Transformation of STEM Education: Where Gladly Will They *All* Learn

Shirley M. Malcom, Ph.D.

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ADVANCING SCIENCE, SERVING SOCIETY

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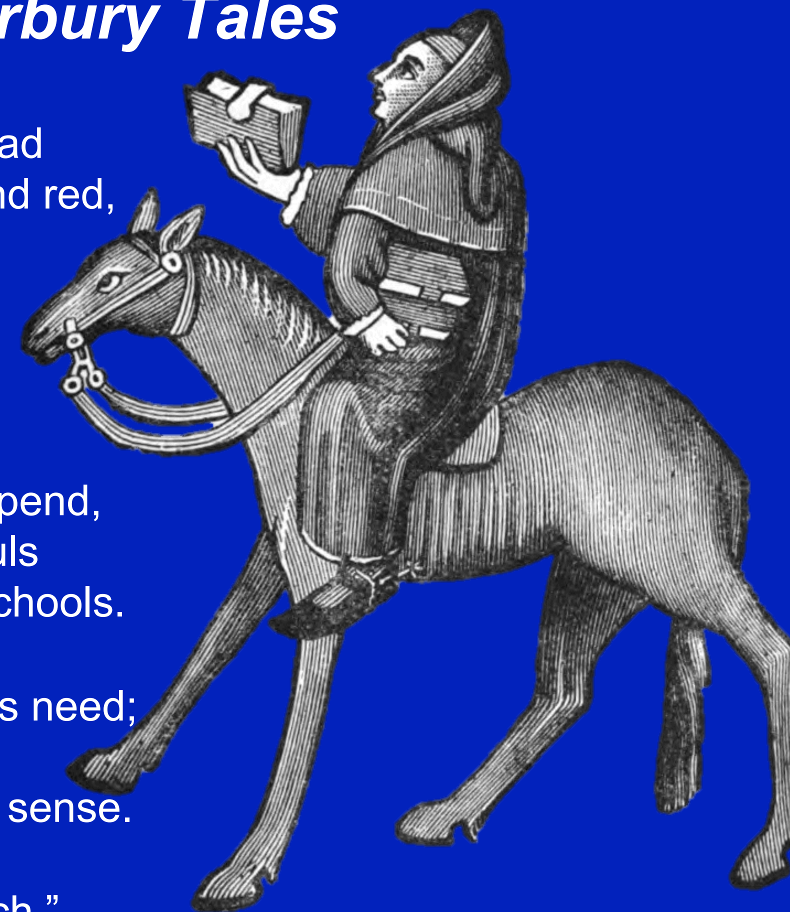
What I Learned from Gigi – or Engaging a Tough Audience

- Believing that they can learn
- Expecting them to learn
- Giving them clear messages of the belief and the expectations
- Giving them the tools and resources (strategies, content, ways of thinking)
- Engagement as a requirement
- "Interest" as a prerequisite; "joy" as the ideal

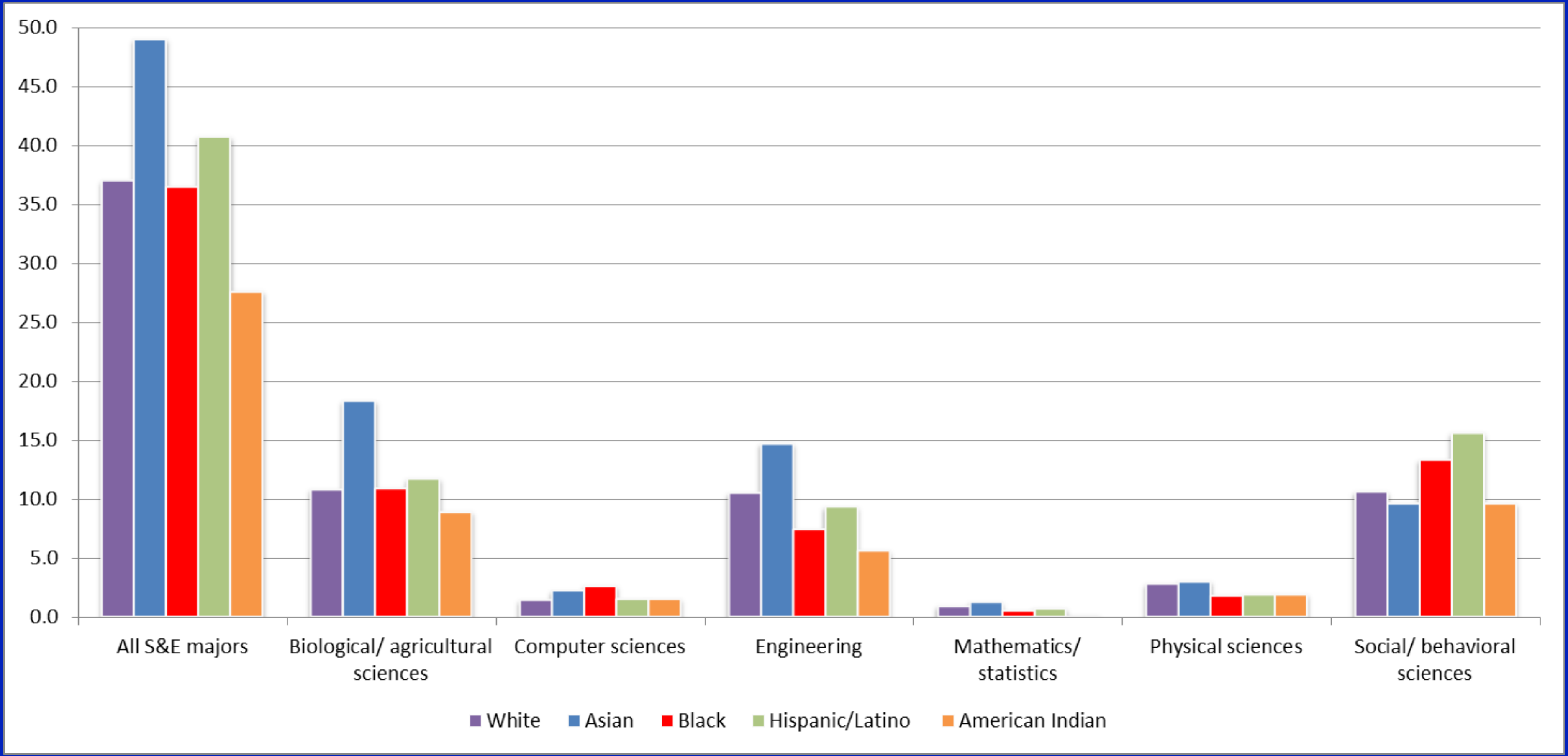
Prologue from *The Canterbury Tales*



“For he would rather have at his bed's head
Some twenty books, all bound in black and red,
Of Aristotle and his philosophy
Than rich robes, fiddle, or gay psaltery.
Yet, and for all he was philosopher,
He had but little gold within his coffer;
But all that he might borrow from a friend
On books and learning he would swiftly spend,
And then he'd pray right busily for the souls
Of those who gave him wherewithal for schools.
Of study took he utmost care and heed.
Not one word spoke he more than was his need;
And that was said in fullest reverence
And short and quick and full of high good sense.
Pregnant of moral virtue was his speech;
And gladly would he learn and gladly teach.”

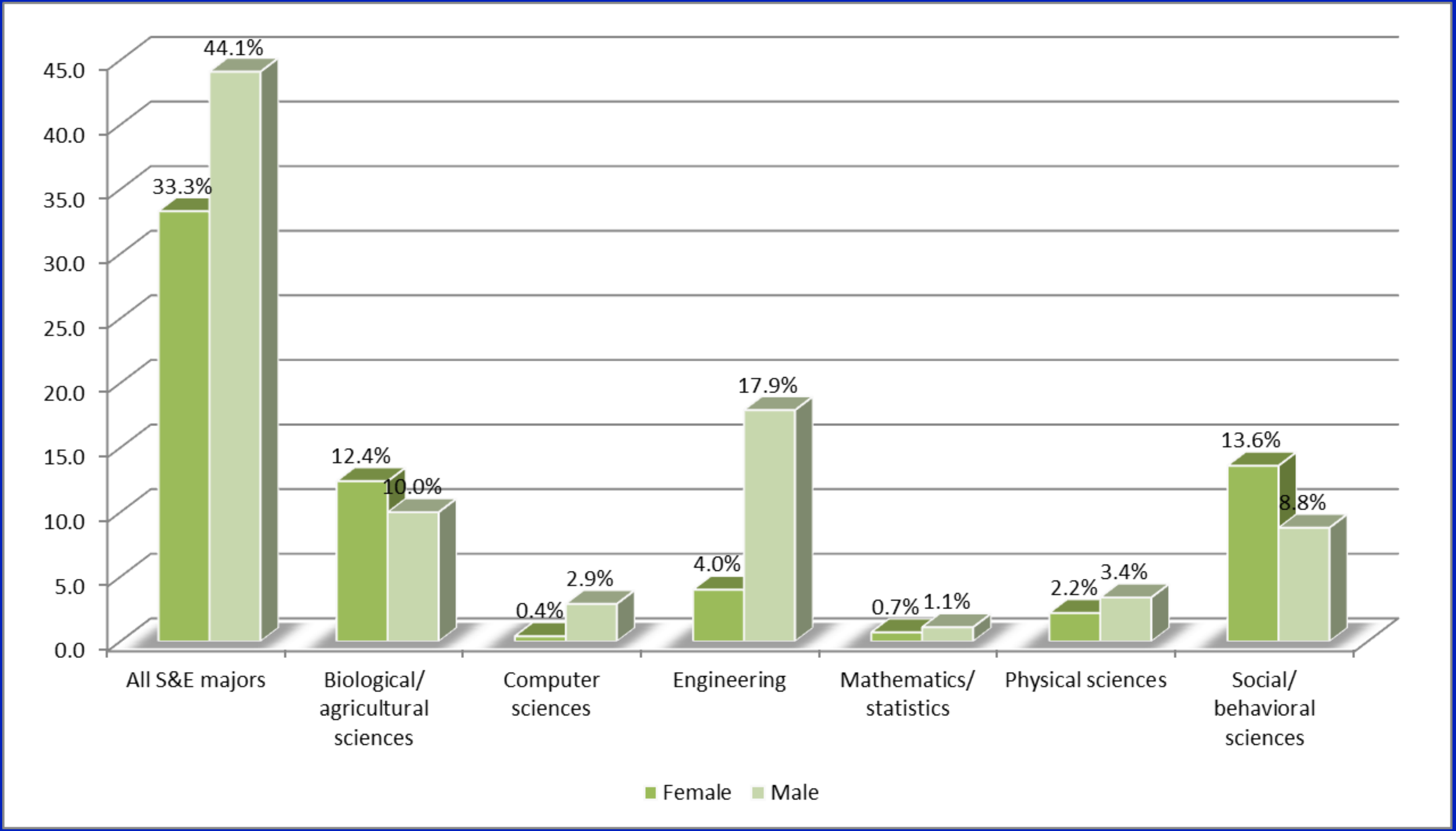
--Geoffrey Chaucer

Beyond the requirement–
Intentions of freshmen to major in S&E, by race/ethnicity: 2010 (%)



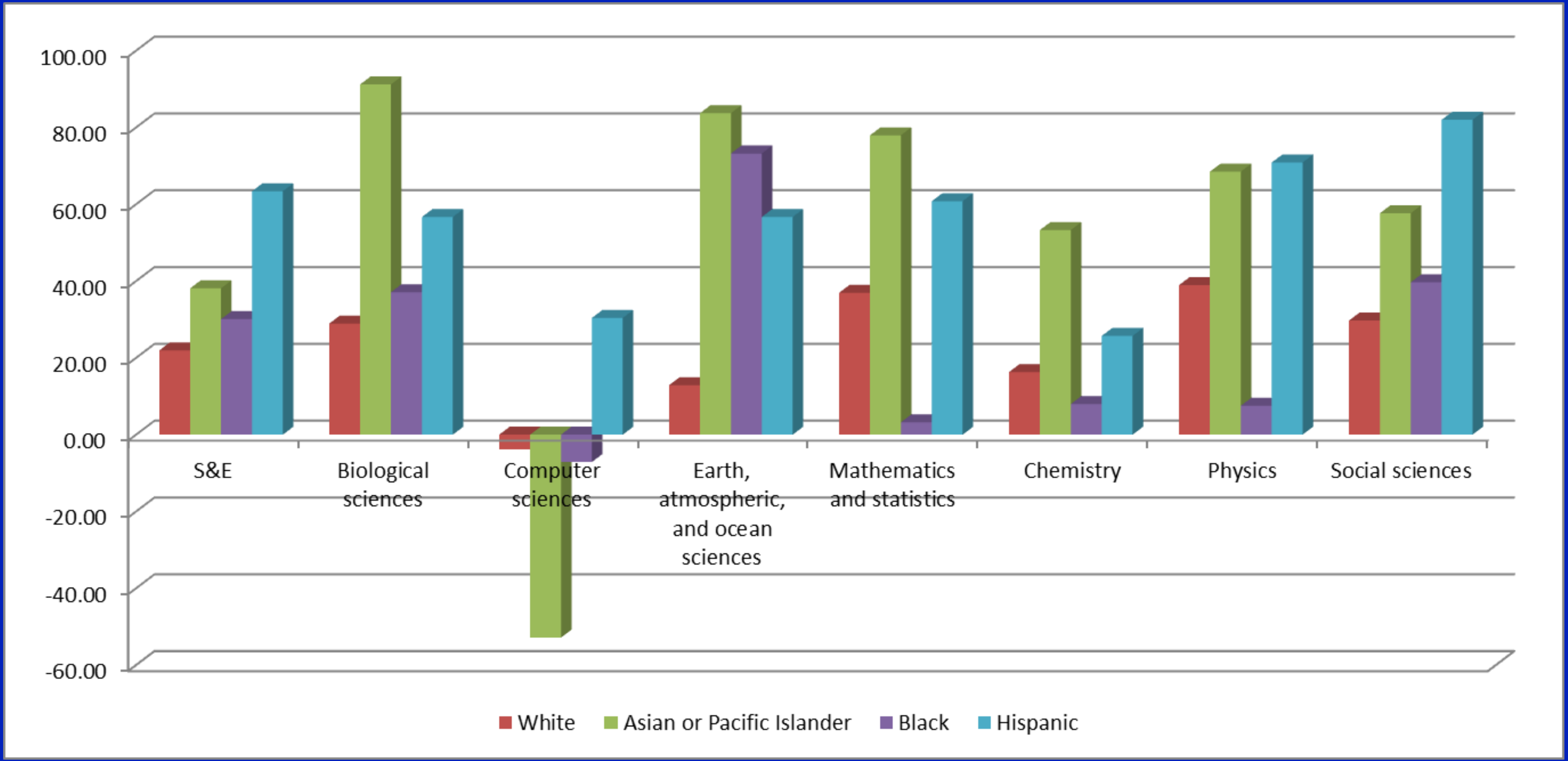
Source: http://www.nsf.gov/statistics/wmpd/2013/pdf/tab2-8.pdf

Beyond the requirement–
Intentions of freshmen to major in S&E, by sex: 2010



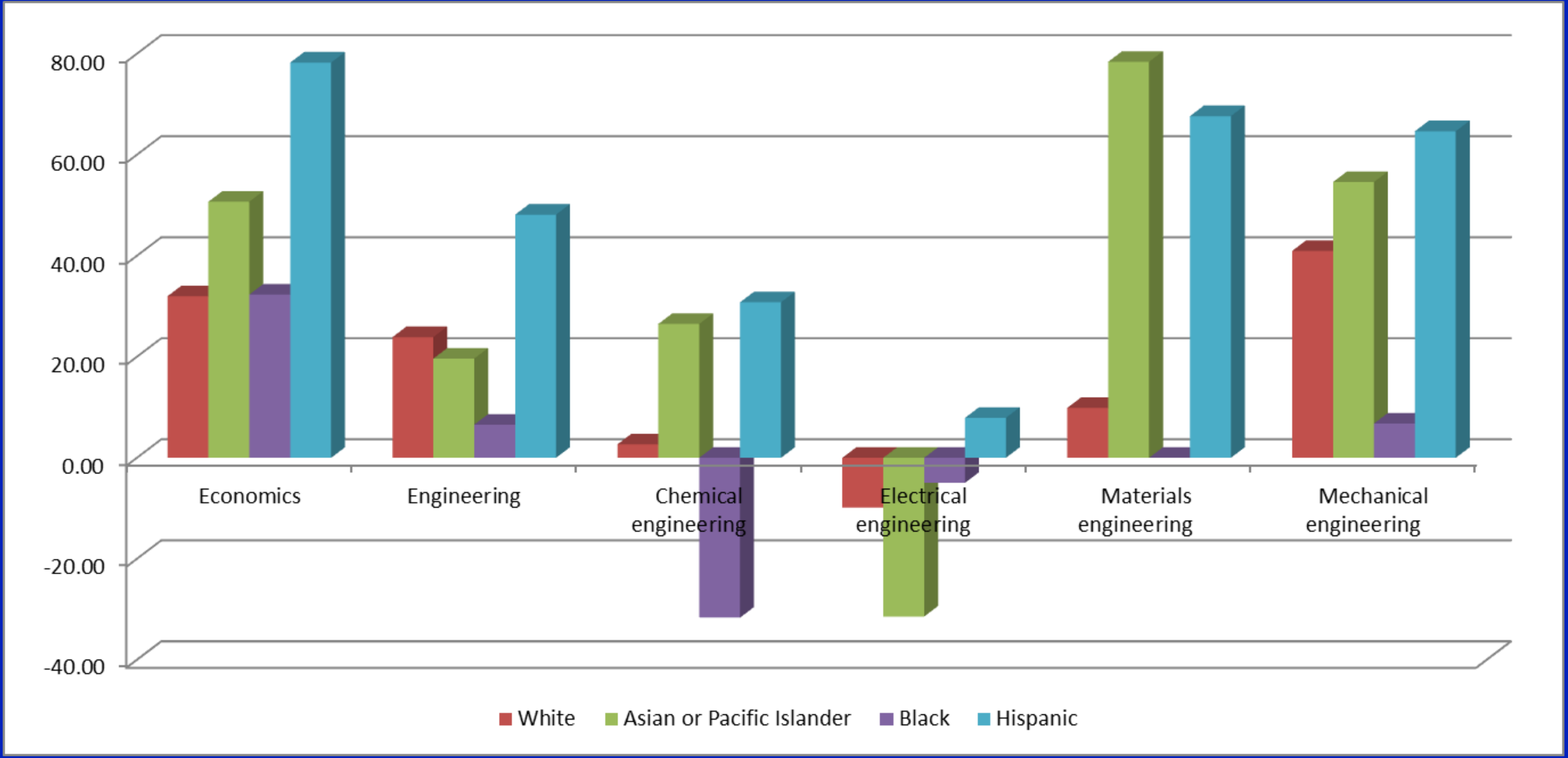
Source: http://www.nsf.gov/statistics/wmpd/2013/pdf/tab2-8.pdf

Percent Change Bachelor's degrees awarded, by field and race/ ethnicity: 2001 & 2010



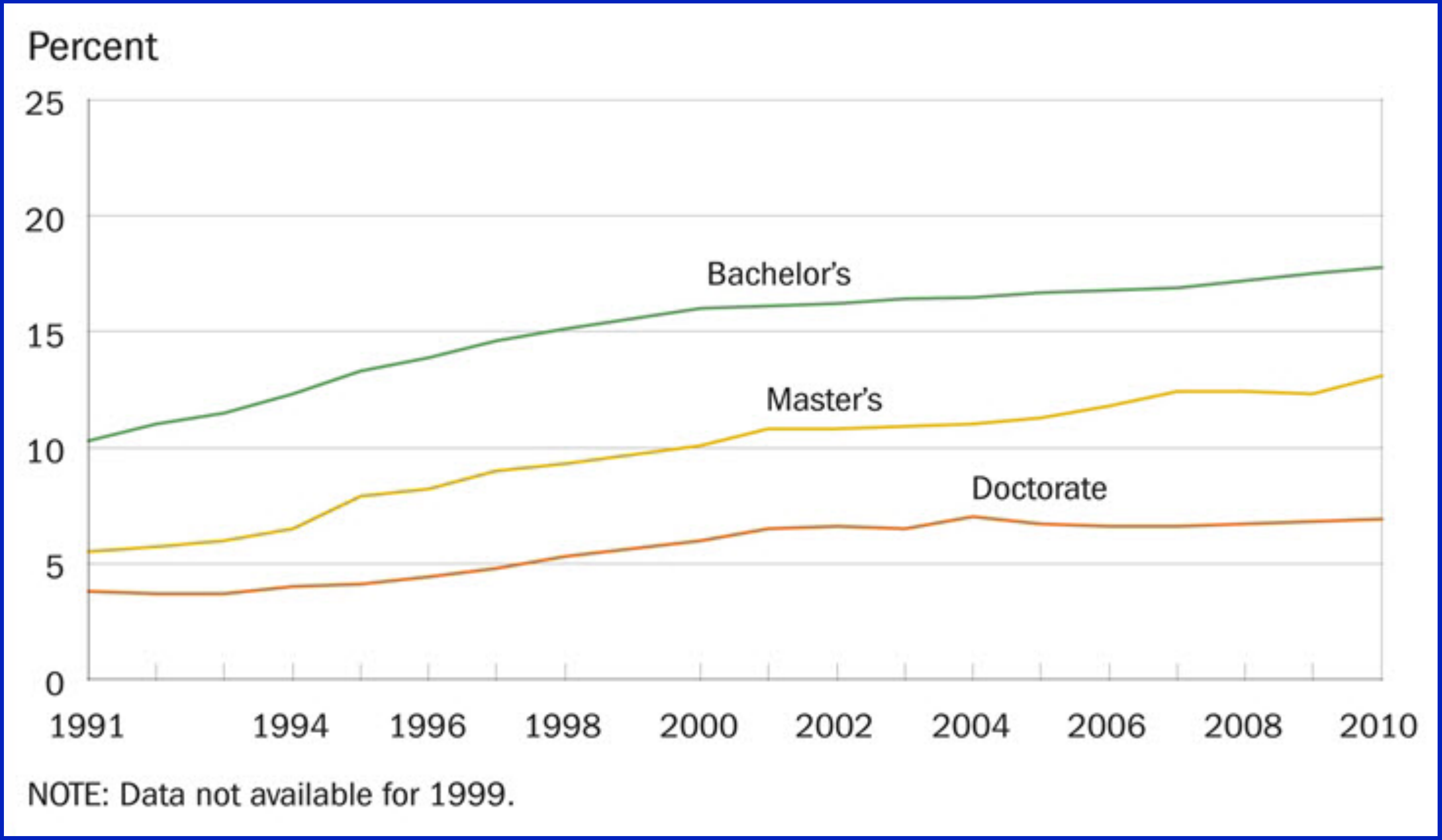
Source: http://www.nsf.gov/statistics/wmpd/2013/pdf/tab5-3.pdf

Percent Change Bachelor's degrees awarded, by field and race/ethnicity: 2001 & 2010



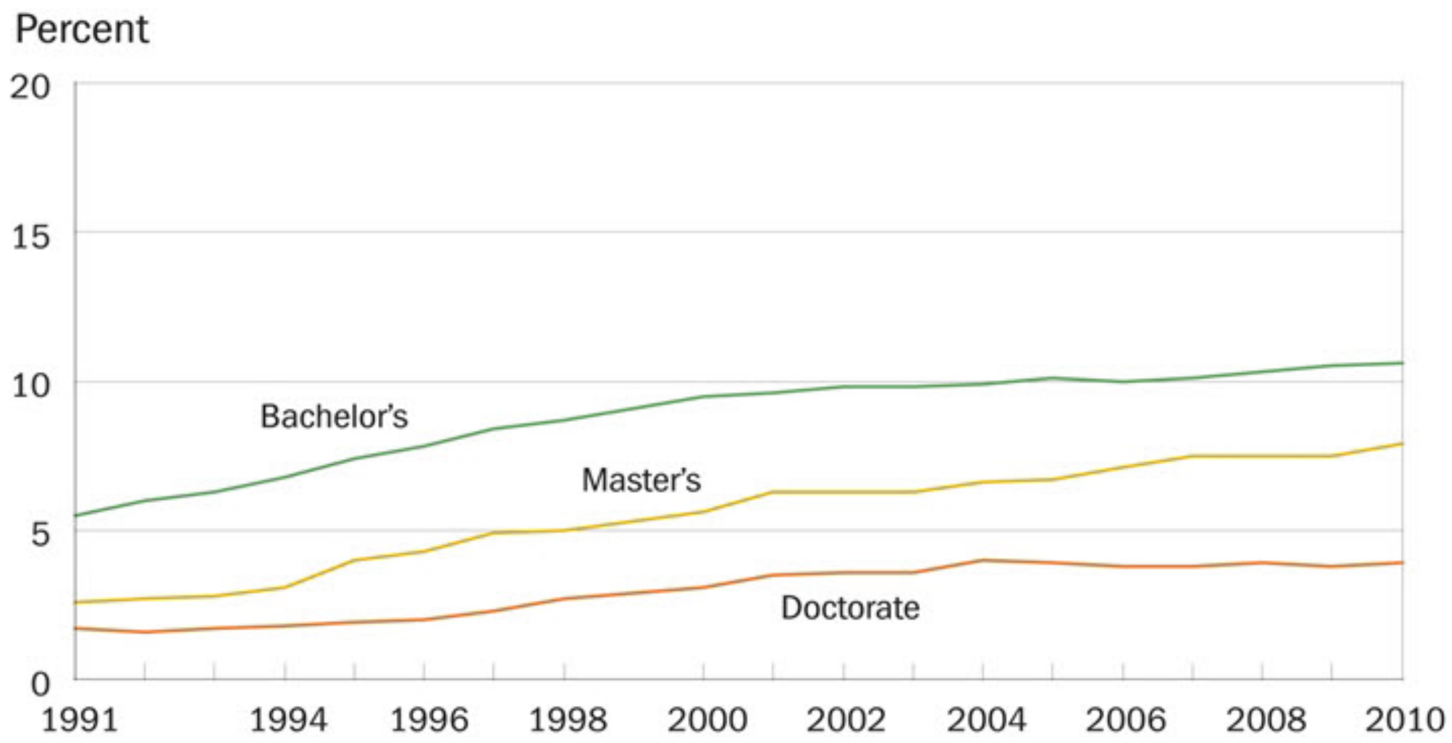
Source: http://www.nsf.gov/statistics/wmpd/2013/pdf/tab5-3.pdf

Science and engineering degrees earned by underrepresented minorities: 1991–2010



Source: http://www.nsf.gov/statistics/wmpd/2013/digest/theme2_2.cfm

Science and engineering degrees earned by underrepresented minority women: 1991–2010



NOTE: Data not available for 1999.

Source: http://www.nsf.gov/statistics/wmpd/2013/digest/theme2_3.cfm

The Course, the Credit and the Curve

- Compartmentalizing
- Time commitment
- What is your major? What is your question?
- Culture of the curve—separating “wheat from chaff”
- Bias—implicit and otherwise

Learning from Learning Sciences

- The learner– cognitive-, social- and cultural psychological aspects
- The learning environment
- The instructional practices
- Learning tools
- Experts and novices

Learning from Gender and Race/Ethnic Studies

- The nature of bias
- Reactions to bias-- Stereotype threat
- Gendered and racialized roles, behaviors
- STEM and bias

Science faculty's subtle gender biases favor male students

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Edited* by Shirley Tilghman, Princeton University, Princeton, NJ, and approved August 21, 2012 (received for review July 2, 2012)

Despite efforts to recruit and retain more women, a stark gender disparity persists within academic science. Abundant research has demonstrated gender bias in many demographic groups, but has yet to experimentally investigate whether science faculty exhibit a bias against female students that could contribute to the gender disparity in academic science. In a randomized double-blind study (*n* = 127), science faculty from research-intensive universities rated the application materials of a student—who was randomly assigned either a male or female name—for a laboratory manager position. Faculty participants rated the male applicant as significantly more competent and hireable than the (identical) female applicant. These participants also selected a higher starting salary and offered more career mentoring to the male applicant. The gender of the faculty participants did not affect responses, such that female and male faculty were equally likely to exhibit bias against the female student. Mediation analyses indicated that the female student was less likely to be hired because she was viewed as less competent. We also assessed faculty participants' preexisting subtle bias against women using a standard instrument and found that preexisting subtle bias against women played a moderating role, such that subtle bias against women was associated with less support for the female student, but was unrelated to reactions to the male student. These results suggest that interventions addressing faculty gender bias might advance the goal of increasing the participation of women in science.

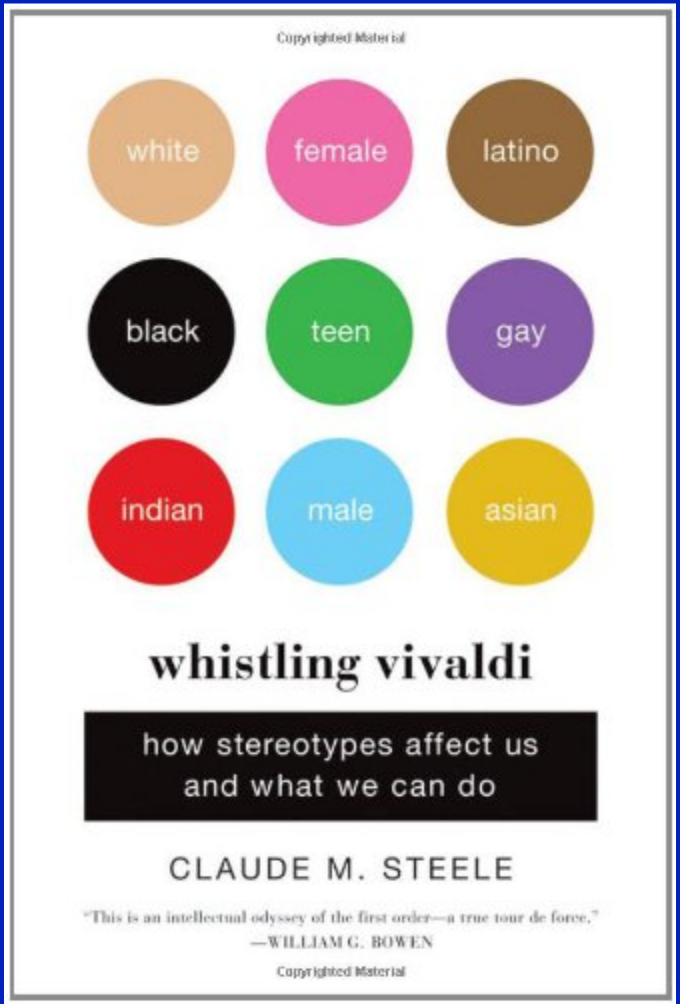
diversity | lifestyle choices | science education | science workforce

A 2012 report from the President's Council of Advisors on Science and Technology indicates that training scientists and engineers at current rates will result in a deficit of 1,000,000 workers to meet United States workforce demands over the next decade (1). To help close this formidable gap, the report calls for the increased training and retention of women, who are starkly underrepresented within many fields of science, especially among the professoriate (2–4). Although the proportion of science degrees granted to women has increased (5), there is a persistent disparity between the number of women receiving PhDs and those hired as junior faculty (1–4). This gap suggests that the problem will not resolve itself solely by more generations gender disparity in science (9–11), and that it "is not caused by discrimination in these domains" (10). This assertion has received substantial attention and generated significant debate among the scientific community, leading some to conclude that gender discrimination indeed does not exist nor contribute to the gender disparity within academic science (e.g., refs. 12 and 13).

Despite this controversy, experimental research testing for the presence and magnitude of gender discrimination in the biological and physical sciences has yet to be conducted. Although acknowledging that various lifestyle choices likely contribute to the gender imbalance in science (9–11), the present research is unique in investigating whether faculty gender bias exists within academic biological and physical sciences, and whether it might exert an independent effect on the gender disparity as students progress through the pipeline to careers in science. Specifically, the present experiment examined whether, given an equally qualified male and female student, science faculty members would show preferential evaluation and treatment of the male student to work in their laboratory. Although the correlational and related laboratory studies discussed below suggest that such bias is likely (contrary to previous arguments) (9–11), we know of no previous experiments that have tested for faculty bias against female students within academic science.

If faculty express gender biases, we are not suggesting that these biases are intentional or stem from a conscious desire to impede the progress of women in science. Past studies indicate that people's behavior is shaped by implicit or unintended biases, stemming from repeated exposure to pervasive cultural stereotypes (14) that portray women as less competent but simultaneously emphasize their warmth and likeability compared with men (15). Despite significant decreases in overt sexism over the last few decades (particularly among highly educated people) (16), these subtle gender biases are often still held by even the most egalitarian individuals (17), and are exhibited by both men and women (18). Given this body of work, we expected that female faculty would be just as likely as male faculty to express an unintended bias against female undergraduate science students. The fact that these prevalent biases often remain undetected highlights the need for an experimental investigation to determine whether they may be present within academic science

PSYCHOLOGICAL AND COGNITIVE SCIENCES



"…despite the strong sense we have of ourselves as autonomous individuals, evidence consistently shows that contingencies tied to our social identities do make a difference in shaping our lives, from the way we perform in certain situations to the careers and friends we choose."

Learning from Higher Education Research

High-Impact Educational Practices

First-Year Seminars and Experiences

Many schools now build into the curriculum first-year seminars or other programs that bring small groups of students together with faculty or staff on a regular basis. The highest-quality first-year experiences place a strong emphasis on critical inquiry, frequent writing, information literacy, collaborative learning, and other skills that develop students' intellectual and practical competencies. First-year seminars can also involve students with cutting-edge questions in scholarship and with faculty members' own research.

Common Intellectual Experiences

The older idea of a "core" curriculum has evolved into a variety of modern forms, such as a set of required common courses or a vertically organized general education program that includes advanced integrative studies and/or required participation in a learning community (see below). These programs often combine broad themes—e.g., technology and society, global interdependence—with a variety of curricular and cocurricular options for students.

Learning Communities

The key goals for learning communities are to encourage integration of learning across courses and to involve students with "big questions" that matter beyond the classroom. Students take two or more linked courses as a group and work closely with one another and with their professors. Many learning communities explore a common topic and/or common readings through the lenses of different disciplines. Some deliberately link "liberal arts" and "professional courses"; others feature service learning.

Writing-Intensive Courses

These courses emphasize writing at all levels of instruction and across the curriculum, including final-year projects. Students are encouraged to produce and revise various forms of writing for different audiences in different disciplines. The effectiveness of this repeated practice "across the curriculum" has led to parallel efforts in such areas as quantitative reasoning, oral communication, information literacy, and, on some campuses, ethical inquiry.

Collaborative Assignments and Projects

Collaborative learning combines two key goals: learning to work and solve problems in the company of others, and sharpening one's own understanding by listening seriously to the insights of others, especially those with different backgrounds and life experiences. Approaches range from study groups within a course, to team-based assignments and writing, to cooperative projects and research.

Undergraduate Research

Many colleges and universities are now providing research experiences for students in all disciplines. Undergraduate research, however, has been most prominently used in science disciplines. With strong support from the National Science Foundation and the research community, scientists are reshaping their courses to connect key concepts and questions with students' early and active involvement in systematic investigation and research. The goal is to involve students with actively contested questions, empirical observation, cutting-edge technologies, and the sense of excitement that comes from working to answer important questions.

Diversity/Global Learning

Many colleges and universities now emphasize courses and programs that help students explore cultures, life experiences, and worldviews different from their own. These studies—which may address U.S. diversity, world cultures, or both—often explore "difficult differences" such as racial, ethnic, and gender inequality, or continuing struggles around the globe for human rights, freedom, and power. Frequently, intercultural studies are augmented by experiential learning in the community and/or by study abroad.

Service Learning, Community-Based Learning

In these programs, field-based "experiential learning" with community partners is an instructional strategy—and often a required part of the course. The idea is to give students direct experience with issues they are studying in the curriculum and with ongoing efforts to analyze and solve problems in the community. A key element in these programs is the opportunity students have to both *apply* what they are learning in real-world settings and *reflect* in a classroom setting on their service experiences. These programs model the idea that giving something back to the community is an important college outcome, and that working with community partners is good preparation for citizenship, work, and life.

Internships

Internships are another increasingly common form of experiential learning. The idea is to provide students with direct experience in a work setting—usually related to their career interests—and to give them the benefit of supervision and coaching from professionals in the field. If the internship is taken for course credit, students complete a project or paper that is approved by a faculty member.

Capstone Courses and Projects

Whether they're called "senior capstones" or some other name, these culminating experiences require students nearing the end of their college years to create a project of some sort that integrates and applies what they've learned. The project might be a research paper, a performance, a portfolio of "best work," or an exhibit of artwork. Capstones are offered both in departmental programs and, increasingly, in general education as well.

LEAP

Table 1

Relationships between Selected High-Impact Activities, Deep Learning, and Self-Reported Gains

	Deep Learning	Gains General	Gains Personal	Gains Practical
First-Year				
Learning Communities	+++	++	++	++
Service Learning	+++	++	+++	++
Senior				
Study Abroad	++	+	++	
Student-Faculty Research	+++	++	++	++
Service Learning	++	+++	+++	++
Senior Culminating Experience	++	++	+++	++

+ $p < .001$, ++ $p < .001$ & Unstd $B > .10$, +++ $p < .001$ & Unstd $B > .30$

Table 2

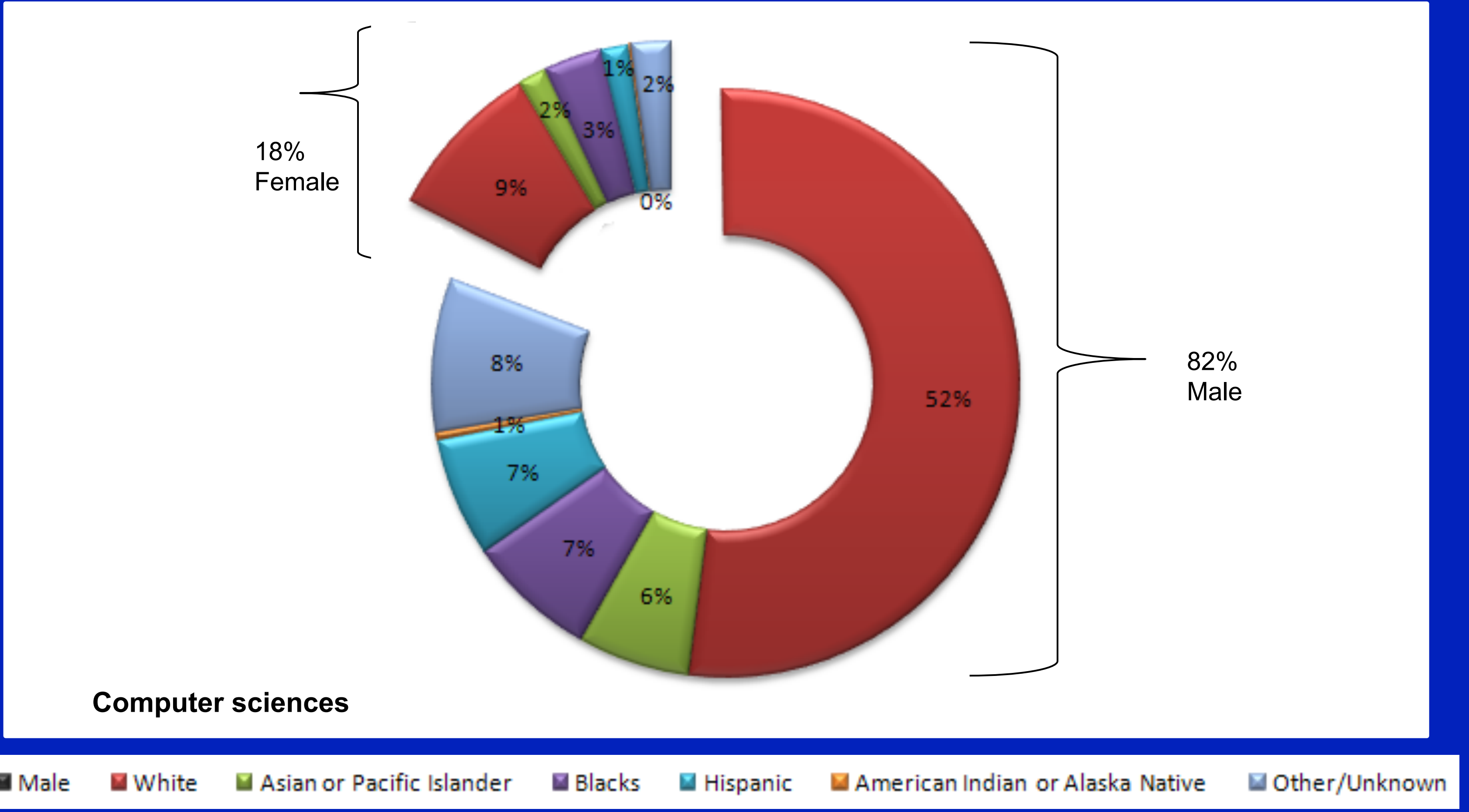
Relationships between Selected High-Impact Activities and Clusters of Effective Educational Practices

	Level of Academic Challenge	Active and Collaborative Learning	Student-Faculty Interaction	Supportive Campus Environment
First-Year				
Learning Communities	++	+++	+++	++
Service Learning	++	+++	+++	++
Senior				
Study Abroad	++	++	++	+
Student-Faculty Research	+++	+++	+++	++
Service Learning	++	+++	+++	++
Senior Culminating Experience	++	++	+++	++

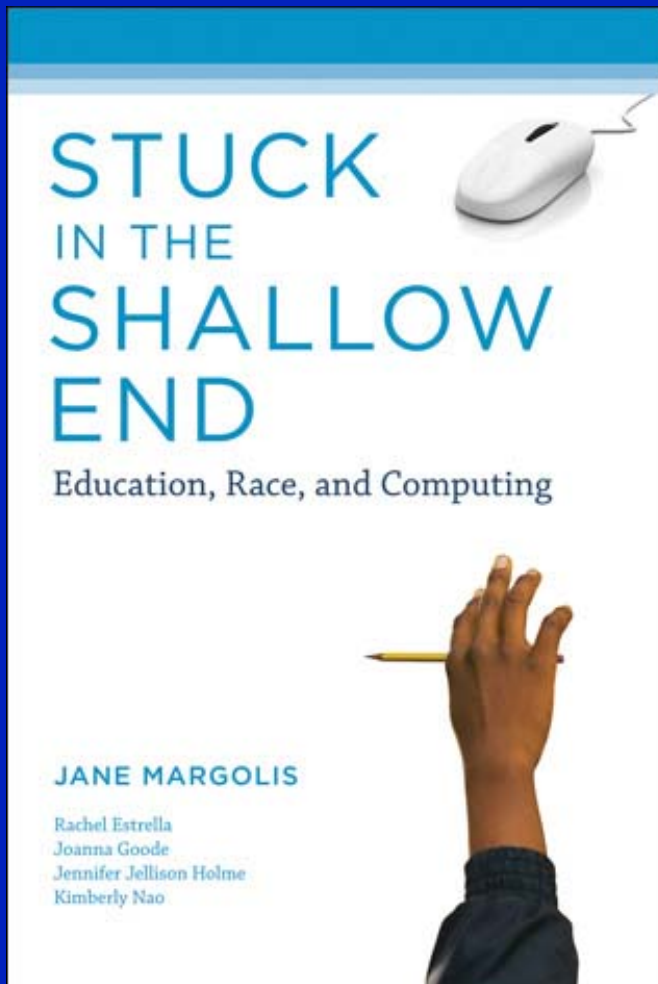
+ $p < .001$, ++ $p < .001$ & Unstd $B > .10$, +++ $p < .001$ & Unstd $B > .30$

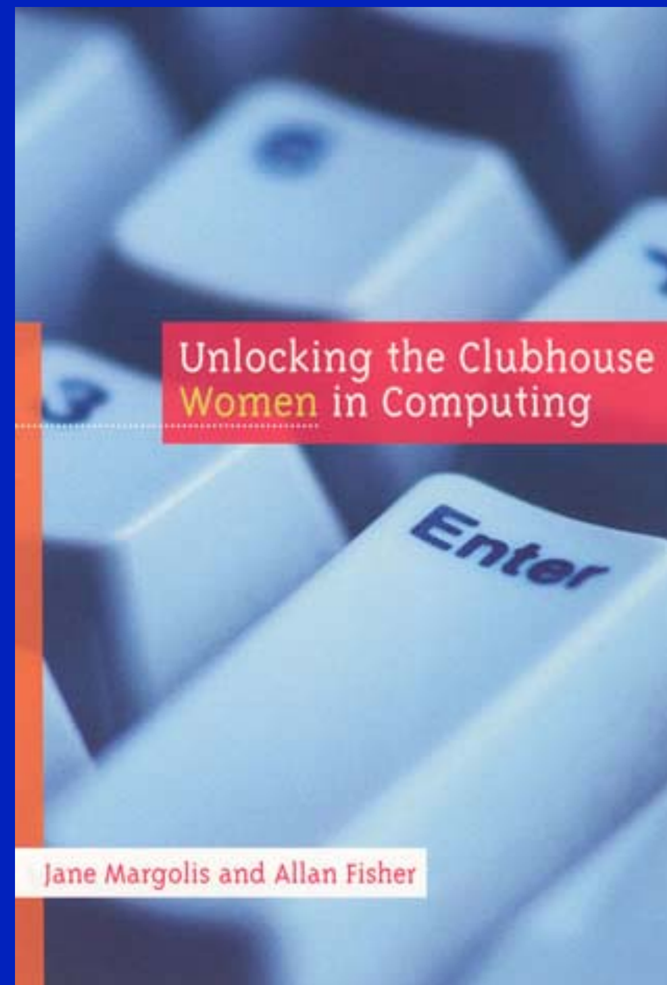
Source: http://www.aacu.org/leap/documents/hip_tables.pdf

% Bachelor's Degrees, disaggregated by race/ethnicity in "*Low Performance*" Computer Science, 2010

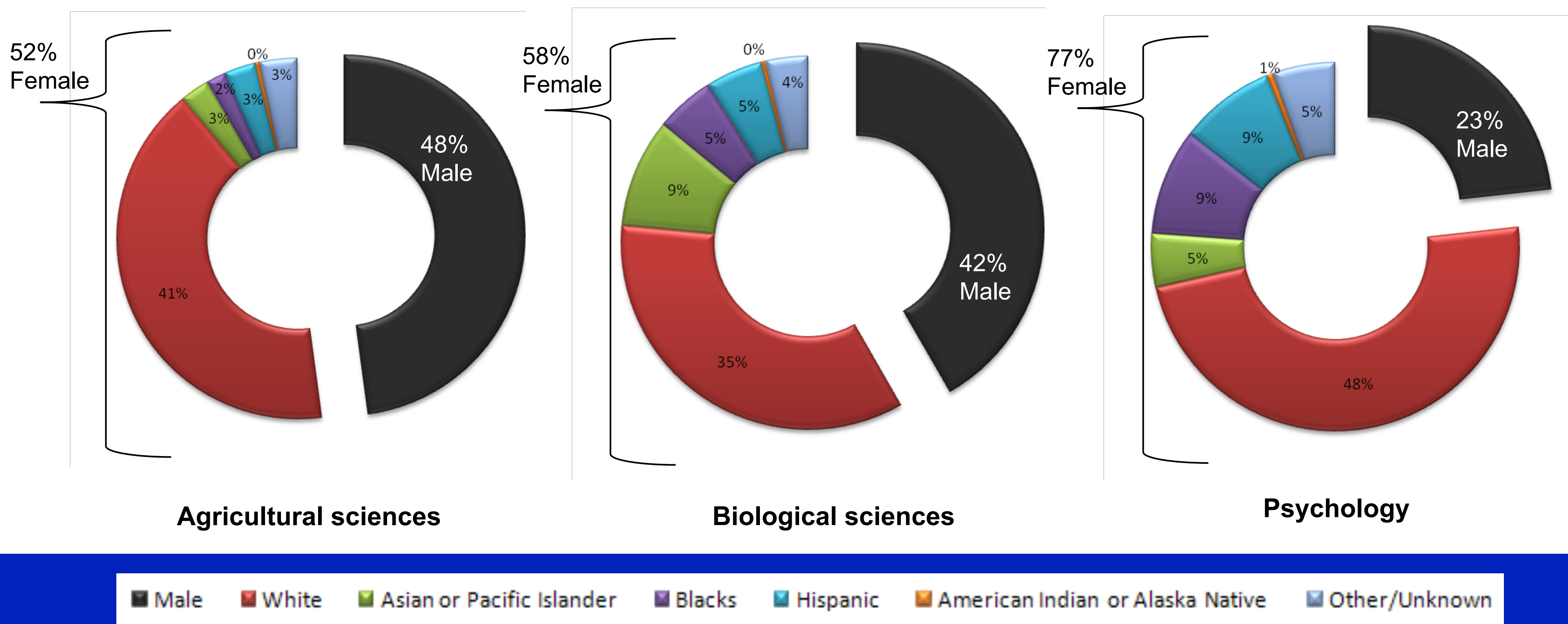


Source: Calculated from NSF, NCES 2010, Table 5.2


STUCK
IN THE
SHALLOW
END
Education, Race, and Computing
JANE MARGOLIS
Rachel Estrella
Joanna Goode
Jennifer Jellison Holme
Kimberly Nao

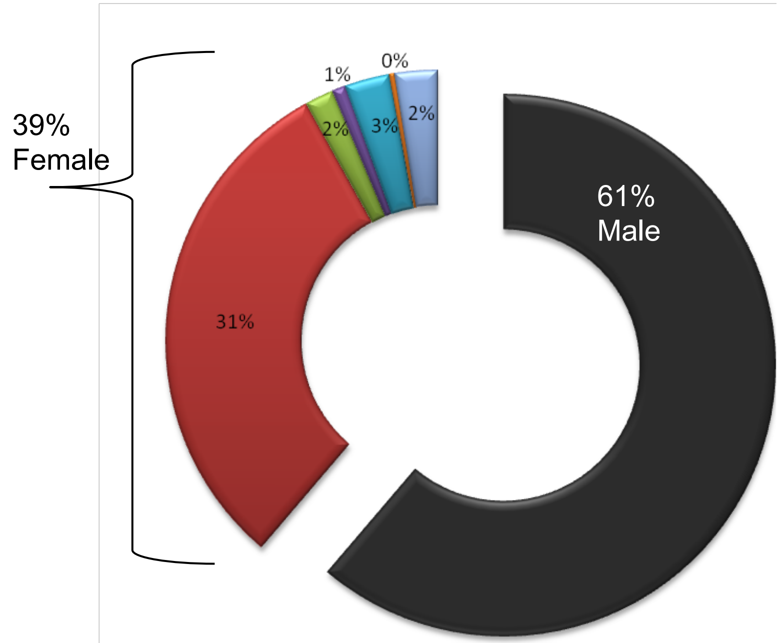

Unlocking the Clubhouse
Women in Computing
Enter
Jane Margolis and Allan Fisher

% Women Bachelor's Degrees, disaggregated by race/ethnicity in select "*High Performance*" STEM Fields, 2010

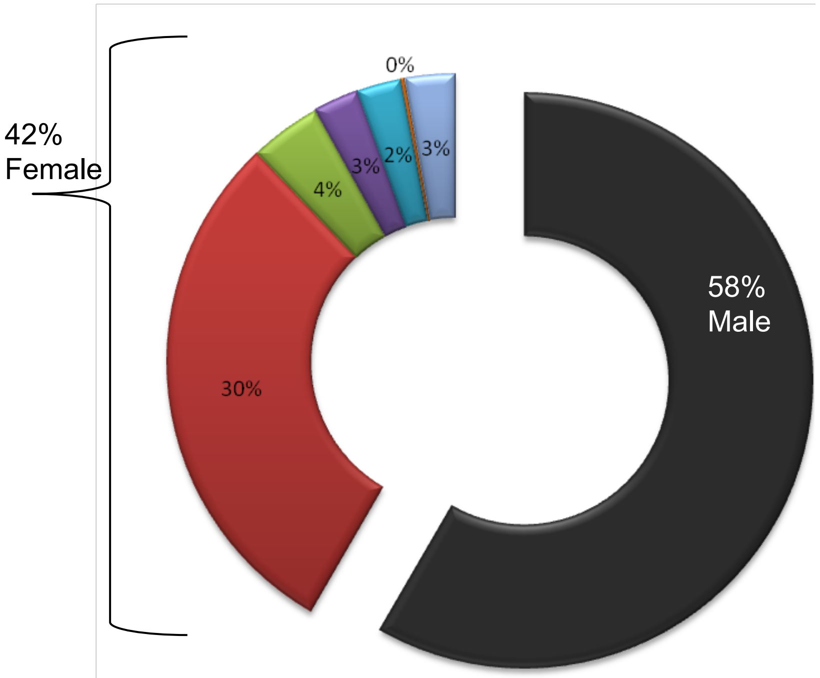


Source: Calculated from NSF, NCES 2010, Table 5.2

% Women Bachelor's Degrees, disaggregated by race/ethnicity in select "*Average Performance* STEM Fields, 2010



Earth, atmospheric, and ocean sciences

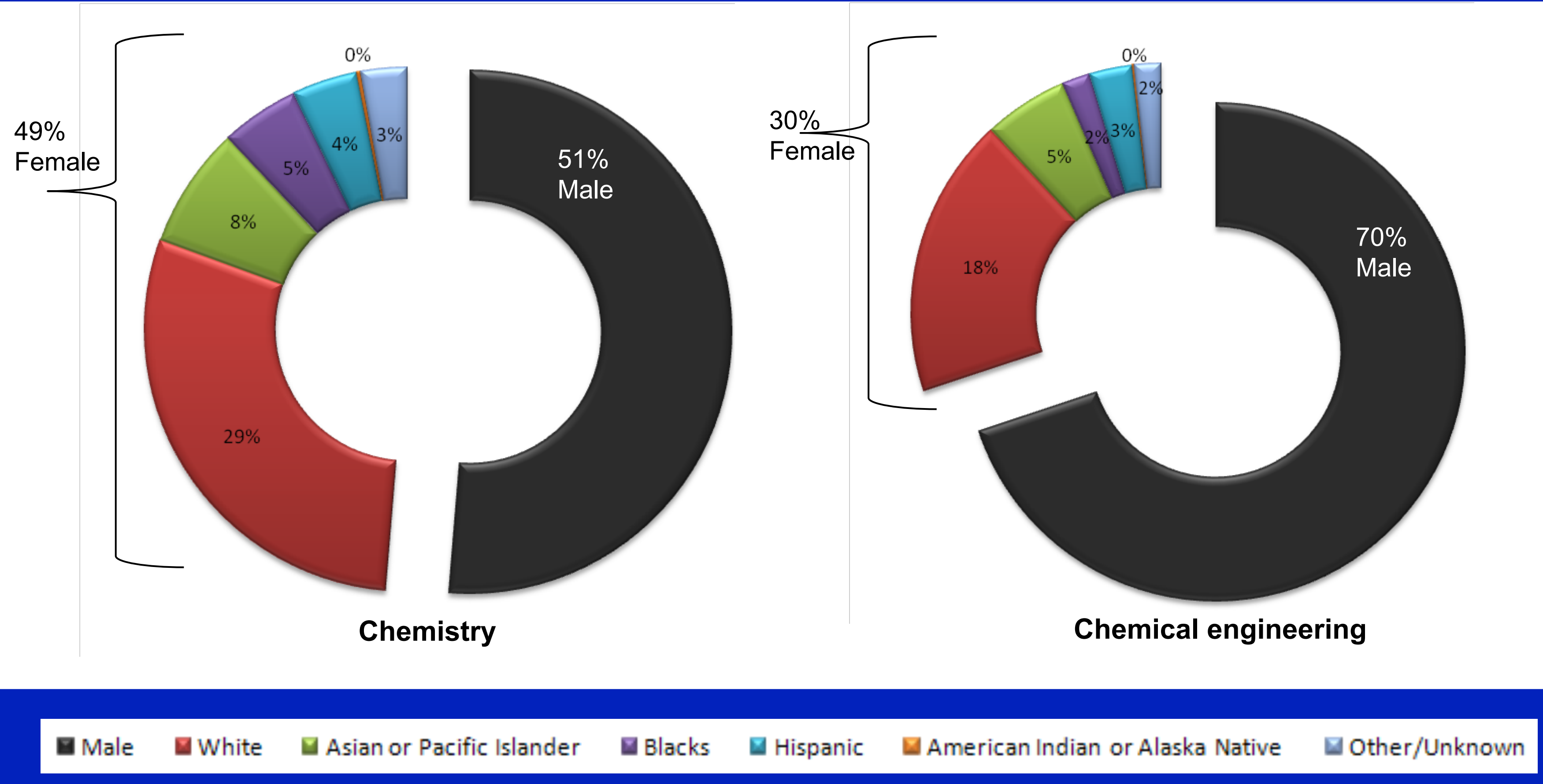


Mathematics and Statistics

Male | White | Asian or Pacific Islander | Blacks | Hispanic | American Indian or Alaska Native | Other/Unknown

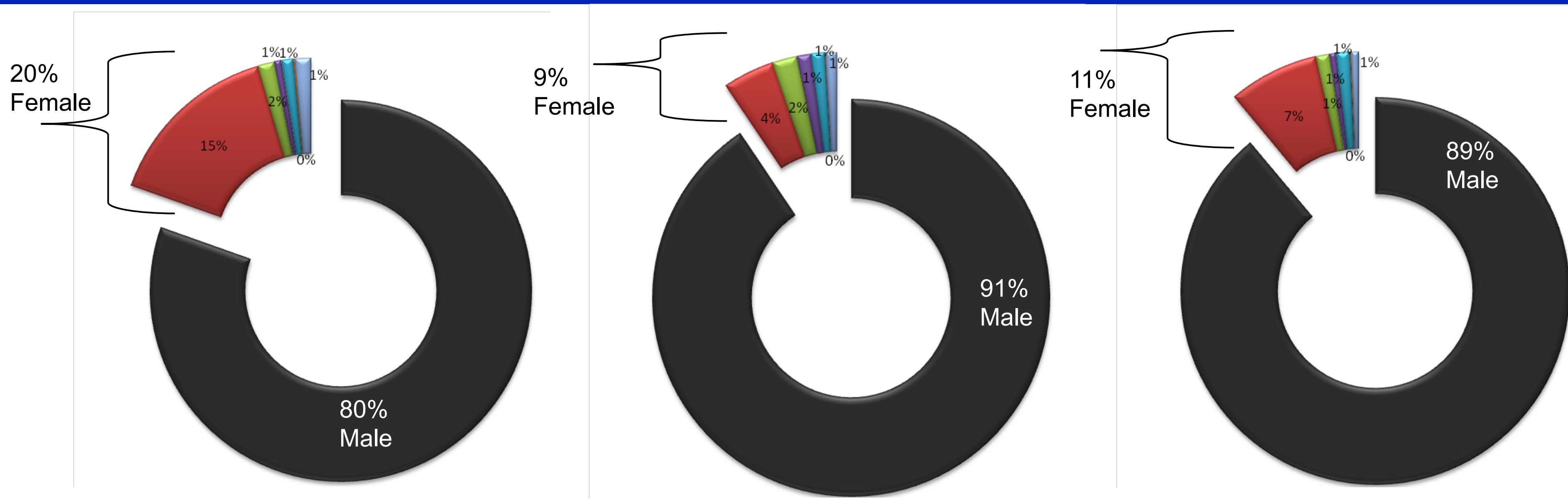
Source: Calculated from NSF, NCES 2010, Table 5.2

% Women Bachelor's Degrees, disaggregated by race/ethnicity in select "*Average Performance* STEM Fields, 2010



Source: Calculated from NSF, NCES 2010, Table 5.2

% Women Bachelor's Degrees, disaggregated by race/ethnicity in select "*Low Performance*" STEM Fields, 2010



Physics **Electrical engineering** **Mechanical engineering**

Male | White | Asian or Pacific Islander | Blacks | Hispanic | American Indian or Alaska Native | Other/Unknown

Source: Calculated from NSF, NCES 2010, Table 5.2

Transformation of STEM Education: Where Gladly Will They **All** Learn

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EDUCATIONFORUM

SCIENCE EDUCATION

Increasing Persistence of College Students in STEM

An evidence-based framework offers a guide for efforts to increase student persistence in STEM majors.

Mark J. Graham,[1,2] Jennifer Frederick,[1] Angela Byars-Winston,[3] Anne-Barrie Hunter,[4] Jo Handelsman[1]*

A 2012 report by the President's Council of Advisors on Science and Technology (PCAST) predicts that the U.S. workforce will suffer a deficit of one million college graduates in science, technology, engineering, and mathematics (STEM) over the next decade (*1*). The report calls f
addressing the shortfall by in
tion of college stu
acad

often as white students (*8*). Such stark statistics invite a hard look at research and practice that bear on retention.

The concept of persistence originates in social and cognitive psychology as one man-
ifestati motivation (*6*). In education,
viewed as a driver of student
Among the important con-
ng motivation is the powerful
fidence (i.e., self-efficacy),
rement for persistence (*9*).
nperative that persistence
otivation and confidence

identifies learning and
ication as determinants
rch demonstrates their
ng student behavior (*2*,
modulated by myriad
of the most success-
itiatives pay careful
nts (*3*). Moreover,
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and, consequently,
our academic suc-
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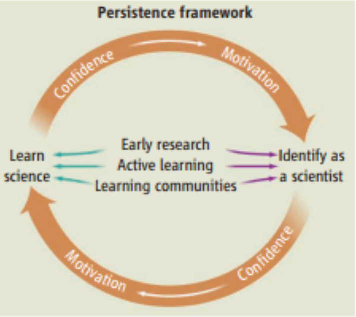

The Persistence Framework. Confidence is belief in one's own ability; motivation is intention to take action in pursuit of goals; learning is acquiring knowledge and skills; and professional identification is feeling like a scientist.

study in STEM fields. Of their 508 STEM majors between 1993 and 2006, Meyerhoff boasts 86% retention in STEM (*3*), twice the nationwide average for all students and more than four times the average retention for African-American students. Other programs such as the Biology Scholars Program at University of California, Berkeley (*11*), more broadly target gender, racial, and ethnic groups. Another approach is the peer-led Gateway Science Workshops at Northwestern University (*12*), which are open to all beginning STEM students. The Posse programs that focus on urban-schooled science students (*1*), and the LA-STEM and Howard Hughes Medical Institute (HHMI) Research Scholars Programs at Louisiana State Uni-

POLICYFORUM

SOCIAL SCIENCE

Scientific Diversity Interventions

Fair treatment of other scientists is an essential aspect of scientific integrity, warranting diversity interventions.

Corinne A. Moss-Racusin,[1]* Jojanneke van der Toorn,[2] John F. Dovidio,[3] Victoria L. Brescoll,[3] Mark J. Graham,[3] Jo Handelsman[3]

Although the representation of women and racial or ethnic minorities within the scientific community has increased in recent decades, the overall pace of diversification remains relatively slow (*1*). A number of factors may be involved (*2*), but one possible explanation for this limited
gender and racial or ethnic
demia (*1*, *3*).

ventions are effective. Once identified, these interventions should be incorporated into existing training offered to scientists, such as courses in responsible conduct of research (RCR). These courses are already required for researchers who receive funding from U.S. federal granting agencies. Although U.S. guidelines for RCR course content contain critical topics, they do not include diversity issues generally or bias specifically (*5*).
fair treatment of other scientists is an
scientific integrity, RCR
ortunities to

pants in exercises, activities, and discussions) produce superior learning outcomes (*10*) and increase the effectiveness of diversity interventions (*8*). Interventions often induce ironic negative effects (such as reactance or backlash) by implying that participants are at fault for current diversity challenges (*9*, *11*). Although some interventions have been in place for decades, few have undergone evaluation to determine whether they produce measurable effects (*6*, *9*). A cohesive framework of the design elements and outcomes of successful interventions is needed to ensure that programs are scientifically rigorous and
desired objectives.
domized controlled trials
of diversity

Assessment—Measuring What We Value

- SAT's, ACT's, GPAs, SES and zip codes
- Early research experience
- "Blind review"
- Lower expectations and halo effects
- "*Grutter, Gratz and Fisher*"

Performance and Potential/Promise

- Nature and nurture
- Choosing winners and making winners
- Adding value
- Baccalaureate origin institutions for PhDs

The Playbook and the Game Plan

- What one COULD do vs. what one needs to do
- Gladly would they all learn—professional development of faculty
- Leadership to support development of previously uninvolved faculty, making them unsatisfied with teaching as they were taught—Where they would gladly teach
- Filling the gaps

The Educational Value of Diversity

- Joe De Simone's Mentor Award
- Evaluation of STCs– Comparing their engagement of URG students with that of parent departments
- Scott E. Page– *The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools and Societies*
- Finding and building community

Putting the Pieces Together

- Drawing on research from many different fields
- Understanding the populations being served in a disaggregated way
- Understanding the signs and points of loss
- The nature of the experience from the perspectives of learners, faculty and institution
- Developing shared goals
- Developing a “game plan” (drawing from a playbook of research based practices)

Putting the Pieces Together (cont'd)

- Filling the gaps (Disaggregate, disaggregate)
- Keeping score (How well are we doing?)
- Making mid-course adjustments
- Supporting collaboration and systemic approaches
- Distinguishing between causes and symptoms
- Responsibility, accountability and leadership

Potential Drivers of Transformation?

- Shifting demographics?
- Changes in college going populations?
- Shifting pathways in higher education?
- Trans-disciplinarity / interdisciplinarity
- MOOCs and other technology based experiments?
- Changes in graduate preparation?

Impediments to Transformation?

You tell me!