
INTRODUCTION

The STEM pipeline starts in elementary school and extends through the professoriate and the rest of the workforce. Most experts in higher education believe that American higher education and industry would benefit from many more people trained in science, technology, engineering and mathematics fields.

But how to find and keep them? And as relates to the pipeline

metaphor, how can we get them all the way through? Analyses of STEM pipeline issues, after all, regularly note leaks all along the way.

The articles and essays in this compilation examine these issues from a variety of perspectives, from undergraduate education through graduate studies and postdoctoral education. Some of the articles focus on efforts to diversify the

STEM talent pool in numerous ways. Others focus on teaching styles.

All of these articles are about college and university efforts based on the view that institutions can do a better job to attract and retain STEM talent.

Inside Higher Ed will continue to cover these issues, and welcomes your ideas for future articles.

--The Editors



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NEWS

A selection of articles by *Inside Higher Ed* reporters

GENDER STEREOTYPES IN STEM

By Kaitlin Mulhere

Research suggests link between ethnicity, gender stereotypes and interest in science, technology, engineering and mathematics.



he gender gap in science, technology, engineering and math fields has been well-documented through various studies and reports. And increasing gender diversity in the so-called STEM fields is a key goal of groups spanning the education, government and labor market sectors.

But few reports on gender participation in STEM analyze women under the microscope of different demographic backgrounds to determine whether there's variation between different cultures or ethnicities, according to the authors of research published online in September 2014 in the American Psychology Association's *Cultural Diversity & Ethnic Minority Psychology* journal.

The study, which compared white and black women's participation in and perception of STEM fields,

found that black women were more likely than white women to show an interest in studying STEM disciplines when they enter college.

The research also shows that African Americans were less likely than white Americans to view STEM programs as masculine, which may help explain why the participation levels vary between the two ethnic groups.

The authors argue that race and ethnicity influence the gender stereotypes that women hold, which in turn influence their interest in the sciences, said Laurie O'Brien, an associate professor of psychology at Tulane University and one of the article's lead authors.

Despite the findings of higher initial interest reflected in the journal article, other data show black women are underrepresented in the number of STEM bachelor's

degrees actually earned, according to the paper.

Most studies to date on women in STEM fields don't identify the ethnicity of participants, often because there is not enough ethnic diversity to measure for variation between different groups.

That raises questions about whether what's known about the underrepresentation of women in STEM fields accurately describes the experiences of nonwhite women, the authors write.

All too often people think of women as a monolithic group, O'Brien said. But there are important differences between white women, African-American women and women from other ethnic groups.

"I think sometimes those differences get pushed under the rug," she said.

Colleges that want to diversify



Source:iStockPhoto

their STEM populations need to look not just at race or gender, but at the intersection of the two, O'Brien said. The experiences of black women in higher education may be very different from the experiences of white women.

O'Brien worked with professors Alison Blodorn from the University of California at Santa Barbara, Glenn Adams from the University of Kansas, Donna Garcia from California State University at San Bernardino and Elliott Hammer from Xavier University of Louisiana.

Their research is based on four similar but separate studies of college students at the beginning of their academic careers.

Science, technology, engineering and mathematics are often associated with independence, a characteristic frequently linked with masculinity, according to the article. That stereotype is one of the key contributors to the gender

disparity.

"Stereotypes have far-ranging effects and become self-reinforcing as they shape the career goals, performance and interests of women and men in ways that are consistent with stereotypes," the authors write.

To measure participants' subconscious thoughts about gender and STEM, the researchers flashed on a computer screen words related to STEM fields, such as biology or calculus, and words related to the liberal arts, such as arts and literature. Participants then had to categorize those words with others that related to either men (boy, father, brother) or women (girl, mother, sister).

In each of three studies with this type of test, African-American women held weaker gender-STEM stereotypes than white women did.

Those findings support a growing body of research finding

that white Americans are more likely than black Americans to see independence as a masculine characteristic, according to the article. Likewise, studies suggest black Americans value independence and self-reliance in women to a greater extent than white Americans do.

In all of the studies, black women were significantly more likely to declare a major in STEM fields than white women were, while there was no significant difference between the participation levels of white and black men.

In one, where the authors analyzed data on more than 1.7 million freshmen from 1990 through 1999, 23 percent of black women said they planned to major in STEM fields compared to 16 percent of white women.

In another study, which included about 800 students from four different universities, 37.6 percent

of black women were STEM majors compared with 18.8 percent of white women. Women at a historically black university included in the study were more likely than black women at the other universities to major in STEM fields.

Part of the difference in women's interest in STEM fields is explained by the gender stereotypes, but they don't explain the entire relationship between ethnicity and interest in STEM, O'Brien said, adding that more research is needed on the topic.

The findings of this research, though, are especially interesting in light of data from the National Science Foundation that show black women are less likely than white women are to actually earn a bachelor's degree in science and math fields

According to the NSF, among women graduating with bachelor's degrees in 2010, 10 percent of white women earned a STEM degree, compared to 8 percent of black women. (The authors of this study used a list of STEM programs identified by the U.S.

Department of Homeland Security, but excluded psychology, since women are not underrepresented in that discipline.)

"That suggests the factors that affect somebody's interest in STEM aren't the same things that affect their attrition in STEM," O'Brien said.

Attrition in STEM fields is a problem several colleges are trying to tackle. It's important to recognize that it may require different efforts, first to attract underrepresented populations and then to keep them there, she said. ■

UNEQUAL ALL AROUND

By Colleen Flaherty

New research finds that STEM fields aren't actually worse than other disciplines in attracting talented students to doctoral study.

Conventional wisdom says that while there are many barriers for women pursuing advanced degrees, the "pipeline" to the sciences, technology, engineering and math is particularly leaky. But a September 2014 paper from the American Institutes for Research suggests that the overrepresentation of male Ph.D. recipients compared to women isn't a worse problem in STEM than in non-STEM fields,

when preparation and interest are taken into account.

"That's kind of the headline finding to me, that in three-quarters of academic fields there's a gender imbalance toward men," said Andrew Gillen, a senior researcher in the institutes' education program and co-author of "Exploring Gender Imbalance Among STEM Doctoral Degree Recipients." "You have a huge number of fields [beyond STEM] where you see

a strong gender imbalance, and that's definitely surprising, to me at least."

To arrive at their results, Gillen and his co-author, Courtney Tanenbaum, a fellow education researcher at the institutes, didn't just focus – as other research has – on the total number of men and women receiving doctoral degrees in STEM and other fields. Arguing that such an approach is valuable only if enrollment of men

Academic Field	Doctoral Degrees per 100 Undergraduate Degrees (Men)	Doctoral Degrees per 100 Undergraduate Degrees (Women)	Women's Doctoral Degrees per 100 Undergraduate Degrees as a Percentage of Men's
Communication Disorders Sciences and Services	17.6	3.6	20.7
Missions/ Missionary Studies and Missiology	18.3	3.8	20.8
Law	32.4	9.9	30.5
Family and Consumer Sciences / Human Sciences, General	4.2	1.4	32.3
Teacher Education and Professional Development, Specific Levels and Methods	1.3	0.5	34.6
Bible / Biblical Studies	1.2	0.5	36.8
Health Services / Allied Health / Health Sciences, General	8.9	3.3	37.3
Public Administration and Social Service Professions, Other	16.1	6.3	39.1
Animal Sciences	7.1	2.9	41.2
Mathematics	10.4	4.3	41.5

■ Indicates STEM Field

and women in degree programs is equally split, they aim instead to compare the number of “prepared and interested” men and women – those who majored in STEM as undergraduates – to the number of eventual Ph.D. recipients.

Using data from the Education Department's Integrated Post-secondary Education Data System (IPEDS), Gillen and Tanenbaum calculated the number of doctoral degrees awarded per 100 bachelor's degrees in scores of disciplines. (They averaged the number of baccalaureate degrees awarded in each year from 2002 to

2007, and did the same for Ph.D.s awarded from 2010 to 2012.)

In the animal sciences, for example, seven Ph.D.s were awarded to men for every 100 baccalaureate degrees. For women, that figure was just about 3 out of 100 – 41 percent of the Ph.D. earning rate for qualified and interested men, as defined by the study. (A rate of 100 percent indicates perfect gender balance). The authors argue that figure is much more telling than a one-to-one comparison of Ph.D.s awarded to men and women in the animal sciences in the relevant time

period: 71 and 70, respectively.

Applied to 135 disciplines, the analysis paints an interesting picture: Men are overrepresented in 103 fields, or 76 percent – and not just in STEM. In fact, the STEM fields are slightly more gender-balanced than non-STEM fields are. Among the 55 STEM fields analyzed, men are overrepresented in 75 percent and women are overrepresented in 26 percent. In the 80 other fields, men are overrepresented in approximately 77 percent and women are overrepresented in 23 percent.

Academic Field	Doctoral Degrees per 100 Undergraduate Degrees (Men)	Doctoral Degrees per 100 Undergraduate Degrees (Women)	Women's Doctoral Degrees per 100 Undergraduate Degrees as a Percentage of Men's
Forestry (Non-STEM)	9.1	20.3	222.9
Slavic, Baltic and Albanian Languages, Literatures, and Linguistics	4.7	9.6	205.7
Forestry (STEM)	14.2	26.5	187.2
Fine and Studio Arts	0.5	0.9	175.3
Information Science/ Studies	1.3	2.2	173.7
Engineering-Related Fields	11.5	19.1	166.6
Computer Engineering	4.8	7.7	158.7
Engineering Physics	12.1	18.6	153.8
Teacher Education and Professional Development, Specific Subject Areas	1.5	2.2	151.0
City/Urban, Community and Regional Planning	10.5	15.8	150.6

■ Indicates STEM Field

The top 10 academic fields in which men are overrepresented among doctoral degree recipients include just two STEM disciplines: animal sciences and mathematics.

Interestingly, the top 10 fields in which women are overrepresented among doctoral degree recipients include five STEM fields, as defined by the study: forestry, information science, engineering-related fields, computer engineering and engineering physics.

Among STEM fields, the researchers found that the biological and biomedical sciences had the biggest gender imbalance, skewing male, and that engineering

– contrary to popular belief – is relatively gender-balanced.

The authors say that their approach illustrates there is “a considerable loss of women candidates between the bachelor’s and doctoral degrees.” They recommend data-driven approaches to retaining student interest, and recommend a “qualitative understanding of student experiences” to aid those efforts.

Gillen said the study didn’t look at why women don’t go on to receive Ph.D.s in greater numbers, such as whether women drop out of Ph.D. programs at higher rates

than men or simply don’t start them in the first place.

But he said his data suggest that intervening early, at the undergraduate level, could reap the best results. And that’s key because this study does not consider why more female students aren’t completing undergraduate degrees in various disciplines.

“Efforts should be focused mostly at the undergraduate level, if you want to correct those gender imbalances,” he said. “Because once you get to the doctoral level, the gender imbalances aren’t that bad compared to the rest of the academic fields.” ■



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UNSUSTAINABLE POSTDOCS

By Colleen Flaherty

National Academies report sees system in disarray and calls for better pay, more mentoring and speedier path to their own labs.

Postdoctoral fellowships make a lot of sense in theory: They offer recent Ph.D.s, especially those aspiring to careers in academic research, a place to develop professionally and – hopefully -- build a research profile before or while hitting the job market. But too often, these fellowships are underpaid, under-mentored positions where young academics languish during what are potentially their most creative, productive years.

That's the upshot of a December 2014 report from the National Academy of Sciences, National Academy of Engineering and Institute of Medicine, which is highly critical of the structural factors driving the growth of postdoctoral ranks, and which recommends a series of reforms – including a big raise for postdocs working on federally-funded biomedical research. The report focuses on postdocs working in the science, technology, engineering and math (STEM) fields, but also cites the

growth of postdocs in the social sciences and humanities.

It's unclear what, if any, difference the report will make in the long term, since an earlier, 2000 report on postdocs from the National Academies drew many of the same conclusions, but didn't force systemic change – although more universities have introduced support services for postdocs. The postdoc problem is also highly complex, and its causes extend beyond any one group of actors or institutions. But advocates say the report comes at watershed moment and echoes recent warnings from other prominent scientists that the current postdoc system is unsustainable.

A Significant Shift

“When you talk to people my age, they usually say their postdoctoral years were some of the best of their lives,” said Gregory A. Petsko, lead author of the report and the Arthur J. Mahon Professor of Neurology and Neuroscience at Weill

Cornell Medical College. “They had relatively strong academic freedom, and they were working on challenging problems under low pressure -- not having qualifying exams or a thesis to worry about – and they weren't particularly concerned about what happened to them when they finished. You never expected you wouldn't be able to find [a job].”

All that's changed, of course, since the 1970s when Petsko was a postdoc, he said, “and not in a good way.” The plight of postdocs worsened in the last decade in particular, he said, due in part to the failure of federal science agencies to have budgets large enough to keep up with demand. Recent Ph.D.s also face a much tougher tenure-track academic job market, even in the STEM fields.

“Today's postdocs are not as happy as we were,” he said. “Their level of anxiety is much greater, and their workload is more burdensome and, in some cases, it's really very tough.”



Petsko said his fellow report committee members – mostly biological and physical sciences professors, with a few administrators and social science faculty members from institutions across the country – wanted to see just how much the landscape had changed, and make suggestions about improving it. But they faced what is perhaps the most significant and telling finding of the study: an overall lack of institutional-level data about how many postdocs are working in which fields.

Incomplete Data

In an “astonishing number of cases,” universities couldn’t even come close to an accurate estimate about how many postdocs they employed, Petsko said. That’s due in part to the fact that postdocs are

called different things in different places, he said, but the lack of data added to the committee’s sense that postdocs are the “invisible people on their campuses.”

In the absence of comprehensive, institutional-level data, the committee looked at federally funded surveys of Ph.D.s, including the Survey of Earned Doctorates. Members also talked to postdoctoral researchers, senior officials from the National Science Foundation and National Institutes of Health, and leaders of various research programs and institutions.

The committee found that the number of postdoctoral researchers in science, engineering and health increased 150 percent between 2000 and 2012, “far surpassing” both the percentage increases in

graduate students and in tenure and tenure-track faculty positions over the same period. In 2012, some 40 percent of all doctorate recipients said they planned on postdoctoral study; the rate was 50 percent for all life science, physical science, social science and engineering Ph.D.s.

It’s estimated that there are between 60,000 and 100,000 postdoctoral researchers working in various research fields in the U.S. According to 2012 data, most (65 percent) work in the life sciences. Some 13 percent work in the physical sciences and 11 percent work in engineering. Geosciences postdocs make up 3 percent of the population, as do those in math and computer sciences. Psychologists account for 2 percent, as do social scientists. “Other” accounts for the

last 1 percent.

Although the number of postdocs in the social sciences is still relatively low compared to STEM fields, the number has “increased a great deal” in the last two decades, said Paula Stephan, a fellow committee member and a professor of economics at Georgia State University -- from 18 percent of new Ph.D.s in 1992 to 38 percent in 2012. Like STEM Ph.D.s, most economists and other social scientist Ph.D.s work exclusively in research, but some humanities postdoc positions involve teaching, she said.

The overwhelming majority of postdocs work in academe, but approximately 11 percent work in national labs and other federally funded research facilities. Those working outside academe tend to have better salaries, shorter appointments and better chances at long-term employment.

Over all, according to 2006 data, postdocs tend to have two-year appointments but spend a median of three to four years in the position. “It’s not unusual to find biomedical researchers who have completed several postdoctoral appointments that total more than five years,” the report says.

Median pay for recent science, engineering and health doctorate recipients working as postdocs is much lower than median pay for recent Ph.D.s not working as postdocs: \$43,000 versus \$76,000,

according to 2010 data.

The report also says that while the NSF has required institutions to have postdoctoral researcher mentoring plans since 2009, data suggest that mentoring is uneven and goes largely unevaluated.

Recommendations for Change

Petsko said he was “sympathetic” to principal investigators, especially junior faculty members, who have little time or experience to provide adequate mentoring as they chase grants and try to publish career-making articles in “boutique” journals that often require rigorous revisions. But he said that the dynamic often makes postdocs inexpensive lab workers, as opposed to trainees building their careers.

The report recommends stronger mentoring and academic and alternative academic career training for postdocs. It says graduate students also need better guidance on whether seeking a postdoctoral position is a next, logical step, based on their career plans.

That’s reflected in part by how postdocs are funded: While the number of postdocs working in institutional fellowships and traineeships has stayed relatively steady, at about 5,000 since 1980, the number of postdocs funded by federal research grants has risen dramatically, from less than 15,000

in 1980 to nearly 35,000 in 2009.

The report makes other recommendations for change, including a term limit of five years, with “cumulative” research experience. Universities also should be more accurate in how they track and employ postdocs, reserving that title only for people receiving advanced training in research. Colleges and universities should create staff scientist positions for longer-term employees who don’t fit that profile, and compensate them appropriately, the report says.

Regarding compensation for postdocs, the report says current salaries are too low. It recommends a minimum salary of \$50,000, saying that the NIH’s National Research Service Award for postdocs of \$42,000 has become the “de facto” pay at many institutions across disciplines.

Petsko said it would be great to see how many institutions played “copycat” if NIH raised the award amount to \$50,000, and adjusted it each year for inflation.

The report says institutions should make salary data, along with all other data about postdoc employment, publicly available, and that the NSF should serve as their primary collector.

Praise, and Hope (If Not Doubt)

Jessica Polka, a second-year postdoctoral fellow in systems

biology at the Harvard Medical School who is involved in postdoctoral outreach in the Boston area, said the report “succinctly and eloquently summarized the feelings of a lot of postdocs,” and that the recommendations addressed “some of the biggest problems facing postdocs today.”

Polka said she particularly supported the report’s recommendation to create staff scientist positions for people who wish to remain in research without pursuing a faculty position. She said the only missing recommendation, in her view, was a discussion of how many postdocs are appropriate for a given field, “since these positions should be tied to the number of relevant jobs rather than to demand for hands in the lab.”

Petsko said the the report doesn’t recommend quotas for Ph.D. program admissions or postdocs, since, in his view, there’s no such thing as “too many” educated scientists. Instead, he said, the report focuses on the idea that labs should only hire as many Ph.D.s as they can properly train -- not simply as many as they can afford.

Over all, Polka said she was optimistic that the report would lead to some reform for postdocs. “Nothing can be done without starting a conversation,” she said, noting that she was happy in her position but knew of other postdocs elsewhere who were not. She said

she hoped to be on the research-intensive, tenure-track job market within the next few years, and was working to bolster her research record before that time.

Kiernan Mathews, director of the Collaborative on Academic Careers in Higher Education at Harvard, was equally supportive of the report, but slightly more skeptical that it would lead to long-term change.

“Ultimately, my reaction to the NAS report is ‘Yes!’ But who is going to make all of this happen?” he said via email. “Many of the changes they are advocating are changes in departmental cultures and institutional/market incentives. That kind of change doesn’t just happen because we all agree it should. It takes changing one person at a time, all at the same time, and that’s damn near impossible.”

Still, Mathews said the report touched on an important topic with ramifications for the future of the profession as a whole, namely that the growing expectation for postdoctoral experience in faculty hires is leading to an “older and more financially constrained” academic workforce. That has a disproportionate effect on women, he said, who often put off starting families until they achieve stability in their careers.

Both Petsko and Stephan, the committee members, said real change would require long-term

commitment on the part of federal agencies, faculty members, universities and postdocs themselves. But they said an immediate, helpful first step would be increasing the salary of postdocs.

Addressing additional skepticism surrounding change the report might effect, Stephan said it comes at a time when many scientists feel that their “backs are to the wall,” and the research treadmill system has to slow down.

She noted a much-cited 2014 article in the *Proceedings of the National Academy of Sciences*, which raised many of the same concerns discussed in the postdoc report.

Bruce Alberts, former president of the National Academy of Sciences and current Chancellor’s Leadership Chair in Biochemistry and Biophysics for Science and Education at the University of California at San Francisco, co-authored that article, called “Rescuing U.S. Biomedical Research From Its Systemic Flaws.”

He said he hadn’t read the entire postdoc report, but said it was “in general agreement” with his concerns. He emphasized that if graduate student admissions won’t be reduced, academe needs to “much more transparently report” career outcomes and other data for Ph.D. programs. He also said professors need to do a better

job of connecting students and postdocs to those in other careers, suggesting that the NIH might require such activity.

In an emailed statement, NIH's Office for Extramural Research wrote that "NIH believes that postdoc compensation should correspond to their advanced skills and many years of training" and "has taken steps to increase [stipends] to better reflect the level of experience that postdoctorates bring to their positions, and to

provide for regular cost of living increases."

The office noted that institutions are free to "supplement those levels for trainees and fellows," and set their own postdoc salary levels.

Regarding the report's call for more mentoring of postdocs, the office said that "NIH's extramural and intramural programs have long recognized the importance of mentorship in research training, and especially given constrained

resources NIH supports and expects that faculty will mentor postdocs so that they can set and achieve goals related to their career progress."

NIH said it encourages mentorship by "encouraging grantee organizations to develop an institutional policy requiring an [individual development plan] for graduate students and postdocs supported by any NIH grant," for example, not just training grants and fellowships. ■

HEALING WAR WOUNDS

By Charlie Tyson

Disabled veterans at U. of Pittsburgh's college transition program work in a lab to develop assistive technologies -- gaining STEM training and helping other veterans with impairments.

Jon Miller is 32 years old, from a town outside Pittsburgh that, according to the latest census data, has a population of 434. He has been in the Army Reserves for more than 15 years. He enrolled at the University of Pittsburgh in January 2013, planning to major in civil engineering. He wanted to build bridges.

The transition to college life, after deployments in Iraq and

Afghanistan, was tough. "I had a lot of anxiety," Miller said. "When you go through the military, and especially when you're this age, you want to strive to not only pass but get toward the top."

Unlike many veterans, Miller isn't noticeably hurt. But he has breathing problems, possibly the effect of chemicals used in warfare. He also has gaps in his knowledge. His major in civil engineering required him to draw

on skills that had atrophied – or on concepts he'd never mastered in high school.

"I refer to it as Swiss cheese," he said. "When you go through school as fast as they pump you through, you get a lot of holes."

Student veterans have made strides. Congress in 2014 passed a bill requiring public universities to offer recent veterans in-state tuition (returning veterans are often "stateless" for residency



A veteran in Pittsburgh's summer program works in a machine shop.

purposes). And chapters of Student Veterans of America, an association that helps returning veterans integrate into campus life, have grown rapidly in number in the last two years, said Chris Cate, the organization's vice president of research.

Yet despite the increasing public recognition of the distinctive obstacles student veterans face, for many returning veterans college remains jarring. Political momentum may help resolve some of the challenges student veterans contend with, such as delayed GI bill payments and inconsistent campus policies for transferring military credits. But addressing other problems – such as an inability to relate to non-

veteran peers, or cognitive and physical disabilities caused by injury – requires painstaking day-to-day work.

Such work is happening at the University of Pittsburgh, where a college transition program for disabled veterans interested in STEM disciplines has earned the admiration of national student veterans' groups.

Through August 2014, 25 veterans, including Miller, have completed a 10-week summer program housed in the University of Pittsburgh's Human Engineering Research Laboratories. The lab specializes in assistive technology – devices for people with disabilities -- and receives funding from the Department of Veterans Affairs.

Rory Cooper, the lab's director, is an Army veteran who sustained a spinal cord injury while serving.

All the participants have cognitive or physical impairments – most commonly traumatic brain injury and post-traumatic stress disorder. The program, called ELeVATE (Experiential Learning for Veterans in Assistive Technology and Engineering), began in summer 2011, with the help of a \$470,000 grant from the National Science Foundation. Five or six veterans participate each year. The fourth group of participants finished the program at the end of July 2014.

Veterans in the transition program all take remedial mathematics and writing courses and participate in professional development

activities, such as a recent resumé workshop sponsored by Google Pittsburgh. The remedial courses are small -- with just five or six veterans in the classroom -- and the teachers offer personalized instruction, Miller said.

The bulk of their time, however, goes toward applied projects in the lab. The program matches veterans with projects in which they have interest or expertise. For example, a student who served as an electrician in the military might be assigned to an electronics project, Goldberg said. Working closely with a graduate student mentor and a faculty mentor, the veterans build and design assistive technology projects. One developed a low-cost power wheelchair.

Mentors receive training on how to work with participants with cognitive impairments, Goldberg said. Well-honed techniques include breaking tasks down into smaller steps and explaining concepts methodically. The work is difficult -- but the participants are resilient.

"We think of ourselves as a safe space to fail because we think failure is an important part of the process," Goldberg said.

Many institutions have reintegration programs for veterans. But Pittsburgh's program is alone in allowing veterans to help other veterans through

rehabilitation research, Cate said. In addition, more and more veterans in recent years have become interested in STEM, he said.

The participants receive a \$4,000 stipend and a \$2,100 housing stipend. Non-local participants get \$500 to defray start-up and travel costs. The program costs roughly \$10,000 per student, said Mary Goldberg, education and outreach project director at Pittsburgh's department of rehabilitation science and technology, in which the labs are based.

A majority of participants come into the program with some college credit, and two in the program's history came in already having completed a bachelor's degree. Roughly 40 percent, however, are transitioning to college for the first time. After the summer program, most participants start or continue at college in the fall.

On average, the participants are about 30 years old, with roughly eight years of military service behind them, Goldberg said. About 70 percent come from the Pittsburgh area. The program has graduated just one woman, although Goldberg hopes to change that through better marketing.

The program's leaders hope Pittsburgh's effort will provide a template for other institutions developing services for veterans.

The University of Texas at Arlington replicated the program this summer and plans to do so again, Goldberg said. And two to three other institutions have expressed "very sincere interest" in piloting the program, she said.

Pittsburgh's own expansion capabilities are modest. Goldberg said the program could accommodate up to 10 veterans a year, roughly twice the current number. Although the program gets 10 to 12 applicants for each summer's cycle, not everyone is a good fit, Goldberg said.

"It's important we feel we identify participants who are ready and prepared for the program," she said. "It's pretty intense."

Steve Gonzalez, assistant director of the American Legion, a veterans' service organization, visited the Pittsburgh lab and was moved by what he saw: other veterans, close to his age, absorbing sophisticated knowledge and building complex devices. The program, he said, helped its participants -- hampered by cognitive and physical impairments -- to "not know any limitations."

"We as veterans in some cases underestimate ourselves," he said. "And I think some people believe we are limited by our physical abilities or our mental abilities. [But] if someone's willing to teach, I guarantee you, you will find veterans who are willing to learn." ■

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MISSING MINORITY PH.D.S

By Scott Jaschik

Most black and Latino doctoral students in STEM fields are not earning their degrees within 7 years, and many are leaving their programs, new study finds.

ATLANTA -- The Institute on Teaching and Mentoring, whose annual meeting took place here in November 2014, gathers 1,300 minority Ph.D. students and postdocs, and some of their advisers in what is billed as the largest annual gathering of minority doctoral students. Many here talk about the challenges created for black and Latino students who end up -- as doctoral candidates or later as junior faculty -- with few colleagues who share their backgrounds.

The institute celebrates the success of new minority Ph.D.s in a ceremony in which they put on their doctoral robes, but what of those who didn't make it to the finish line?

Data presented here by the Council of Graduate Schools suggest that higher education could significantly diversify the Ph.D. pool by holding on to more of those black and Latino students who start programs but do not finish. Only 44 percent of black and

Latino Ph.D. students in STEM (with STEM defined to include behavioral and social sciences) earned a doctoral degree within seven years, according to the new study. That's only slightly more than the 36 percent who leave their programs. (Another 20 percent are still in their programs, without a Ph.D., after seven years.)

The new data come from a council study that looked at the progress of more than 7,000 black and Latino graduate students enrolled from 1992 through 2012 at 21 research universities. The work was supported by the National Science Foundation, which along with the council wanted to find out if there had been much progress since previous studies. (The official report is still a few weeks away, but the data were presented at a session here.)

A 2004 report, for example, found that across all disciplines, the 10-year doctoral completion rate for students of all races and ethnicities was 57 percent, while the rates

were 51 percent for Latinos and 47 percent for African Americans.

The new study also looked at 10-year rates, and found that the overall black and Latino STEM Ph.D. completion rate in that time frame was 54 percent. But many in the room (primarily graduate faculty members in STEM fields) said that they had a hard time viewing 10-year completion as success. "Does anyone here want to keep students for 10 years? What are they doing?" asked one participant.

Robert A. Sowell, who recently retired as vice president of the Council of Graduate Schools and is finishing work on this study, said the results were disappointing in part because so many efforts have been started by so many groups in recent years to improve the completion rates of Ph.D. programs for all students and in particular for minority students.

For the latest study, the focus was on seven-year completion rates and only black and Latino



candidates were tracked. (Sowell said Native Americans are also underrepresented but the pool was too small to offer meaningful analysis on completion rates.) The study found significantly higher completion rates for Latino than for black students (48 percent vs. 40 percent).

There were differences by type of STEM field. The seven-year completion rates were higher for engineering (48 percent) and life sciences (52 percent) than for physical sciences and mathematics (39 percent) and social and behavior science (38 percent). For every STEM specialty, and for black and Latino students alike, women are completing at higher rates than men.

In addition to compiling the data on completion rates, the council also conducted both a survey and focus group interviews with black

and Latino graduate students.

In the survey (1,640 responses), the study found mixed evidence on whether graduate programs in STEM are doing a good job in making black and Latino doctoral students feel that they are treated equally. Seventy-seven percent reported that standards were the same for all graduate students, and only 13 percent reported that they experienced racism in the program. But only 31 percent reported that they felt that faculty members understood issues that affect underrepresented minority students. People who attended the session were mixed on whether the 13 percent figure was surprisingly low or high.

The survey also found black and Latino students reporting mixed personal experiences while in their doctoral programs. A very high percentage (95 percent) said

they felt supported by a network of students. But 62 percent reported being worried about their mental or physical health while in grad school, 53 percent reported that they were losing interest in the field, and 40 percent said they felt burdened financially.

The students were also asked open-ended questions about what would most help minority doctoral students finish. The top responses were that faculty members be clear about expectations, and review student progress regularly.

In the focus groups, several themes also emerged. One is that many black and Latino students feel that they are constantly being evaluated and that they feel pressure to perform well, in part because of their minority status. One student said: "I have to look on point and maybe it's just in my head, but I feel have to be that

much better” than other students. Another doctoral student said: “If I were to miss class, it would be noticeable.”

Another common theme was

that family members supported them, and were proud, but had no idea what their doctoral education was about.

They reported comments from

parents such as: “When do you finish?” “What is that you really do?” “When am I having grandkids?” and “What kind of doctor are you going to be?”” ■

A BOOST FOR ACTIVE LEARNING

By Doug Lederman

Students in science and math fields learn more and fail courses less when their instructors use methods other than lecturing, a massive study finds.

Scott Freeman and the other scholars behind a May 2014 study comparing the efficacy of lectures with more “active” forms of instruction in the science classroom are not aiming low in describing the significance of their findings.

Just as the U.S. surgeon general’s 1964 report on smoking provided strong evidence linking tobacco use to ill health, Freeman said, the study he and his colleagues produced “provides overwhelming evidence that active learning works better than lecture.” That may not mean that instructors stop lecturing, he said, “but it shouldn’t be about the evidence anymore.”

The study, published in *Proceedings of the National*

Academy of Sciences by a team of researchers at the University of Washington and University of Maine, is a meta-analysis of 225 previous studies comparing student outcomes in science, technology, engineering and mathematics courses that use lectures alone versus those that incorporate group problem-solving, use of clickers, workshops or other forms of “active learning.”

On average, students in sections characterized by active learning scored 6 percent better on examinations than did their counterparts in lecture-only classrooms, and those who were in lecture-driven sections were 1.5 times likelier to fail than were their peers in active learning classes. About a third of all students in

traditional lecture classes either withdrew or got Fs or Ds, compared to about one-fifth of students in sections with active learning approaches.

The researchers say their findings held across all STEM disciplines and in class sizes and course levels of all sorts.

“[T]he data suggest that STEM instructors may begin to question the continued use of traditional lecturing in everyday practice,” the authors write.

“Although traditional lecturing has dominated undergraduate instruction for most of a millennium and continues to have strong advocates, current evidence suggests that a constructivist ‘ask, don’t tell’ approach may lead to strong increases in student



performance.”

In an interview, Freeman, principal lecturer in the biology department at Washington, demurred when asked if it was appropriate to extend his analogy about the surgeon general’s 1964 smoking report to the two studies’ conclusions: as tobacco is bad for smokers, is lecturing bad for students?

“I’m not sure I would go quite that far, but some people have,” he said, citing a recent article in which Mary Ann Rankin, senior vice president and provost at the University of Maryland at College Park, was quoted calling lectures

“toxic” to student health.

Freeman acknowledged that the study presents a stark dichotomy, contrasting lecture-only courses with those in which instructors used any of a range of other techniques, and without distinguishing among courses based how much active learning they incorporate. (He describes his own 500- to 700-student courses as including about 60 percent students talking to each other and about 40 percent him explaining concepts or problems to them.)

An examination of nine studies that produced the “most extreme values” in terms of positive student

outcomes showed that seven were entirely lecture-free, Freeman said -- though he noted that number was too small to draw truly meaningful conclusions.

'False Polarizations'

It is precisely the survey’s binary distinction that bothered Frank Furedi, a former sociology professor at the University of Kent who is among numerous scholars who have written defenses of the lecture in recent years.

Furedi complained about the “false polarizations” in the PNAS study.

“Only an idiot would rely entirely

on lectures -- that hasn't happened for 200 years," he said. "The art of teaching is getting that balance between giving the lectures creatively to impart information and organizing more intensive interactive discussions with students, in different formats."

Furedi also said that he was unsurprised that the study found

students in courses with active learning to be less likely to fail -- but that there were multiple ways to interpret that result.

"The whole dynamic toward grade inflation is far more prominent among the departments that focus on active learning, at least in the European context," he asserted. "One of the reasons why people

use active learning is because they're worried about losing students, boring students, Furedi said. "If you're simply interested in keeping bums in seats, it rewards people for time served.

"Active learning may get good results in terms of retention, but it may be an illusory outcome." ■

THE STEM ENROLLMENT BOOM

By Scott Jaschik

Since the recession, undergraduate enrollments have gone up dramatically, but primarily in engineering and biology and not at expense of humanities and social sciences, study finds.

P HILADELPHIA – Policy makers regularly talk about the need to encourage more undergraduates to pursue science and technology fields. New data suggest that undergraduates at four-year institutions in fact have become much more likely to study those fields, especially engineering and biology.

And while much of the public discussion of STEM enrollments has suggested a STEM vs. liberal arts dichotomy (even though some STEM fields are in fact liberal arts disciplines), the new study suggests

that this is not the dynamic truly at play. Rather, STEM enrollments are growing while professional field enrollments (especially business and education) are shrinking.

The research, presented here in April 2014 at the annual meeting of the American Educational Research Association, is by Jerry A. Jacobs, professor of sociology at the University of Pennsylvania, and Linda Sax, professor of education at the University of California at Los Angeles.

Much of the data typically discussed on student enrollment patterns come from the National

Center for Education Statistics. But the new study is based in large part on the "freshman survey" conducted annually by UCLA on a national pool of freshmen at four-year institutions. In their paper, Jacobs and Sax write that this data set enables them to spot trends much earlier than is possible with the federal database, since that information is based on graduation (which comes much later than enrollment) and because government cuts have led to delays in federal data.

Using data collected by UCLA, Jacobs and Sax write that from



Bioengineering students at SUNY Binghamton

1997 through 2005, the proportion of freshmen planning to enroll in STEM fields declined, hitting a low in 2005 of 20.7 percent. After modest gains in 2006 and 2007, real increases started to show up in 2008.

The percentage of freshmen planning to major in STEM increased from 21.1 percent in 2007 to 28.2 percent in 2011, just as the recession was prompting many students and families to focus on the job potential of various fields of study. That represents a 48 percent increase in just a few years.

The growth was not consistent across STEM fields. Engineering saw a 57.1 percent increase (consistent with findings from the American Society for Engineering Education) and biology saw gains

of 28.2 percent. But the physical sciences saw gains of 11.1 percent, and mathematics was up by 12.6 percent.

Generally, the STEM gains were seen for both male and female students, so gender gaps that remain in some STEM fields weren't significantly changed.

The paper notes that disciplines such as biology and mathematics, while STEM fields, are located in arts and sciences programs at many institutions, so that a "STEM vs. liberal arts" comparison doesn't make sense.

But the fields showing declines during this period were not traditional liberal arts fields, but applied fields. The paper notes that business and education saw declines of 5.9 percent, suggesting that they -- more than the liberal

arts -- are losing freshmen.

Jacobs said in an interview that those concerned about STEM education shouldn't pursue that goal at the expense of the humanities.

He said that the critical thinking skills associated with the humanities are needed by all kinds of students. Those who want more STEM students should focus on attracting more female students, some of whom may not feel encouraged in the area, rather than offering "criticism of the humanities," as a number of politicians have done lately.

Jacobs said that he was pleased to find that the increase in STEM enrollments was coming from professional programs, rather than from liberal arts programs. ■

'FALLING BEHIND?'

By Elizabeth Redden

Book challenges the conventional notion that the U.S. is producing too few science and engineering graduates to meet its workforce needs and remain globally competitive.

The U.S. isn't producing enough highly skilled graduates in the science, technology, engineering and mathematics (STEM) fields to meet the country's workforce needs. To remain competitive in an increasingly globalized world the U.S. needs to step up its own production of STEM graduates and amend its immigration policies to better recruit the best and the brightest from abroad.

Such is the conventional wisdom in the halls of Congress and many corners of higher education. But what if it's wrong?

Michael S. Teitelbaum's 2014 book *Falling Behind?: Boom, Bust & the Global Race for Scientific Talent* (Princeton University Press) calls into question the conventional notion that the U.S. is falling behind in the production of talented STEM graduates. Teitelbaum argues that the recurrent calls of a generalized shortage of STEM workers are 1) "inconsistent with nearly all available evidence" and 2) self-

serving, promoted as they are by technology industry employers and their lobbyists invested in expanding the H1-B guest worker visa program and their access to larger and therefore cheaper pools of labor.

"Over the past two decades, lobbying and public relations efforts to convince U.S. political elites that the country faces damaging and widespread shortages in its critical science and engineering workforce can only be described as stunning successes," writes Teitelbaum, a demographer and senior research associate at the Labor and Work Life program at Harvard Law School.

"It is conventional now to hear seemingly sincere pronouncements about the dangers of such shortages from politicians of all ideological persuasions and from much of the mass media. This apparently broad consensus prevails notwithstanding almost universal inability by objective labor market analysts to find any

convincing empirical evidence to confirm the existence of such generalized shortages."

Teitelbaum is far from alone in making this counter-conventional argument. In his book he cites a wide array of scholars who make arguments about stagnating wages for science and engineering Ph.D.s compared to professionals with similarly advanced levels



of education – J.D.s, M.D.s, and M.B.A.s – and who find no evidence of generalized workforce shortages. (Teitelbaum is careful to note that there may well be shortages at any given time in particular subfields or in particular geographic regions, but that those aren't the same as generalized, nationwide shortages in the science and engineering fields.)

An article in *Issues in Science and Technology* in summer 2013 by Hal Salzman, a professor at Rutgers University's John J. Heldrich Center for Workforce Development, summarizes some of the main points of evidence for the anti-shortage argument, including data showing that the nation produces more than twice the number of STEM graduates each year than the number who find STEM jobs, and that wages for jobs in information technology and other STEM fields haven't increased as one might expect if there were indeed ongoing talent shortages.

In an interview, Salzman noted a contrast, the subfield of petroleum engineering, in which there does indeed seem to be a shortage – and wages went up, as did the number of graduates with degrees in the field. "When we can see a documented shortage, and salaries respond, so do students," he said. "We've never seen any evidence that the labor market is not responsive to labor market

signals of wages."

On the other hand, those who argue that there is evidence of inadequate supply of STEM workers point to data showing that holders of STEM degrees earn a wage premium compared to college graduates who majored in other fields. "The relative advantage of STEM over other majors in the labor market remains strong," said Anthony P. Carnevale, a professor and director of the Georgetown University Center on Education and the Workforce.

Carnevale's analysis of online job postings also shows that while STEM jobs make up 11 percent of jobs for bachelor's degree-holders they make up 28 percent of ads, and those ads are posted for longer durations, suggesting they take a long time to fill (though Salzman noted an alternative explanation -- that it could also suggest that companies aren't under a crunch to fill jobs and can afford to be picky and wait for an exceptional candidate to come along). Over all Carnevale has found that people with STEM degrees are highly in demand in the economy, so much so that they can take their STEM degrees and "divert" to even higher-paying fields.

Robert D. Atkinson, the president of the Information Technology and Innovation Foundation, a think tank that receives much of its funding from the IT industry, said the nation needs more STEM graduates, not

fewer.

"Our logic is the U.S. is in intense, serious global competition for innovation-based industries and jobs, we're not doing anywhere near as well as we should and high-skilled STEM workers are one of the components we need to be successful and why not do everything that we can to make sure that we have them?"

Atkinson argued that one reason why wages don't necessarily go up in response to domestic shortages is that the STEM job market is global and companies can hire talent in, say, Estonia, at a lower cost. "The reason the shortage is not as bad as it could have been or is – I admit that the shortage is not catastrophic right now -- but the reason the shortage is not worse is largely because of immigration, both H-1B and regular," he said.

Yet in *Falling Behind*, Teitelbaum argues that there's been "no shortage of shortages" over the past 60 years, writing that the U.S. scientific establishment has gone through cycles of alarm, boom and bust, each characterized by "the sounding of alarms about the insufficiency of the current or future science and engineering workforce, followed by governmental responses leading to booming growth in the number of scientists and engineers entering the workforce, followed by changes in circumstances that produce a bust in demand and chilly labor

markets for new entrants.”

Specifically Teitelbaum identifies five such “alarm, boom, and bust” cycles after World War II, each 10-20 years in length, the first three of which were spurred by Cold War anxieties – the second began after the Soviets launched the Sputnik satellite – followed by the booms and busts in high-tech (1995-2005) and biomedical sciences after the doubling of the National Institutes of Health budget from 1998 to 2003.

Teitelbaum argues that a conflation of educational and employment challenges is one area of confusion. Policy makers regularly bemoan American students’ mediocre performance on international standardized tests of math and science, but Teitelbaum argues that the mediocre overall scores mask the large disparities and extremes in student performance that characterize the American educational system.

And he says that more than enough students are performing well on the top end to eventually fulfill the needs for the science and technology workforce (numbers for this vary depending on what you count, but Teitelbaum estimates that jobs that require high levels of science and math make up about 5-10 percent of the country’s overall jobs).

“The poor performance of the bottom quartile is a very legitimate

cause for real concern in terms of equality of opportunity and the overall education of the future citizenry and workforce, but it has rather less to say than might be supposed about the implications for the future U.S. science and engineering workforce,” he writes.

While Teitelbaum writes that it is true that the American advantage in research and development and higher education in science and engineering has eroded somewhat as countries in Europe and Asia have begun to catch up, he emphasizes that declines in U.S. dominance should be seen in relative terms.

He describes, however, good reasons to be concerned about “symptoms of malaise” in the U.S. science and engineering infrastructure, among them an unsustainable appetite for expansion (as he writes “the system appears to have a tendency to expand beyond whatever funds are available – no matter how large”), the instabilities of research funding and careers, and the lengthening of advanced training and unattractive career paths for Ph.D.s in science and engineering.

He makes a series of recommendations, several of which are aimed at better linking the academic production system and labor market needs. He recommends improving career information available to prospective

Ph.D. students and incentivizing universities to reduce their reliance on the labor provided by Ph.D. students and postdoctoral research assistants in favor of hiring more staff scientists. He also describes a need to “clarify the goals of using federal research funds to finance unlimited and increasing numbers of international Ph.D. students and postdocs.”

“Is the main goal ... to increase the size of the U.S. science and engineering workforce?” he asked “[T]o lower research costs by staffing federally supported research labs with poorly paid research assistants?” Or “to create international research connections, or to enhance the research capacity of their countries, if and when they return home?”

Asked in an interview whether students should be encouraged to study STEM fields, Teitelbaum said yes, that the skills they learn will serve them well in any field they pursue (a point driven home by Carnevale’s research). “I think it is a good idea to encourage more people to go into majors in science and engineering but I don’t think I would base that urging on claims that there are shortages of scientists and engineers,” Teitelbaum said. “You’re promising something that you probably can’t deliver on, which is attractive and stable careers in science and engineering occupations.” ■

VIEWS

A selection of essays and op-eds from *Inside Higher Ed*

NETWORKS AND THE STEM GENDER GAP

By Santa J. Ono and Valerie Gray Hardcastle

Colleges and universities can't leave it to chance -- they must deliberately change a culture that often encourages female researchers to become isolated in their jobs, write Santa Ono and Valerie Gray Hardcastle.



The recent threat to boycott an upcoming international chemistry conference because of its all-male speaking program reminds us how far we still have to go when it comes to women in the science, technology, engineering and math (STEM) fields. The challenge remains that many STEM professions remain male-dominated, especially in academia.

For well over a decade, the National Science Foundation has tried to move the needle on the gender gap in STEM disciplines by supporting efforts to recruit, hire and retain more female faculty. While these efforts have had some impact, the reality is that real success means more than numbers.

At the University of Cincinnati,

with support from the NSF, we are taking a close look at the obstacles that female STEM faculty continue to face.

Role models for women scientists are few and far between. Even with increasing numbers of women obtaining STEM doctoral degrees, they remain underrepresented in nearly all STEM academic positions -- and it is even worse for women of color.

We are finding that to attain the transformational outcomes that our universities and our nation need for a more diverse STEM professoriate, systemic change is necessary -- specifically, we need to create a culture, climate and experience in higher education that allows women as well as men to thrive.

The family-friendly policies and

recruitment efforts that many universities have adopted have certainly have been steps in the right direction.

However, what more pointedly nourishes and encourages career success is the opportunity to network and to be mentored. In male-dominated STEM departments, men, by and large, are able to network with ease. For women, those support systems are not a given.

Our preliminary survey data show that in our STEM departments a greater percentage of women seek formal mentoring relationships than do their male counterparts. We suspect that this is the case because women just do not have access to informal and natural avenues to connect with their colleagues.

Faculty and graduate students often establish relationships with mentors and collaborators through socializing after hours or at conferences. Many departments do not offer formal mentoring or networking systems, either for women or for men.

But without these kinds of opportunities offered throughout the academy systemically, women face perennial challenges in gaining the visibility that they need for success and in learning how to negotiate expectations or how to find research partners on grants.

For both men and women in scientific, technological or medical research, networks matter today more than ever. They matter not just for a researcher's individual career, but also for all of us if we want to maximize scientific collaboration to bring about the best advancements that science can offer. In an age of cross-disciplinary investigation, networks are the force that powers innovation and discovery.

While women especially do not have the opportunities to network with colleagues in the same way

that their male counterparts do, the climate that remains so adverse to women does little to help men either – many of whom have comparable child-care and home-care responsibilities to women these days.

Going to work after work is fast becoming a viable option for no one.

So how can we achieve the systemic change needed to nurture supportive STEM networks? We must deliberately and thoughtfully change our culture that encourages women to become isolated in their jobs.

The academy must develop a new tool kit to help both women and men create healthy, professional networks for advancement of both science and their own careers. These new approaches should include:

- intentional and proactive mentoring and sponsorship for everyone, not just hit-or-miss for those who can routinely show up at social gatherings;
- well-thought-out and documented expectations for

professional behavior;

- programs that introduce STEM faculty to others connected to their disciplines;
- specific programming that teach faculty how to network.

We just concluded Women's History Month. It is time for higher education to write a new chapter in that history.

Achieving the best science means creating pathways for all STEM researchers, whether man or woman, to collaborate, interact and learn from one another. It means more than educational opportunity and greater numbers entering the system. It means providing a structure that supports success.

Santa Ono is president of the University of Cincinnati and a professor of biological sciences and a professor of pediatrics. Valerie Gray Hardcastle is a professor of philosophy, psychology and behavioral neuroscience and the executive director of UC Leadership, Empowerment and Advancement for Women STEM Faculty (UC LEAF). ■

RIGOROUS AND PRECISE THINKING

By Ruth Starkman

Teaching writing and mathematics in the same course leaves Ruth Starkman considering the way humanities and mathematics students approach problems.



Everything would have been perfectly ordinary that October morning in my freshman writing course at Stanford University. Bright autumn light reflected up from the Main Quad to our third floor. Unfed, sleepy-eyed freshmen offered ideas about the assigned reading, which I tracked on the board.

As I often do, I drew a doodle to describe a concept in the reading. This doodle — so I thought — demanded less artistry and complexity than my usual sketches of Thomas Hobbes's "arrant Wolfe," for which I hash out two mangy-looking wolves squinting at each other, or Immanuel Kant's famous "crooked timber," for which a bent log suffices to get the idea across. Here, I simply tossed up a rectangle with a triangle inside.

My students gasped.

"What's wrong?" I asked.

"Um ... everything." They wagered cautiously.

"Well," I tried. "This is just like the one Lockhart shows in his essay."

I was referring to a drawing in Paul Lockhart's famous 2002 "Lament" about the state of mathematics education. Here it is, precisely as it appears in the essay, not the version I drew in class.

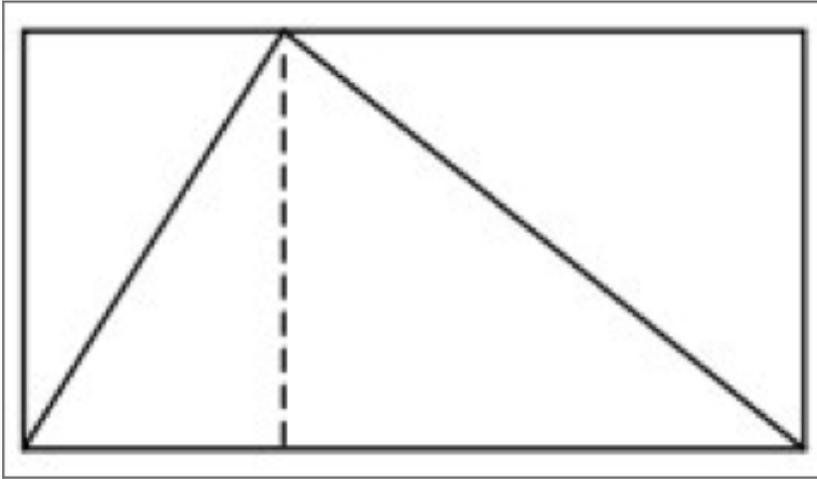
"Sorry ... no ... not really, well ... it's not even close," they ventured, as if not to hurt my feelings.

My students, mostly young aspiring mathematicians, found themselves so ill at ease here, because their teacher with a humanities doctorate had not bothered to notice that the triangle inside the rectangle touches both corners of the same length and thus forms several other triangles. My doodle — whatever it looked like, I can't remember — was simply an approximation, a lonely triangloid adrift in a rectangular sea of lopsidedness.

My students had expected greater precision. After all, the course title "Rigorous and Precise Thinking" had suggested as much. Secondly, this was a college writing course, which, as the rumor goes,

is supposed to be a smackdown of style, argument and organization, where freshmen quickly learn they must jettison comfortable high school formats and every illusion of their personal literary genius. Expectations for rigor and many other new adventures ran high in this new course, an experimental hybrid college writing/mathematical thinking and proof writing class, one of five liberal arts courses in a new program called Education as Self-Fashioning.

Like the other four ESF classes, this one intended to "engage actively in the types of thinking promoted through these different conceptions of education for life, so as to try those lives on for ourselves ..." and offer students a "chance to shape [their] educational aspirations in dialogue with fellow students and an exciting group of faculty from across a wide range of disciplines — from the humanities and social sciences through the natural sciences and mathematics." I was



the writing instructor paired with Professor Ravi Vakil, an American-Canadian mathematician working in algebraic geometry.

Vakil invented the course concept as a rejoinder to C.P. Snow's "Two Cultures" hypothesis with the hope of showing undergrads, and even the world, that writing in the humanities and writing in math gained force and excellence through similar structures of precise reasoning. Vakil more than delivered on the rigor and precision. His lectures introduced students to proof writing, number theory, set theory, and many other advanced forms of math most academics expect to address only with advanced university students. For my part, I was simply to help students elaborate the readings from Plato, Descartes, Douglas Hofstadter, Bertrand Russell, Paul Lockhart and many others, while teaching writing.

Tellingly, my imprecise doodle proved to be not my first, second,

nor even third example of lack of rigor. In fact, the moment seem to demonstrate the deep divide between Snow's "two cultures," since I evidently betrayed a lack of familiarity with the basic truths of measurement, "mass, or acceleration, pretty much the scientific equivalent of a humanist asking skeptically, Can you read?" Without a doubt, much of that difference proved disciplinary — the very limit this course hoped to transgress.

Yet, we experienced no ordinary rift between the two cultures. The class had read Snow's famous 1959 Rede Lecture and chuckled at his description of subverbal grunting mathematicians ruining a young humanist's dinner party experience. My students saw themselves as beyond what old Stanford lingo designates as the split between "fuzzies" and "techies." Interested equally in learning all things humanist and STEM, e.g., Shakespeare and

thermodynamics and beyond, these students insisted that math and math culture far surpassed the cartoonish figures of Snow's dinner party. Nor (my students believed) were humanists so incorrigibly "fuzzy" as to not be able to reproduce a mathematical doodle — or were they?

Had I inadvertently proven Snow's point, right before the eyes of my epistemologically optimistic students? In fact, both the students and I discovered that many of the clichés about our respective fields proved instructive. I really do need to be more careful in my doodling — and thinking about my doodling — if I am drawing triangles (with mathematical aspirations) and not wolves (no matter how humanistically inclined).

The awkward doodle moment proved not the existence of two never-the-twain-shall-meet cultures, but rather a need for me to look more closely at the other side. Once I recovered from the initial jolt of difference, I began to realize the opportunity for me to reconsider my pedagogy. Not having seen a university math professor teach proof writing before, I witnessed several fascinating interactions while attending Vakil's sections of our course. Most striking, when Vakil wrote a problem on the board, the room jumped to life with students calling out and frantically waving their arms. He would ask: "How can you prove the square

root of 2 is irrational?" and it was as though Vakil were standing at the board waving a bloody steak at a group of famished tigers. Everyone wanted to offer some solution.

Seldom have I been bombarded with solutions or suggestions when I ask students to show me "textual proof" that Sigmund Freud has a Hobbesian view of nature ... hint hint ... homo homini ... wolf sketch, ... *Civilization and Its Discontents*, try page number and reference... Freud 1930a [1929], SE 21:111. That special classroom enthusiasm surely arose from Vakil's charisma and love of his subject, but the response was new to me because humanities courses that I know at least demand a very different kind of invention. Vakil asked a question and students racked their brains trying to imagine which set of mathematical tools or ideas they might use to solve the problem. Confident that they all share these tools, or at least know of such tools, the students seemed to feel much more at ease trying out different approaches.

In humanities courses, previous knowledge certainly helps, especially with literary references, but at the end of the day, a humanist's tools remain much more contested and may not be applicable in different contexts. For example, students asked me why I requested they not use the third-person plural perspective "we." I told them writing in the humanities

differs from math, where one can simply write in a proof "we assume that $x=2$." Humanists can neither be sure who that "we" is, nor what to "assume" nor how one can know x . All such terms are permanently available for debate.

In contrast, the mathematicians' particular disciplinary certainty also revealed a fierce loyalty and love of the subject, which produced a very different discourse than I traditionally hear from humanities students who feel a strong affinity with their work. These math students spoke a Russellian language of awe toward the "cold and austere" "supreme beauty" and "elegance" of math. Perhaps other humanists have encountered students who express an emphatic humility before their subjects, but that this for me was as new as the students' shock at my imprecise drawing. For I learned that day, that my students had not yet adopted a humanistic skepticism toward mathematical precision. For them precision is very real, especially in a world of increasing complexity and Gödelian incompleteness.

For humanists, precision lies elsewhere, side by side with ambiguity, and we pursue it with nuance rather than with proofs. My task therefore became one of translation. I understood little of the doodles and equations that Vakil and the students so hotly debated in his sections, but I knew that I had helped my students articulate

arguments within the very different confines of humanistic inquiry. Where they were convinced of certain mathematical truths in the landscape of defined terms, they nevertheless arrived in my class with the classic freshman enormity of themes.

Asked to find "precise" topics in math to write about for their research papers, nearly all 29 students first chose grandiose topics like "the definition of intuition," "the connections between art and math" or "math and humanistic knowledge." With such great ambitions in mind, they also fervently believed in math as a liberal art capable of teaching the exact same virtues of critical (self) reflection as any of the great classical texts I teach from Greek virtue ethics to Rawls.

Most provocatively, they claimed that by practicing mathematical reasoning they were indeed preparing themselves in the fashion of liberal arts education for ethical citizenship. They claimed with confidence their rigorous and precise thinking could lead them to ethical reasoning as equally well as a discussion of the Plato's "Apology." For my part, I could not see how debating a triangle or even practicing some form of applied math as statistics would help me lead the "examined life" in a qualitative fashion.

In class, Vakil often reflected on the limits of mathematical

reasoning in a mode reminiscent of Greek virtue ethics; that is, perfecting one's art whether mathematical or literary skill, is surely a virtue, but not one that can replace ethical action. When asked whether excellence in math could prevent one from doing evil, no one doubted the inadequacy of that proposition. History has no shortage of evil uses of math, and the students could quite easily number these. Yet, many of the students persisted in their strong claims for math.

One student asserted a mathematical imperative in times of emergency: "Just imagine it's war or a crisis: you have a moral obligation to shut up and do the math." By which she meant one is ethically compelled to run a statistical analysis to develop a more concrete understanding of

actual dangers. Another student expressed less certainty about quantitative methods. "Statistics aren't bulletproof, you know; what matters ultimately is thinking clearly, and math trains the mind for such emergencies."

Vakil softened these strong claims for both applied and pure math:

I'm less certain that this [mathematical reasoning] in any way replaces the approach to the virtues of critical self-reflection through great philosophical texts. I hope that our students will better appreciate the importance of such texts, because of an appreciation of the problems that earlier thinkers were grappling with (and that we should grapple with today). Similarly, I doubt that this is sufficient to lead them to ethical reasoning, although I would make

a milder claim that thinking clearly in this way can assist in carrying out ethical reasoning.

Vakil also elaborated ways in which math could serve ethics, both by providing empirical data and asking Socratic questions about knowledge and decision-making. In the end, we hoped the students finished the course knowing a bit more about practices of rigorous thinking in our respective disciplines, and that they would see these as equally essential and complementary. Could this sprawling, seven-unit course provide a model for future courses? We're not sure, but are happy to share our data and materials. ■

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IDEALISTIC ENGINEERS

By Scott R. Hummel

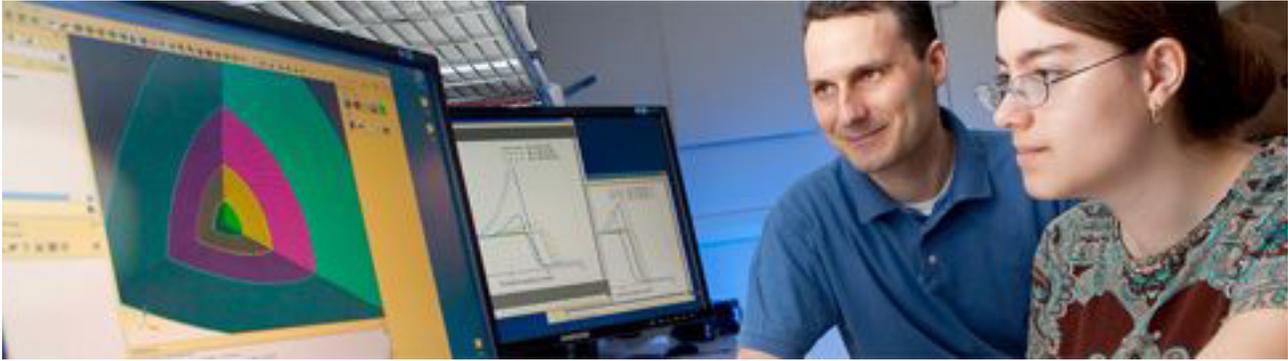
Scott R. Hummel considers why enrollments are up in engineering -- and the kinds of students being attracted to the field.



Inside *Higher Ed* recently took note of research by Erin Cech, an

assistant professor of sociology at Rice University, who found that engineering students leave college

less concerned about public welfare than when they started. According to the article, her



research was based on surveys of students at four engineering colleges.

Instead of trying to counter the survey data that led Professor Cech to conclude engineering education makes students cynical, I would instead like to highlight some of the motivations and actions of engineers and engineering students and then consider whether these indicate a desire to improve the human condition.

Lafayette College hosts a Science, Technology, Engineering, and Math (STEM) summer camp for elementary school students. At the camp last summer, I was asked by a camper to explain what engineers do. Engineering covers such a vast array of applications and technologies that summarizing the whole of engineering to a group of 10-year-olds in a sentence or two was a challenge. I've heard it said that engineers are "problem solvers" but that description seems a bit vacuous. Medical doctors are problem solvers, but they're not engineers. The description of an

engineer as a "problem solver" is, at the very least, incomplete. I needed to think of something better for the camper, but I'll get back to that later.

Let's dig a bit deeper and look at the motivation for engineering problem solving. Why do engineers develop things like smartphones, medical devices, and (my favorite on this frigid winter day) central heating? The cynical answer here would be the money. Engineers do have relatively high compensation rates compared to many liberal arts degree recipients and they have excellent job prospects. However, it is not money that motivates students to become engineers. The high salary may initially attract students to the programs, in a similar way that high salaries attract people to become medical doctors, but the hope of future earnings does not drag students into a lab at 2 a.m. to complete an analysis. Passion does.

Data support the premise that engineering students want to have a positive impact and improve the human condition.

Over the past decade, enrollment in undergraduate engineering programs across the United States has increased by nearly 25 percent. Over this same period, environmental engineering enrollment has grown nationally by over 75 percent and biomedical engineering has grown by an astonishing 170 percent. The very nature of these degree programs is to help people and the environment. This provides direct evidence that engineering students are deeply committed to using their talents to improve people's lives. More traditional engineering disciplines have also grown in numbers partly due to employment prospects, but also because prospective students see engineering as a way to simultaneously have a financially rewarding career while bettering the world.

Students who pursue engineering careers want to combine their math and science skills with their creative abilities in what is called engineering design.

Although the engineering design process is taught at

every engineering school, there is no single agreed upon “best” design process. Just like different companies have different design principles and practices, faculty and engineering programs have different variations of the design process as well. That said, engineering design always starts off with the same first step; recognizing a need. Engineers, at their core, are trying to make things more efficient, easier to use, and more effective.

One of the most progressive engineering design processes, made popular by Stanford University’s Design Institute, is called Design Thinking.

An early step in Design Thinking is to empathize with the client.

Whether an engineer is developing a prosthetic leg to enable an amputee to walk, a process to produce a drug to lower cholesterol, or a bridge to better

connect people’s lives, engineers are empathizing with the condition of those impacted by their design.

One can gain insight into the values embraced by the field of engineering by looking at its professional organizations. In addition to the traditional ones founded to improve safety and reliability of engineered systems, organizations such as Engineers Without Borders, Engineering World Health, and the National Academy of Engineering’s Grand Challenges were formed in the last 25 years to make a positive impact on the human condition.

Recently a new type of organization was created called Engineering for Change. This community brings together the combined talents of engineers, social scientists, NGOs, local governments, and community advocates to improve the quality of life in communities around the world

by promoting the development of affordable and sustainable solutions to the most pressing humanitarian challenges. These types of service organizations are thriving at engineering schools across the country with broad participation from students who are doing impactful work to help people live happier and healthier lives.

Engineers are optimists who believe that they can design and create solutions to help solve the problems facing society.

This brings me back to the response I gave the camper who wanted to know what engineers do. “Engineers make people’s lives better through the use of technology,” I told her.

There is nothing cynical about that. ■

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