Mathematical Sciences Education: what is wrong and why should you care?

2016 SIAM Annual Meeting, Boston

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14 July 2016

- Professor of Mathematics; Chair of Mathematics, Statistics, and Computer Science
- Member of Citizens Redistricting Commission
- AMS Congressional Fellow

"One of these things is not like the others, ♪ ♫
One of these things just doesn't belong,..." ♫ ♫

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"Changes can be implemented gradually, without taking too much time or causing unnecessary upheaval. . . . Even partial changes can significantly improve student learning."

(NRC, 2015)

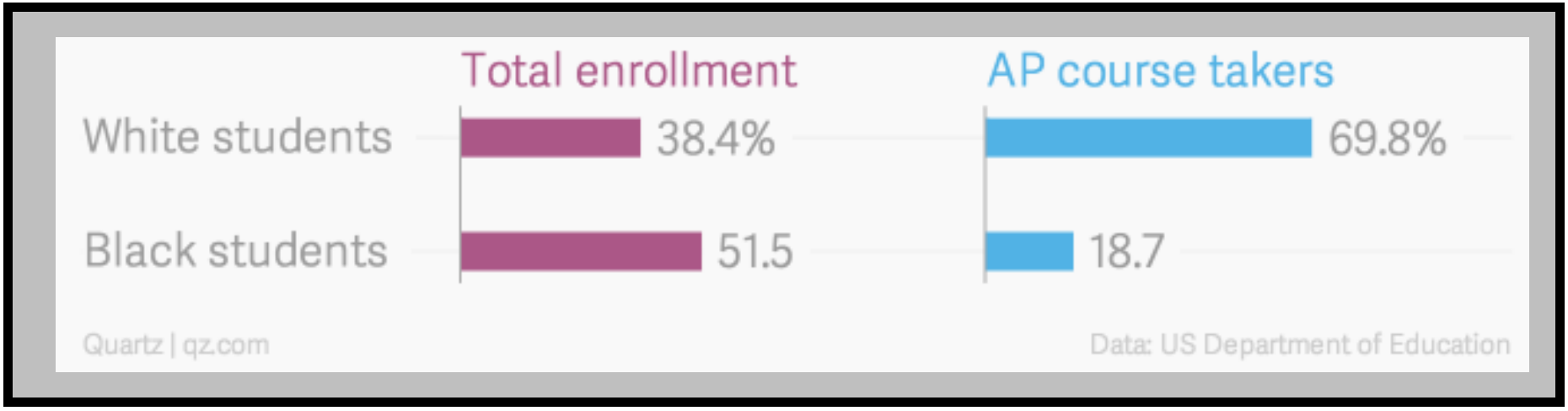
Introduction

a personal story

1966

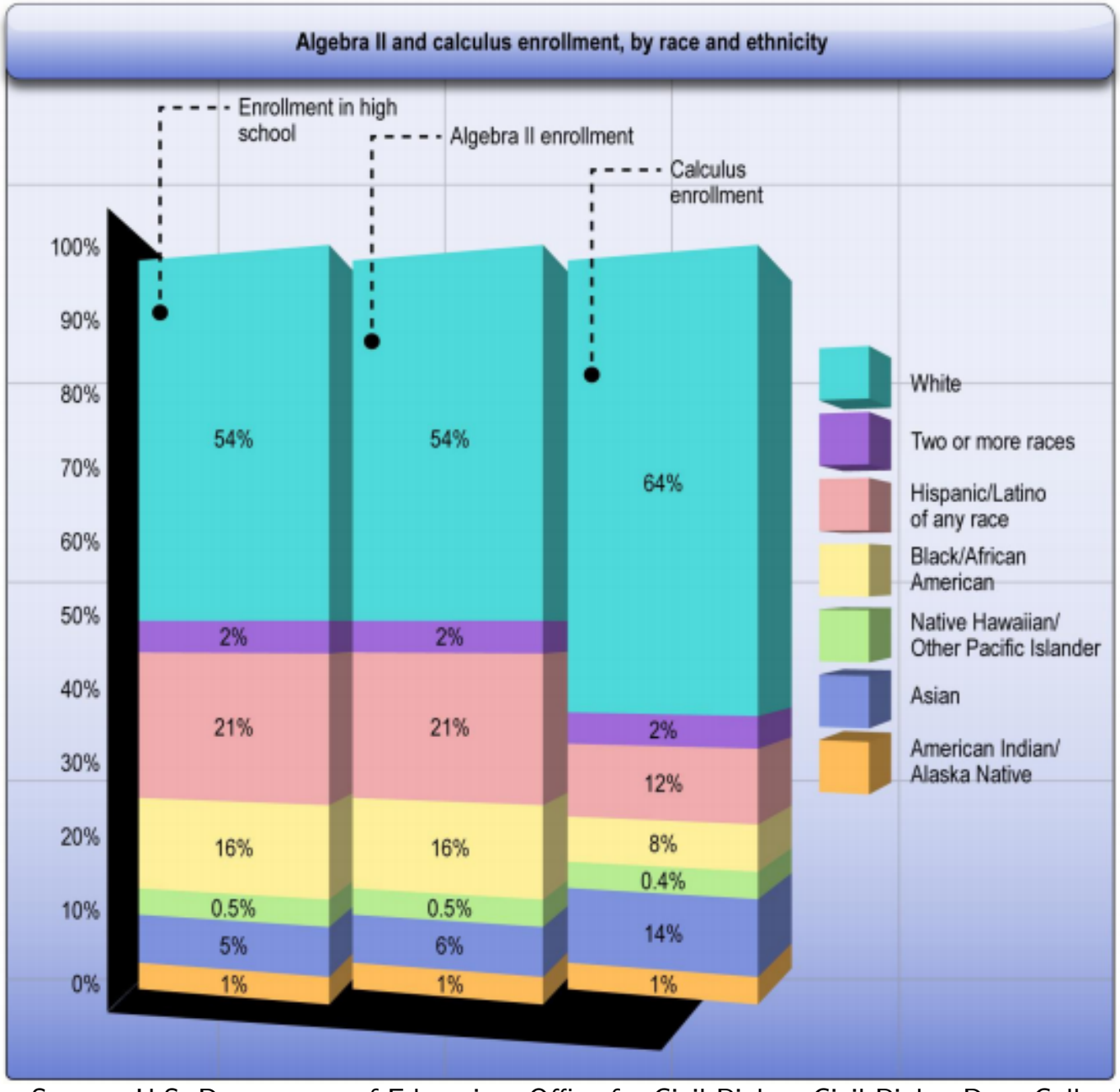

DISCRIMINATION IS REAL AT GLENFIELD SO - SO REAL
SOON But Maybe NOT TOMORROW
Our school is inferior Our children are NOT inferior
OUR SCH
IS
INFERIO
OUR CHIL
are
NOT!

50 years later



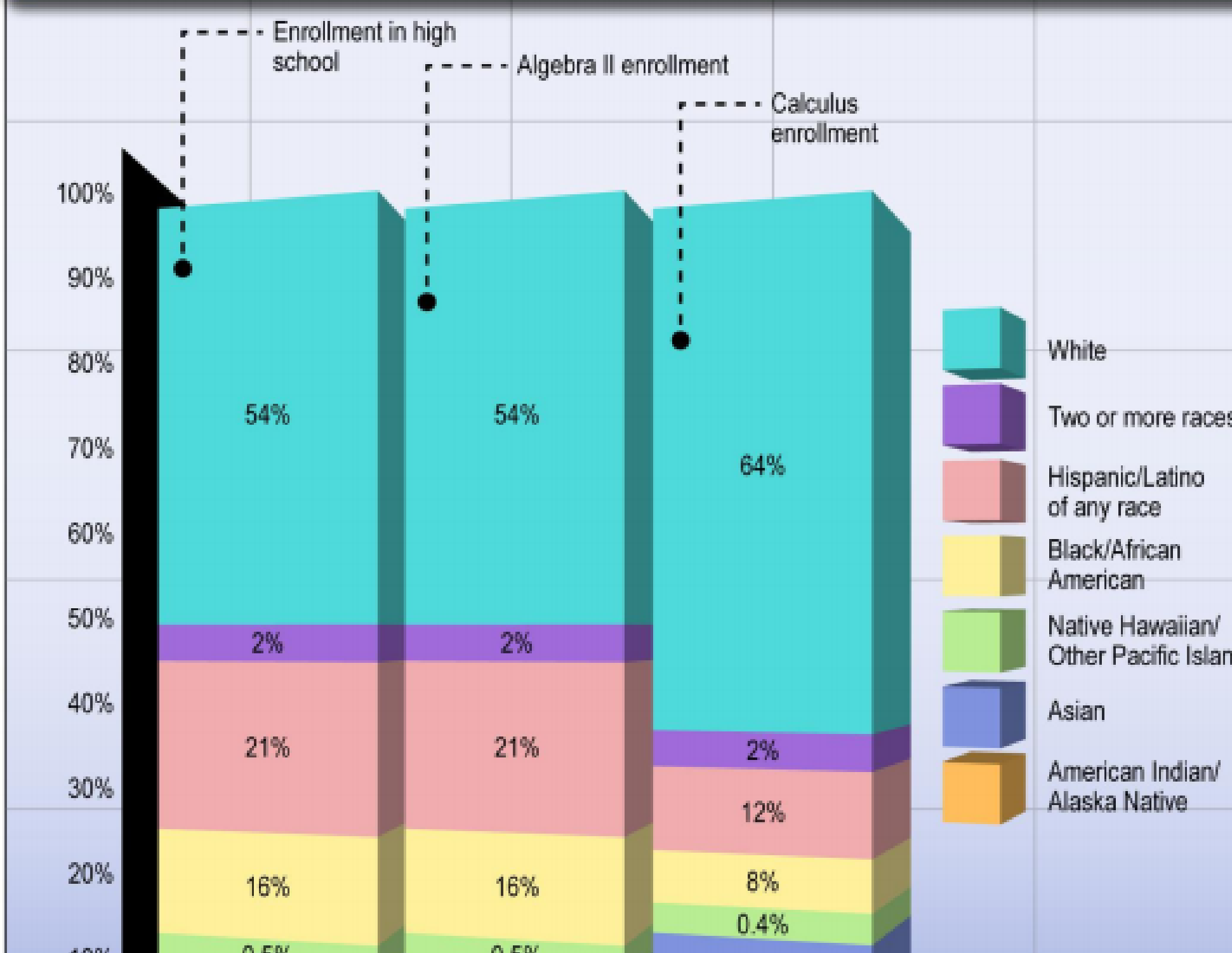
"You can look in a classroom and know whether it's an upper level class or a lower level class based on the racial composition of the classroom."

Source: *Finally, the US admits it: AP classes are way too white*, Quartz, November 17, 2014

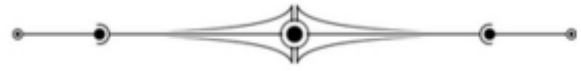


Source: U.S. Department of Education, Office for Civil Rights, Civil Rights Data Collection, 2011-12.

The mathematics classroom remains one of the most segregated places in the United States


Enrollment in high school
Algebra II enrollment
Calculus enrollment
100%
90%
80%
70%
60%
50%
40%
30%
20%
54%
54%
64%
2%
2%
2%
21%
21%
12%
16%
16%
8%
0.4%
White
Two or more races
Hispanic/Latino of any race
Black/African American
Native Hawaiian/ Other Pacific Islan
Asian
American Indian/ Alaska Native

The demographics



# of higher education in 2016

Women in the mathematical sciences

- How much more likely are women than men to choose *not* to continue beyond Calc I, even when Calc II is required for their major?
- What % of full-time tenured faculty in doctoral math departments are women?
- What % of SIAM members are women?

Women in the mathematical sciences

- How much more likely are women than men to choose *not* to continue beyond Calc I, even when Calc II is required for their major? about twice as likely
- What % of full-time tenured faculty in doctoral math departments are women? 14%
- What % of SIAM members are women? $< 15\%$

Women in the mathematical sciences

Women are lost at every key point along the way

41% of bachelor's degrees in math are earned by women

32% of new math and statistics PhDs are female

25% of new postdoctoral positions went to women

Two-year colleges and the mathematical sciences

1113 Associate's degree granting

991 Baccalaureate

741 Master's

335 PhD

Two-year colleges and the mathematical sciences

- What % of college students attend 2-year college?
- What % of 4-year college students who transfer to another college do so to attend 2-year college?
- What % of Hispanic college students attend a 2-year college?
- What % of low-income college students attend a 2-year college?

Two-year colleges and the mathematical sciences

- What % of college students attend 2-year college? 50%
- What % of 4-year college students who transfer to another college do so to attend 2-year college? 50%
- What % of Hispanic college students attend a 2-year college? 56%, compare to 25-30% of white students
- What % of low-income college students attend a 2-year college? 44%, compare to 15% of high-income students

Two-year colleges and the mathematical sciences

$> 60\%$ of 2-year college students take math courses that are not college credit-bearing

$> 70\%$ of those students never complete these math courses

Conclude: Over 40% of students who start at a 2-year college never finish simply due to math barrier

Success in mathematics is the most significant barrier to degree completion in both STEM and non-STEM fields.

For individuals, higher education offers the potential for social mobility.

"....over the entire career, the typical bachelor's degree graduate worker earns $1.19 million, which is twice what the typical high school graduate earns..."

Source: *Major Decisions: What Graduates Earn Over Their Lifetimes*, Hershbein & Kearney, September 2014

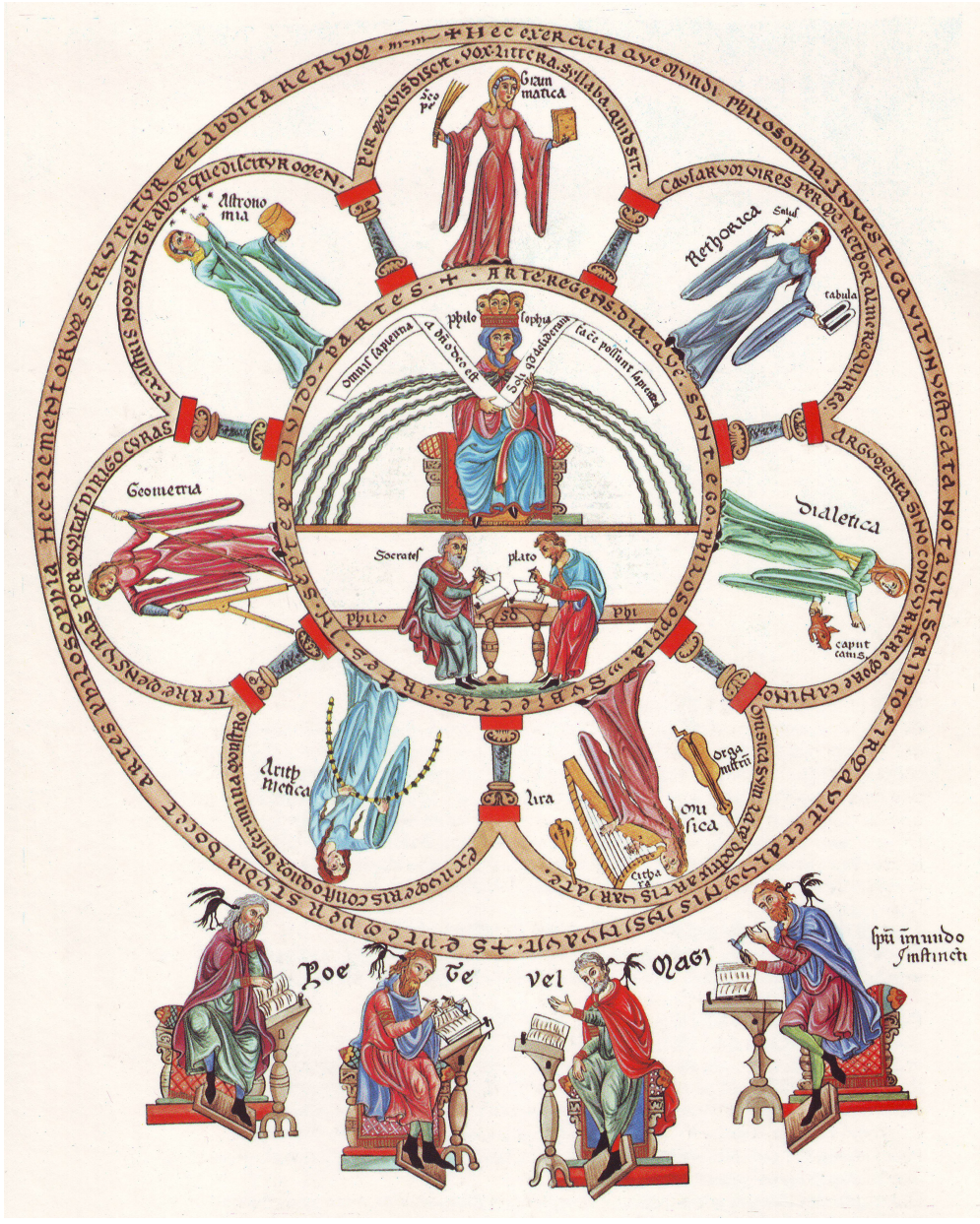
A brief history

of the mathematical sciences in higher education

Calls for innovation and transformation of education in the mathematical sciences are not new

Until 1950

- During 1700s and 1800s, math played significant role in liberal arts undergraduate education in America. Also in the "new" scientific schools like Rensselaer (1824) and MIT (1861)
- Lincoln signed Morill Act in 1862 establishing the land-grant institutions
- In same year, the first math PhD in US was awarded (at Yale)



Until 1950

- 1850-1900 college enrollments declined
  - "elective system" was instituted to boost enrollments
  - did lead to increasing enrollments college-wide, but dramatically decreasing enrollments in math
- Growing need for engineers and technically oriented professionals in industry and agriculture saved collegiate mathematics from being totally decimated
- In 1910 Harvard was first college to require students to have an academic major
- In 1915 Mathematical Association of America (MAA) born to focus on collegiate curricula

1950-1970

- In Cold War/Sputnik-era, science education become popular
- College enrollments quadrupled
- 1950s
  - calculus became the ultimate goal of HS math
  - AP calculus came into being
  - MAA *Committee on the Undergraduate Program in Mathematics (CUPM)* formed (1953)
- Related fields also grew – departments of computer science and statistics started splitting off from math departments

Trends since 1970

- University faculty turn to research
  - Reduced teaching for faculty
  - Freshman courses more often taught by grad students
- Liberal arts colleges have disproportionate success producing future PhDs
- 2-year colleges experience huge growth
  - Increasingly a starting point for 4-year degree seekers
  - Growth in developmental math enrollments (200,000 in 1970 to 1,100,000 in 2010, while enrollments in college credit-bearing math classes only doubled)

Trends since 1970

- Focus on high school to college transition, the role of AP calculus, and "calculus reform."
- 1981 CUPM report encouraged broader scope for the mathematical sciences; led to proliferation of "tracks" in undergraduate curriculum, and advocated "interactive teaching" and "guided discovery."

Why change *now*?

WHY NOW?

Answer 1

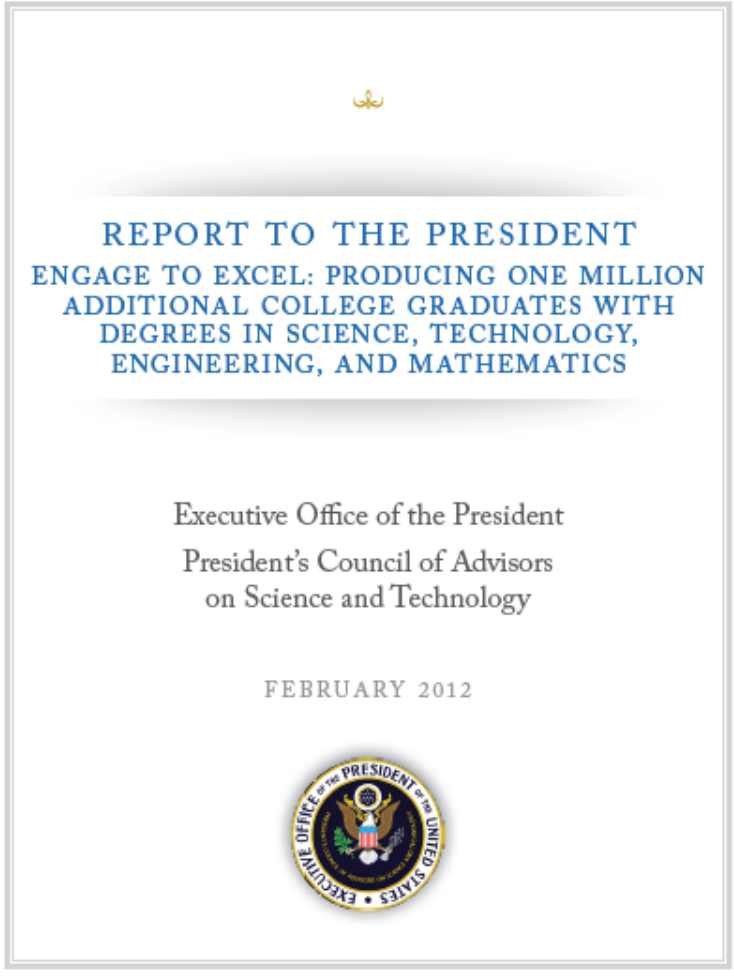
Discipline-based education research, which matured in 1980s and 90s, has produced new ways of understanding knowledge, thinking, and learning.

Mathematicians are beginning to use this research to inform how they teach.

WHY NOW?

Answer 2

There is renewed federal interest in higher education in general, and undergraduate STEM education in particular.



President Obama identified post-secondary education as key to a stronger economy and to 21st century success of the nation, and asked PCAST to prepare a report on producing one million more STEM graduates over the next decade.

PCAST's *Engage to Excel*

- points to a US Department of Commerce report projecting a 17% increase in the need for STEM-trained graduates over next decade, and
- suggests that "faculty from mathematics-intensive disciplines other than mathematics" should develop and teach courses in college-level mathematics, and that there should be a "new pathway for producing K-12 mathematics teachers from ... programs in mathematics-intensive fields other than mathematics."

Other White House interest

February 2015

The White House Names Dr. DJ Patil as the First U.S. Chief Data Scientist

January 2016

White House announces new education initiative
Computer Science for All

$120 million in computer science funding to become available from the NSF

Other federal government interest NSA, VA, DHS, DoD, DoE, DARPA, NASA, ...

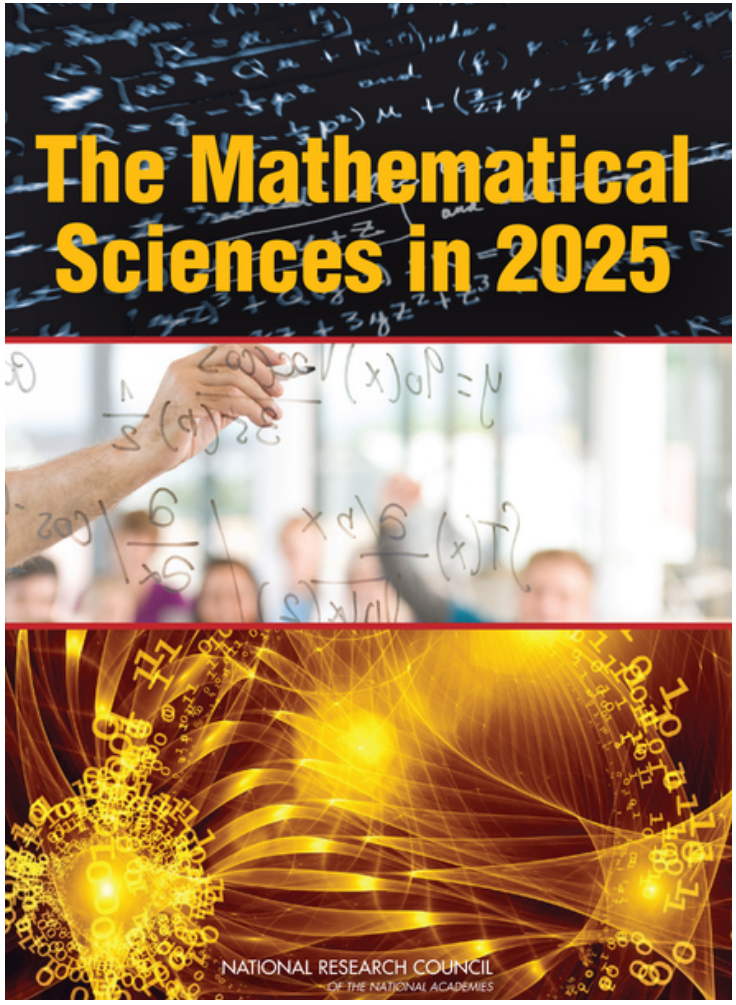
WHY NOW?

Answer 3

Other important stakeholders interested

National Research Council's
The Mathematical Sciences in 2025

- describes how mathematics has become essential to modern science
- recommends that undergraduate education in the mathematical sciences reflect this new stature
- highlights many up-to-date advances in mathematics



NAE GRAND CHALLENGES FOR ENGINEERING

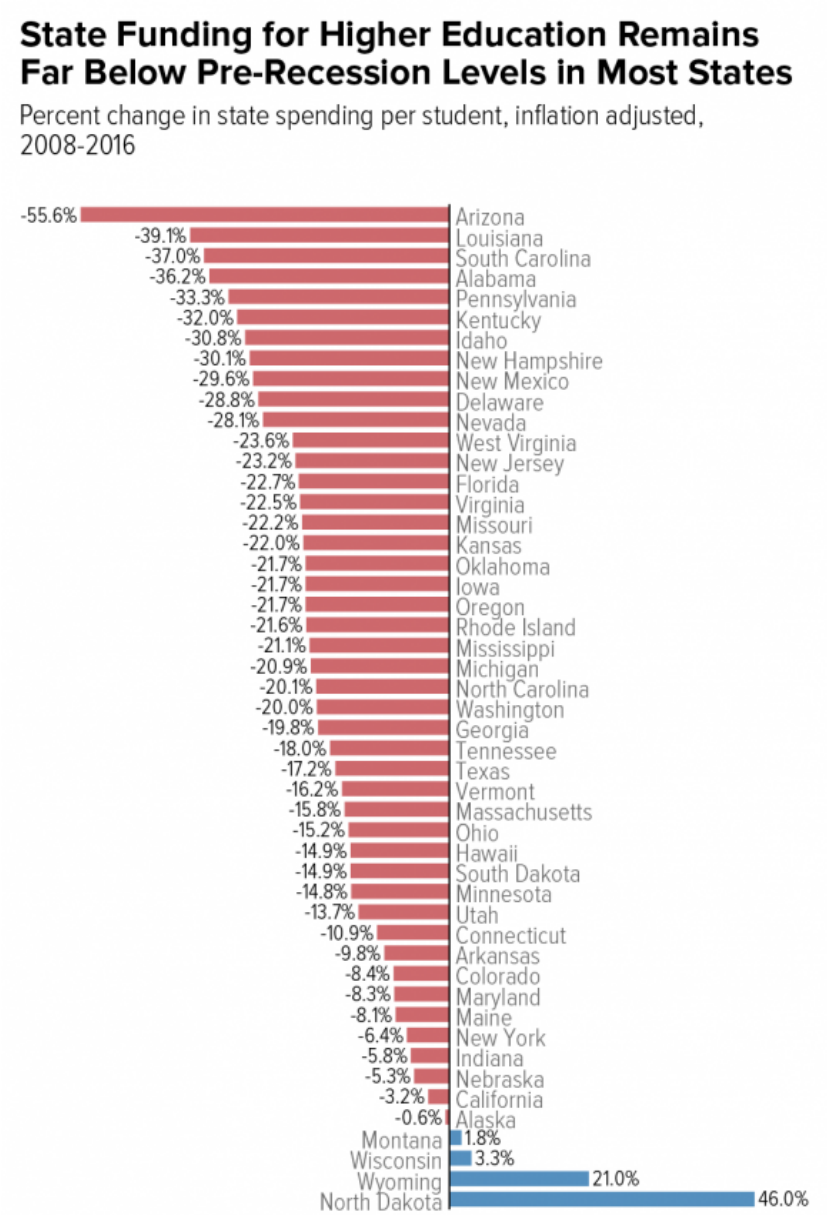
NATIONAL ACADEMY OF ENGINEERING

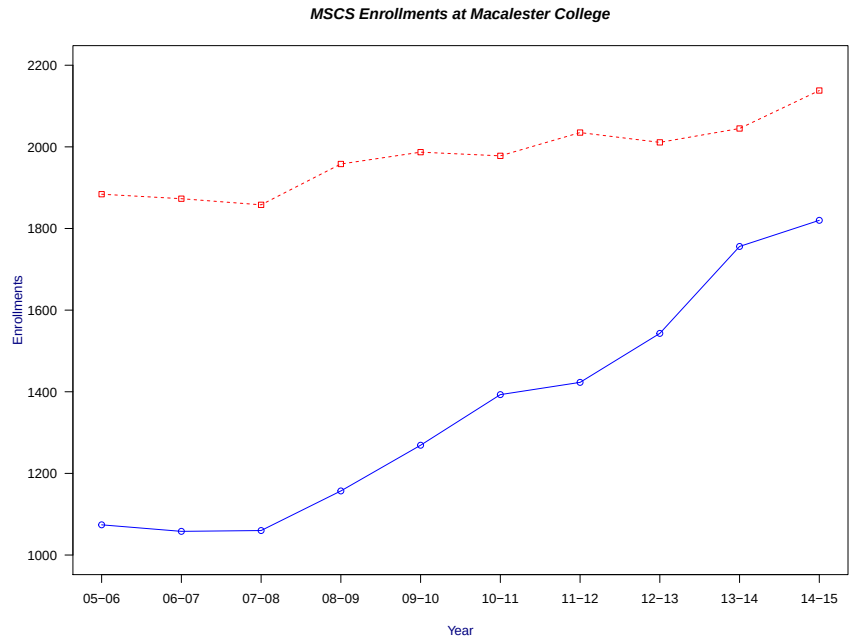
Develop Carbon Sequestration Methods
(modeling of porous media)

Prevent Nuclear Terror
(network analysis, data mining, cryptography)

WHY NOW?

Answers 4, 5, 6, . . .





Mathematical sciences are dynamic. Our work is *never* done!!!

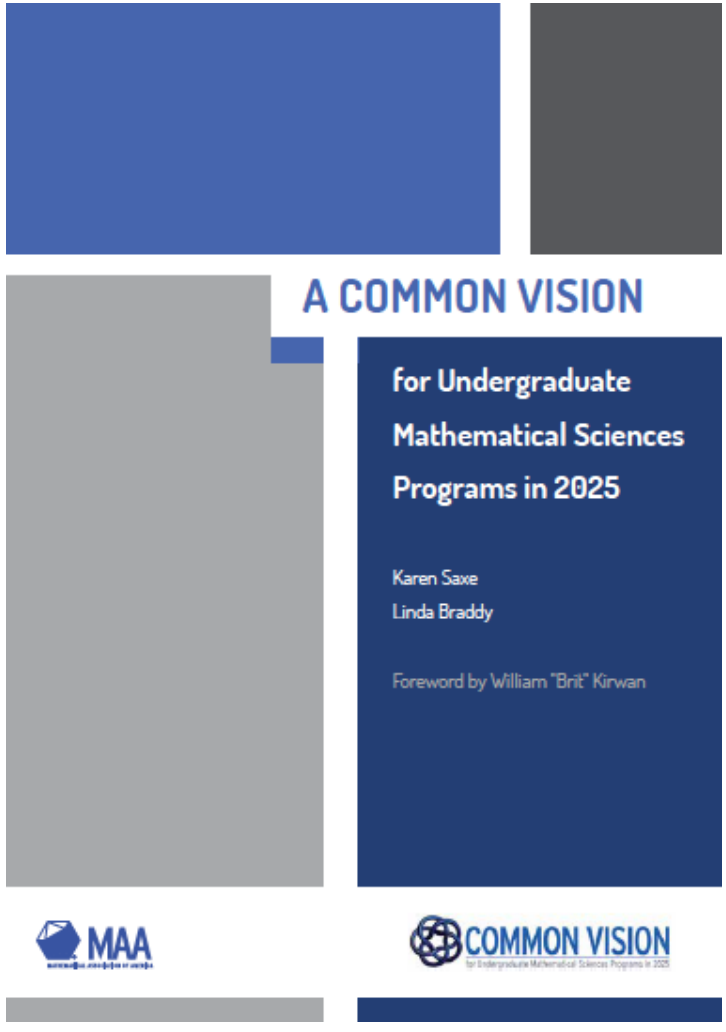
Two current initiatives

Common Vision and *TPSE*

Common Vision for Undergraduate Mathematical Sciences Programs in 2025

Karen Saxe, PI
Linda Braddy, co-PI, MAA
John Bailer, ASA
Rob Farinelli, AMATYC
Tara Holm, AMS
Vilma Mesa, RUME
Uri Treisman, TPSE
Peter Turner, SIAM

NSF DUE-1446000



Common Vision for Undergraduate Mathematical Sciences Programs in 2025

Transforming Post-Secondary Education in Mathematics

TPSE Math

Transforming Post-Secondary Education in Mathematics

About | Blog | Meetings | MAG | Links

Transforming Post-Secondary Education in Mathematics (TPSE Math), sponsored by Carnegie Corporation of New York and the Alfred P. Sloan Foundation, aims to effect constructive change in mathematics education at community colleges, 4-year colleges and research universities.

Spearheading the effort are:

- Eric Friedlander, University of Southern California
- S. James Gates, Jr., University of Maryland
- Mark Green, University of California - Los Angeles
- Phillip Griffiths, Institute for Advanced Study
- Tara Holm, Cornell University
- Karen Saxe, Macalester College
- Uri Treisman, University of Texas at Austin
- William (Brit) Kirwan, University System of Maryland, *Senior Advisor to TPSE Math*

Vision: Post-secondary education in mathematics will enable any student, regardless of his or her chosen program of study, to develop the mathematical knowledge and skills necessary for productive engagement in society and in the workplace.

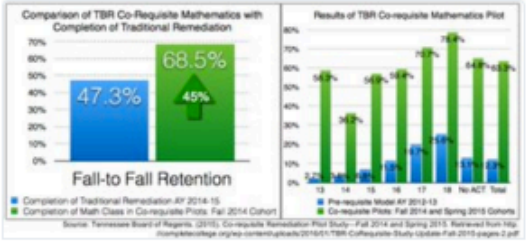
Mission: TPSE Math will facilitate an inclusive movement to strengthen post-secondary education in mathematics by working closely with--and mobilizing when necessary--faculty leaders, university

Tweets by @tpsemath

TPSE Math Retweeted

Philip Uri Treisman
@uritr

"2.Experiment in the classroom" @tpsemath to "study, catalog & promote" innovation. @DanBerett mentions @TNRegents



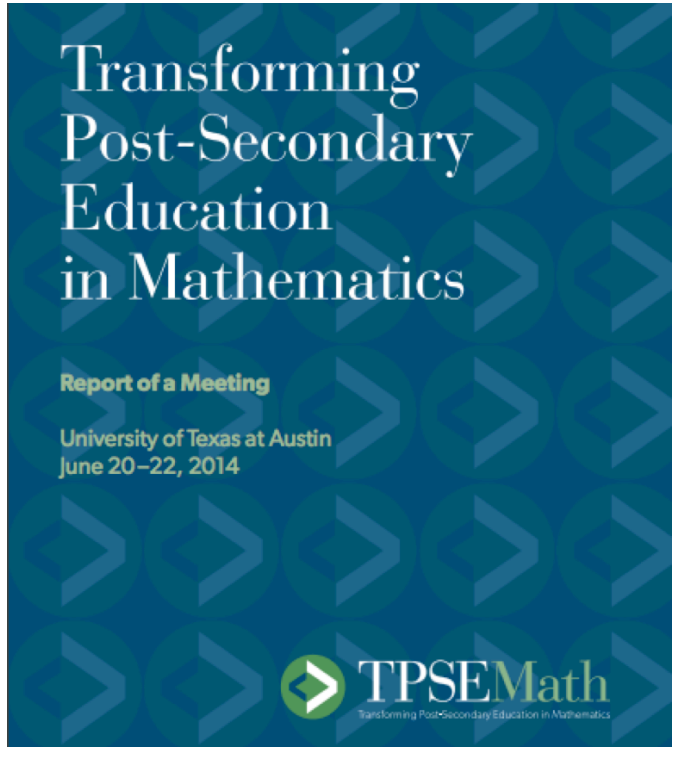
14 Apr

TPSE Math Retweeted

Philip Uri Treisman
@uritr

@tpsemath approach to transform #math #highered?


UNIVERSITY OF
18
56
MARYLAND


Transforming
Post-Secondary
Education
in Mathematics
Report of a Meeting
University of Texas at Austin
June 20–22, 2014
TPSEMath
Transforming Post-Secondary Education in Mathematics

TPSE is now positioned to forge alliances with state and federal agencies, the policy community, university administrators, higher education associations, and professional organizations to secure the financial and structural support necessary to improve

- Curriculum pathways (lower & upper division, allowing students to reach the math relevant to their field of study)
- Graduate co-curricular training
- Leadership and capacity development

"Leadership matters – success in this area depends upon the value assigned to it by a department's leadership"

Opportunities

How can you make change?

Most initiatives are institution-specific, through a consortium of institutions, or through our professional associations

Celebrate the differences between institutions

What works at a school needs to fit its academic mission, the students it serves, the energy of its faculty members, and its financial constraints

Examples of success – Department/Institution level

Example 1 – large public research-oriented university

University of Illinois
1100 undergraduate majors
22,000 student classes

We have "the possibility of boosting confidence by departmental approaches to structuring the curriculum and course pedagogies, such as confidence, study habits, sense of community, and so on" (NRC, 2013)

Examples of success – Department/Institution level

Initiative: Active learning in large calculus courses

- 3 semesters
- $\sim$7500 students per year
- Taught by teams including experienced faculty member
- Incentives for faculty

Examples of success – Department/Institution level

Initiative: Mathematical visualization and community engagement

At the Illinois Geometry Lab, undergraduate students work closely with graduate students and postdocs on visualization projects set forth by faculty members, as well as to bring mathematics to the community through school visits and other activities.

Examples of success – Department/Institution level

Example 2 – small private liberal arts college

MACALESTER COLLEGE

Macalester College
275 undergraduate majors
2100 student classes

"The educational offerings of typical departments in the mathematical sciences have not kept pace with the changes in how the mathematical sciences are used." (NRC, 2013)

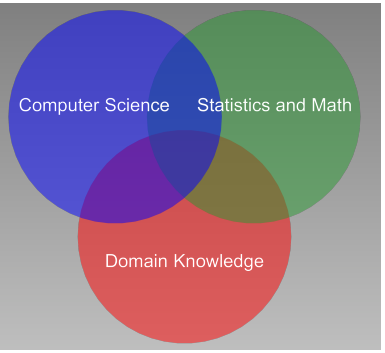
Examples of success – Department/Institution level

Initiative: Narrow gap between how math is experienced in our classrooms and in the workplace; broaden participation

MACALESTER COLLEGE

Data Science Minor

Department of Mathematics, Statistics, and Computer Science



Data Science

Macalester's data science program develops the concepts and skills needed to extract actionable information from masses of data. New to the liberal arts curriculum, data science is a natural fit. It enables students and researchers to work with data in many disciplines: the social sciences (e.g. census, voting, crime, and survey data), the natural sciences (e.g. gene sequences, remote sensing), humanities (e.g. digitized historical records, archeological data), and the arts (e.g. music databases). Macalester's data science minor combines course work in computer science and statistics with studies in "domain areas" that make use of data science and are found across the liberal arts curriculum.

Minor Requirements

Pre-Approved Domain Areas

Two courses from a domain area below. Other areas approved on a case-by-case basis

Astronomy
- PHYS 120: Astronomical Techniques
- PHYS 440: Observational Astronomy

Bioinformatics
- BIOL 260: Genetics
- COMP 302: Computational Biology

Computational Linguistics
- LING100: Intro to Linguistics
- LING 294: Computational Methods

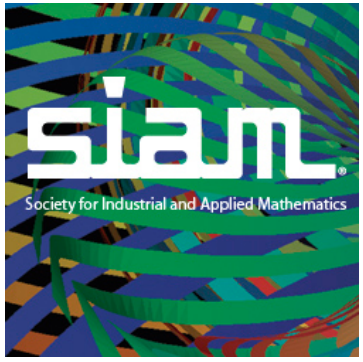
Data-Driven Journalism
- MCST 114: News Reporting and Writing *and one of*
- MCST 355: Electronic Journalism
- MCST 357: New Media

Ecology
- BIOL 285: Ecology *and one of*
- BIOL 342: Animal Behavior/Ecology
- BIOL 344: Aquatic Ecology
- BIOL 345: Field Botany

Environmental Science and Policy
- ENVI 231: Environmental Econ *and one of*
- ENVI 130: Science of Renewable Energy
- ENVI 140: The Earths Climate System
- ENVI 150: Climate and Society
- ENVI 160: Dynamic Earth, Global Change

Examples of success – Professional association level

Since 2000, SIAM activities in undergraduate education have been growing rapidly both within SIAM community and in partnership with other professional associations

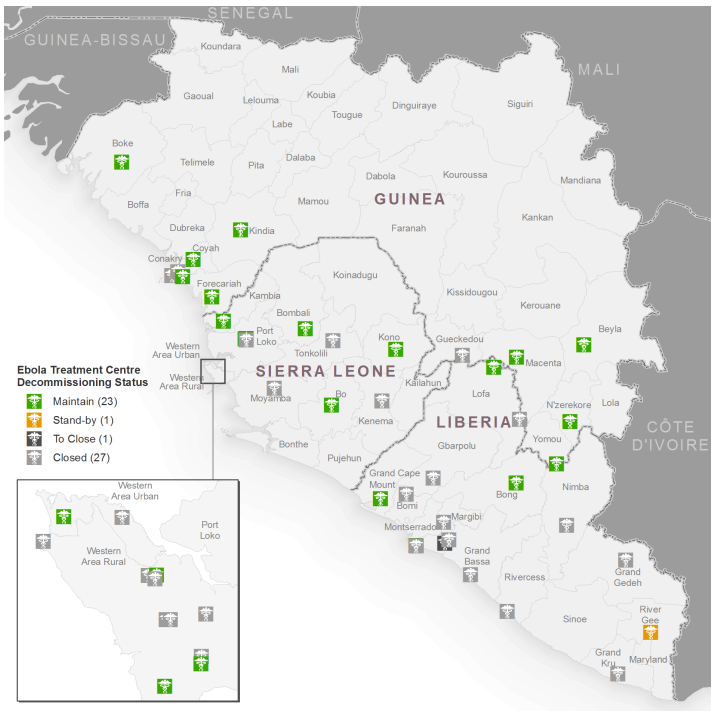


2008 SIAM Undergraduate Research Online (SIURO) launch
2012 First *Modeling across the Curriculum* workshop
2014 Second *Modeling across the Curriculum* workshop
2014 *Applied Mathematics Undergraduate Programs* report
2015 SIAM Activity Group in Applied Mathematics Education (SIAG/ED) launch

Examples of success – Professional association level

PICMath

To prepare math students for industrial careers by engaging them in research problems that come directly from industry

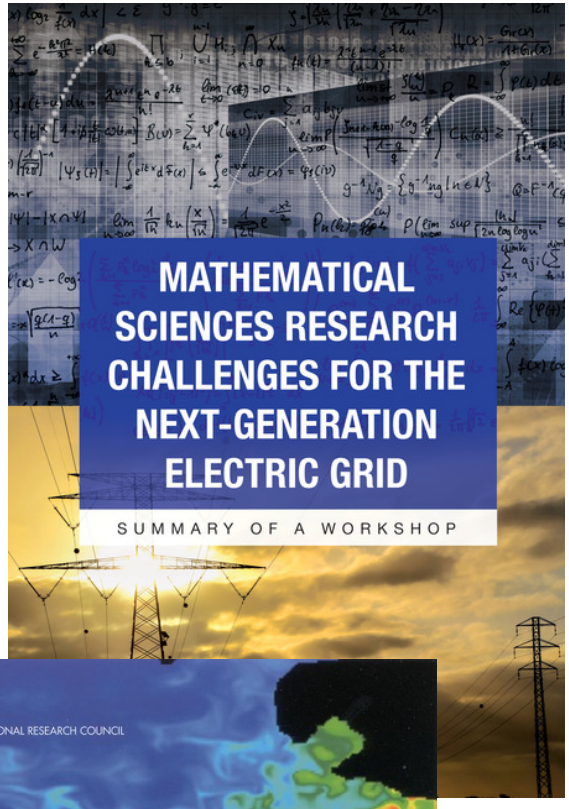


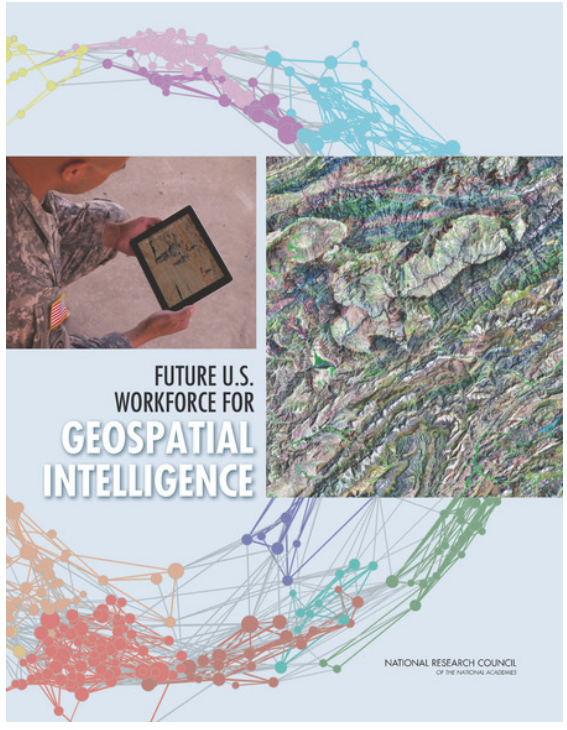
Summer Faculty Training Workshop provides faculty with content for Spring Semester Research Course focused on solving industrial problems

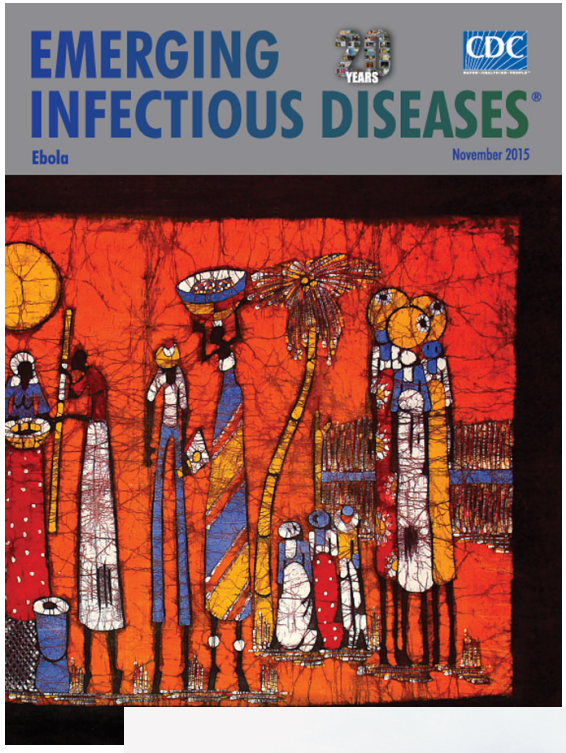
But, really, why should you *care*?

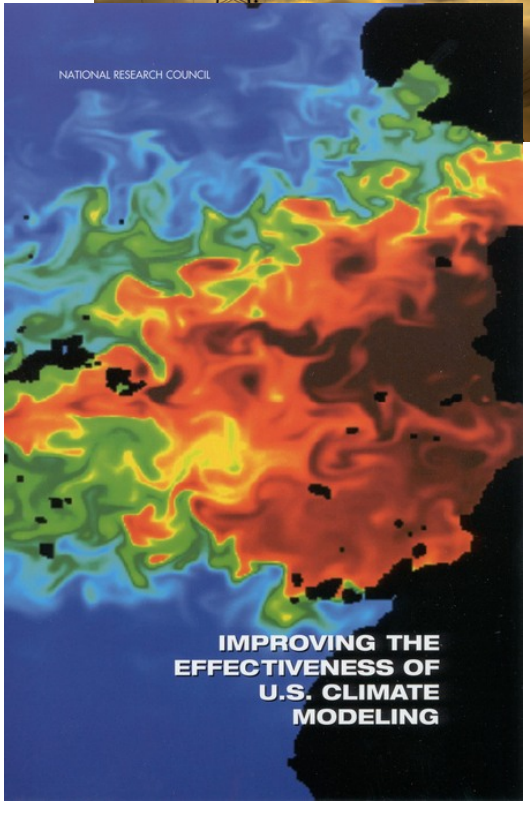
This truly is on our doorstep

- All of us will have a greater number of transfer students, a greater number of students who are first-generation, and generally our students will have wider variety of experiences before they reach us
- Education is considered one of the levers we have to address income inequality
- We need to take responsibility ("own") teaching and learning in mathematical sciences, considered broadly (data science)

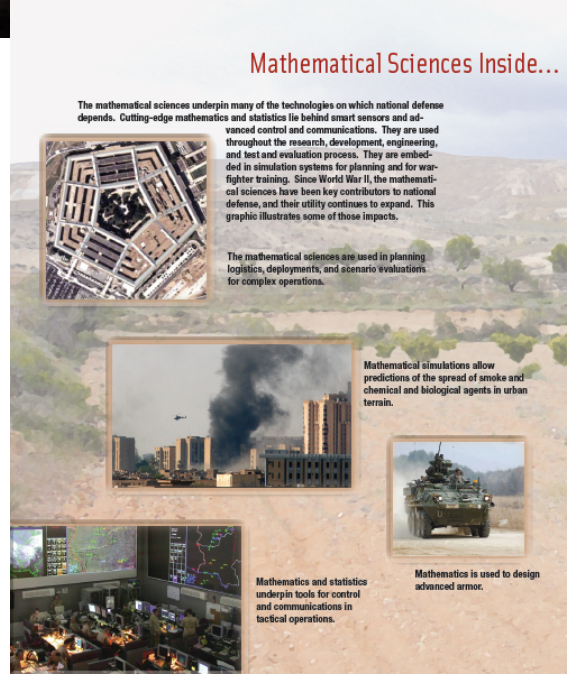








The big issues facing humanity require mathematics to tackle



But, really, why should you *care*?

Students are part of *every* post-secondary institution's mission

Administrators want to improve

- Single course success rates
- Persistence of students through mathematics courses
- Timely degree-completion rates

Even small changes to programs in the mathematical sciences can help solve administrators' problems

Helping will reap benefits for you, and your department

What should you *do*?

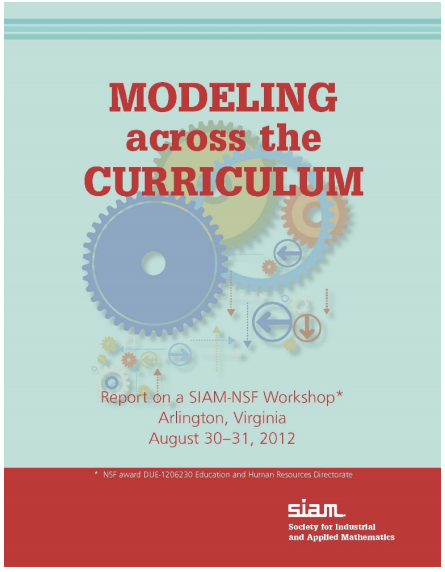
- Find like-minded colleagues and build community
- Look at reports
- Apply for NSF funding to improve undergraduate courses and programs
- Take a sabbatical with aim to enrich your undergraduate teaching
- Participate in SIAM activities
  - SIAM Activity Group on Applied Mathematics Education
  - SIAM Education Committee

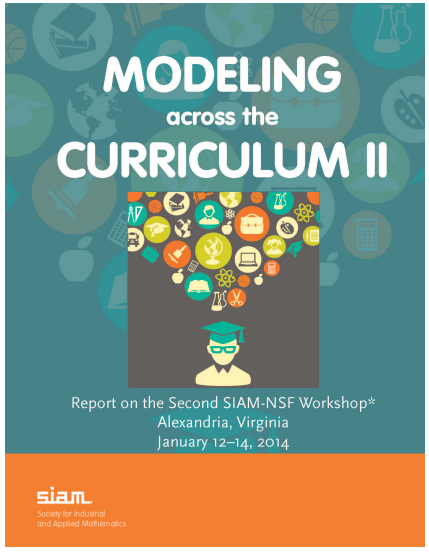
And, always, respect your students. Care about them. Talk with them.

Build community

- Have a monthly lunch/happy hour
- Combine this with a reading group

Look at reports



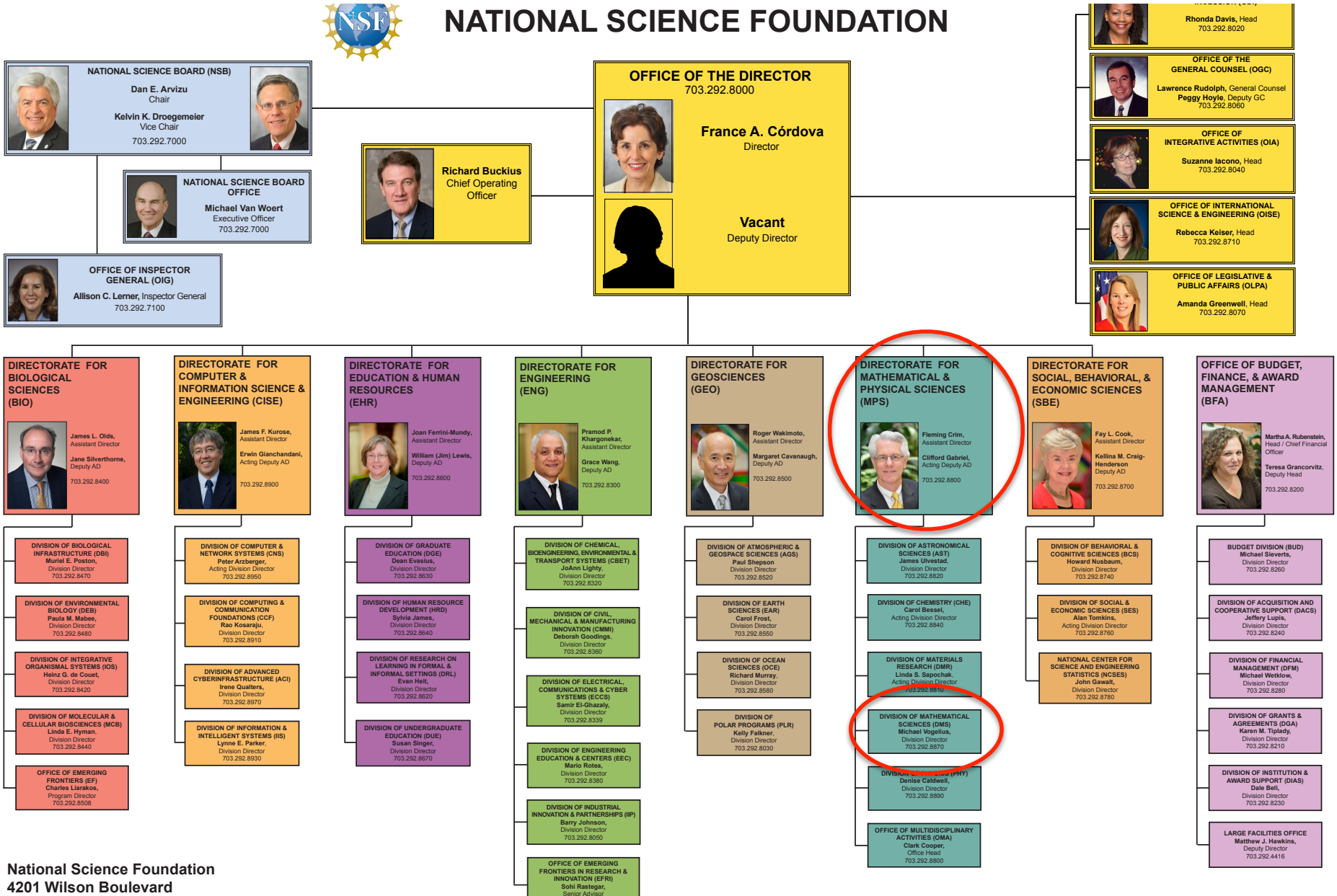


SIAM Undergraduate course design:

- Using modeling and applications as a skeleton on which the calculus sequence is built.
- A first year modeling/applied mathematics course that precedes and motivates the study of calculus and other fundamental mathematics for STEM majors.

Also read SIAM GAIMME, MAA CUPM, and ASA reports....

Apply for NSF funding



National Science Foundation
4201 Wilson Boulevard

Enriched Doctoral Training in the Mathematical Sciences

Mathematical Methods for Water Problems

co-PI's: Peter Constantin, Simon Levin, Ignacio Rodriguez-Iturbe, Ning Lin

Major Goals: To expose students to societal problems related to water, and to the mathematical challenges related to modeling and analyzing them.

PRINCETON UNIVERSITY

Michael Van Woert
Executive Officer
703.292.7000

Officer

Vacant
Deputy Director

OFFICE OF INSPECTOR GENERAL (OIG)
on C. Lerner, Inspector General
703.292.7100

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Education and Human Resources (EHR) Goals

- Prepare STEM workforce and increase the technological, scientific and quantitative literacy of all Americans
- Broaden participation and close achievement gaps in all STEM fields
- Support and integrate research about learning and learning environments to improve education

DUE Mission

Promote excellence in undergraduate science, technology, engineering, and mathematics (STEM) education for all students

Advanced Technological Education (ATE) focuses on the education of technicians for the high-technology fields, emphasizes 2-year colleges

Improving Undergraduate STEM Education (IUSE) is broad; offers support for new curriculum, including data science and computational approaches, as well as implementation of active learning-oriented instruction

NSF Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) seeks to increase the number of low-income students obtaining undergraduate degrees and entering the workforce or graduate programs in STEM

Robert Noyce Teacher Scholarship Program (Noyce) for recruiting and preparing highly effective K-12 STEM teachers

DUE Division Of Undergraduate Education

"Gamified" Digital Forensics Course Modules for Undergraduates

PI Yin Pan, Rochester Institute of Technology

- Develop modules for lower level courses to help 2-year college students continue in advanced forensics training as they transfer to a 4-year college

- Pilot with three institutions – Rochester Institute of Technology, Corning & Onondaga Community Colleges
- Long term goal to impact 500 students from at least 20 2-year and 4-year colleges, including community colleges in rural areas

Take a sabbatical

The first academic sabbaticals were launched by Harvard University in 1880. Most of the time, we visit another academic institution.

But, consider government or industry!

Your sabbatical experience enriches your students' experiences.

Take a sabbatical

- Government
  - NSA Sabbatical Program in Mathematics
  - AAAS Science & Technology Policy Fellowships (Executive agencies – NSF, Dept of Defense, etc.) This year will place up to 15 with expertise in "big data and analytics"
  - AAAS & AMS Congressional Fellowships
  - Jefferson Science Fellowship (Dept of State, USAID)
  - National labs. *Examples:* Argonne, Sandia
- Industry
  - Established programs in industry. *Examples:* Google, Facebook
  - Individually initiated. *Example:* Senior Research Fellow, Target Corporation
  - Funding available. *Example:* Grant Opportunities for Academic Liaison with Industry (GOALI) can help fund a sabbatical embedded in industry

Participate in SIAM activities

You haven't missed ...

- **Today** **Education Programs in Data Science and Data Analytics - Part I of II (Part II)**
  10:30 AM - 12:30 PM (4:00 PM - 6:00 PM)
  Room: BCEC Room 251
  Organized by the SIAM Education Committee

- **Tomorrow** **Implementing Transformational Undergraduate Modeling Experiences**
  4:00 PM - 6:00 PM
  Room: Hancock - Lobby Level
  Organized by Sarah Iams (Harvard University) & Chad Topaz (Macalester College)

Participate in SIAM activities

First

SIAM Conference on Applied Math Education

Philadelphia

September 30-October 2

www.siam.org/meetings/ed16/

Sponsored by the

SIAM Activity Group on Applied Mathematics Education

Peter Turner (Chair)

Jeff Humpherys

Padhu Seshaiyer

Ben Galluzzo

Participate in SIAM activities

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www.siam.org/about/ed_comm.php

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Suzanne Weekes (chair)

THANK YOU!!

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maa.org/common-vision

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