Engage to Excel:

A National Mandate for Science Education

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Goals for Today

- Know the findings and recommendations of “Engage to Excel”
- Know the type of evidence on which active learning is based
- Know of some resources to effect change in teaching
- Be prepared for the skeptics

Engage to Excel:

Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics

The President's Council of Advisors on Science and Technology

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REPORT TO THE PRESIDENT

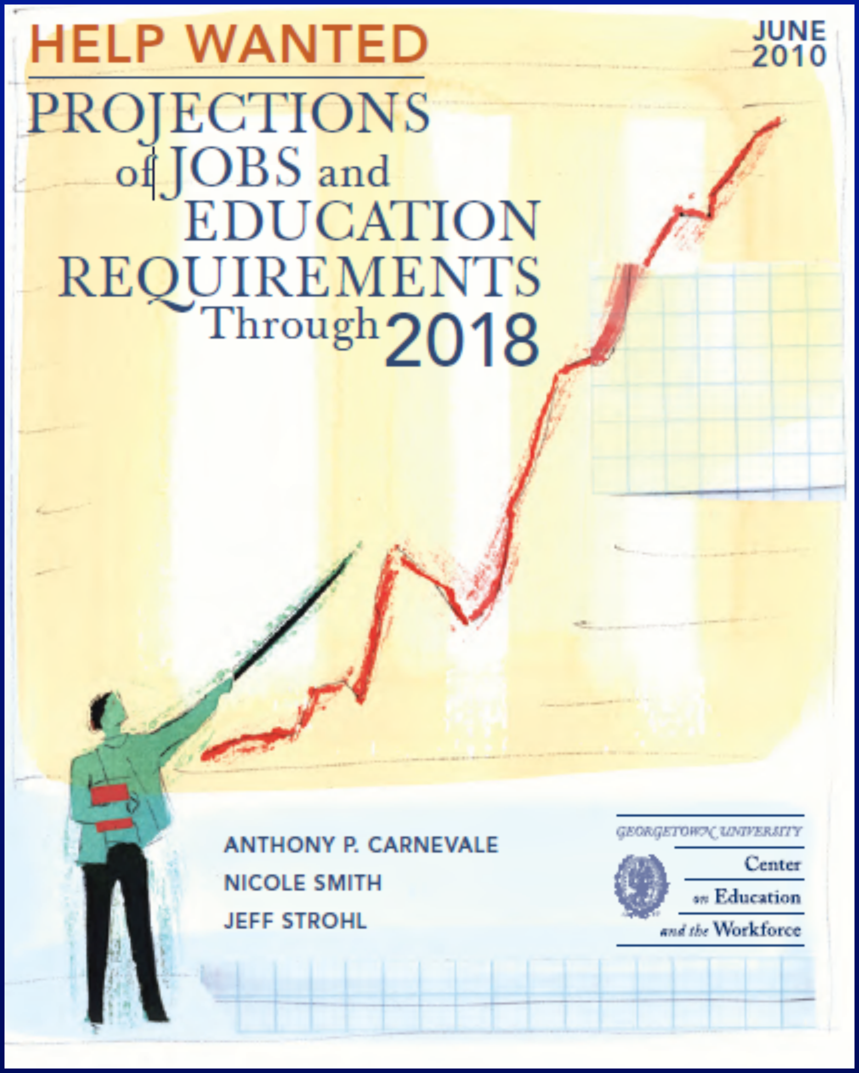
ENGAGE TO EXCEL: PRODUCING ONE MILLION ADDITIONAL COLLEGE GRADUATES WITH DEGREES IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

Executive Office of the President

President's Council of Advisors on Science and Technology

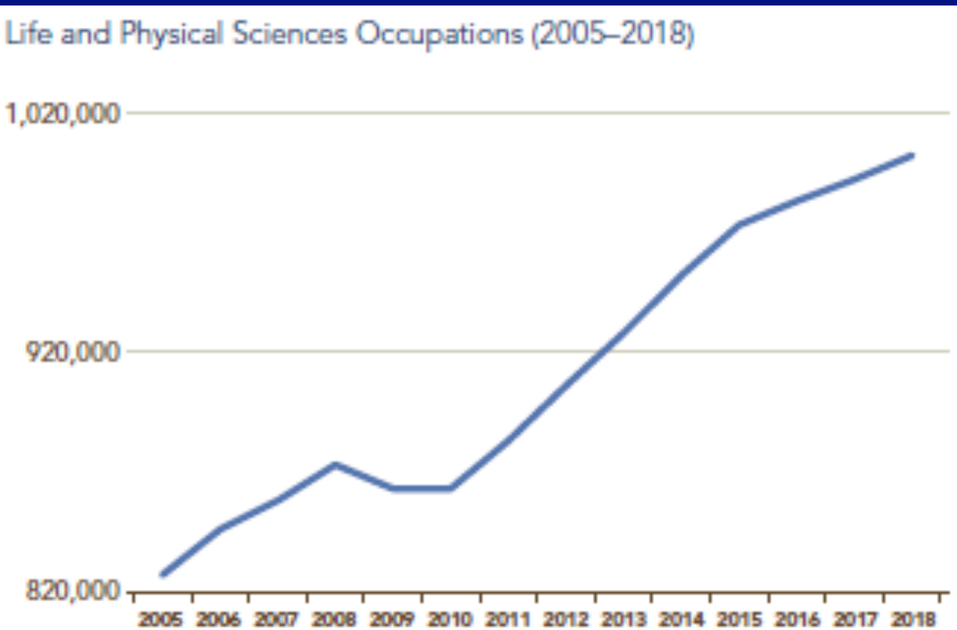
JANUARY 2012

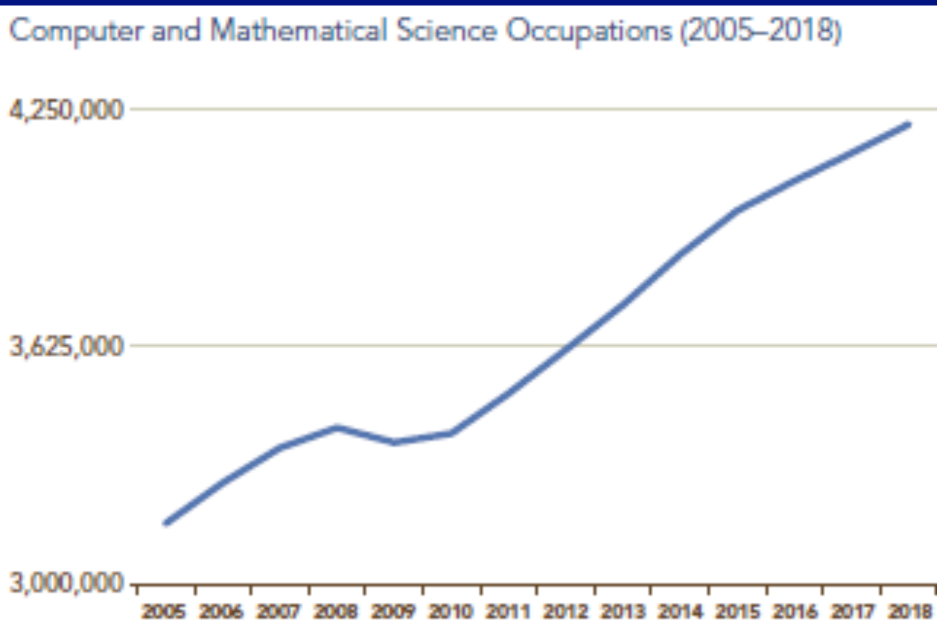
Reasons For Change



- Jobs for STEM college graduates one of the fastest growing sectors of workforce
- Need 1 million more STEM workers by 2018

Most STEM occupations predicted to grow rapidly between now and 2018





Reasons For Change

- Inability of science students to engage in conceptual & analytical thinking
- Poor retention of knowledge (10-20% lecture content)

1 million STEM college graduates beyond current production rates by 2022

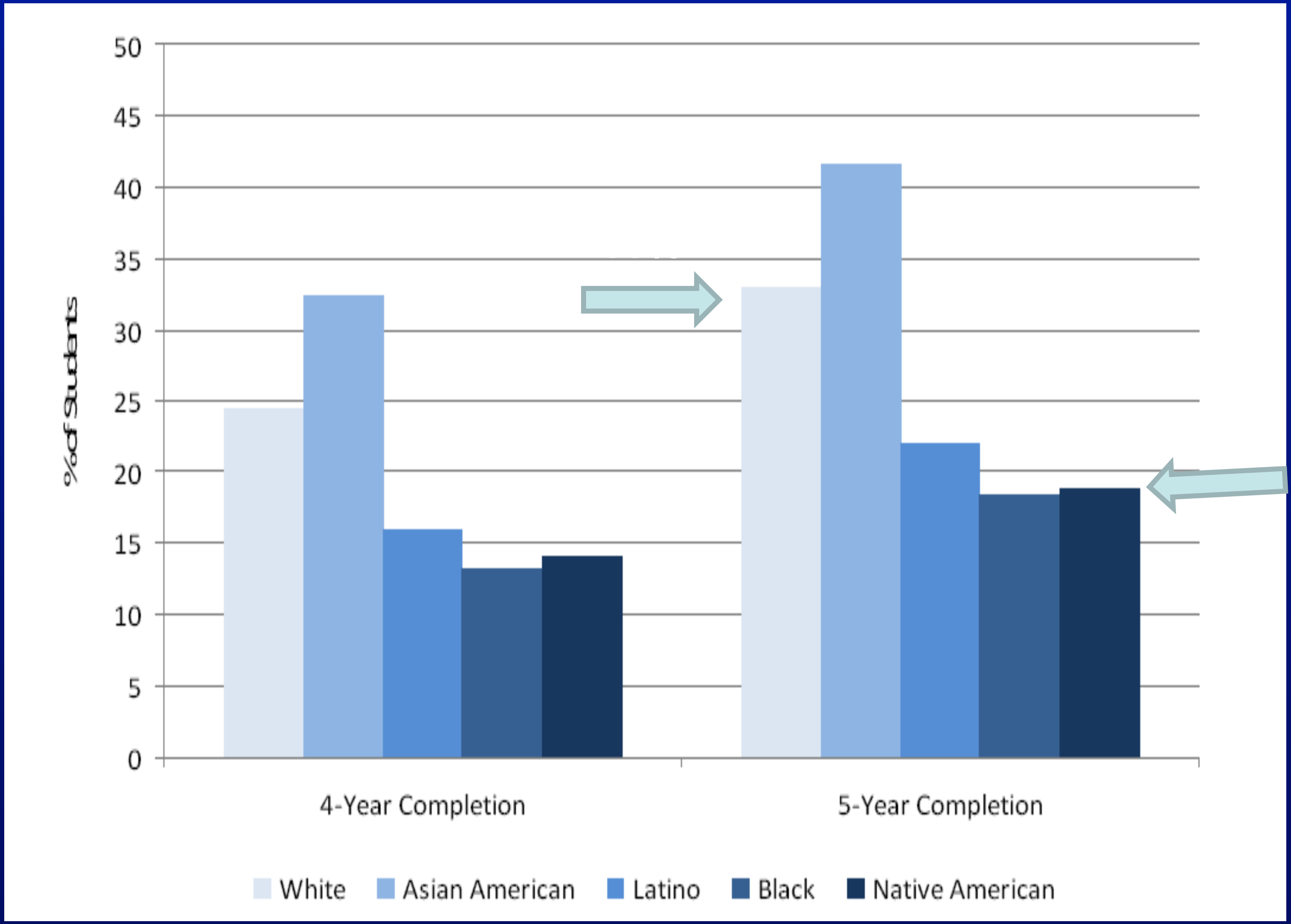
- 100,000/year above current production
- Represents a 34% increase above current 290,000 STEM graduates/year
- Most BS, some Associate degrees

How do we meet the need for an additional 1 million STEM college graduates?

A Challenge and Opportunity

>60% of the students who start college intending to major in STEM graduate with degrees in STEM

Percentage of 2004 STEM Aspirants Nationally Who Completed STEM Degrees In Four and Five Years, by Race/Ethnicity



Source: University of California Los Angeles, Higher Education Research Institute

Fewer than 40% of students who intend to complete a STEM college degree

- **High-performing students** resons for leaving
  - Uninspiring introductory STEM courses
  - Unwelcoming atmosphere from faculty in STEM courses
- **Low-performing students** w/ interest and aptitude…
  - Weed-out mentality
  - difficulty with the math
- **Underrepresented majority** – same issues intensified

Where do we find 1 million more STEM-trained workers by 2022?

Pick the low-hanging fruit

CONCLUSION

Increasing retention from 40% to 50% would generate almost three-quarters of the one million additional STEM degrees needed in the next decade.

Imperatives to Improve STEM Undergraduate Education

Based on extensive research about students' choices, learning processes, and preparation, three imperatives underpin this report:

- Improve the first two years of STEM education in college.
- Provide all students with the tools to excel.
- Diversify pathways to STEM degrees.

Our recommendations detail how to convert these imperatives into action.

Based on evidence-based teaching or "scientific teaching"

"Engage to Excel" Recommendations

1. Catalyze widespread adoption of empirically validated teaching practices.
2. Advocate and provide support for replacing standard laboratory courses with discovery-based research courses.
3. Launch a national experiment in postsecondary mathematics education to address the math-preparation gap.
4. Encourage partnerships among stakeholders to diversify pathways to STEM careers.
5. Create a Presidential council on STEM education with broad leadership.

Recommendation #1

Catalyze widespread adoption of empirically validated teaching practices.

Diverse active learning methods enhance learning

Backward Design

- Set learning goals
- Design Assessments
- Determine whether students meet learning goals

Active Learning

Fast = Rapid

Fast = R__p__d

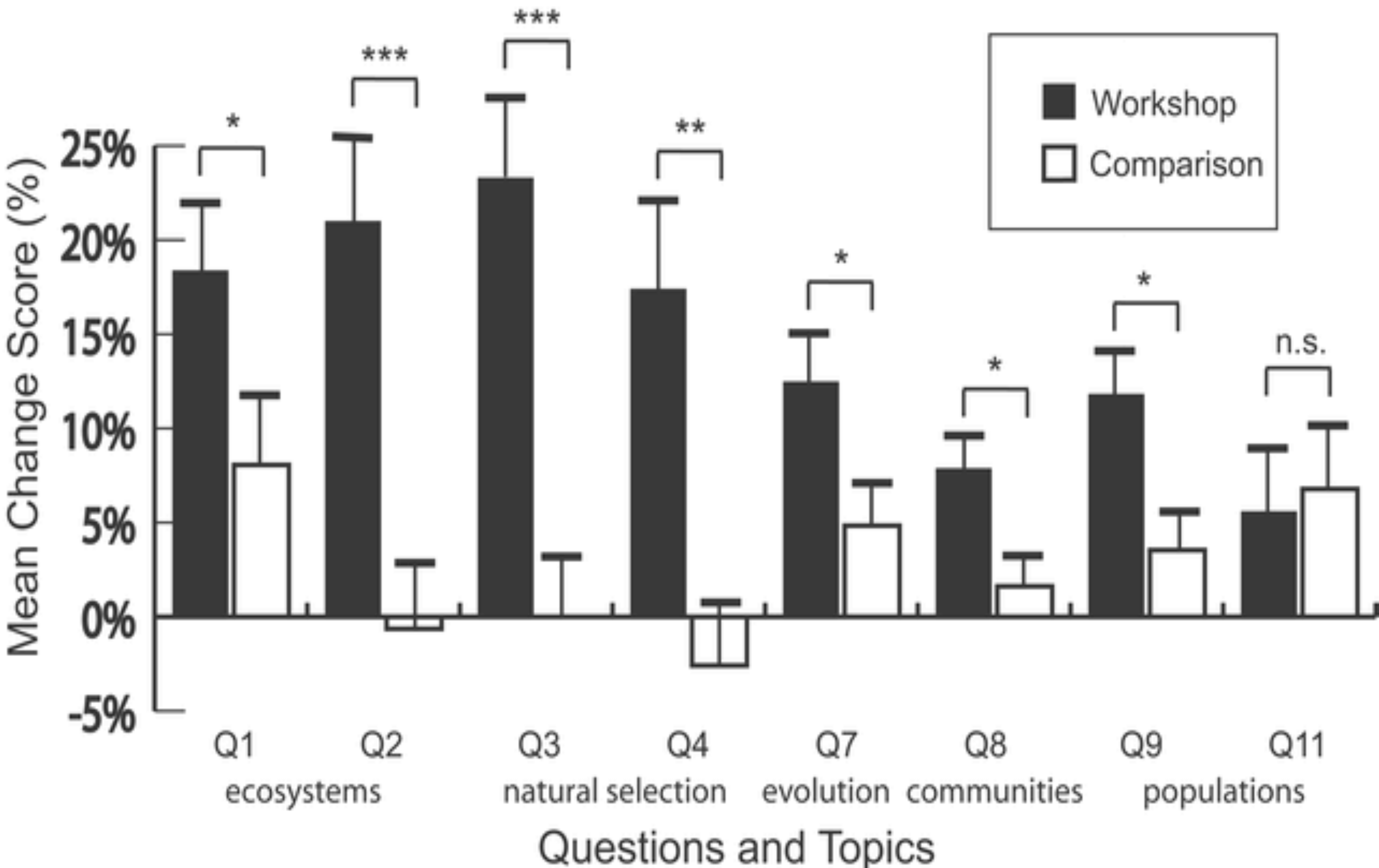


*Figure 2. Mean change scores on spring 1993 concept test, by question. Error bars represent one standard error (*p<0.05; **p< 0.01; ***p<0.001; n.s. p> 0.05).*

Achieving Engagement with Active Learning

Physics Courses

- **Active Learning vs. Traditional Methods**
- **Assessed with common test – Force Concept Inventory**

N = 6,542 students, 62 courses

Average gain with active learning two SD above traditional format

Hake, 1998

Achieving Engagement with Active Learning

- Felder, 1998
  - Students in traditional lecture course twice as likely to leave engineering and three times as likely to drop out of college entirely as those taught with active methods

Evidence that Engagement Increases Learning and Retention (of students and information)

- Controlled studies in lab
- Epidemiological studies in the field
- Controlled studies in classrooms of each discipline

Table 1. Types of active learning that have been demonstrated to enhance learning (all studies cited compare treatment and control groups).

Types of active learning with feedback	Examples of studies that demonstrate enhanced learning
Small group discussion and peer instruction	McDaniel 2007a, b; Rivard 2000; Anderson 2005; Armbruster 2009; Armstrong 2007; Beichner; Buck; Christianson 99; Born 2002; Crouch and Mazur 2001; Fagan 2002; Lasry 2008; Lewis 2005; Tessier 2007 & 2004; Tien 2002;
Testing	Steele 2003;
One-minute papers	Rivard 2000; Almer 98; Chizmar 98;
Clickers	Wood; Smith 2007;
Problem-based learning	Capon 2004; Preszler 2007;
Case studies	Preszler 2009;
Analytical challenge before lecture	Schwartz and Bransford; 98
Group tests	Cortright 2003; Klappa 2009;
Problem sets in groups	Cortright 2005;
Concept mapping	Foncesca 2004; Prezler 2004; Yarden 2004;
Writing with peer review	Pelaez 2002;
Computer simulations and games	Harris 2009; McDaniel 2007; Traver 2001;
Mixture of active methods	Freeman 2007; O'Sullivan 2003;

Summary of Evidence

Resources/Active Learning Table

Recommendation #1
Catalyze widespread adoption of empirically validated teaching practices.

Premise:

Classroom practices that actively engage students promote learning better than lectures.

Actions:

- Train current and future faculty in evidence-based teaching.
  - National Academies Summer Institutes (biology)
  - APS course (physics)
  - Teaching Fellows Programs (MIT, Yale, Wisconsin, Colorado)

Recommendation #1

Catalyze widespread adoption of empirically validated teaching practices.

Premise:

Classroom practices that actively engage students promote learning better than lectures.

Actions:

- Train current and future faculty in evidence-based teaching.
- Provide grants to enable campuses to adopt new teaching practices.
- Develop metrics by which institutions can gauge their progress toward excellence in STEM education.

From Fringe to Mandate

1991 NSF teaching grant – active learning in UW non-majors biology

"your classroom is awfully noisy"

"do we need to teach biology for poets?"

1994 active learning in UW General Biology course

"I did fine with lectures, so there's no problem"

1995 TA training in pedagogy

"The students won't know the answer if I don't give it to them"

1998 Course – "Teaching Biology"

"This doesn't belong in a Biology Dept"

From Fringe to Mandate

2002 Received HHMI Professorship to integrate teaching and research

"We didn't get to vote on this"

2002 Chris Pfund and Sarah Miller

Program for Scientific Teaching

" ……… "

2010 Moved to Yale

"what is scientific teaching?"

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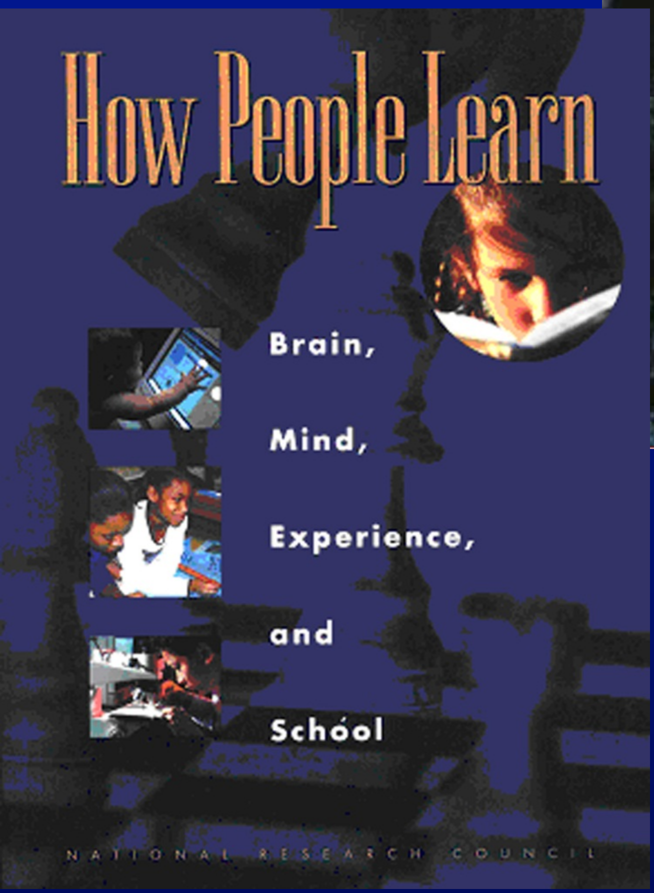
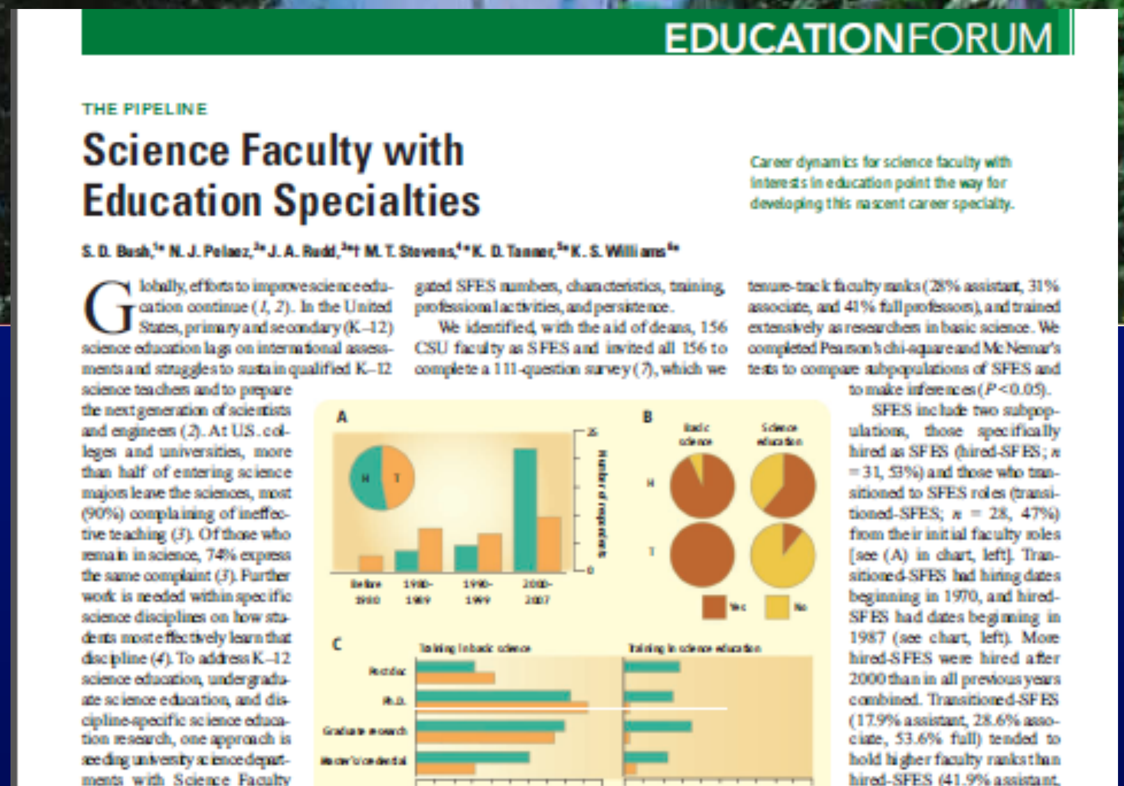
http://www.whitehouse.gov/ostp/pcast





EDUCATIONFORUM

THE PIPELINE

Science Faculty with Education Specialties

Career dynamics for science faculty with interests in education point the way for developing this nascent career specialty.

S. D. Bush,[1*] N. J. Pelaez,[2*] J. A. Rudd,[3*†] M. T. Stevens,[4*] K. D. Tanner,[5*] K. S. Williams[6*]

Globally, efforts to improve science education continue (1, 2). In the United States, primary and secondary (K–12) science education lags on international assessments and struggles to sustain qualified K–12 science teachers and to prepare the next generation of scientists and engineers (2). At U.S. colleges and universities, more than half of entering science majors leave the sciences, most (90%) complaining of ineffective teaching (3). Of those who remain in science, 74% express the same complaint (3). Further work is needed within specific science disciplines on how students most effectively learn that discipline (4). To address K–12 science education, undergraduate science education, and discipline-specific science education research, one approach is seeding university science departments with Science Faculty

gated SFES numbers, characteristics, training, professional activities, and persistence.

We identified, with the aid of deans, 156 CSU faculty as SFES and invited all 156 to complete a 111-question survey (7), which we

tenure-track faculty ranks (28% assistant, 31% associate, and 41% full professors), and trained extensively as researchers in basic science. We completed Pearson's chi-square and McNemar's tests to compare subpopulations of SFES and to make inferences ($P < 0.05$).

SFES include two subpopulations, those specifically hired as SFES (hired-SFES; n = 31, 53%) and those who transitioned to SFES roles (transitioned-SFES; n = 28, 47%) from their initial faculty roles [see (A) in chart, left]. Transitioned-SFES had hiring dates beginning in 1970, and hired-SFES had dates beginning in 1987 (see chart, left). More hired-SFES were hired after 2000 than in all previous years combined. Transitioned-SFES (17.9% assistant, 28.6% associate, 53.6% full) tended to hold higher faculty ranks than hired-SFES (41.9% assistant,

The World as You Enter It

PKAL

CIRTL

Wisconsin Program for Scientific Teaching

Center for Scientific Teaching at Yale

MIT Teaching & Learning Center

National Academies Summer Institute on Undergraduate Teaching in Biology

NRC Report “How People Learn”

Vision and Change

What do the skeptics say about the transformation of science education?

How do you answer?

So…. "The world has changed but why haven't my colleagues?"

An Opportunity Knocks!

"your classroom is awfully noisy"

Oh, yes it is! Let me tell you what one of my students said today….

"do we need to teach biology for poets?"

we do because we need more scientists and scientifically literate teachers and citizens

"I did fine with lectures, so there's no problem"

our students aren't all "you" -- just as we rely on diversity in scientific research, we can use diversity to strengthen our classrooms

Acknowledgments

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UNIV OF COLORADO

» Bill Wood

NSF (1991)

HHMI (2002)

PCAST and STEM ED Working Group

President Obama