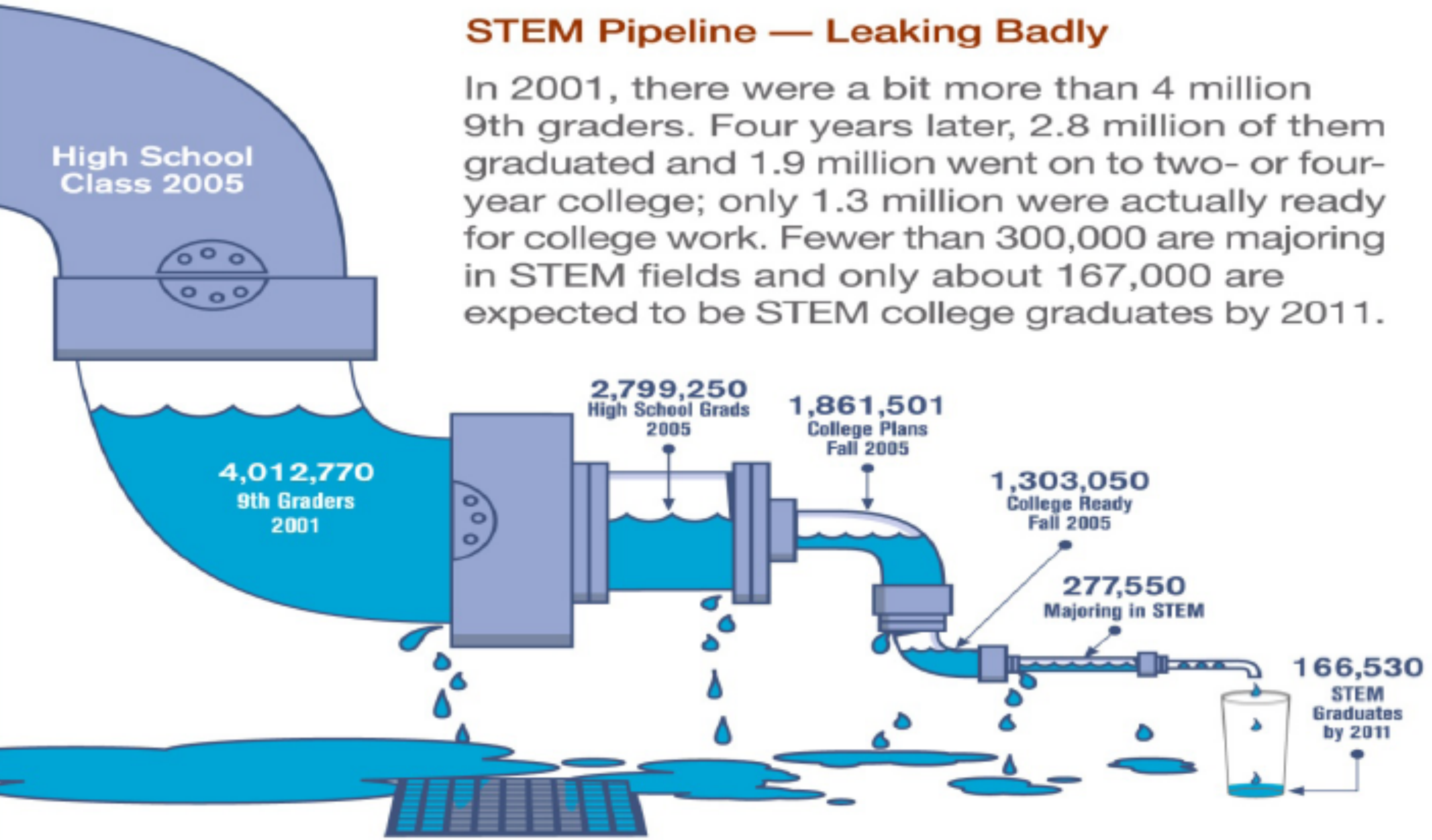
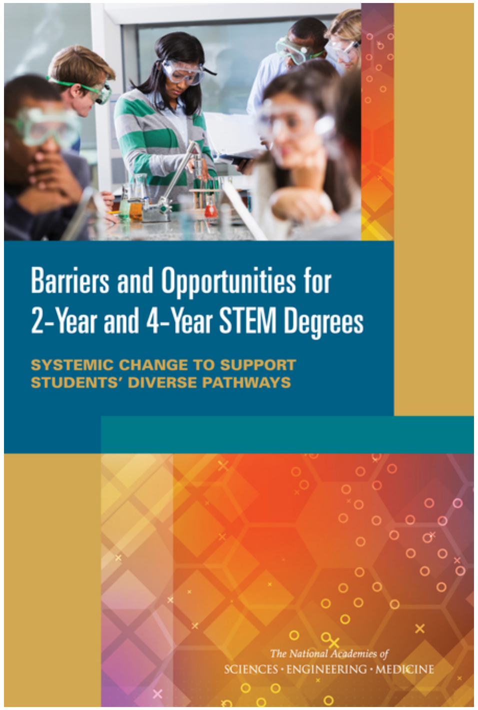


Source: NCES Digest of Education Statistics; Science & Engineering Indicators 2008

Composition of the student body is not the same as 25 years ago

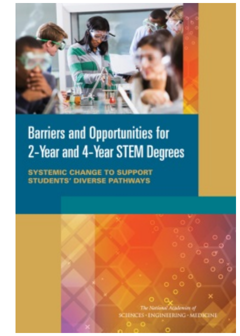
Student Characteristics	1987	2012
Aged 25 and Older	37	40
Enrolled in 2-Year Institutions	43	40
Enrolled Part Time	42	50
Minority	20	42
Employed Part-Time	*	40
Employed Full-Time	26	27
Parents	20	26
Single Parent	7	15
Women	54	57



Students are more likely to be from minority groups and to be parents or single parents.

Modified from presentation by Shirley Malcom

Students take more complex pathways

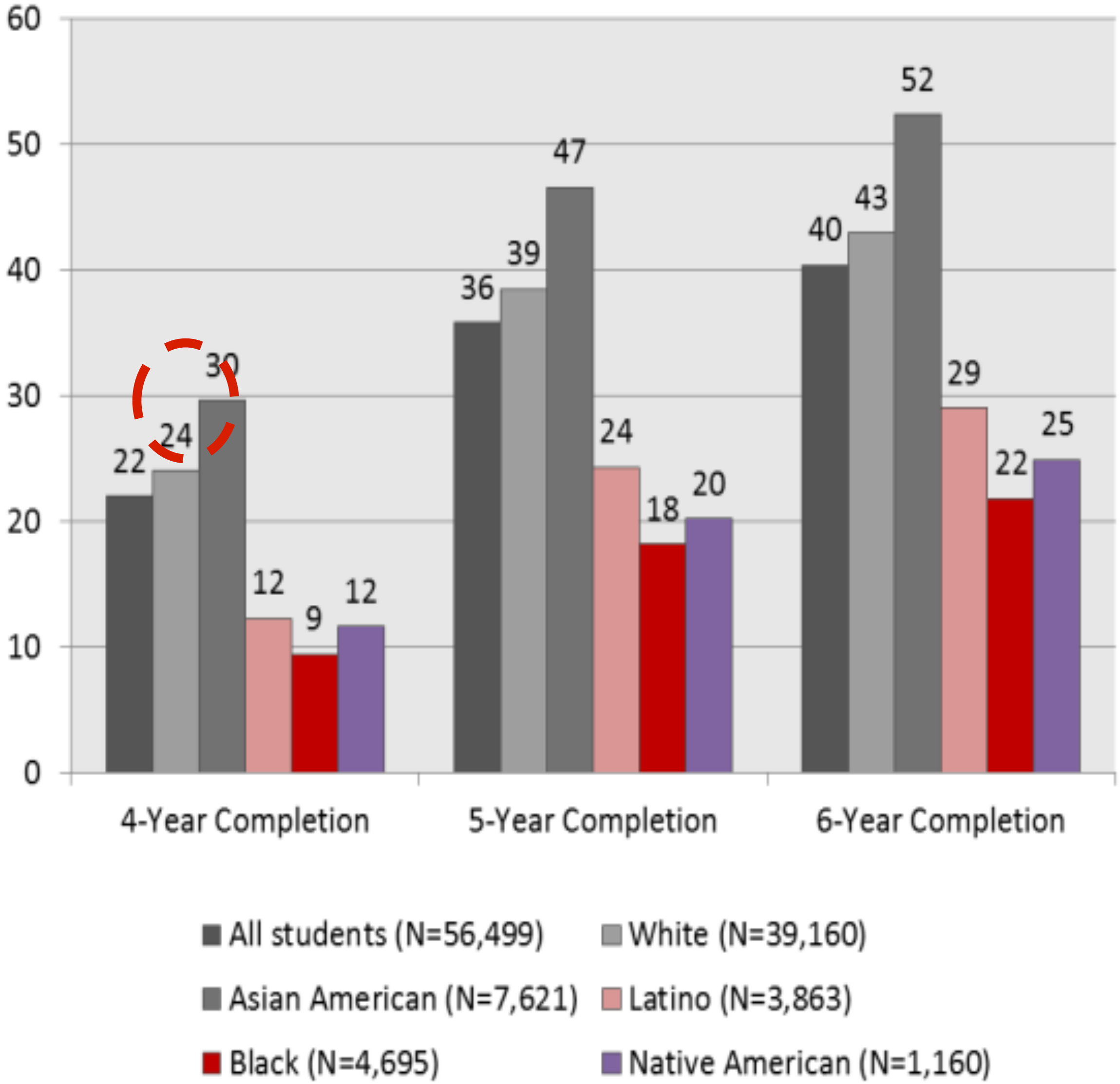


- Often transfer among institutions
- Enter & exit at different phases of study
- Concurrently enroll at more than one institution

	2-Year Institutions				4-Year Institutions	
Enrollment Patterns	All STEM	Science & Eng	Tech	Non-STEM	STEM	Non-STEM
Average Enrollment Intensity						
Always Full Time	33	36	32	27	68	65
Always Part Time	13	8	15	22	1	2
Mixed Part Time and Full Time	53	55	53	51	31	33
Constancy of Attendance/ Number of Stopouts						
0	47	49	46	50	71	72
1	41	43	39	35	22	21
2+	12	8	15	15	7	7
Institutional Attendance						
Attend Only One Institution	49	33	59	62	75	74
Traditional Transfer	25	41	16	19	NA	NA
Attend Multiple Institutions, Swirling	26	26	25	19	25	26

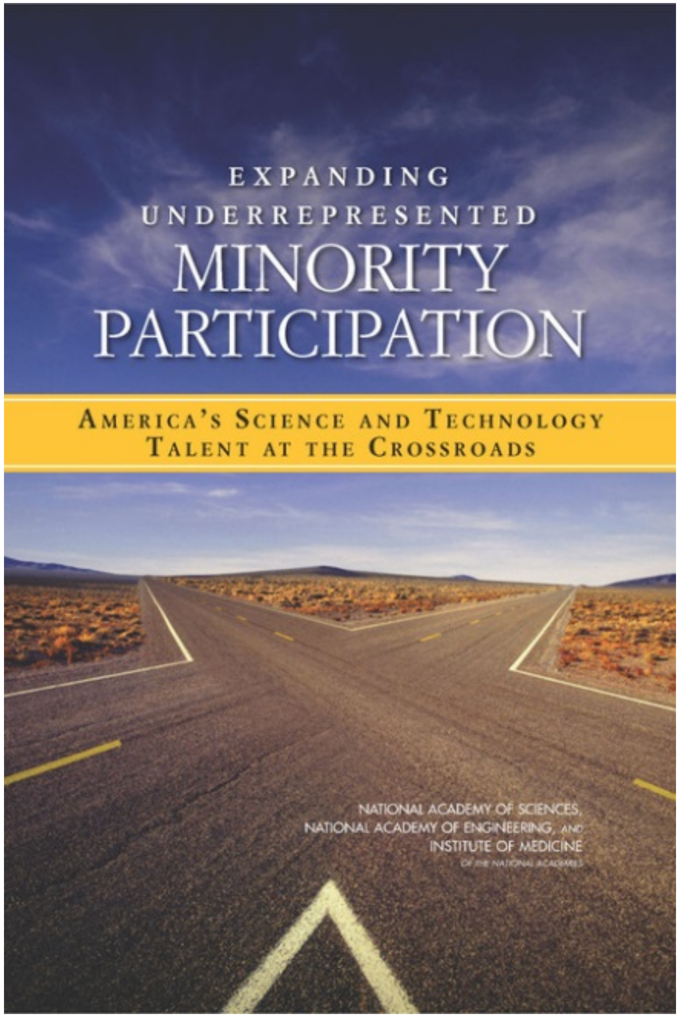
Modified from presentation by Shirley Malcom

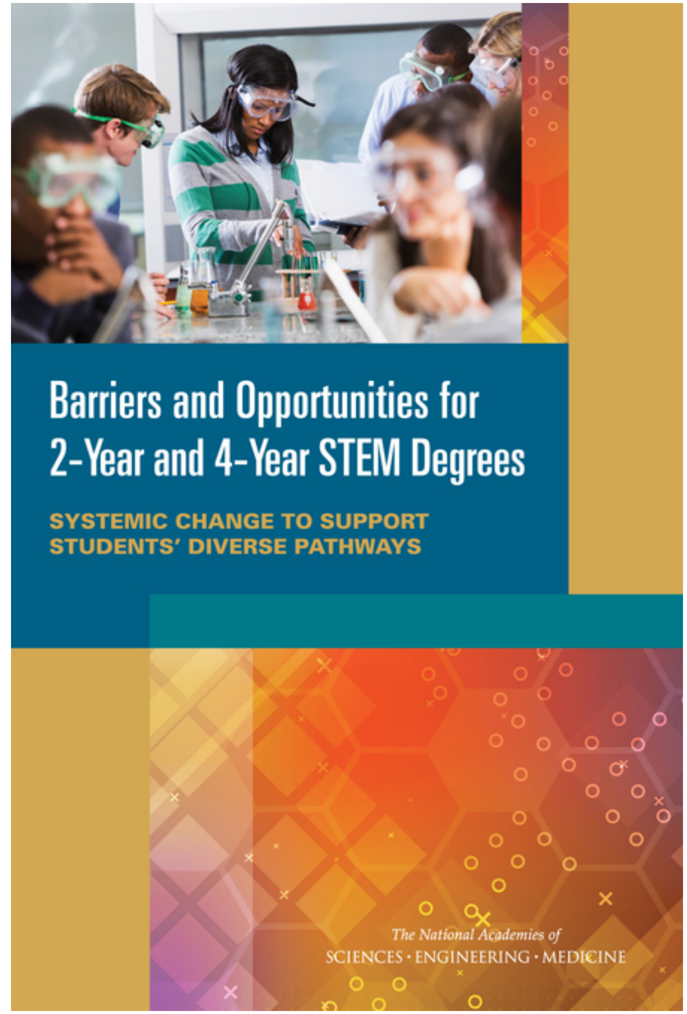
Cumulative percentage of 2004 STEM aspirants who completed STEM degrees in 4, 5, and 6 years



"On-time" completion of credential is infrequent: only 22% of students aspiring to 4-year STEM degree achieve their goal.

Source: Eagan et al., 2014 (Fig 7)



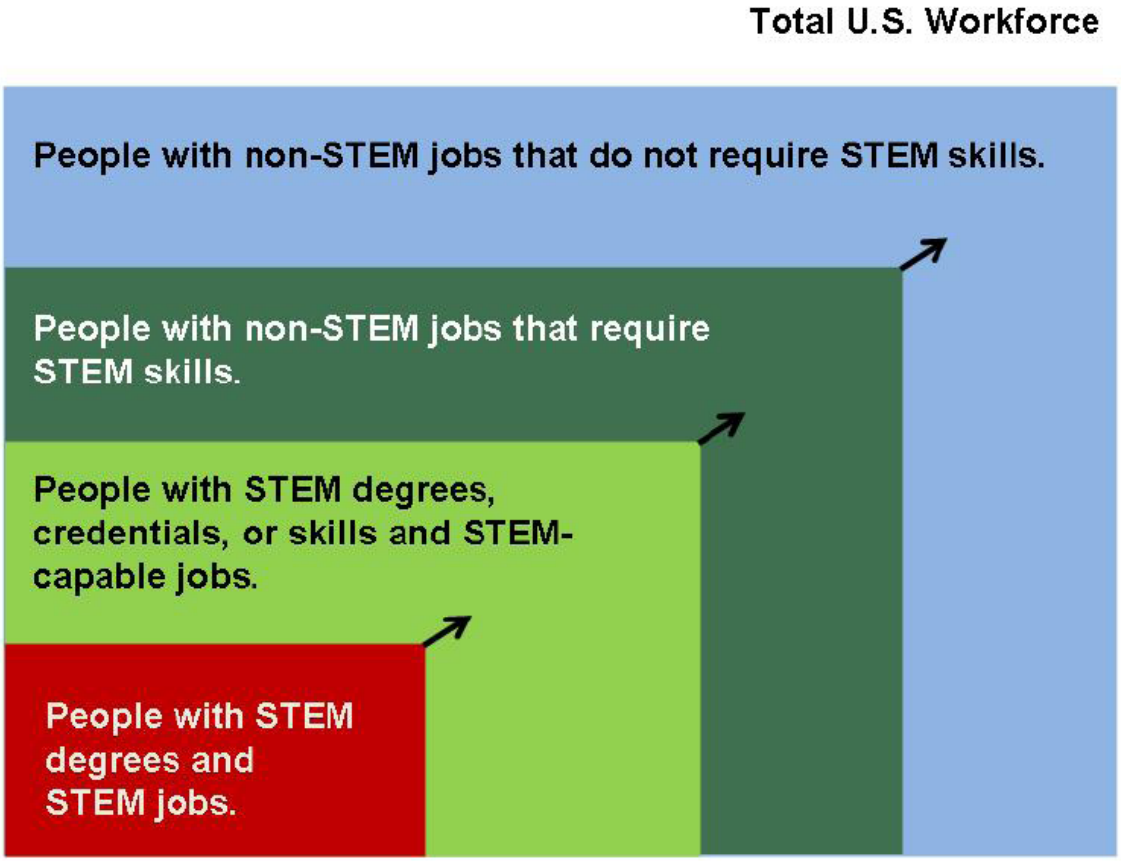


2011

2016

Available for free download at http://nap.edu

STEM Workforce Definition



Note: The categories of jobs that require STEM skills and understandings are expanding, generating additional demand for workers with STEM degrees.

Source: PCAST (2012) *Engage to Excel, Fig. F-1, p.68*

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)

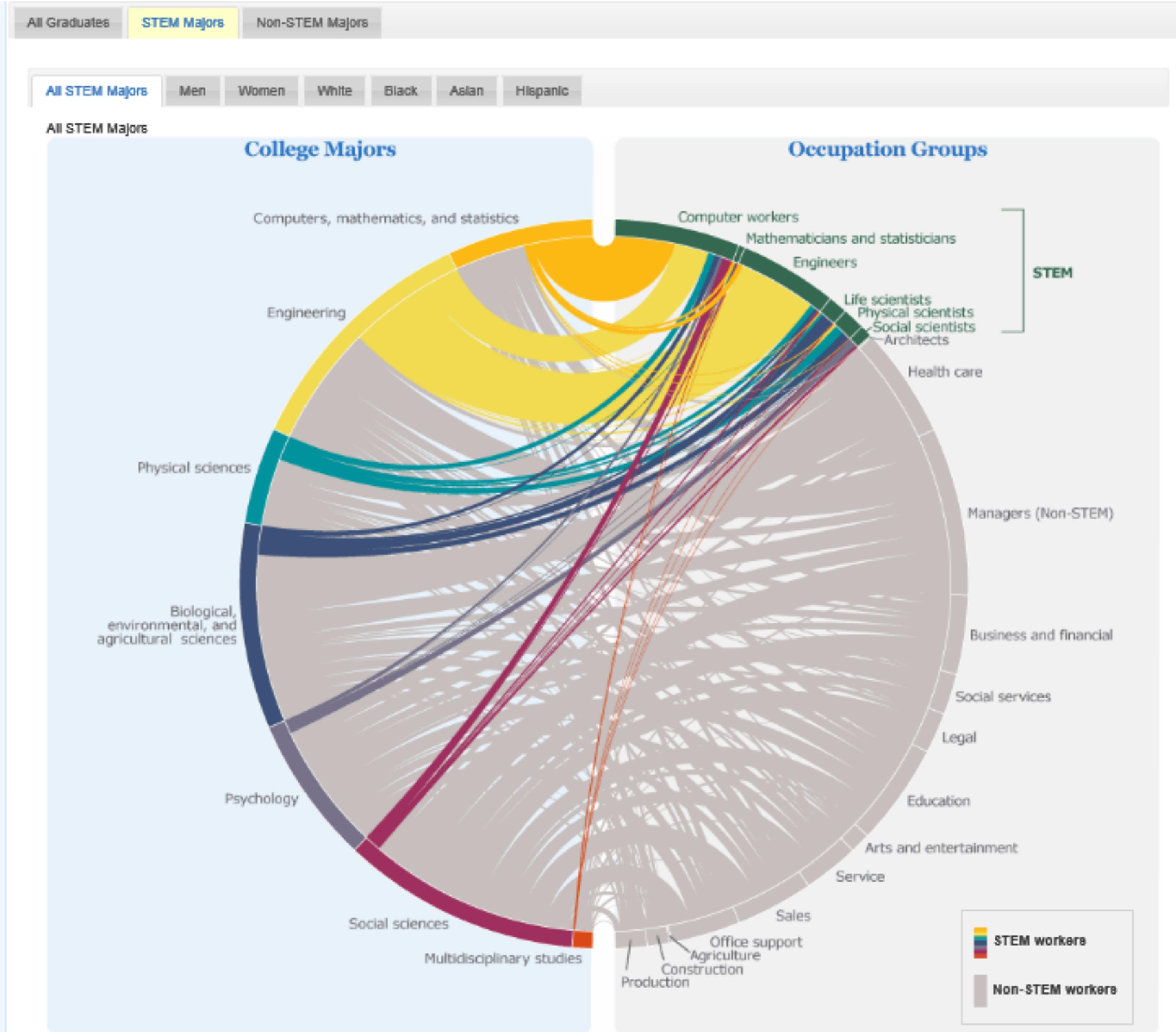
"The illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn."

Alvin Toffler, American Writer and Futurist

A Shifting Job Market

	20th Century	21st Century
Number of Jobs:	1 – 2 Jobs	10 – 15 Jobs

Courtesy of Linda Froschauer

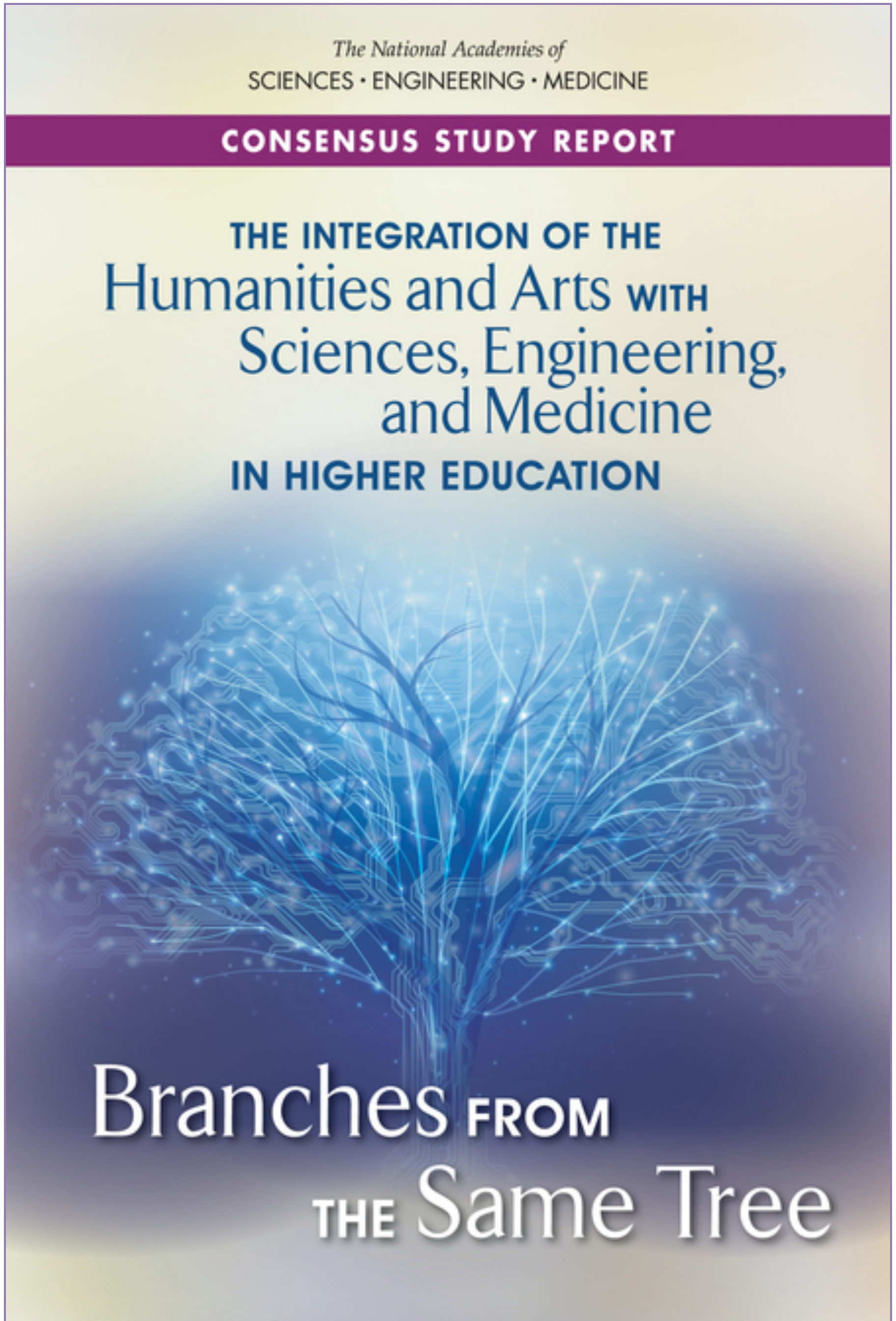


https://www.census.gov/dataviz/visualizations/stem/stem-html/

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



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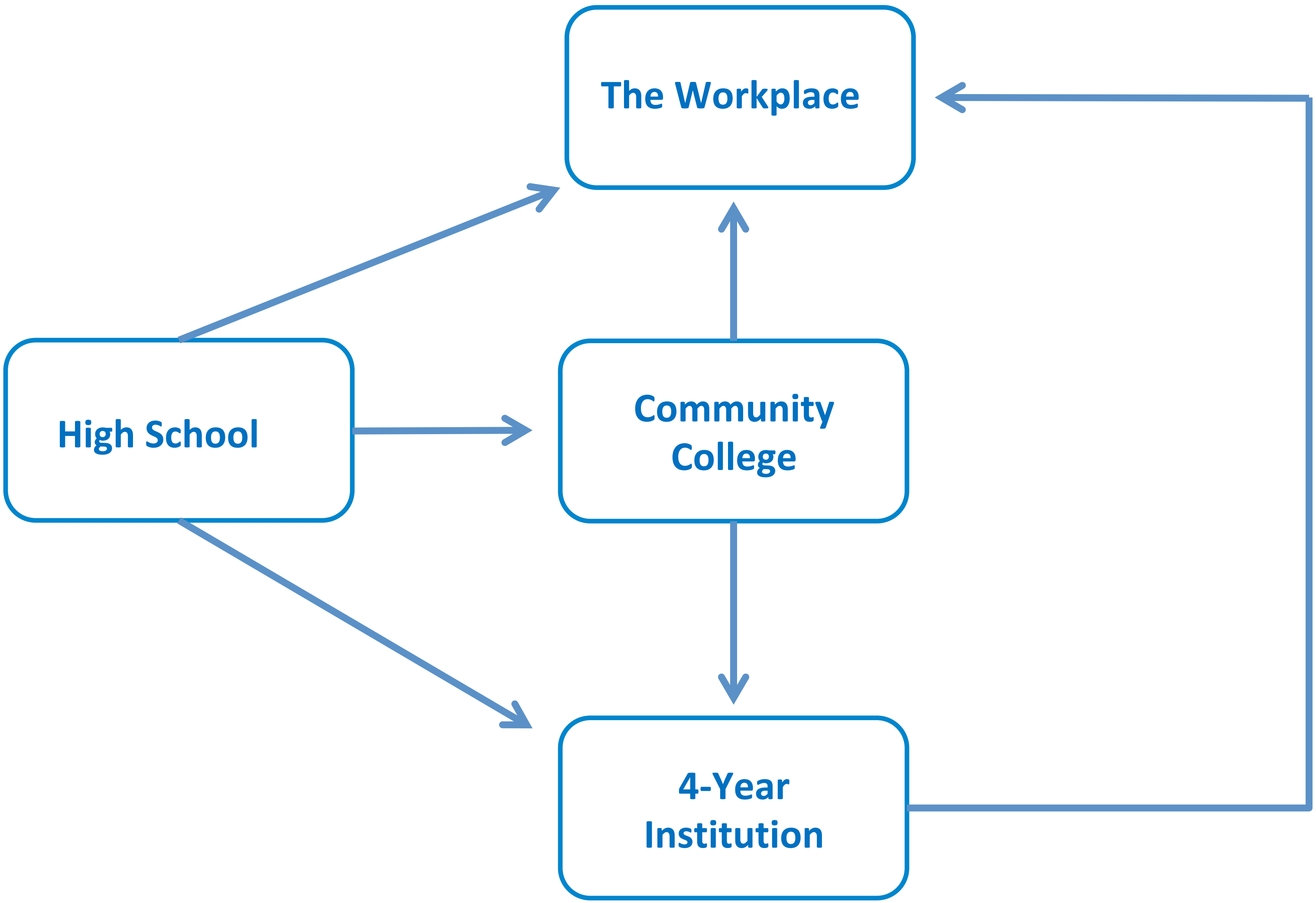
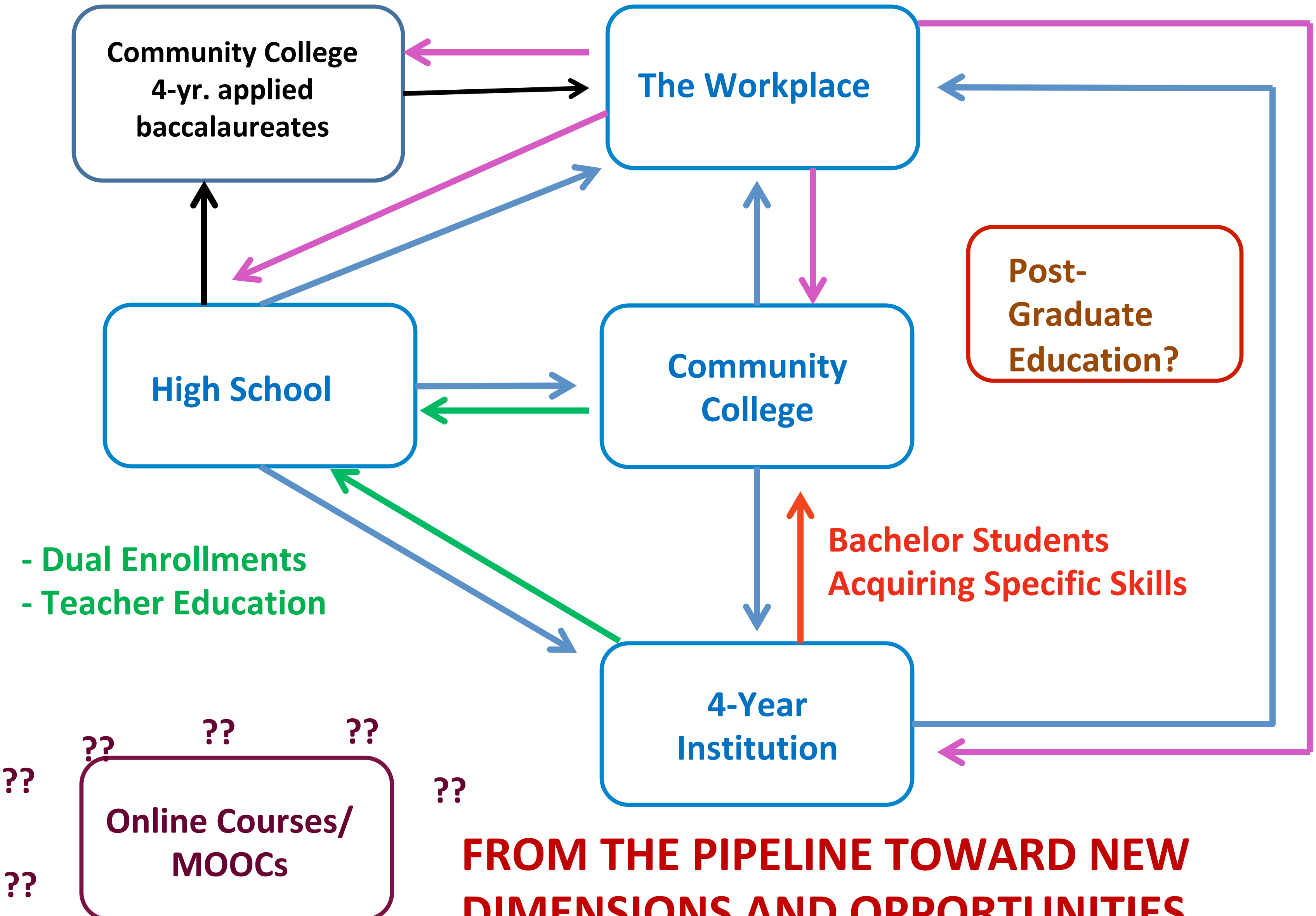
The Evolving Dynamics Between Two- and Four-Year Colleges and Universities

THE EMERGING HIGHER EDUCATION ECOSYSTEM



THE TRADITIONAL PIPELINE

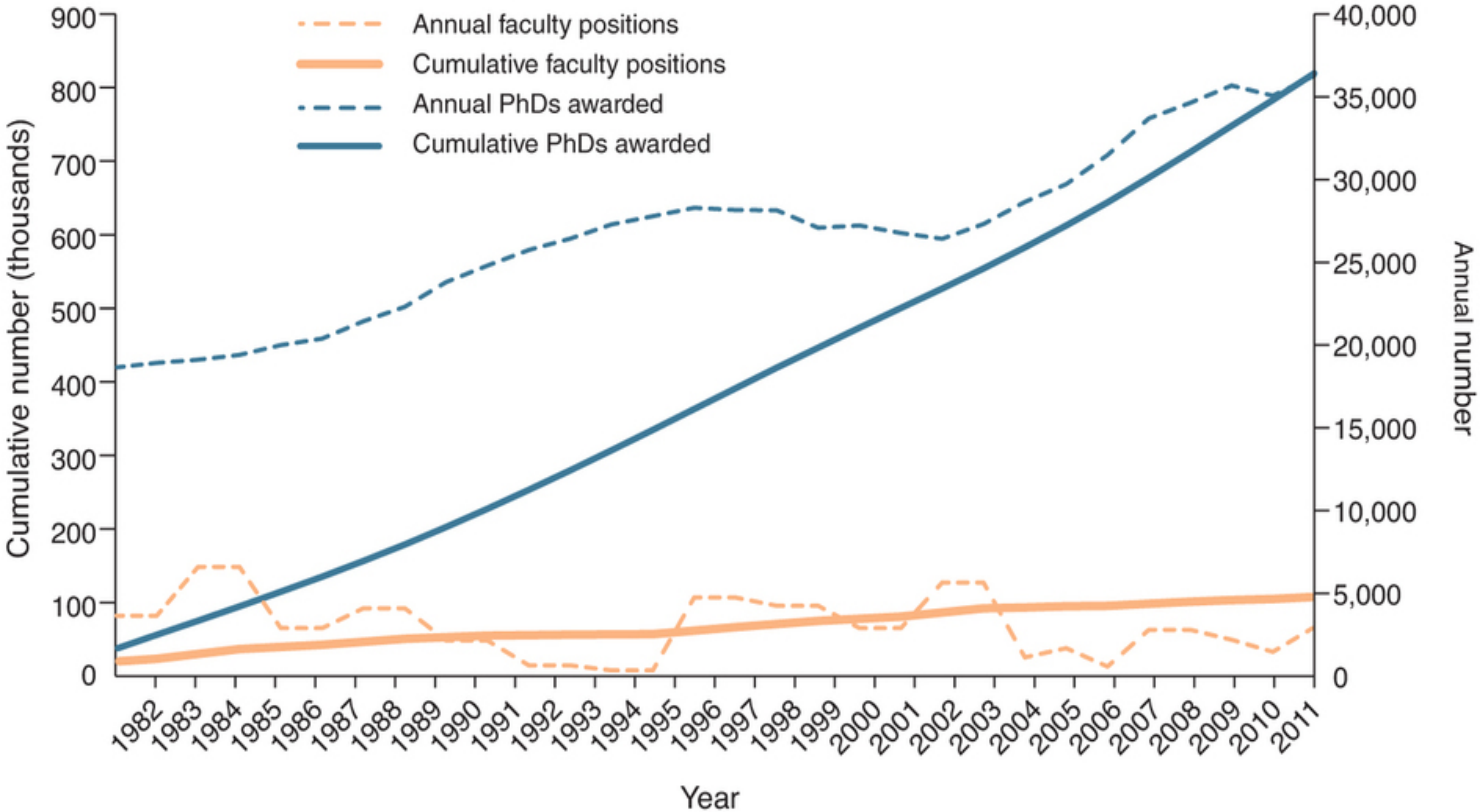
THE EMERGING HIGHER EDUCATION ECOSYSTEM



FROM THE PIPELINE TOWARD NEW DIMENSIONS AND OPPORTUNITIES

The Future of Graduate Education in the Education Ecosystem?

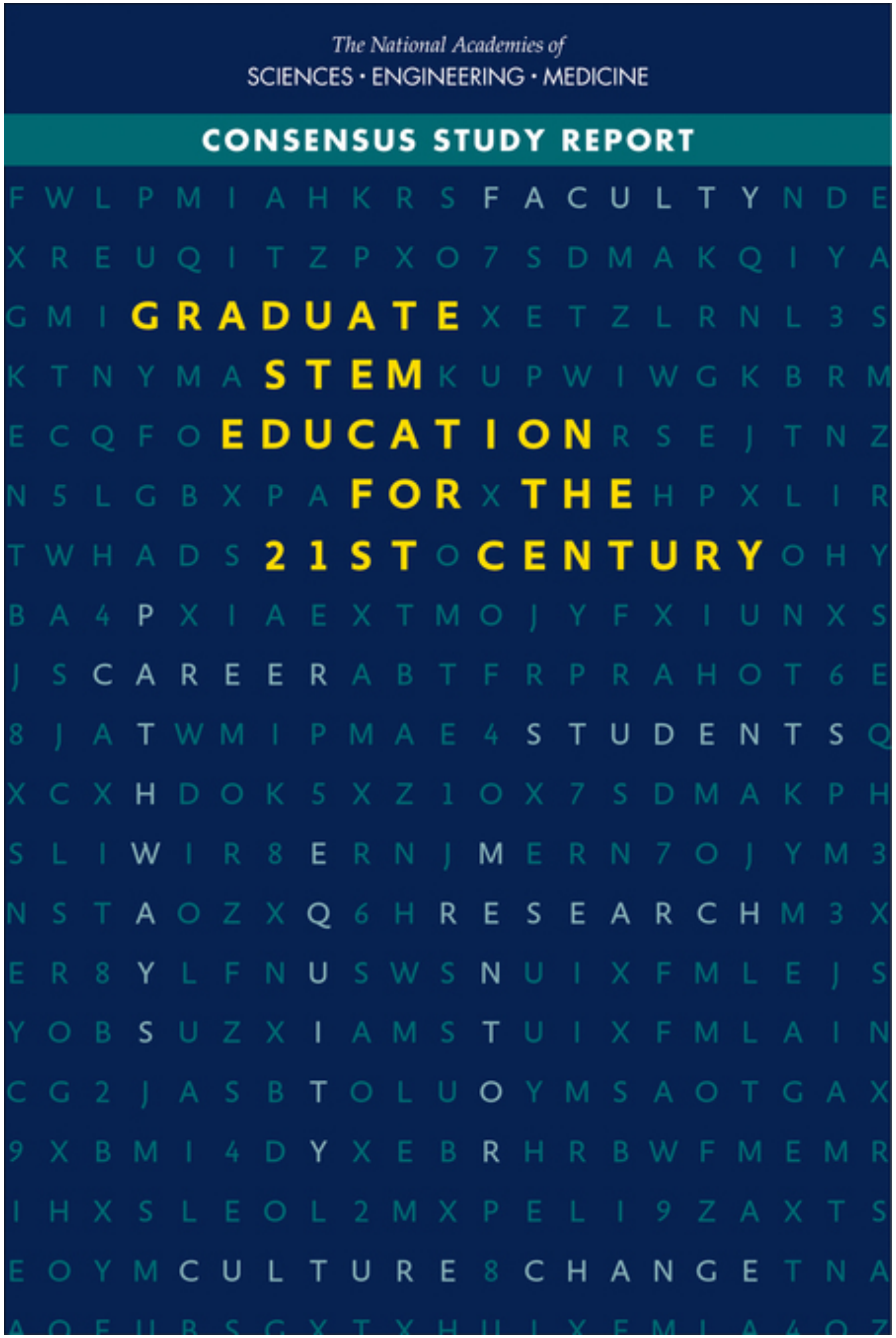
The Discrepancy Between Ph.D. Degrees Awarded and Available Faculty Positions



Nature Biotechnology 31, 938-941 (2013)

The Future of Graduate Education in the Education Ecosystem?

Faculty Research Positions in Academe: The Alternative Career Pathway of the Future?



OVERVIEW:

The majority of students with graduate degrees no longer pursue careers in academe.

But graduate education, especially at the Ph.D. level, primarily prepares people for (research) careers in academe.

The improvement of graduate education in STEM is a systemic problem.

Efforts to improve graduate education must be STUDENT-CENTERED.

Released May 29, 2018.
Available for free downloading at
https://www.nap.edu/25038

Was it sustainable to configure a field so that the quality and (mostly) quantity of peer-reviewed research became the unrivaled metric by which status and advancement were attained?

Why did we not promote the ideal of professors equally skilled in both research and instruction?

Was it wise never to train graduate students how to write clearly, speak publicly, and teach effectively?

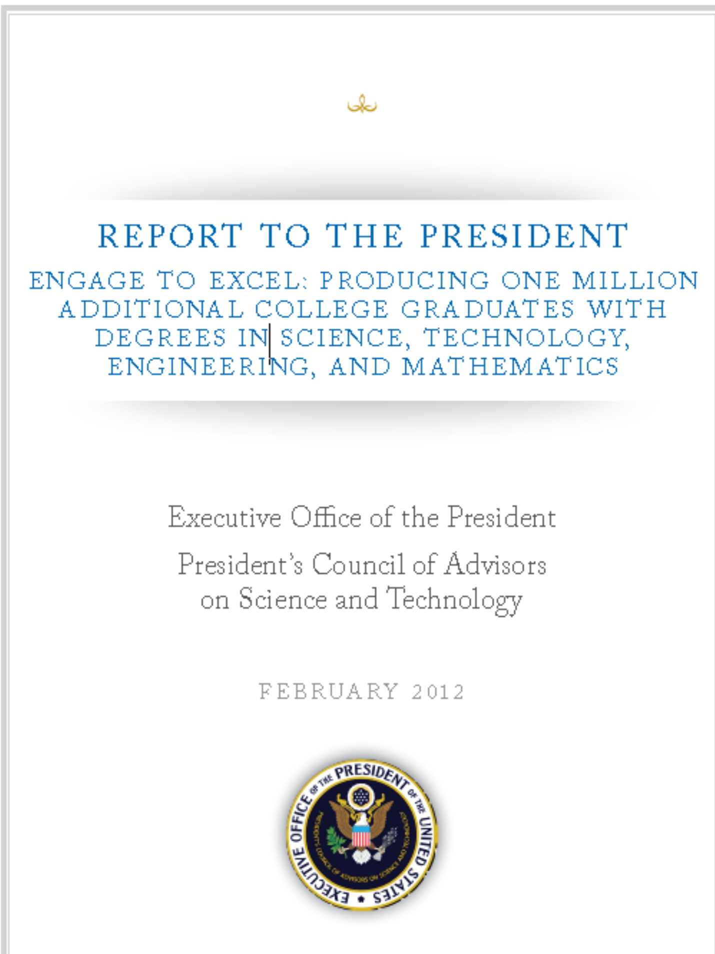
Ought we to have investigated whether there exists a point of diminishing returns—a line beyond which too much publication, too much specialization, becomes intellectually counterproductive?

Why did we fail to examine the long-term impact on both students and scholars of having the latter so singularly focused on publishing?

Why did we invest so little thought in puzzling through how teaching excellence could result in tenure?

The Future of Undergraduate Education Depends on the Future of Graduate Education

Undergraduate Research Experiences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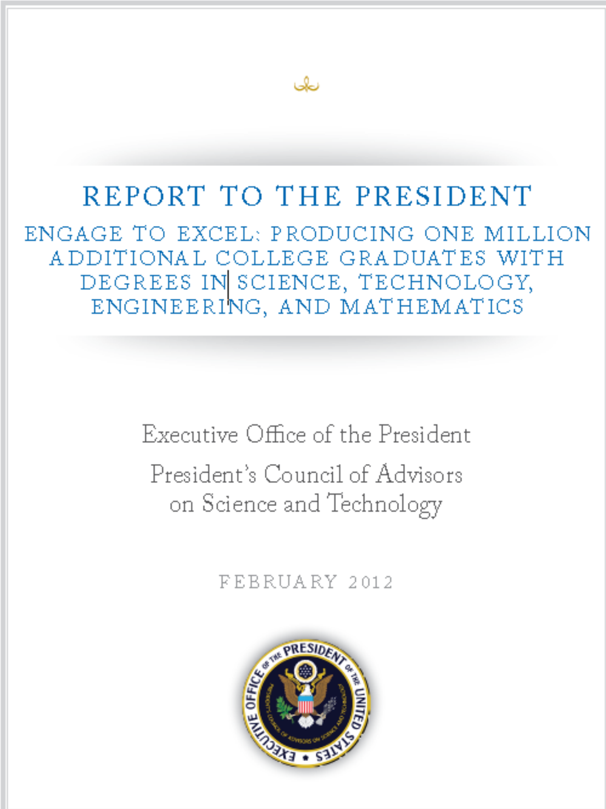
Traditional introductory laboratory courses generally do not capture the creativity of STEM disciplines. They often involve repeating classical experiments to reproduce known results, rather than engaging students in experiments with the possibility of true discovery. Students may infer from such courses that STEM fields involve repeating what is known to have worked in the past rather than exploring the unknown.



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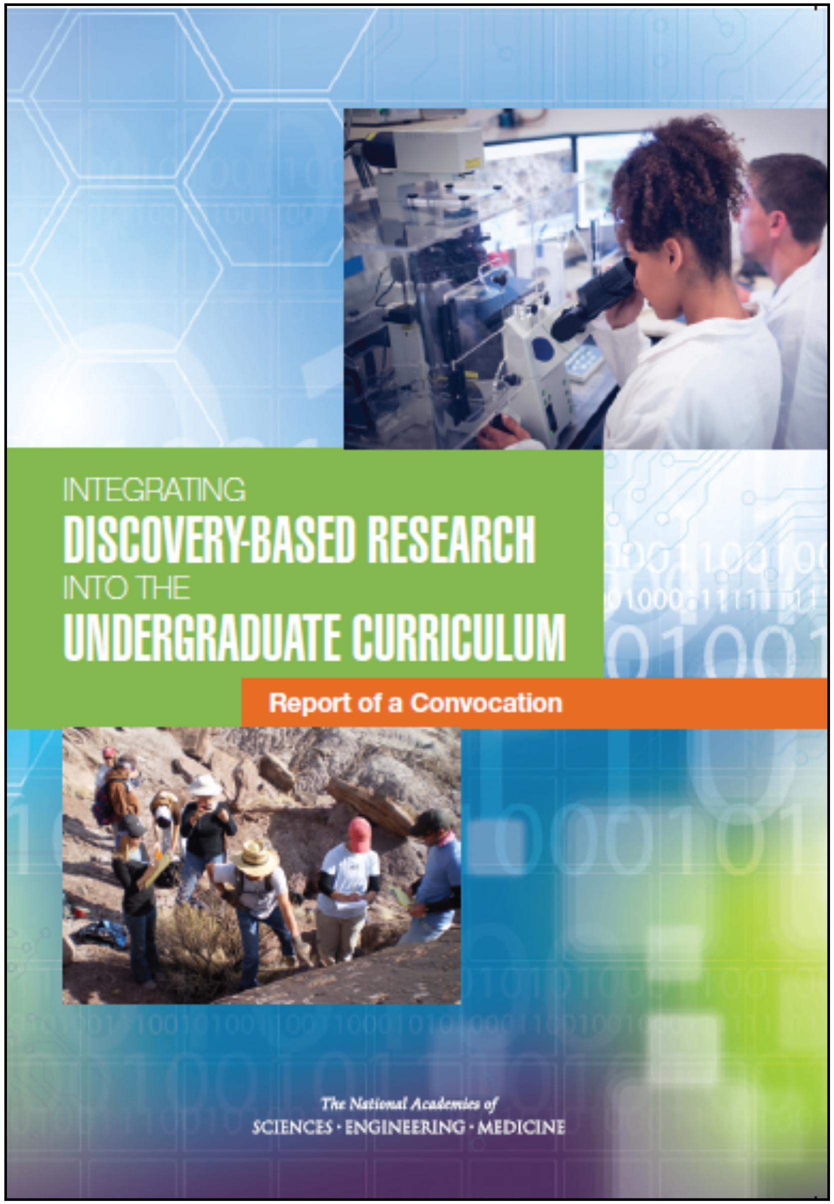
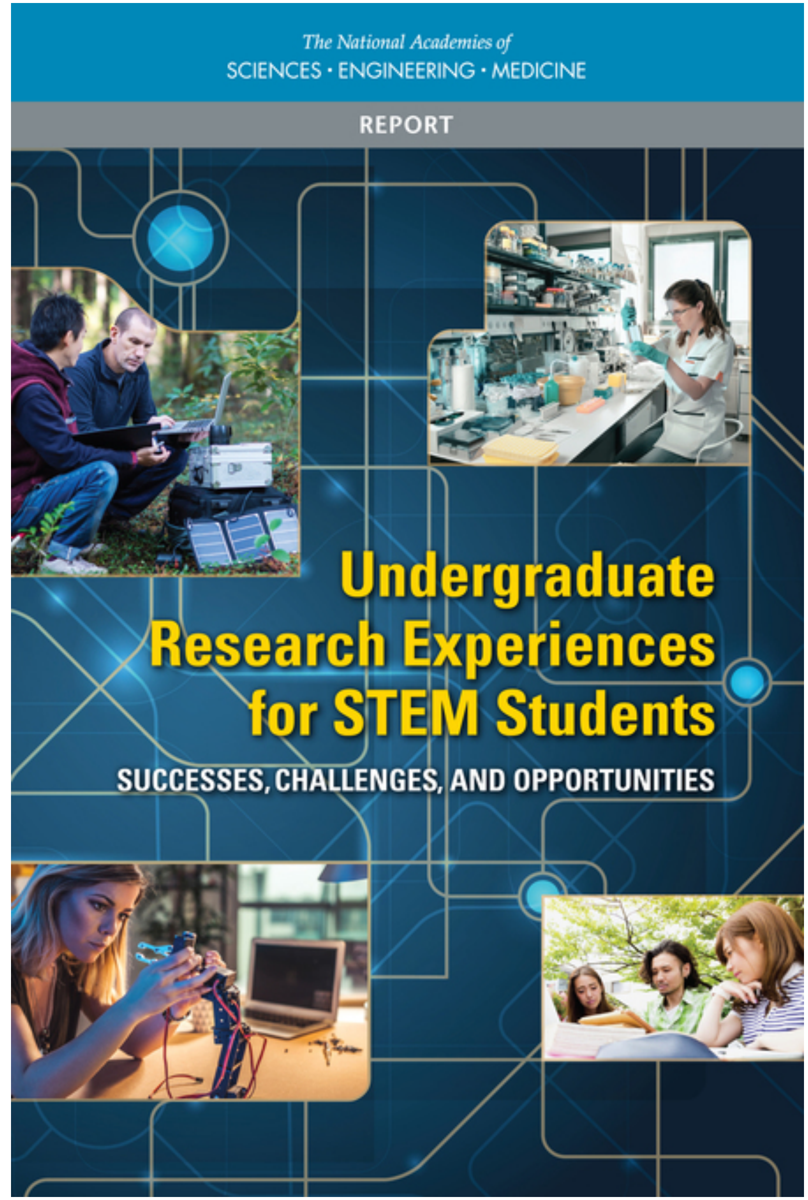
Recommendation 2.
Advocate and provide support for replacing standard laboratory courses with discovery-based research courses.

1. Students should know that they are engaged in a real scientific problem.
2. Students should know that the work they are doing matters to the scientific community.
3. Students should know how their discoveries are contributing to the field.

David Asai, NRC Conference on Implementing Discovery-Based Approaches in Undergraduate STEM Education, May 2015



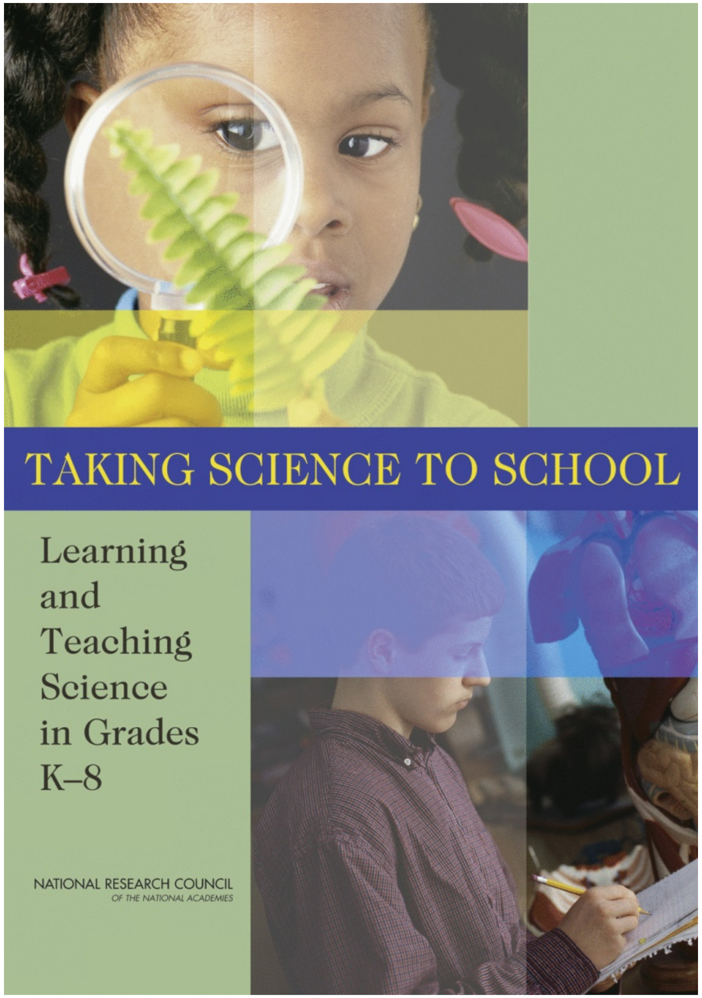


Both available at http://nap.edu

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)

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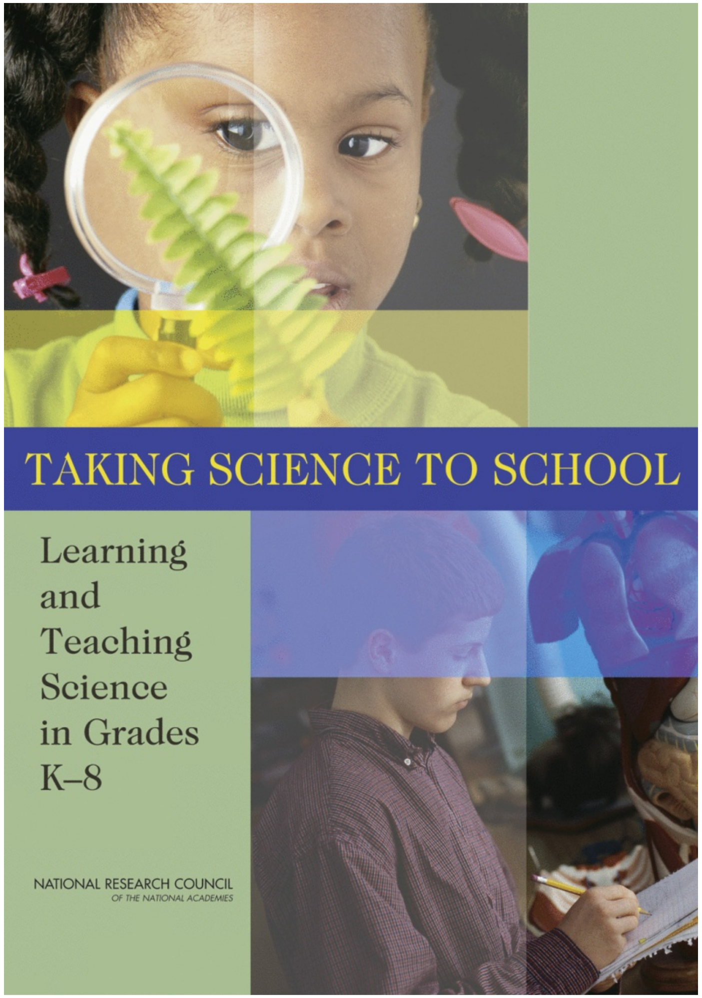
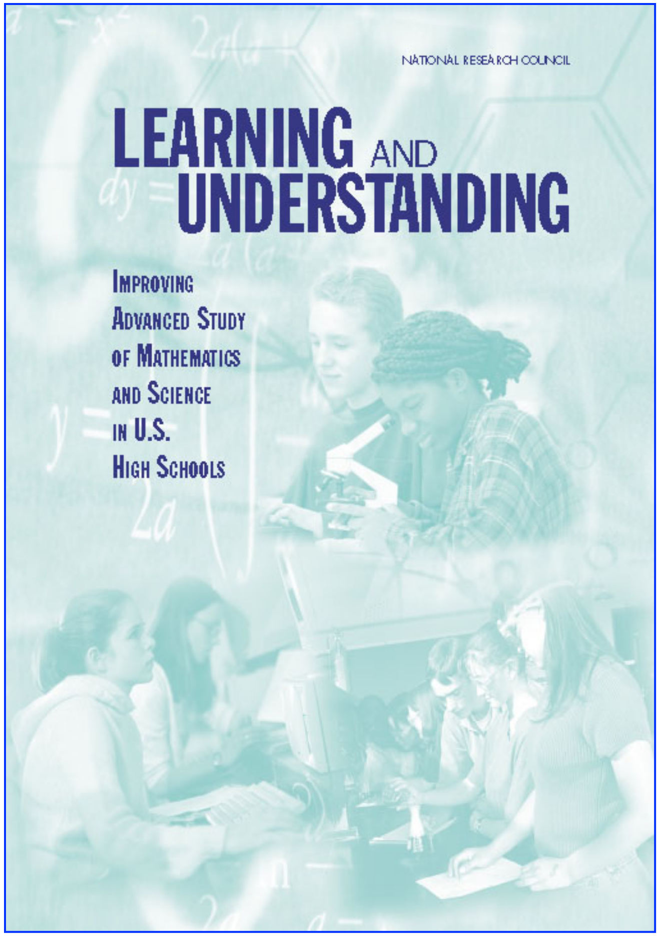


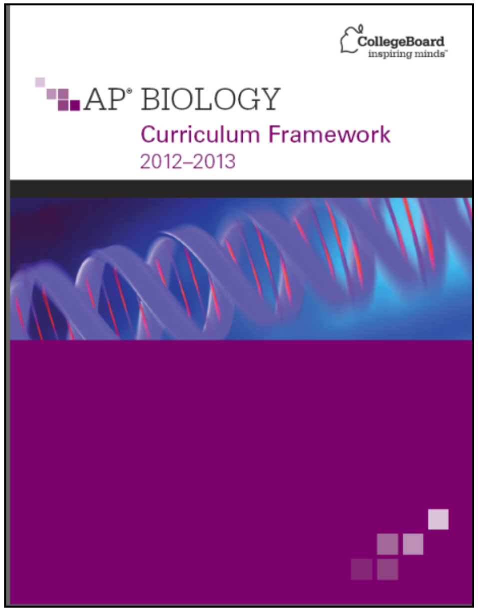
National Research Council (2007)

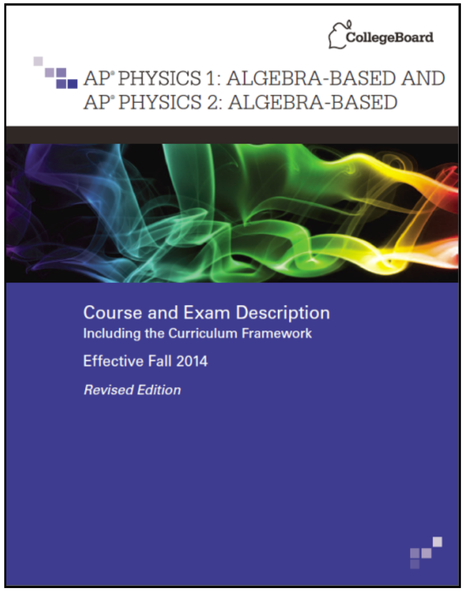
AP Redesign

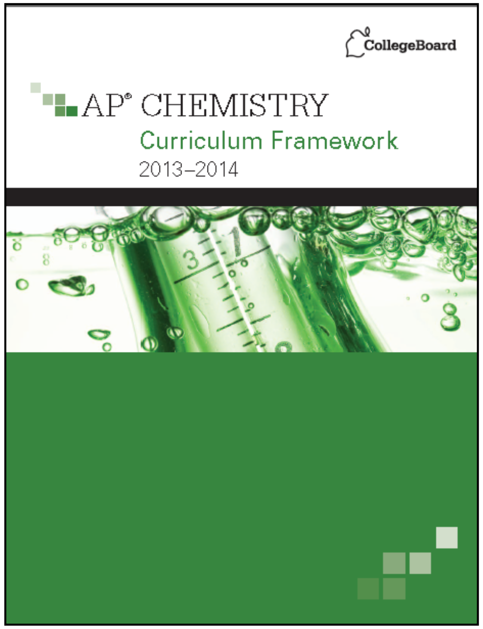
Biology, Chemistry, Environmental Science, Physics (2012-16)



NRC (2002)







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.

Try a college-level biology question

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

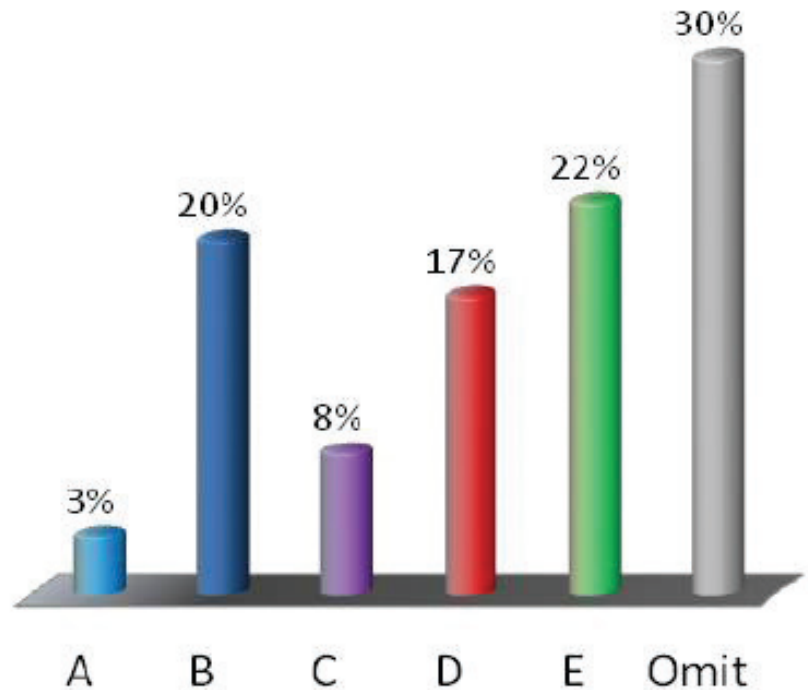
A. Prothalli

B. Fronds

C. Stipes

D. Roots

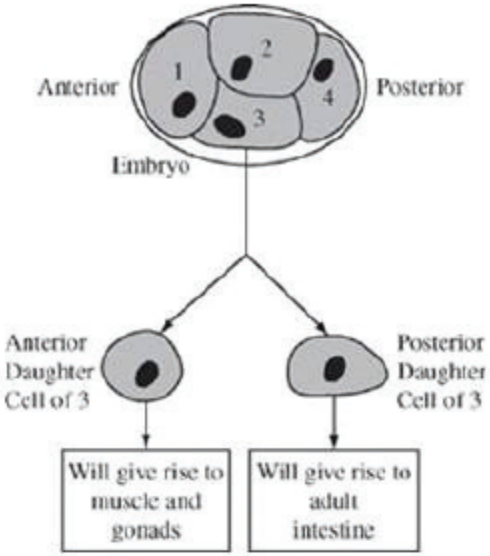
E. Rhizomes



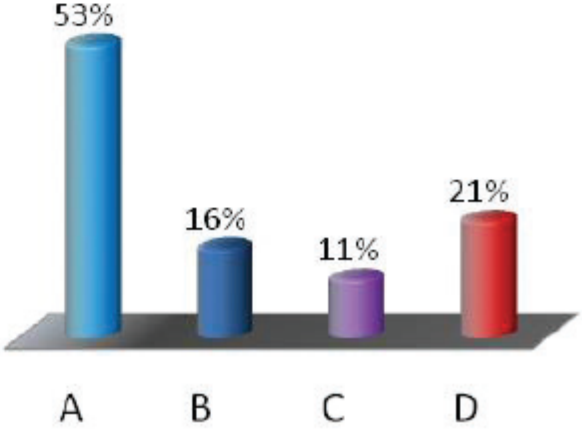
AP

Now try this college-level biology question:

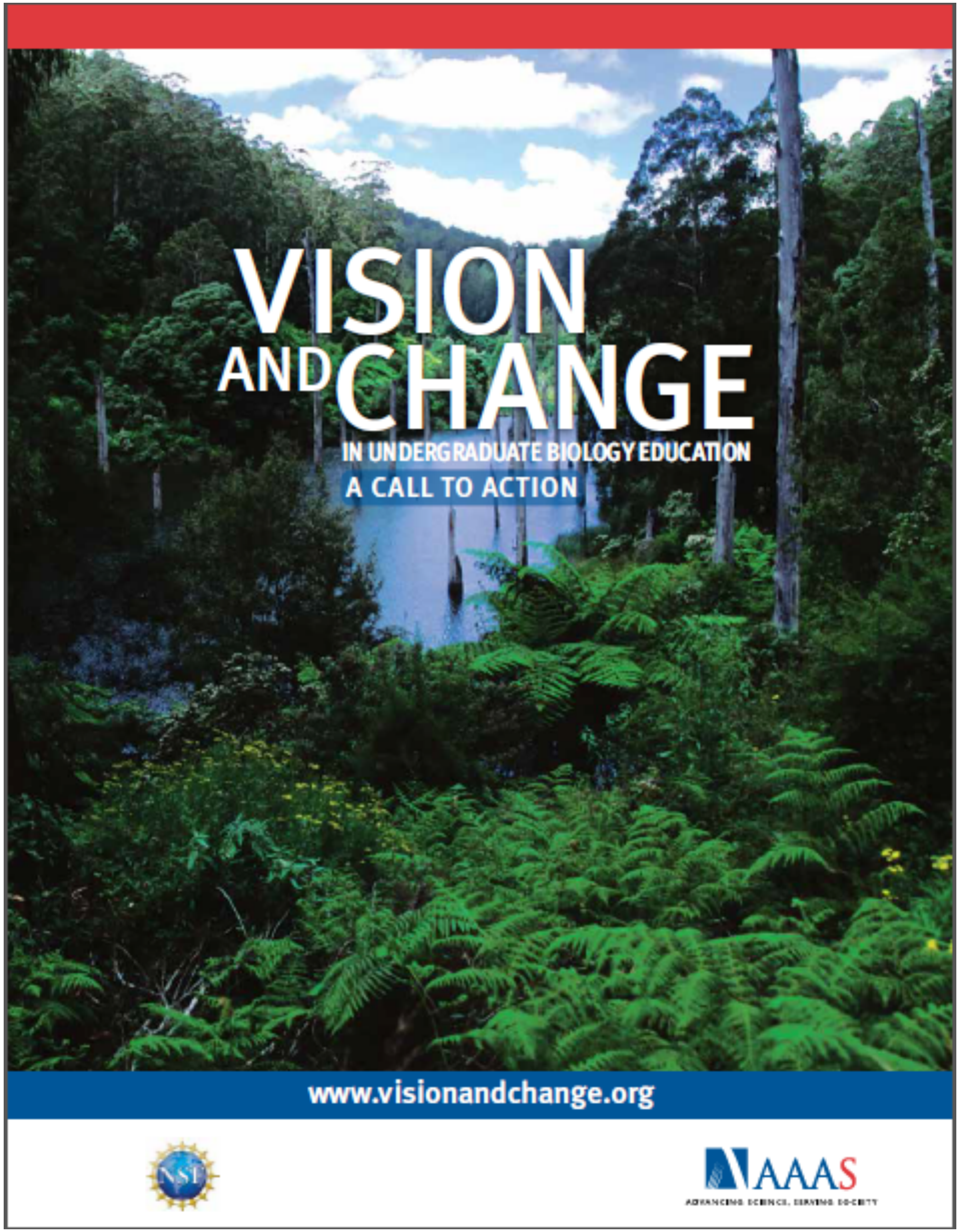
The diagram at right shows a developing worm embryo at the four-cell stage. Experiments have shown that when cell 3 divides, the anterior daughter cell gives rise to muscle and gonads and the posterior daughter cell gives rise to the intestine. However, if the cells of the embryo are separated from one 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.



CollegeBoard



http://visionandchange.org

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.

Common Core State Standards in English/Language Arts (Released in 2010)

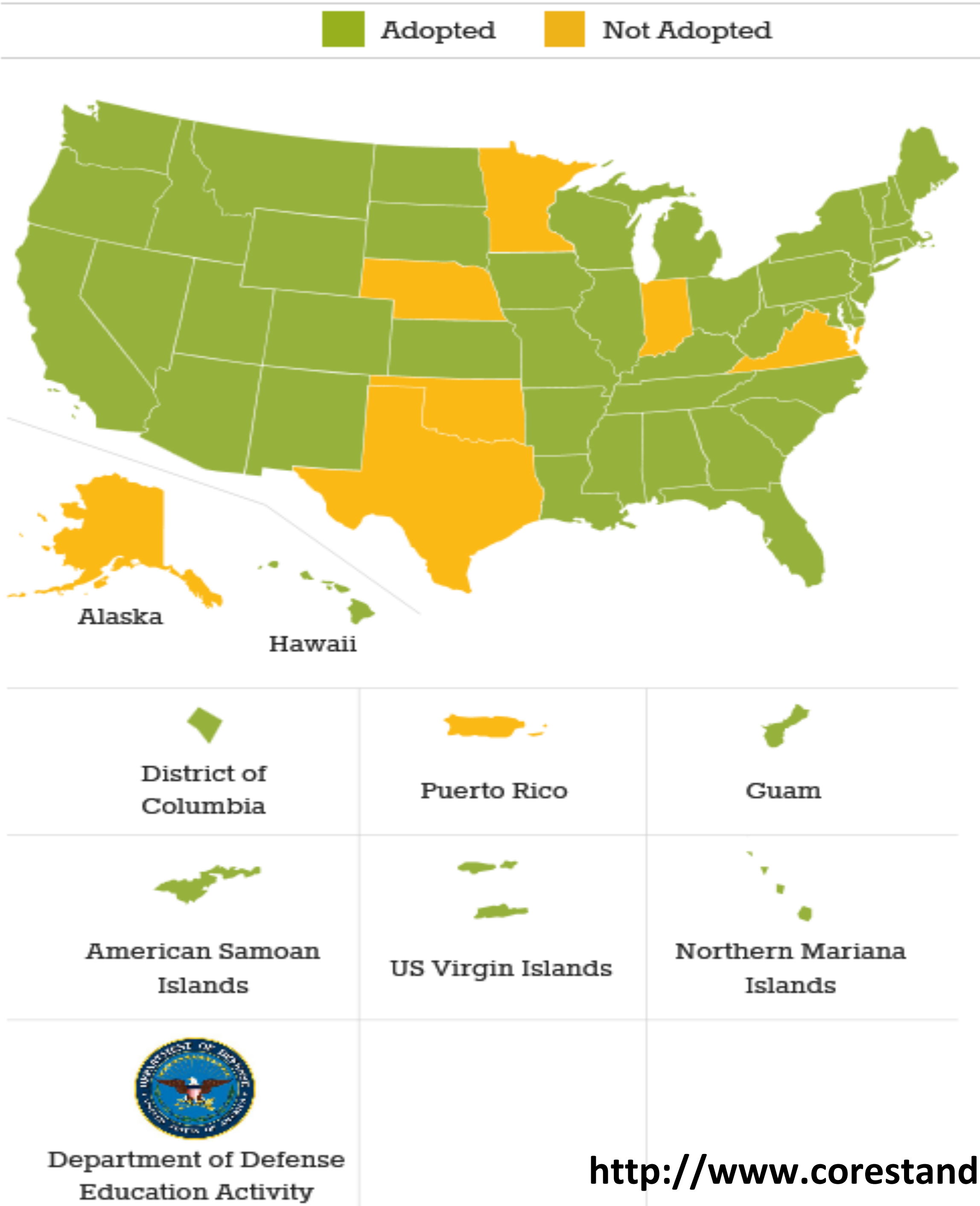
&

Next Generation Science Standards (Released in 2013)

COMMON CORE
STATE STANDARDS INITIATIVE
PREPARING AMERICA'S STUDENTS FOR COLLEGE & CAREER

NEXT GENERATION
SCIENCE
STANDARDS

Adoption of the Common Core State Standards in English/ Language Arts and Mathematics



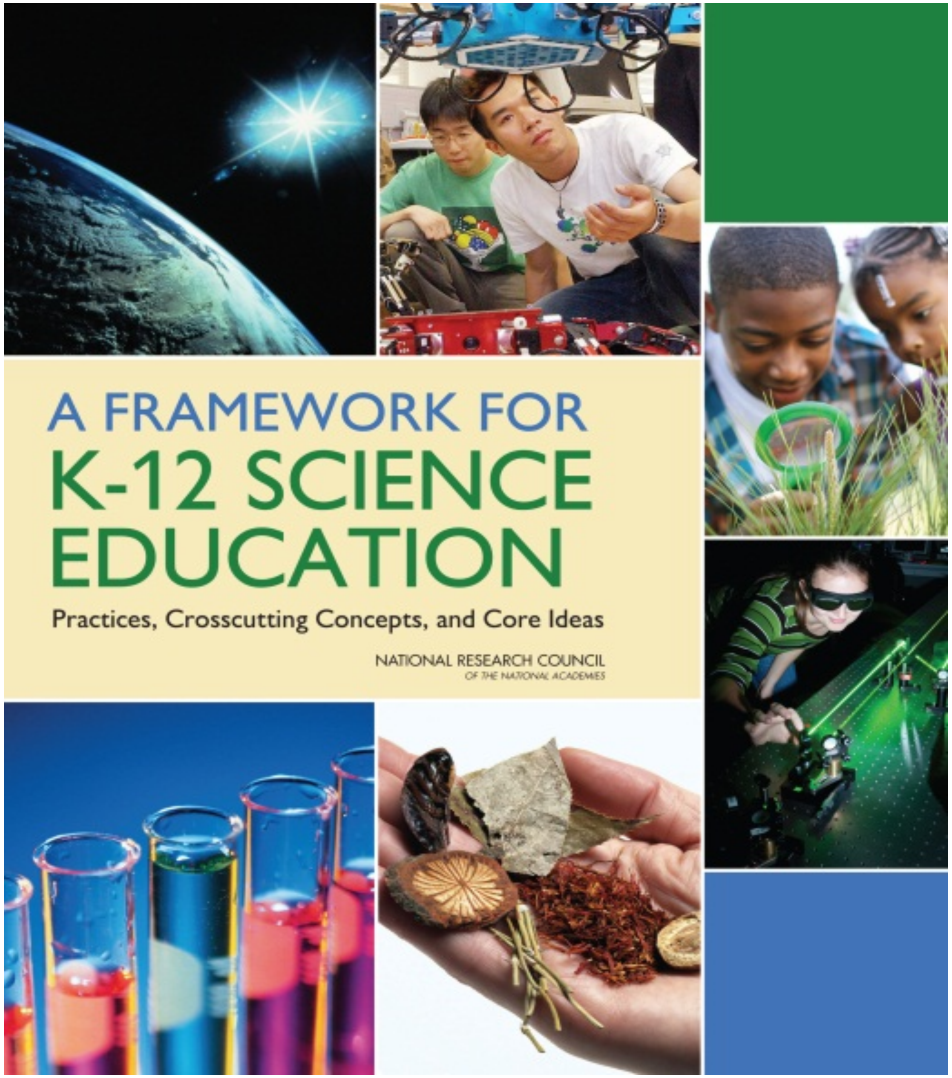
http://www.corestandards.org/standards-in-your-state/

Science and Engineering Practices

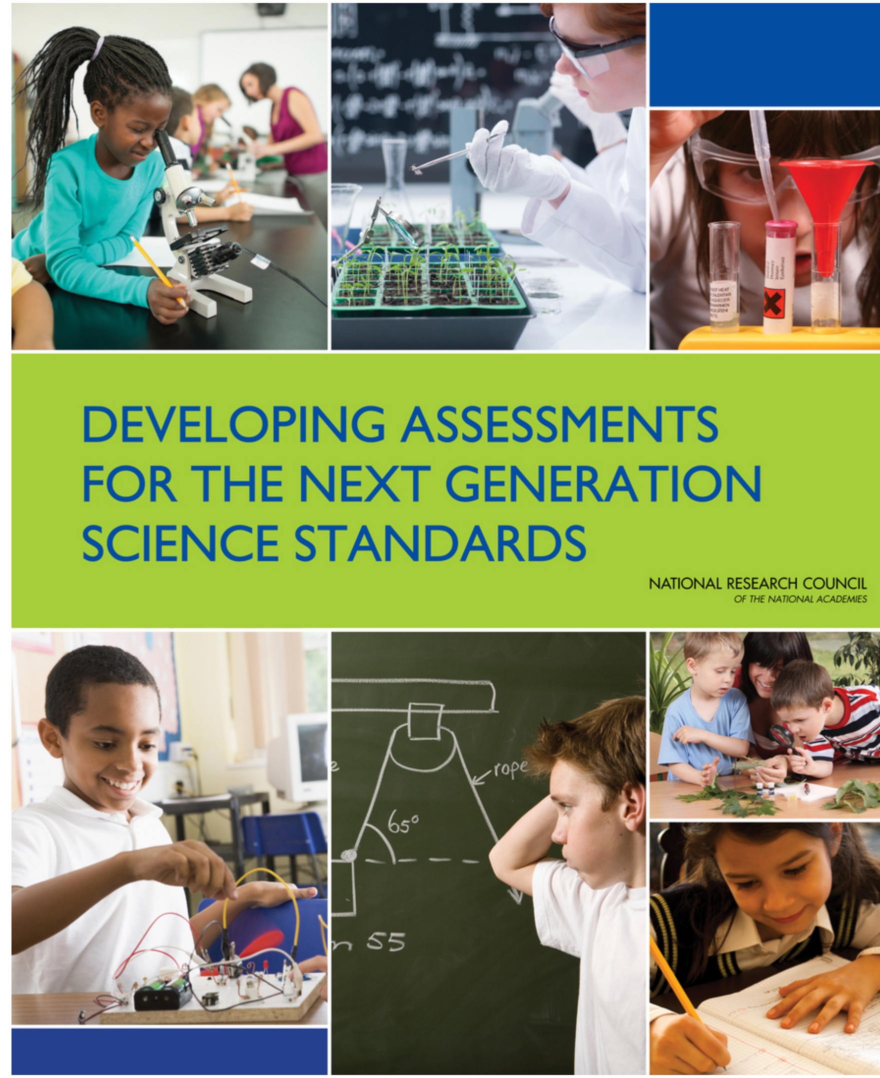
Disciplinary Core Ideas

Crosscutting Concepts

NEXT GENERATION SCIENCE STANDARDS



National Research Council 2012



National Research Council 2013

Dimensions of the Framework

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

NEXT GENERATION SCIENCE STANDARDS

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

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

NEXT GENERATION SCIENCE STANDARDS

Similarities in Thinking

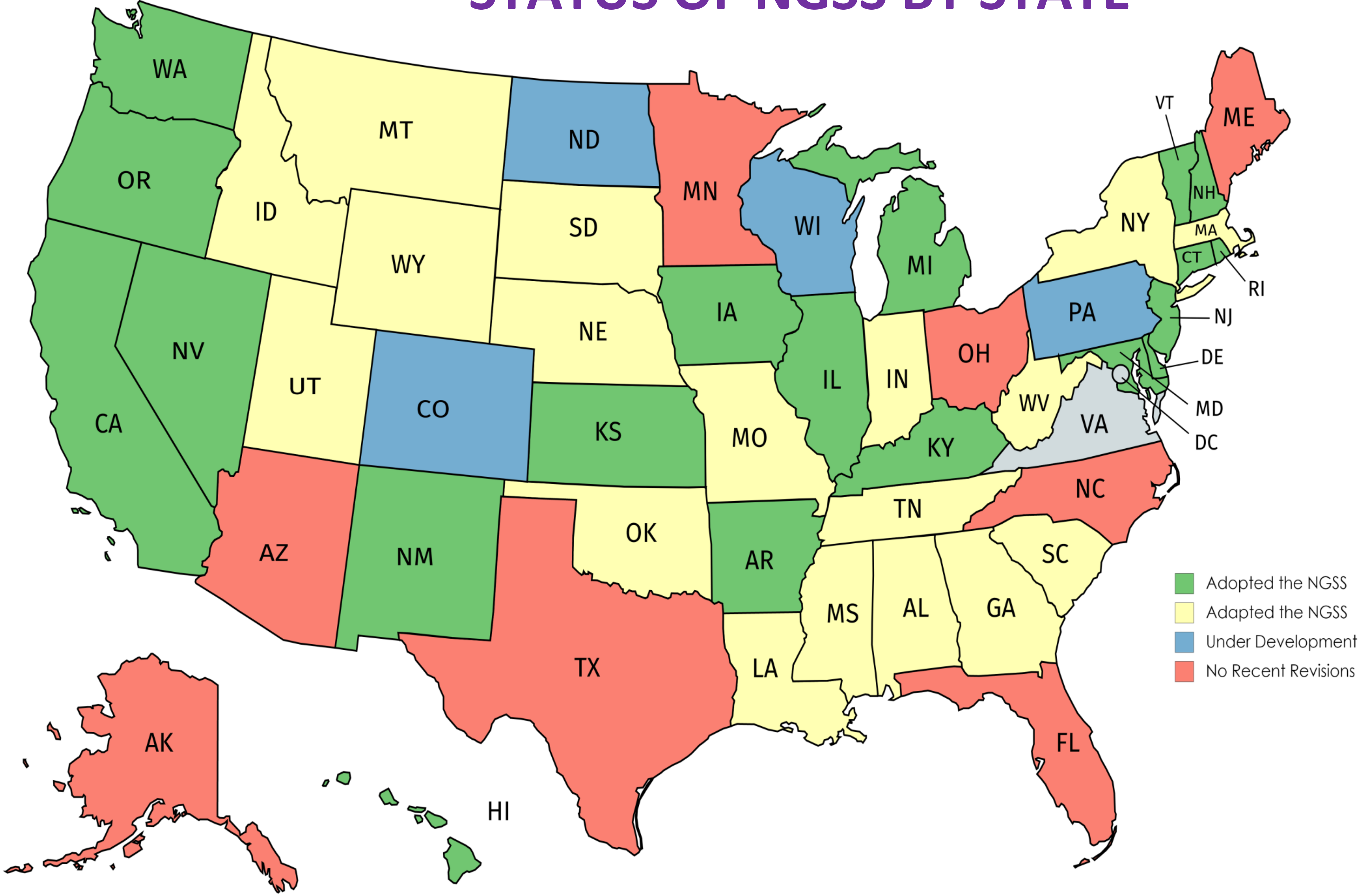
AP Evidence of Learning

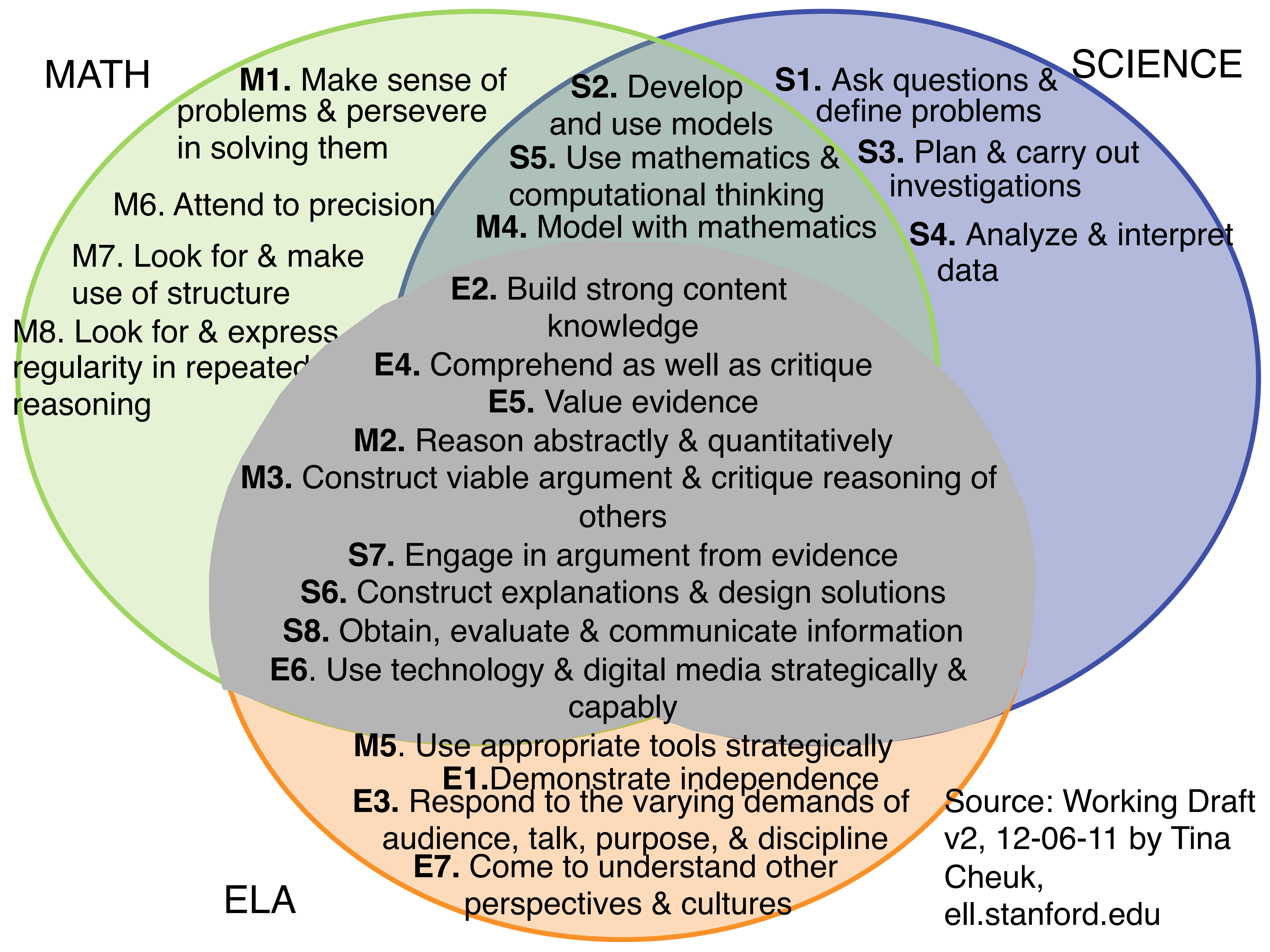
1. The student can use representations and models to communicate scientific phenomena and solve scientific problems.
2. The student can use mathematics appropriately
3. The student can engage in scientific questioning
4. The student can perform data analysis and evaluation of evidence
5. The student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

NGSS Crosscutting Concepts

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.

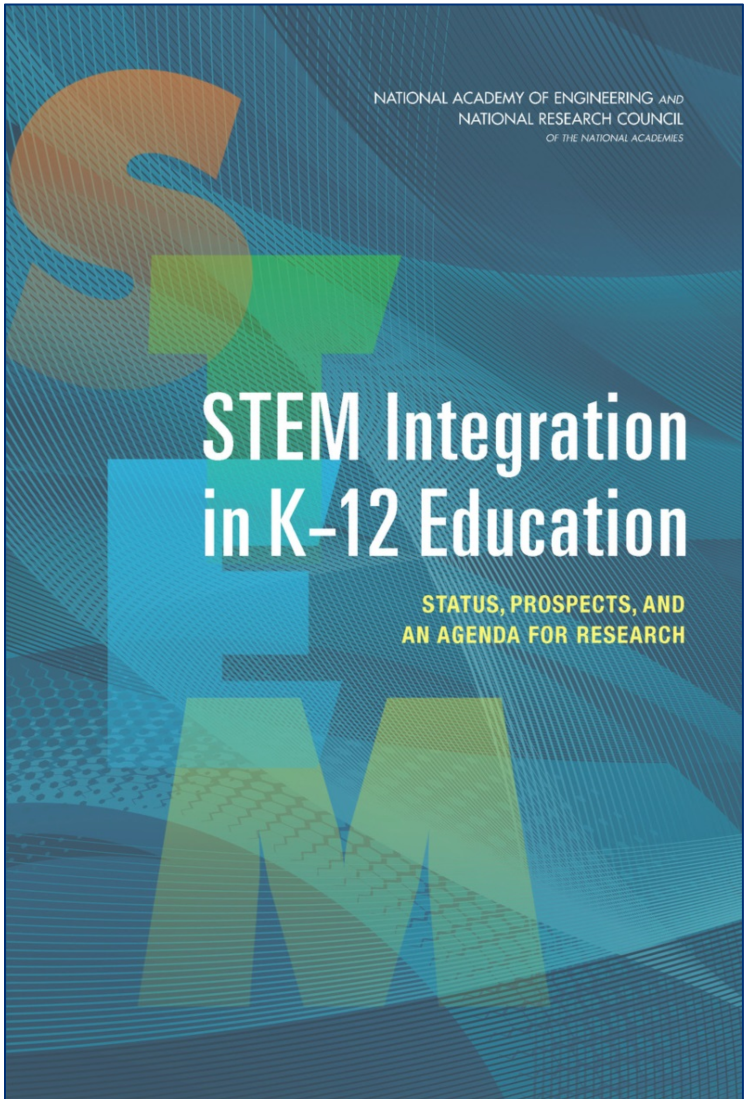
STATUS OF NGSS BY STATE

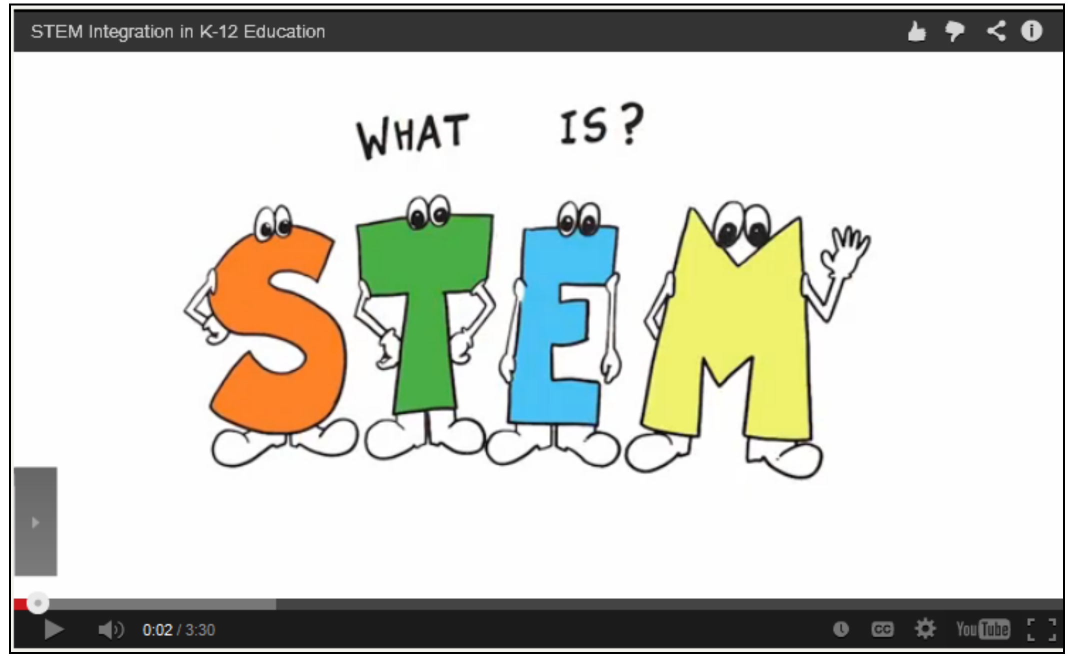




MATH
SCIENCE
ELA
M1. Make sense of problems & persevere in solving them
M6. Attend to precision
M7. Look for & make use of structure
M8. Look for & express regularity in repeated reasoning
S2. Develop and use models
S5. Use mathematics & computational thinking
M4. Model with mathematics
S1. Ask questions & define problems
S3. Plan & carry out investigations
S4. Analyze & interpret data
E2. Build strong content knowledge
E4. Comprehend as well as critique
E5. Value evidence
M2. Reason abstractly & quantitatively
M3. Construct viable argument & critique reasoning of others
S7. Engage in argument from evidence
S6. Construct explanations & design solutions
S8. Obtain, evaluate & communicate information
E6. Use technology & digital media strategically & capably
M5. Use appropriate tools strategically
E1. Demonstrate independence
E3. Respond to the varying demands of audience, talk, purpose, & discipline
E7. Come to understand other perspectives & cultures
Source: Working Draft v2, 12-06-11 by Tina Cheuk, ell.stanford.edu

Marching Toward STEM





Both available without cost at http://www.nap.edu/catalog/18612

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."

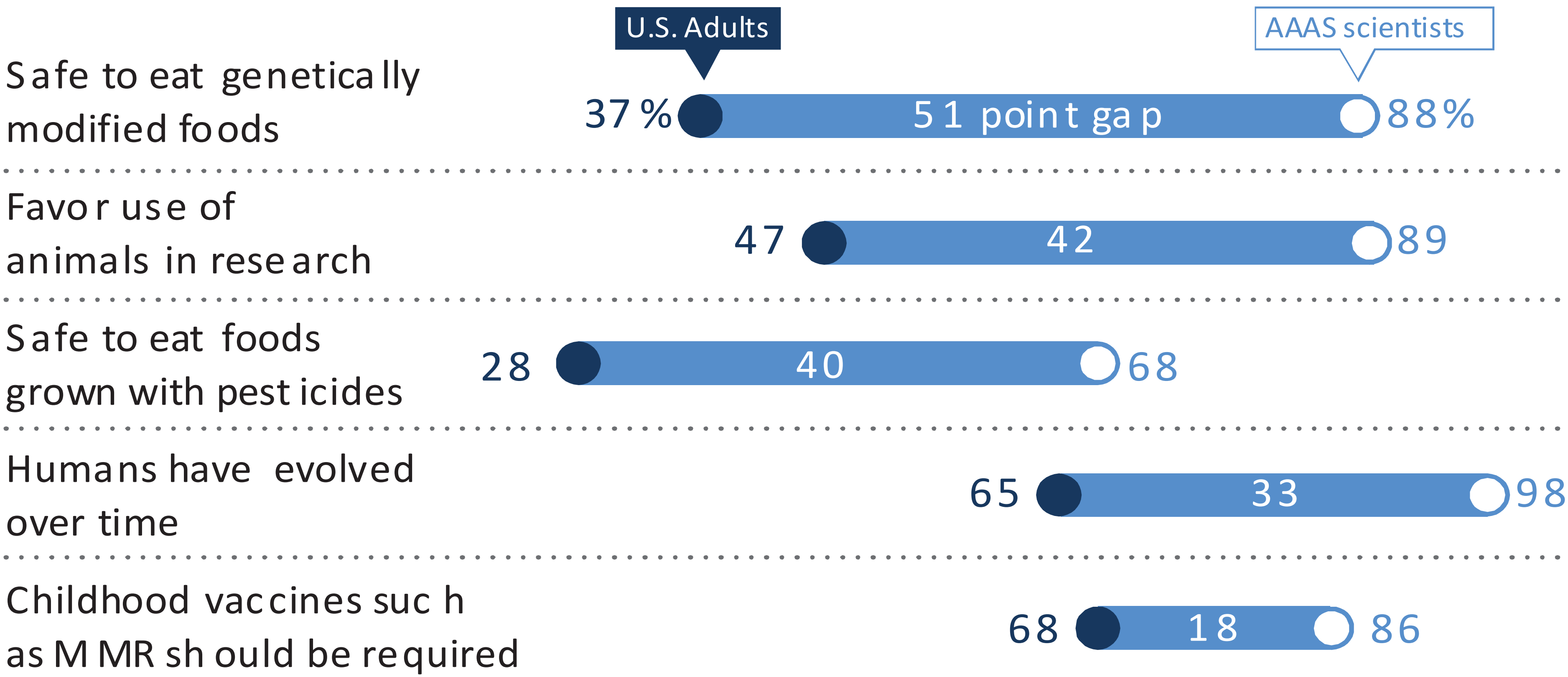
National Research Council (1998)

Science isn't a tall stack of hard facts; it's a difficult and deeply human process that lurches toward an approximation of the truth.

Joel Achenbach
Washington Post, page A1
July 24, 2014

http://www.washingtonpost.com/national/health-science/bicep2-experiments-big-bang-controversy-highlights-challenges-for-modern-science/2014/07/23/707bc9e6-02c6-11e4-b8ff-89afd3fad6bd_story.html

Gaps Between AAAS Scientists and Engineers and the Public on Biomedical Science Topics



Source: Pew Research Center surveys 2014

Thank you!