Expanding the Net: Secondary through Postsecondary Pathways to Physics Careers

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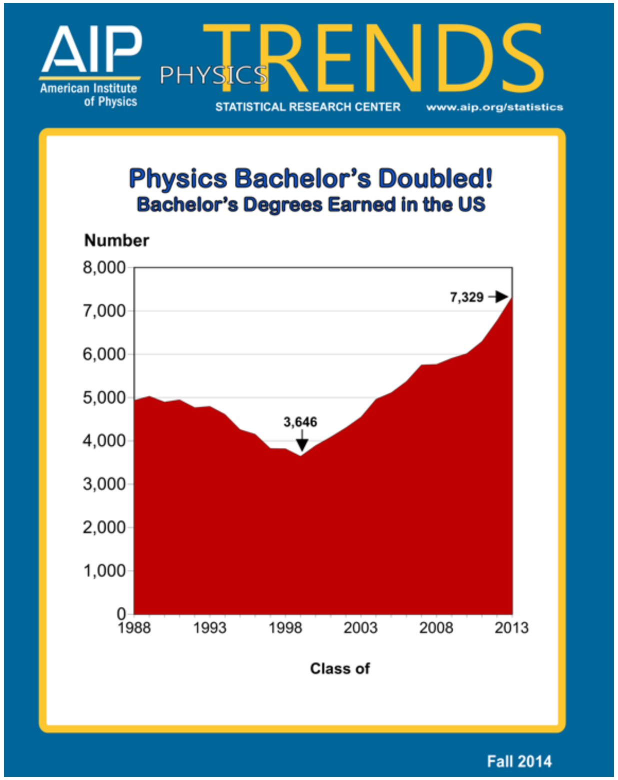
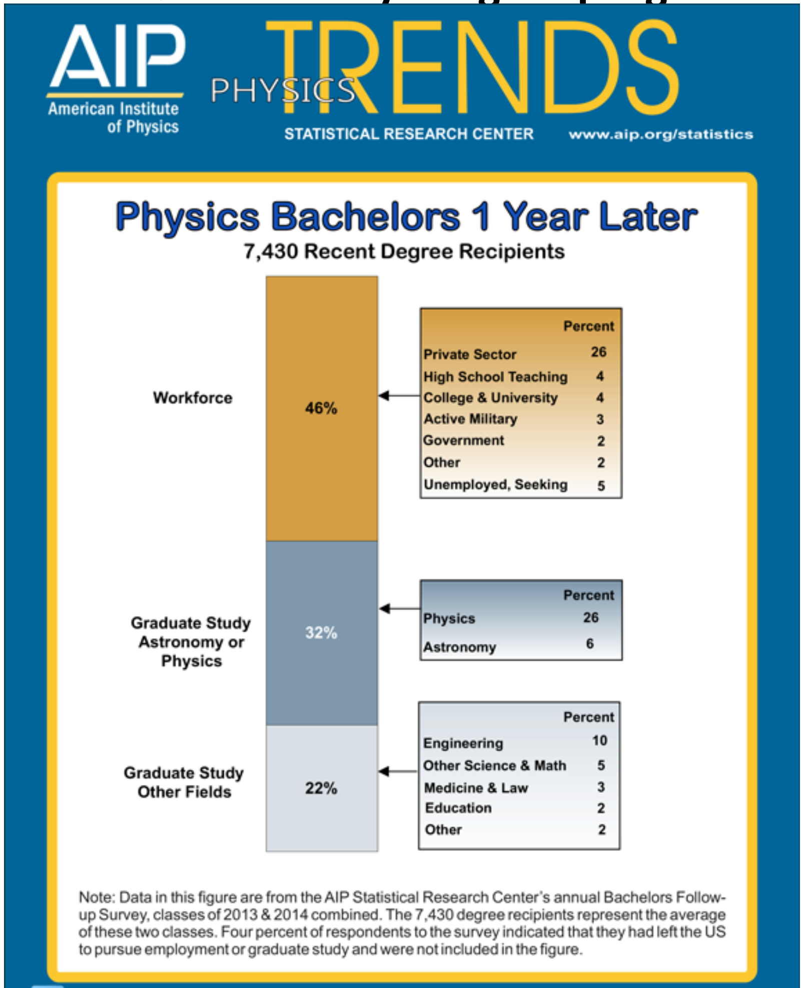
What’s happening in Physics?

Physics is growing!



And 32% are in Physics grad programs



Ok, ok, yes, this all looks good. BUT…

Let's get some context

Contextualizing these #s in demographic shifts

College-going is rising

Share Completing a Bachelor's Degree or More

Year	25-29	30-34	35-44	45-64	Difference: 25-29 minus 45-64
2012	33.5	34.8	34.7	30.9	2.6
2011	32.2	33.9	34.2	30.8	1.4
2010	31.7	34.1	33.1	30.5	1.2
2009	30.6	33.8	32.9	30.2	0.4
2008	30.8	34.0	33.1	30.2	0.5
2007	29.6	32.6	32.6	29.9	-0.3
2006	28.4	31.5	31.1	29.3	-0.9
2005	28.8	32.0	29.9	29.1	-0.3
2004	28.7	31.6	29.5	29.6	-0.9
2003	28.4	31.5	29.4	29.1	-0.7
2002	29.3	31.7	28.5	28.4	0.9
2001	28.4	30.8	28.2	28.0	0.5
2000	29.1	29.5	27.0	27.6	1.5

Notes: Completing high school includes those who attained a degree by equivalence (e.g., GED) as well as those obtaining a high school diploma. "Difference" calculated before rounding.

Source: Pew Research Center tabulations of March Current Population Surveys, 2000-2012

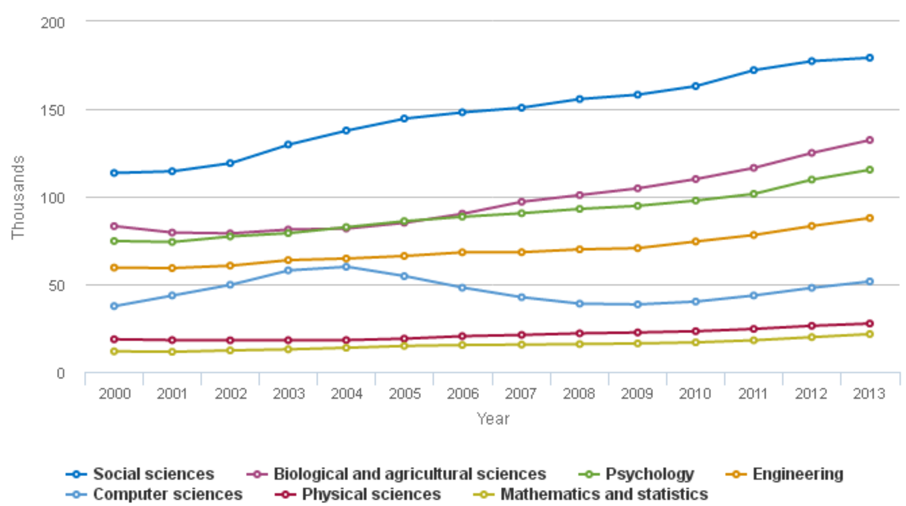
PEW RESEARCH CENTER

Growth in physics … not especially specific to PHYSICS

How does physics compare?

Physical sciences are fairly flat

Figure 2-15
S&E bachelor's degrees, by field: 2000–13



NOTE: Physical sciences include earth, atmospheric, and ocean sciences.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

Science and Engineering Indicators 2016

Within Physical Sciences…

From my analysis of a nationally representative cohort of U.S. high school students who were 10th graders in 2002….

Out of those who completed BA's by 2012…

Chemistry and Physics Degrees	%
All other majors	98.1
Chemistry, incl. Biochemistry	1.5
Physics, including (1) Biophysics	0.3

Now what?

- Goal: More PhDs, scientists, colleagues in physics labs
- Problem: We need to build the farm team, at home
  - Immigration policy restrictions
  - Demographics
    - More women complete college than men
    - Colleges, incl. top colleges have more representation from black, Latino, Native American, Southeast Asian, other less represented groups
    - They’re taking more advanced math and science than ever before (ed reforms, etc.)
  - Physics needs to attract a broader, more representative, but still talented pool

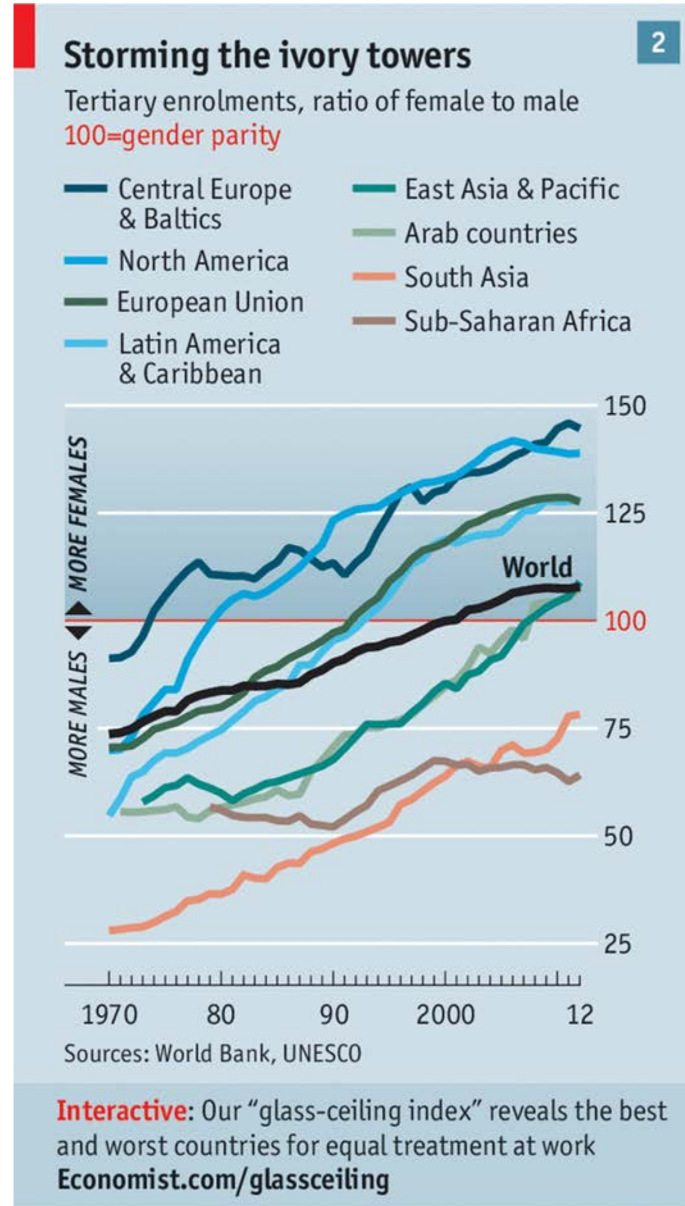
Research Puzzle

Women now outperform men on educational attainment and school performance in U.S. and OECD countries (e.g., Buchmann and DiPrete, 2006; Vincent-Lancerin, 2008)

However, gender inequality persists in certain STEM fields, including Physics (Hill, Corbett, & St. Rose, 2010)

This is especially the case in nations with supposedly low gender gaps (e.g., WEF Gender Gap index) (Charles & Bradley, 2009; Fryer & Levitt, 2010; Hyde & Mertz, 2009)

How can we explain and address this persistent and seemingly culturally-specific gender gap in Physics & related fields?



Economist.com

Contextual framework

How do we approach this puzzle?

Status of Women and Girls in Physics

Physics has an image problem.

Culture of Masculinity in Physics

http://www.nytimes.com/2013/10/06/magazine/why-are-there-still-so-few-women-in-science.html?_r=0

Study of masculinity is rising in sociology & higher ed and could bring real insights to what happens in departments and disciplines

Rejection of “girly girl” women by physics culture, even by women (Francis et. al, 2016)

Culture of Masculinity in Physics

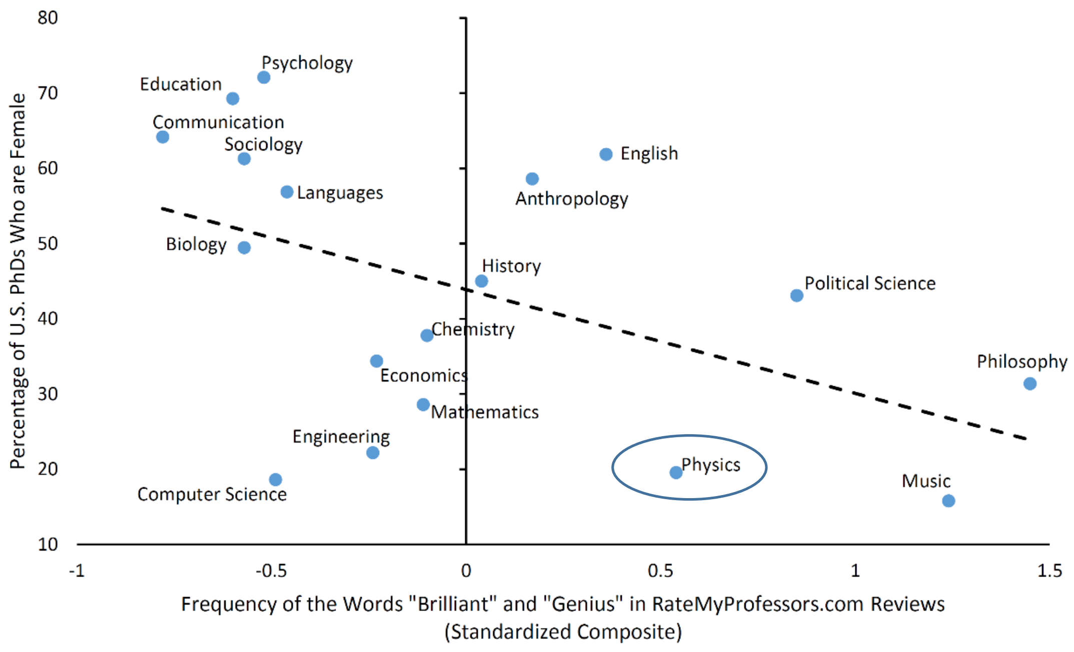
Masculinity performances and sexism aren’t just the realm of fraternities & football – e.g., [Cheryan et al., 2016]

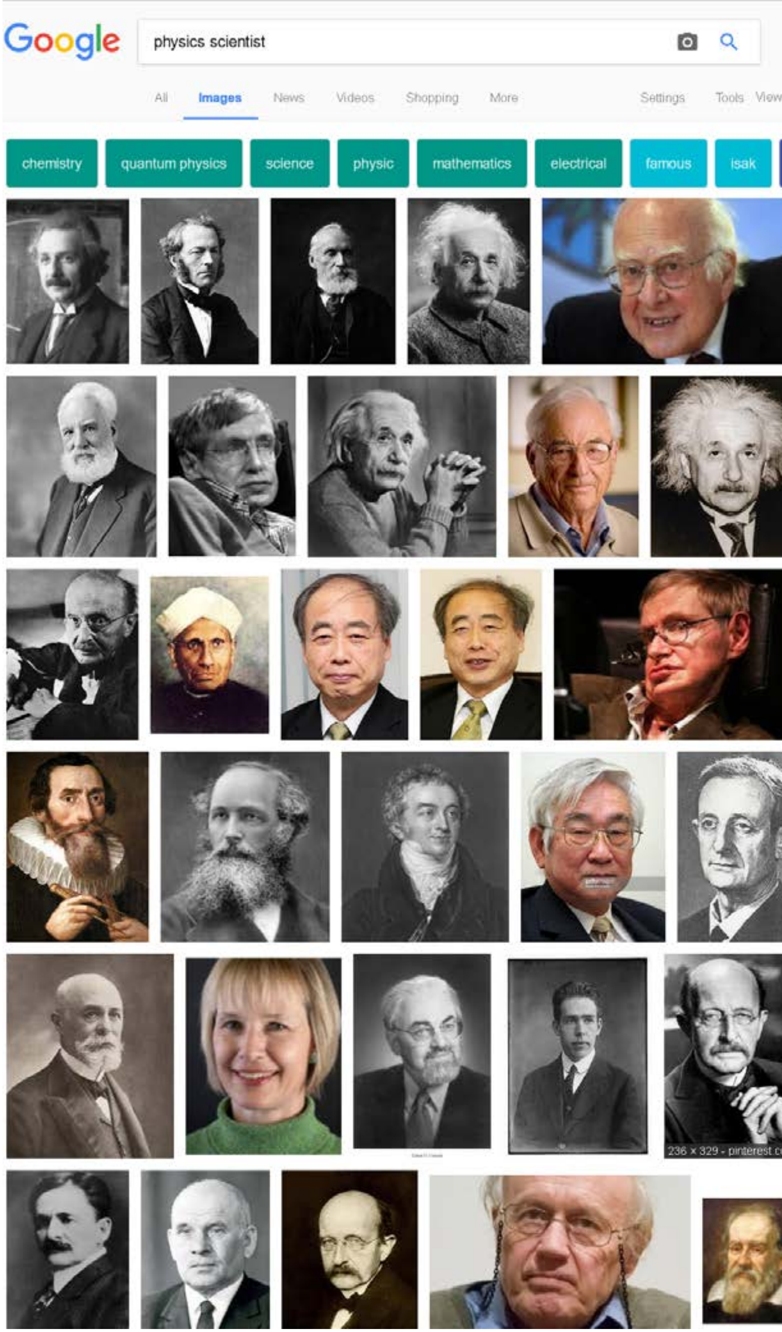
Observational and informant data here and at other institutions

- Undergrad women dress down for physics class to be taken seriously
- Male physics students form tight and exclusive study groups w/activities incl. “hot girls” lists and pornography study breaks (not here to my knowledge!)
- Perception women take physics to meet future husbands

Physics requires brilliance;
this is what we think physicists look like

[See the work of Cimpian, Leslie, & colleagues e.g., 2016]

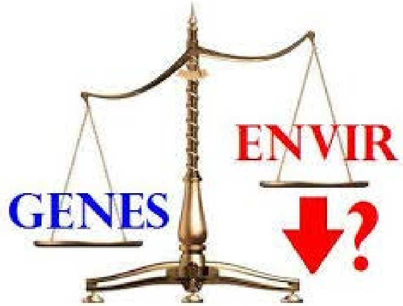




I think I can’t, I think I can’t…

- It’s not just the field – girls think they’re less good, too - decades of research.
- So, is it just biology? Are men – white, European men – just better at Physics and math, genetically?
  - We’re all smarter than that, right?
  - But… even women seem to think so – implicit bias
- The question is, are these beliefs flawed?

Genes vs. Environment



- Biology – that's the way it's always been! And men score higher on tests
- Socio-cultural – then it should be static – fixed trait! So why do we see variation?

- According to the… ok… behavioral/social science research, social science wins – why?
  - Ceci, S. J., Williams, W. M., & Barnett, S. M. (2009). Women's underrepresentation in science: Sociocultural and biological considerations. Psychological Bulletin, 135(2), 218-261. doi:10.1037/a0014412
  - Hyde, J. S., & Mertz, J. E. (2009). Gender, culture, and mathematics performance. Proceedings of the National Academy of Sciences, 106(22), 8801-8807. doi:10.1073/pnas.0901265106
  - Penner, A. M. (2008). Gender Differences in Extreme Mathematical Achievement: An International Perspective on Biological and Social Factors. The American Journal of Sociology, 114(Supplement: Exploring Genetics and Social Structure), S138-S170.
  - Spelke, E. S. (2005). Sex Differences in Intrinsic Aptitude for Mathematics and Science?: A Critical Review. American Psychologist, 60(9), 950-958. doi:10.1037/0003-066x.60.9.950

Variation in girls and women's participation in physics (and stem)

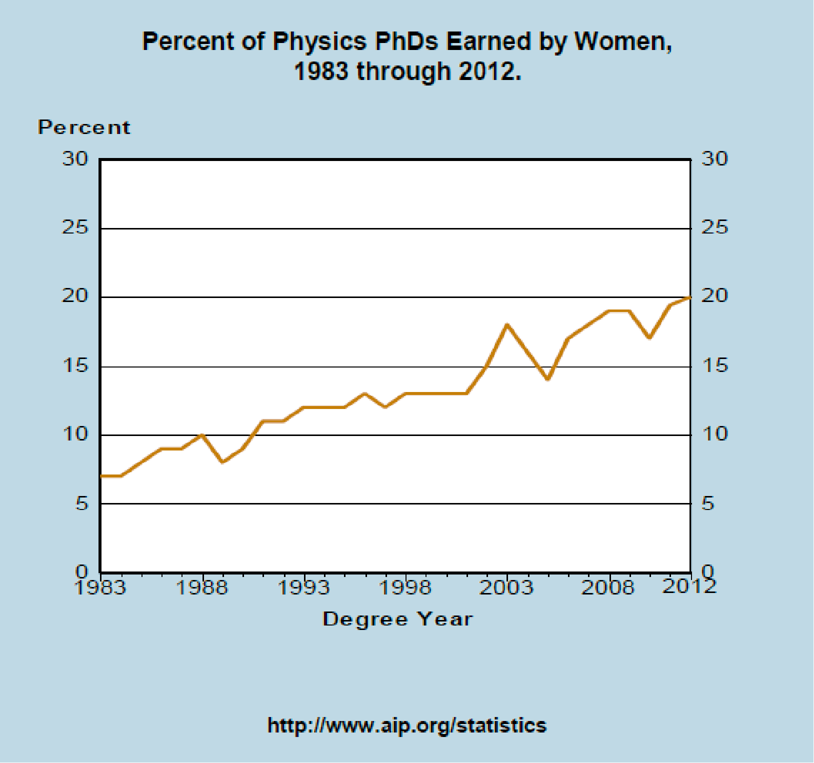
The argument: Variation means it's not innate. Period.

Good news: it's actionable. I'll get to that….

Trends in Degrees Earned

Good news

- Slow but mostly steady climb in PhD recipients
- About 20% of PhDs go to women
- We see corresponding patterns in degrees overall



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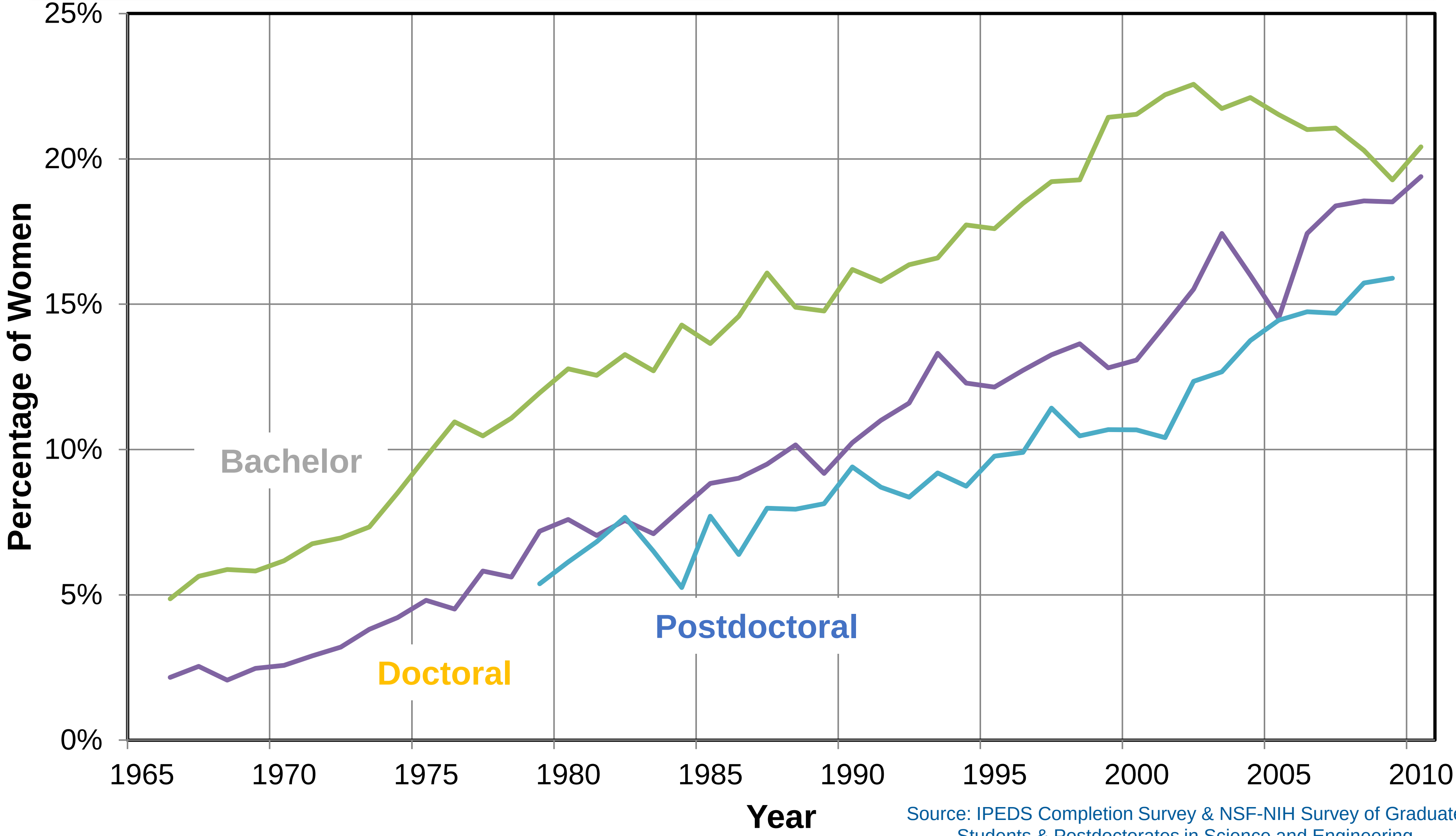
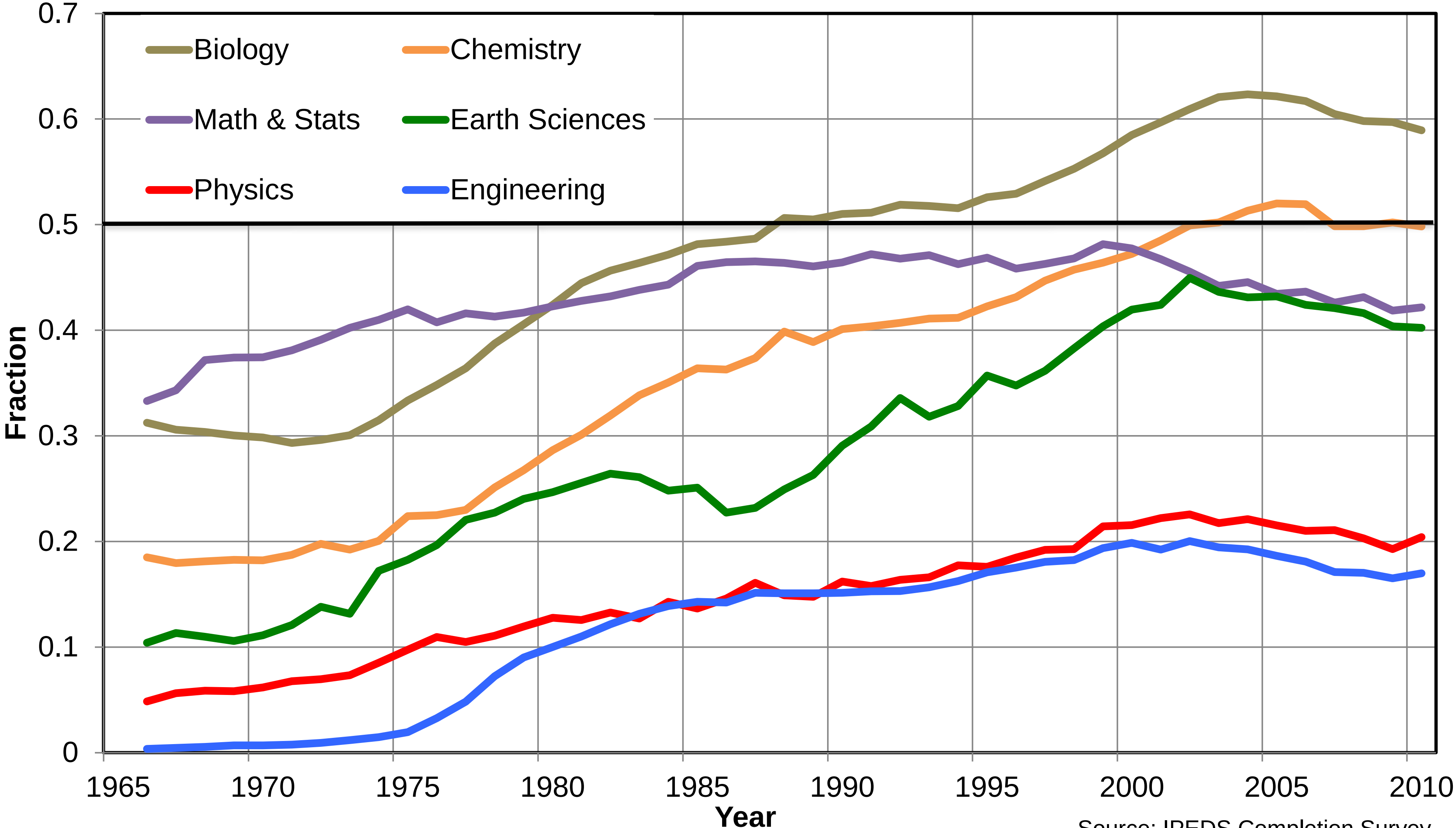
Percentage of Women in Physics 1966 - 2010



Source: IPEDS Completion Survey & NSF-NIH Survey of Graduate Students & Postdoctorates in Science and Engineering

Fraction of Women Earning Bachelor's Degrees
1966 – 2010



Source: IPEDS Completion Survey

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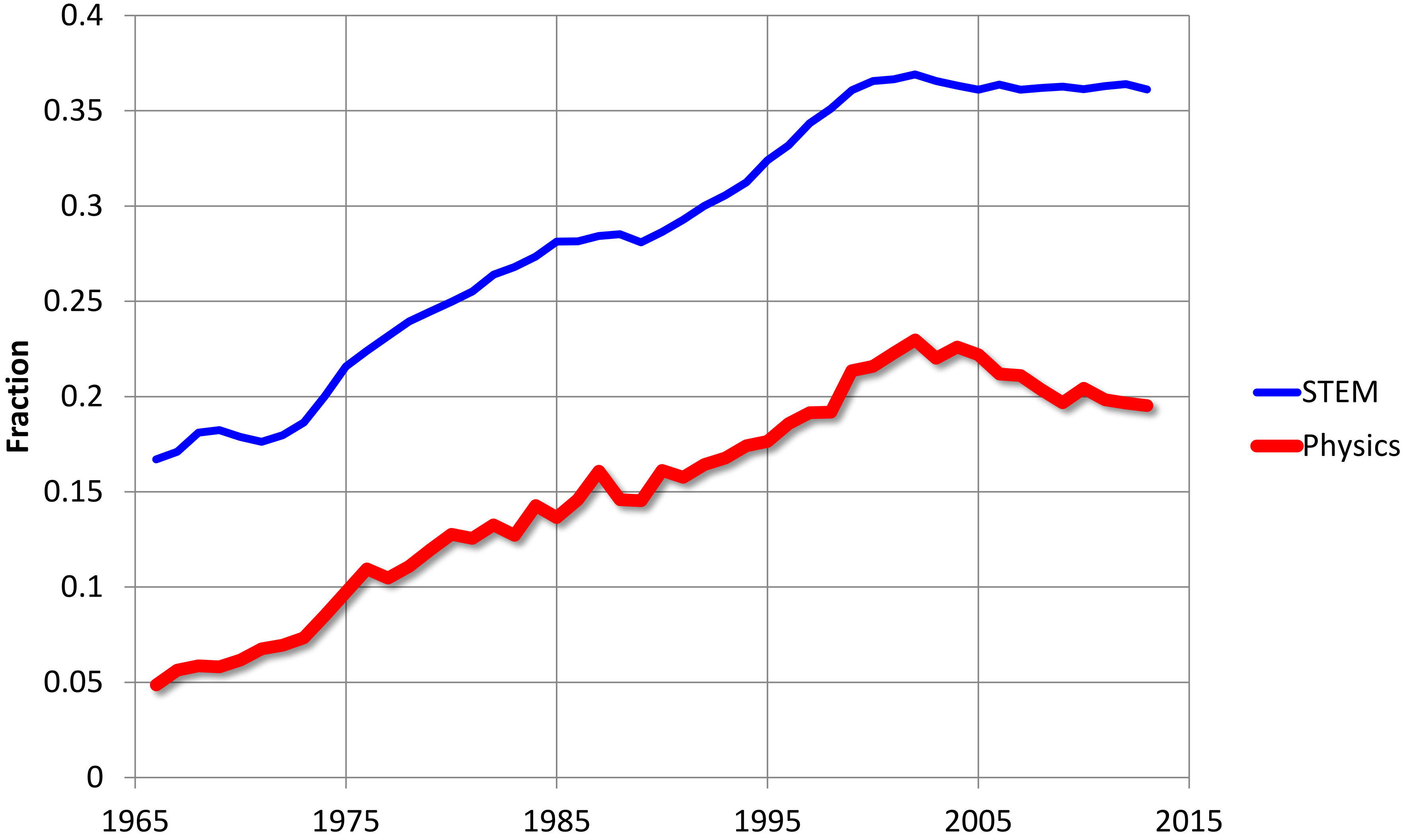
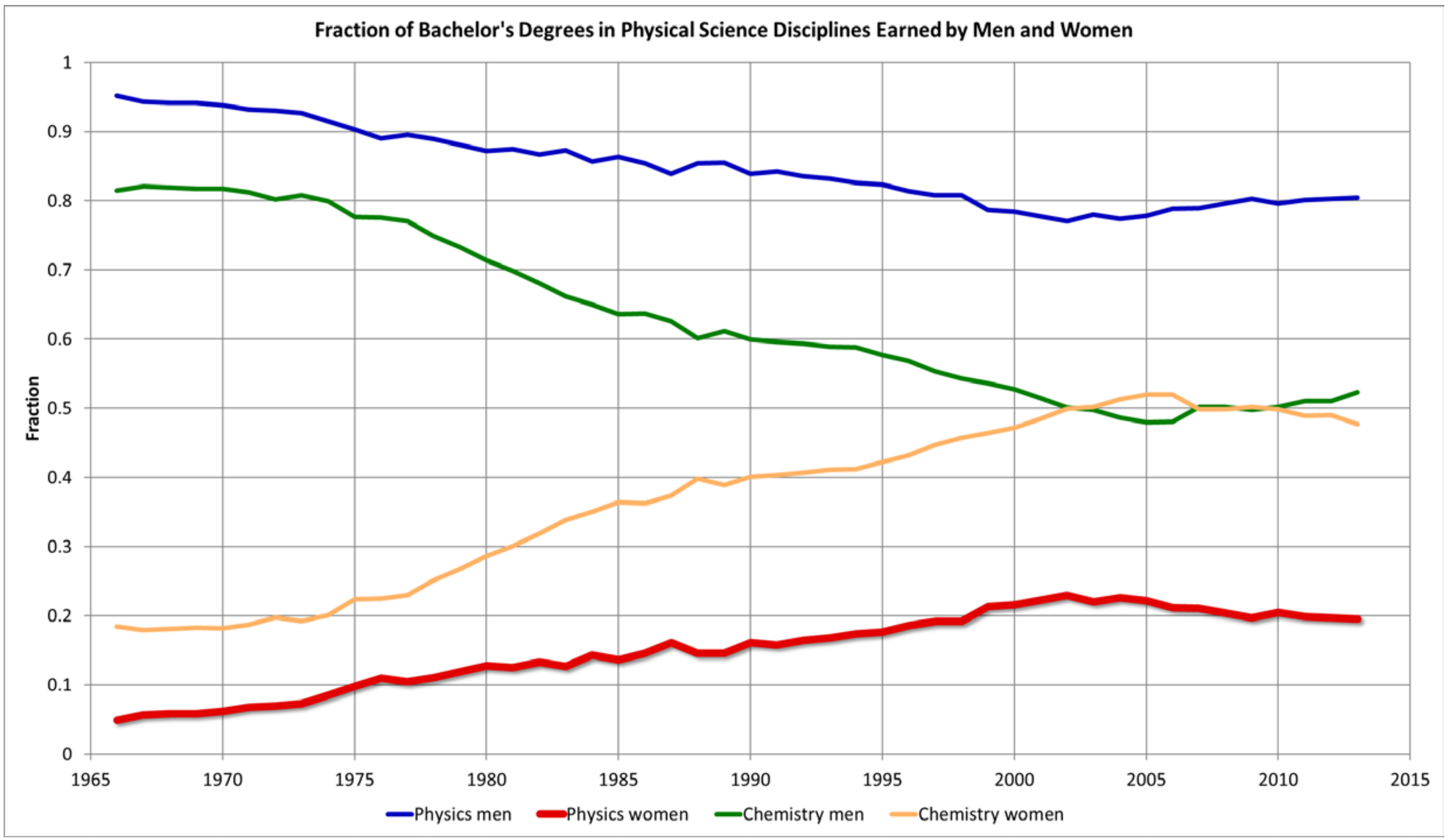
PROMOTING PEOPLE IN PHYSICS

Percentage of Bachelor's Degrees in STEM Disciplines Earned by Women



Now, Chemistry vs. Physics



What makes physics so different?

- Seriously, we’re scientists. This should be a conversation.
- Hypotheses? We’ll write them down and return to them after I show you some of my own data.

One more piece of the puzzle: U.S. & Global Trends for Women in Science

Women earn tertiary degrees at higher rates than men in nearly all of the OECD member nations, including US, Australia, New Zealand, and most of Europe (OECD, 2010)

In fact, the gender gap has flipped. "The once prevalent male advantage in college completion has disappeared in all but four countries." (Buchmann & DiPrete, 2006: 516)

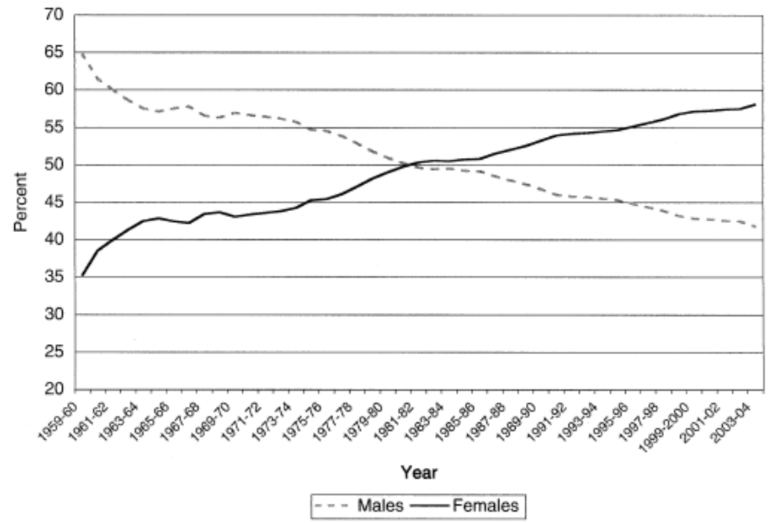


Figure 1. Bachelor's Degrees Awarded to Men and Women in the United States, 1959–2004
Source: U.S. Department of Education. 2004. Digest of Education Statistics, Table 247.

Cross-national Variation in Math

If boys' preference for math and science were biological, it would be the same everywhere. But it's NOT.

- Gender differences in student engagement and math performance vary by country
  - Major studies suggest that gender differences are rooted in "changeable sociocultural factors", using robust data from Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) (Fryer & Levitt, 2009; Hyde & Mertz, 2009; Penner, 2008)

- The social status of women can explain the math gap
  - Meta-analyses of data from TIMMS and PISA indicate "the most powerful predictors of cross-national variability in gender gaps in math" can be explained by "gender equity in school enrollment, women's share of research jobs, and women's parliamentary representation" (Else-Quest, Hyde, & Linn, 2010: 103).

Is this the case as well in non-OECD countries, which are less advantaged and industrialized?

Gender in Non-Industrialized Nations

Comparative data on some developing countries suggests there might be a smaller math in these places, which are thought to be more “traditional” (e.g., Malaysia, Saudi Arabia)

I’ll discuss my work in Cambodia shortly – my photo of a Phnom Penh university below

Empirical studies of pathways to physics & related fields

Other Recent Work w/ Large-Scale National Data

PEMC Majors vs. Other Majors

PEMC majors: physical sciences, engineering, mathematics, and computer sciences (PEMC)

Here are the unadjusted values (no controls, just descriptive data)

Perez-Felkner, L., McDonald, S.-K., Schneider, B., & Grogan, E. (2012). Female and Male Adolescents' Subjective Orientations to Mathematics and Their Influence on Postsecondary Majors. *Developmental Psychology*, *48*(6), 1658–1673.

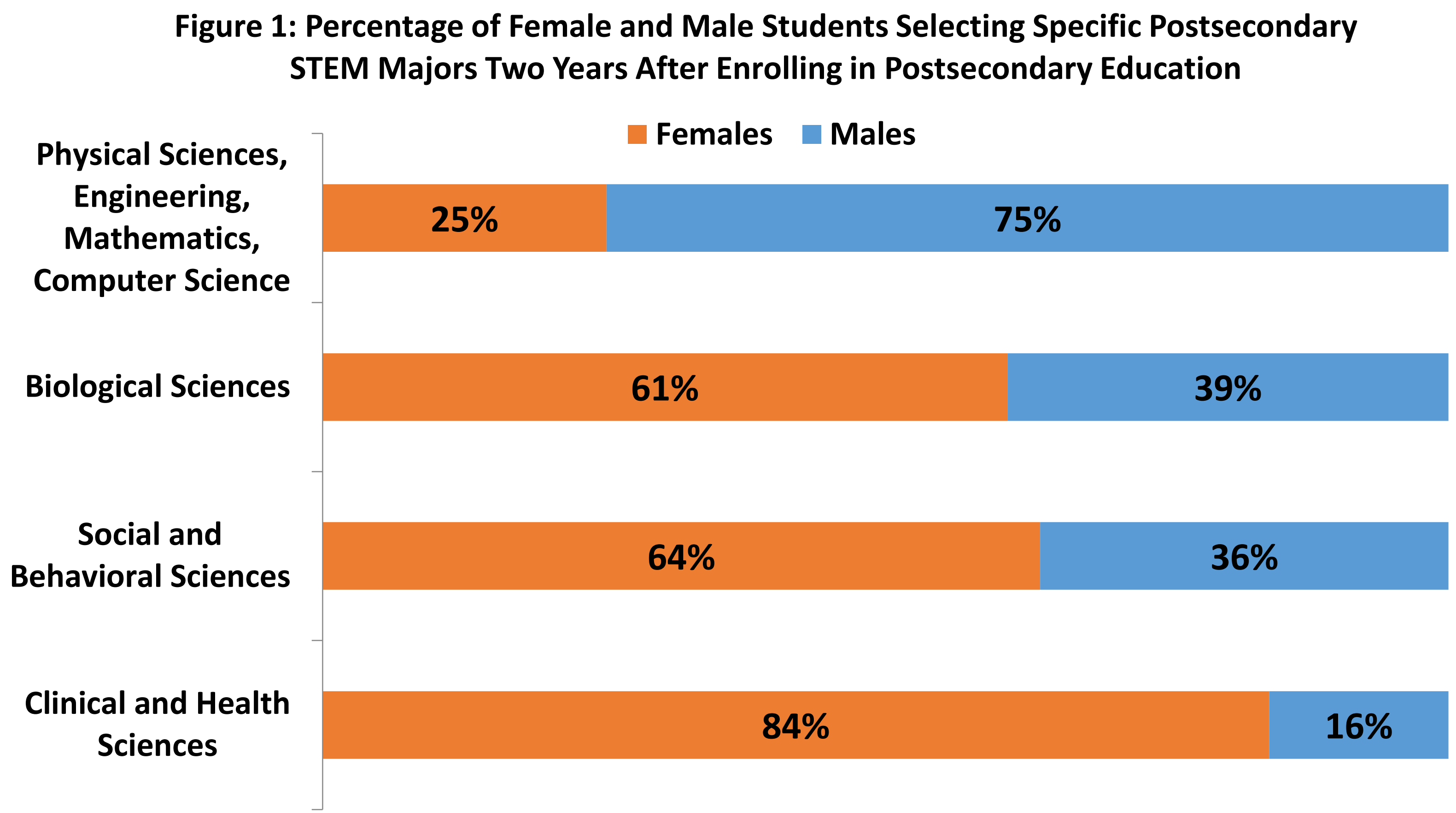
Table 2

Differences in Postsecondary Major, by Gender

Majors	Women N= 1751 Percent	Men N= 1238 Percent	
Humanities	10.9%	11.3%	
Education	12.7%	4.9%	***
Social and behavioral sciences (including psychology and economics)	13.1%	10.9%	
Clinical and health sciences (e.g. nurse assisting, occupational therapy, dentistry)	19.7%	4.6%	***
Biological sciences	7.1%	5.6%	
Physical sciences (chemistry, physics, or related sciences)	**1.8%**	**2.2%**	
Engineering	1.8%	12.9%	***
Mathematics (including statistics)	0.7%	1.5%	*
Computer sciences	1.0%	6.4%	***
Other sciences (agricultural, architectural, and technology)	1.9%	3.0%	*
Other majors	29.3%	36.7%	***
Total	100.0%	100.0%	

Source. U.S. Department of Education, National Center for Education Statistics. Educational Longitudinal Study of 2002 (ELS: 2002)
Note. Data are weighted to population means. Significant differences between female and male means were calculated using the Bonferroni method. *p<0.05, ** p<0.01, *** p<0.001.

Another Visualization: Gender Gap Among Science Majors



Schneider, B., Milesi, C., Perez-Felkner, L., Brown, K., & Gutin, I. (2015). Does the Gender Gap in STEM Majors Vary by Field and Institutional Selectivity? *Teachers College Record*.

PEMC vs. Other Majors – Results

Gendered Differences in the Likelihood of Declaring Specific Science Majors vs. Other Majors

	PEMC Majors		Biological Sciences Majors		Social and Behavioral Sciences Majors		Clinical and Health Sciences Majors	
	OR	SE	OR	SE	OR	SE	OR	SE
Student background characteristics								
Main effect for female gender	**0.014 *****	**0.000**	**2.079 *****	**0.049**	**1.383 *****	**0.019**	**7.102 *****	**0.114**
Race-ethnicity (reference: white)								
Asian	0.956 ***	0.003	0.699 ***	0.004	0.863 ***	0.004	2.540 ***	0.013
African American	3.228 ***	0.014	1.445 ***	0.012	1.372 ***	0.008	0.793 ***	0.006
Latino	0.764 ***	0.004	1.534 ***	0.011	1.354 ***	0.007	0.405 ***	0.003
10th grade math ability test score	1.356 ***	0.002	1.031 ***	0.004	1.505 ***	0.004	0.594 ***	0.002

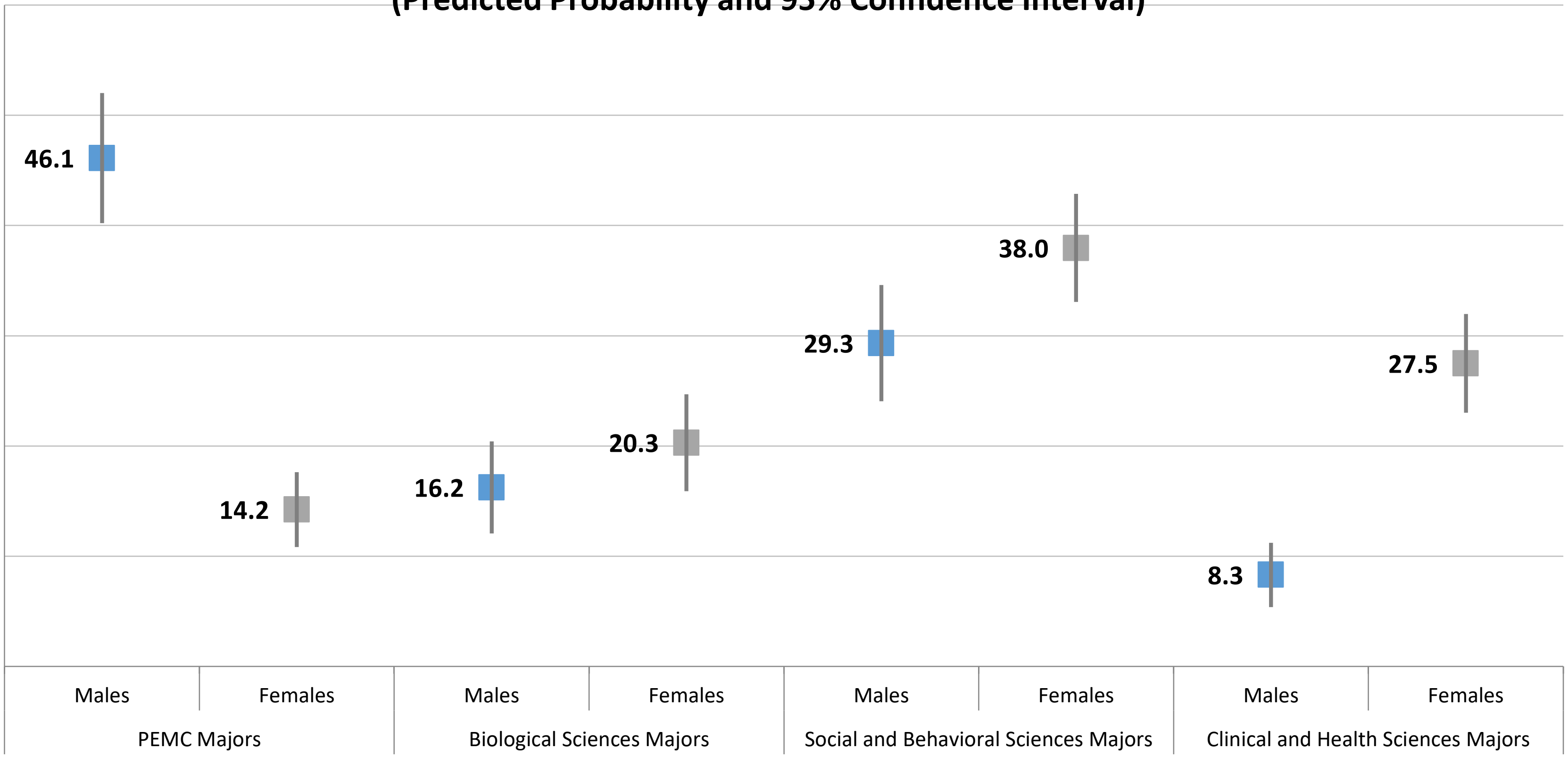
Girls seem more likely to choose majors in less male-dominated fields like biology, clinical and health sciences, and the social and behavioral sciences

- Even when controlling for ability & other factors, incl. interaction effects
- And in predictive models, there's no meaningful difference between the subj. orientations of PEMC major women & men → attrition is PRIMARILY happening before students declare majors in their 2nd year

Perez-Felkner, L., McDonald, S.-K., Schneider, B., & Grogan, E. (2012). Female and Male Adolescents' Subjective Orientations to Mathematics and Their Influence on Postsecondary Majors. *Developmental Psychology, 48*(6), 1658–1673.

What Influences PEMC?
Math Ability?

Figure 2: Probability of Declaring Specific STEM Majors for Students in 75th Percentile of Mathematics SAT Scores, by Gender
(Predicted Probability and 95% Confidence Interval)



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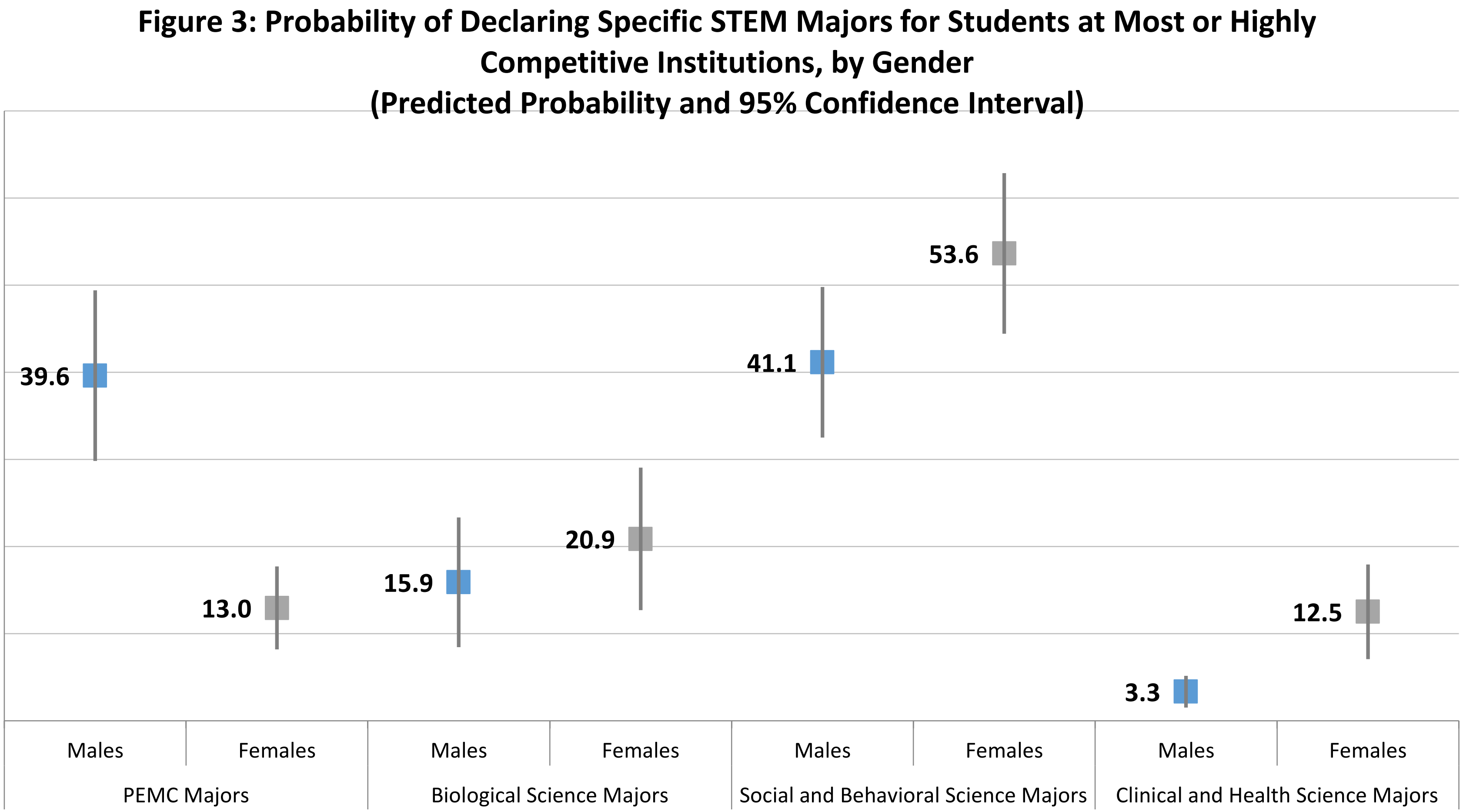
What Influences PEMC?
Social Psychological: Subjective Orientations

Bivariate Correlations between Subjective Orientations and Postsecondary Majors Two Years After High School Graduation

Subjective orientation variables	Physical Sciences, Engineering, Mathematics, or Computer Science (PEMC) Majors	Biological Sciences Majors	Clinical & Health Sciences Majors	Social & Behavioral Sciences Majors	Education Majors	Humanities Majors	Other Majors
Math engagement							
Keeps studying if difficult	**0.081 *** **	0.106 ***	-0.021	0.052 **	-0.033	-0.020	-0.096 ***
Becomes totally absorbed in math	**0.113 *** **	0.076 ***	-0.015	-0.051 **	-0.028	-0.086 ***	-0.004
Valuing math	**0.183 *** **	0.071 ***	-0.018	-0.041 *	-0.039 *	-0.088 ***	-0.045 *
Perceived math ability	**0.214 *** **	0.106 ***	-0.070 ***	0.038 *	-0.036	-0.065 ***	-0.117 ***
Math mindset	**0.086 *** **	-0.002	0.030	-0.019	-0.012	-0.023	-0.058 **
Math participation	0.007	-0.013	-0.038 *	0.033	0.026	-0.004	0.015

Source: Perez-Felkner, McDonald, Schneider, & Grogan, 2012.

What Influences PEMC? Institutional Variation?



Source: Schneider, Perez-Felkner, Milesi, & Gutin, *under review*.

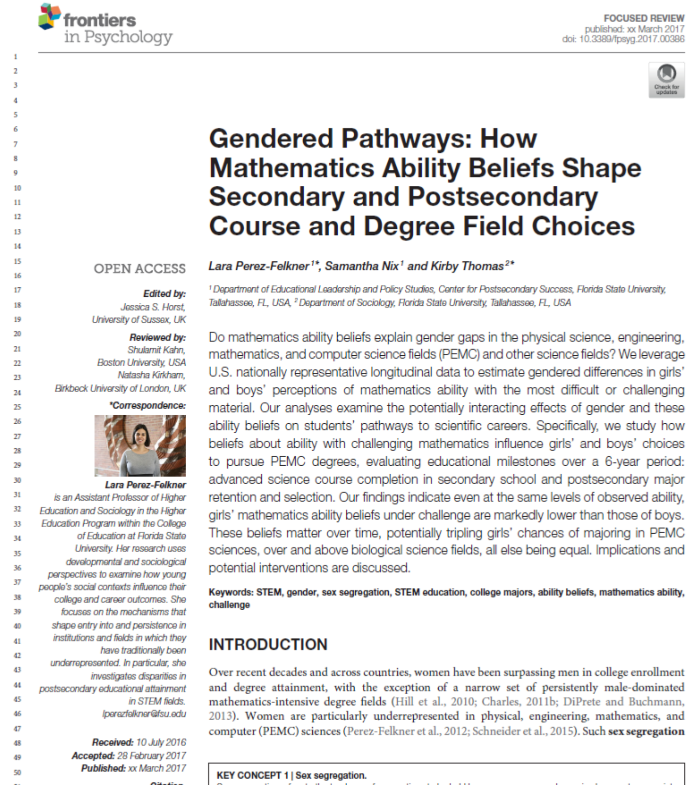
Probability of Major by Race-Ethnicity

Gender Gap in Probability of Earning Degrees in Specific Scientific Fields, By Race-Ethnicity

	Probability difference		
	Full Model		
Group category	Physical & Engineering Sciences	Life Sciences	Social & Behavioral Sciences
All college types, gender diff.			
All students	-0.147	0.120	0.041
Asian students	-0.206	0.134	0.052
Black students	-0.159	0.105	0.047
Latino students	-0.176	0.160	0.044
Other/multiracial students	-0.138	0.141	0.034

Note. The gender gap is calculated as the difference between women's and men's chances of earning degrees in these fields. Specifically, the probability for men is subtracted from the probability for women.

Source: Perez-Felkner, Thomas, Nix, & Thomas, *in preparation*.



frontiers in Psychology

FOCUSED REVIEW
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Check for updates

Gendered Pathways: How Mathematics Ability Beliefs Shape Secondary and Postsecondary Course and Degree Field Choices

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Do mathematics ability beliefs explain gender gaps in the physical science, engineering, mathematics, and computer science fields (PEMC) and other science fields? We leverage U.S. nationally representative longitudinal data to estimate gendered differences in girls' and boys' perceptions of mathematics ability with the most difficult or challenging material. Our analyses examine the potentially interacting effects of gender and these ability beliefs on students' pathways to scientific careers. Specifically, we study how beliefs about ability with challenging mathematics influence girls' and boys' choices to pursue PEMC degrees, evaluating educational milestones over a 6-year period: advanced science course completion in secondary school and postsecondary major retention and selection. Our findings indicate even at the same levels of observed ability, girls' mathematics ability beliefs under challenge are markedly lower than those of boys. These beliefs matter over time, potentially tripling girls' chances of majoring in PEMC sciences, over and above biological science fields, all else being equal. Implications and potential interventions are discussed.

Keywords: STEM, gender, sex segregation, STEM education, college majors, ability beliefs, mathematics ability, challenge

INTRODUCTION

Over recent decades and across countries, women have been surpassing men in college enrollment and degree attainment, with the exception of a narrow set of persistently male-dominated mathematics-intensive degree fields (Hill et al., 2010; Charles, 2011b; DiPrete and Buchmann, 2013). Women are particularly underrepresented in physical, engineering, mathematics, and computer (PEMC) sciences (Perez-Felkner et al., 2012; Schneider et al., 2015). Such **sex segregation**

KEY CONCEPT 1 | Sex segregation.

Gendered pathways

(coming out next week…)

Now let's get to a study

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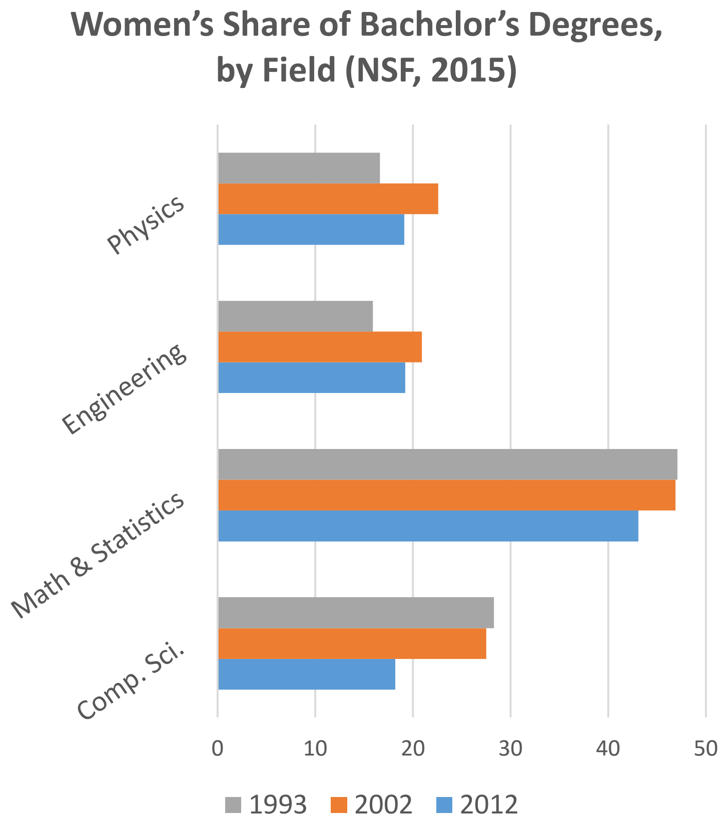
Puzzling Persistence of Sex Segregation in Majors

Why care about sex segregation in undergraduate degree fields?

A. Economic inequality
B. Life course perspectives on educational attainment (*precursors, pipelines, and gatekeeper courses)
C. Labor force, national competitiveness
D. The puzzle – why does horizontal sex segregation persist, and only in some fields?

We examine the role of **ability beliefs** in women & men's differential persistence in specific STEM fields, over time.



Women's Participation in STEM: H.S. →College

- Pre-college experiences
  - Academic preparation (Hanson, 2004; Riegle-Crumb et al., 2006)
  - High school quality (Fletcher & Tienda, 2010)
  - Gendered self-assessments
    (Correll, 2001; Sax, 1994; Perez-Felkner et al., 2012; Parker et al., 2012)
- College contexts and experiences
  - Size and composition of universities (Griffith, 2010)
  - Faculty support (Cole & Espinoza, 2008)
  - Institutional type
    (Hurtado et al., 2011; Leggon, 2006; Perna et al., 2009)
  - College experiences (Chang et al. 2014; Perna et al., 2009)
- Gender disparities vary by field
  - Lack of gender parity in these high-growth and high-earning fields matters

Ability Beliefs and Their Consequences

- In relation to math and science, girls…
  - are socialized to associate those career fields with men (Cheryan, 2012; Lee, 1998)
  - engage less often with those tasks (Eccles, 1994; Eccles & Wigfield, 2002)
  - under-assess their ability (Correll, 2001)
- Stereotype Threat
  - Fear of confirming negative stereotypes about an identity group (Good, Aronson, & Inzlicht, 2003; Spencer, Steele, & Quinn, 1999)
- Growth Mindset (Dweck, 2006)
  - Belief that success in a subject area is rooted in innate ability
  - Girls and underrepresented minorities may have particularly fixed mindsets around mathematics ability.

Conceptual Framework –
Perceived Ability Under Challenge

Mathematics-intensive science fields—physical sciences, engineering, mathematics, and computer science (PEMC)—perceived as

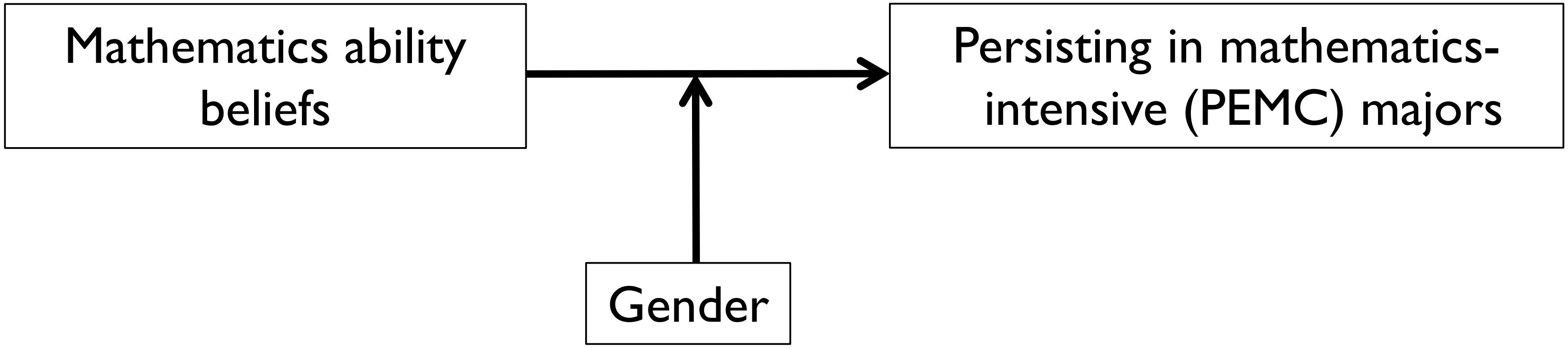
- Requiring talent
- Particularly challenging
- Have the most entrenched gender differences, but not necessarily race/ethnicity differences

Students' assessments of their ability to complete work or understand concepts that they believe is the most difficult or advanced in a specific domain of study.

Research Questions and Hypothesis

RQ1: How do girls' and boys' mathematics ability beliefs relate to subsequent steps on their pathways to mathematically-intensive PEMC majors?

RQ2: How does this relationship vary by gender?



Methods

Data

- Education Longitudinal Study (ELS) 2002 with Postsecondary Education Transcript data (*n* = 4,451 final analytic sample)
  - 10th grade (2002)
  - 12th grade (2004)
  - 2 years after 12th grade (2006)
- *Inclusion criteria*: students who enrolled in degree-granting programs by 2 years after high school (2004)
- *Stratified survey weighting strategy*: bootstrap replicate weights (f2byp1- f2byp200) for base year (2002)-F2 (2006) wave, f2bywt panel weight

Persistence: Science Pipeline, Intended Major, Major Change, Major Declared

- **Physical science, engineering, mathematics, and computer science (PEMC)** fields consist of computer/information science/support (11), engineering (14), engineering technologies/technicians (15), mathematics and statistics (27), and physical sciences (40).
- **Biological sciences** represents biological and biomedical sciences (26).
- **Health sciences** are health/related clinical sciences (51).
- **Social/behavioral and other sciences** include agriculture/operations/related sciences (1), natural resources and conservation (3), architecture and related services (4), family/consumer sciences/human sciences (19), science technologies/technicians (41), psychology (42), and social sciences (45).
- **Non-STEM (reference)** fields are designated as: area/ethnic/cultural/gender studies (5); communication/journalism (9); communication tech/support (10); personal and culinary services (12); education (13); foreign languages/literature/linguistics (16); legal professions and studies (22); English language and literature/letters (23); liberal arts/sci/gen studies/ humanities (24); military science/leadership/op art (28); military technologies (29); multi/interdisciplinary studies (30); parks/recreation/leisure/fitness studies (31); security and protective services (43); public administration/social service (44); construction trades (46); mechanic/repair technologies/technicians (47); precision production (48); transportation and materials moving (49); visual and performing arts (50); business/management/marketing/related (52); and history (54).

Ability Beliefs Relating to Challenge
Domain-Specific

Perceived Ability Under Challenge (Likert scales)

- **<u>Mathematics</u> (10th and 12th grades) and <u>Verbal</u> (10th)**
  - I'm certain I can understand the most <u>*difficult*</u> material presented in __ texts.
  - I'm confident I can understand the most <u>*complex*</u> material presented by my __ teacher.
  - I'm certain I can <u>*master skills*</u> being taught in my __ class.

Growth Mindset (single item; 10th grade)

  - Most people can learn to be good at math.

Perceived Ability Under Challenge
Domain-General

Domain-General Challenge Scale

- When I sit myself down to learn something really ***hard***, I can learn it.
- When studying, I keep working even if the material is *difficult*.
- When studying, I put forth *my best effort*.
- When studying, I try to *work as hard as possible*.
- When studying, I do my best to acquire the *knowledge and skills* taught.

Covariates

Background Characteristics

- Gender, Race/ethnicity, Family income, Parent education

High school ability measures

- GPA, standardized test scores on mathematics and verbal domains, science pipeline

High school context

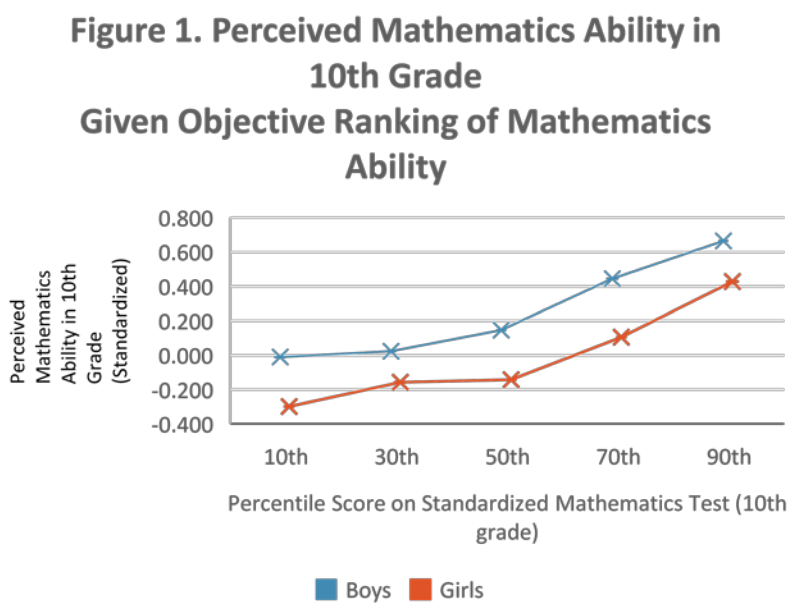
- Percentage free and reduced price lunch, high school region, high school urbanicity

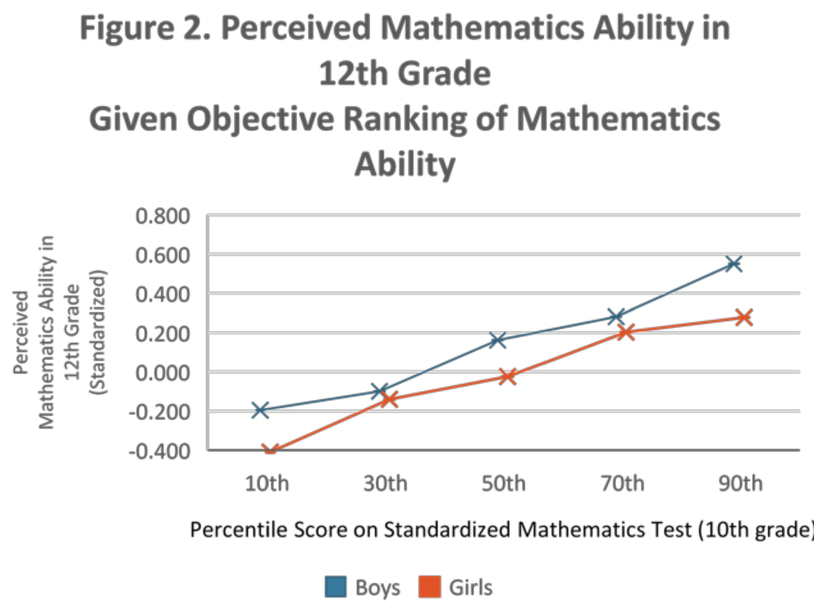
First postsecondary institutional characteristics

- Governance (public/private), type (2 yr./4 yr.), institutional selectivity

Findings

How do Mathematics Ability Beliefs Vary by Gender and Observed Ability?





Biggest differences are in 10th grade but across we see systematic differences in 10th; ;

In 12th grade, biggest diff. at the tails

Overall, boys are significantly more confident in challenging mathematics contexts than otherwise identically talented girls

Do Ability Beliefs Influence Girls’ and Boys’ Scientific Course Completion in High School?

- Yes, but similarly for boys and girls

How Do Ability Beliefs Influence Girls' and Boys' Intended Postsecondary Majors?

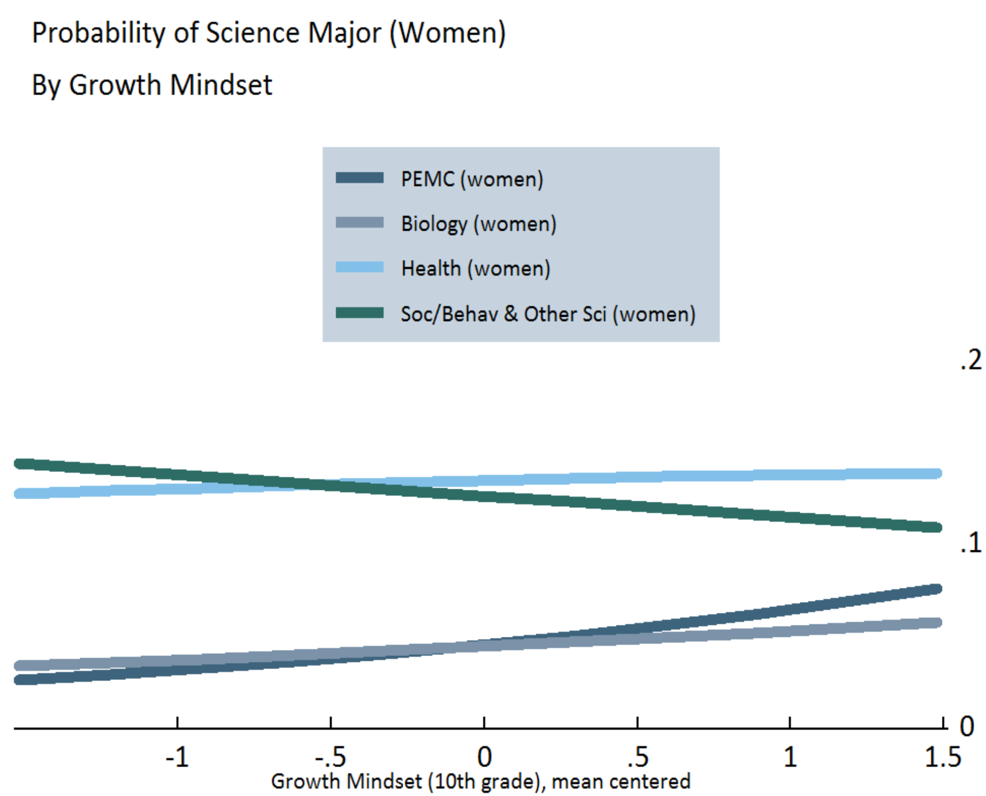
- Postsecondary major retention
- Specific major choice

Still salient in both but ability beliefs operate differently for distinct majors and particular beliefs

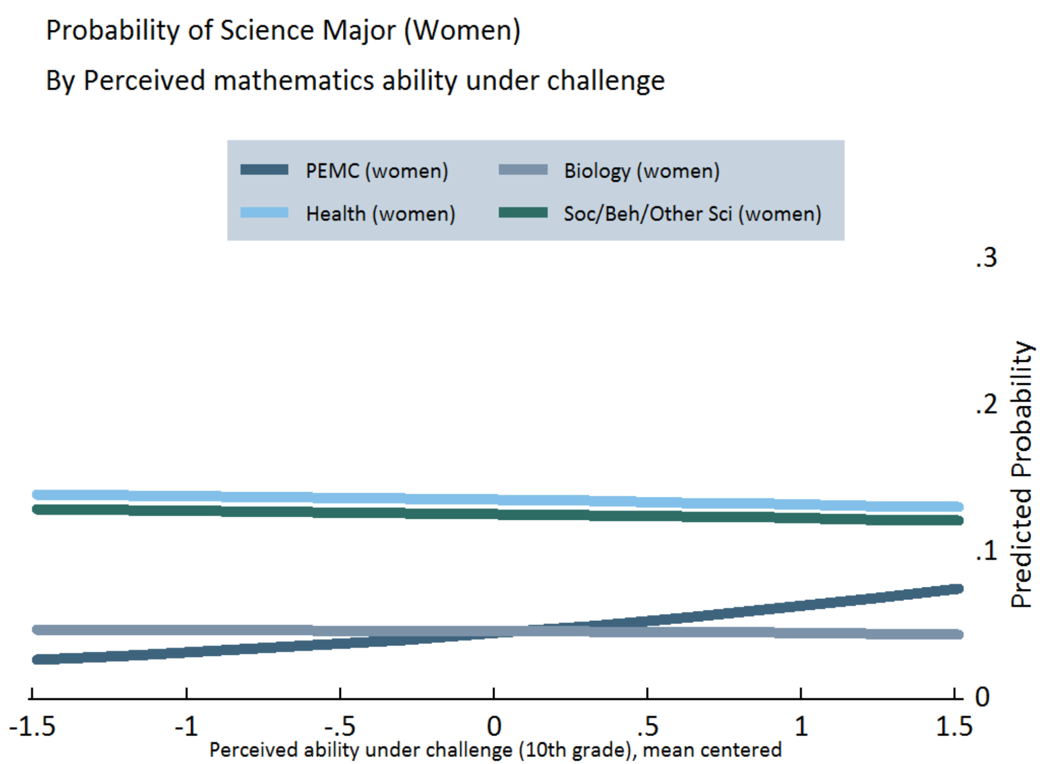
How Do Ability Beliefs Influence Girls' and Boys' Declared Majors?

- All other predictors at their means, our models indicate women have a 4.7% chance of declaring PEMC majors as compared to 14.9% of men.
- All else equal then, being female decreases the students' probability of majoring in PEMC scientific fields by 10.2 percentage points. Gender matters, even with controls.
- How do women and men's chances vary depending on their ability beliefs?
  - 12^{th} grade mathematics challenge:
    - Girls with the most negative perceptions had a 1.8% chance of choosing PEMC majors
    - Those girls with the most positive perceptions of their mathematics ability under challenge had a 5.6% chance
    - Girls' likelihood of majoring in PEMC is 3.1 times greater at the highest value of 12^{th} grade mathematics ability under challenge as compared to the lowest value.
    - Turning to boys, those with the most positive perceptions had a 19.1% chance, 2.8 times higher than those with the most negative perceptions (6.7%), all else being equal.

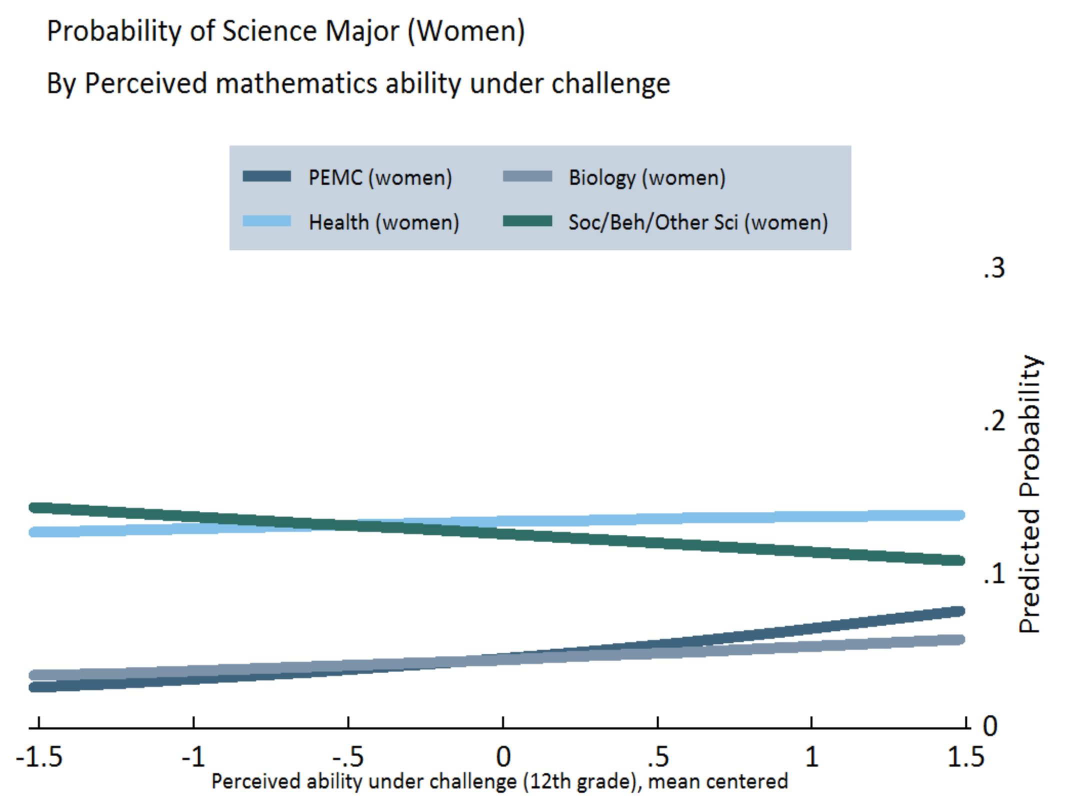
Predicted Probabilities of Choosing Specific STEM Majors, by Growth Mindset in 10th Grade, for Girls on the 75th percentile of Mathematics Ability



Predicted Probabilities of Choosing Specific STEM Majors, by Perceived Mathematics Ability Under Challenge in 10th Grade, for Girls on the 75th percentile of Mathematics Ability



Predicted Probabilities of Choosing Specific STEM Majors, by Perceived Mathematics Ability Under Challenge in 12th Grade, for Girls on the 75th percentile of Mathematics Ability



Discussion and Implications

Where do we go from here?

Implications – This is actionable

Disparities exist, yes, but they're malleable - historically, culturally, socially

- These patterns have changed over time
- And field-, institution-, and country-specific findings show promise for lessening inequality…
- IF motivation and investment in diversity occurs
- International work suggests spaces where these stereotypes did not exist are more conducive to women entering math/science fields – across various Asian countries incl. Cambodia, Pakistan, Thailand…
- Facilitating greater institutional supports – research opportunities, mentoring, diversity programs (we find highly utilized by CS women)

More qualitative research needed, esp. to get at intersectionality

Implications Broadly

- The gap in Physics has been more resistant to change than other fields
  - It may be because there is no career field women see themselves fitting in
  - Biology and Chemistry have reached parity – and Bio students are mostly women – in large part due to women's draw to medicine
- Talented women are deciding early – even in middle school – that they don't fit
- And they continue to turn away from Physics in high school, college, and postgraduate study

So what can we/you do to change this dynamic?

Interventions – pre-college and college

- **For practitioners, policy:** Interventions can be classroom, department, or institution-wide.
- Enhancing girls‘ and women's ability beliefs re: mathematics
  - Esp. around risk, challenge
- Countering stereotypes – among students, teachers, parents, etc.
- *Information and planning*. Middle school should be the primary site for developing STEM ambitions; to be prepared to enter the mathematics pipeline, students should be encouraged to take the more advanced mathematics courses available to them (e.g., Algebra 1) (McDonough, 2004).
- *Values affirmation*. Interventions aimed at affirming young women's place in the sciences might mitigate the negative effects of persistent culturally influenced attitudes to the contrary.
- *Boys' club needs to go co-ed*. From the mass media to extracurriculars and study groups, more effort needs to be made to make women feel included, visible, and valued in physics careers and majors

Interventions – here at FSU and in the field

- Assess and evaluate the efforts you're doing, rigorously
  - What works? What needs more support?
  - What are the experiences of women – and other underrepresented students – racial/ethnic minorities, LGBTQ+, low-income and first-generation status students, international students? Post-docs? Faculty?
- Draw on some best practices from your field and other science fields with similar patters
  - Note: AAUW webinar tomorrow feat. Roxanne Hughes & me on gender in computing & engineering
  - Welcome women and other groups, without making their identities unnecessarily salient

Interventions – here at FSU and in the field

- There are some terrific efforts here but the classrooms and faculty meetings are what they are compositionally and the field is similar
- http://www.tallahassee.com/story/opinion/2016/11/21/fsu-physics-department-named-top/94246170/
- Inquiry-based learning through studio physics can close gaps
  - But… it's not a fix-all
- Cultural, disciplinary change takes sweat, effort, collective purpose, and incentives
- Assess the needs of students, colleagues
- Compare with peer institutions
- And pursue support if needed
  - E.g., https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5383
  - Reaching out to central administration, deans, innovating
  - Identify specific goals, metrics for improvement

Next steps in my research

- New studies focusing specifically on engineering & computer science (NSF-funded), with a desire to expand this to Physics – and turn this into a paper – I welcome input and feedback
- Intersections of gender with race/ethnicity, class, institution type
- Useful for all of us to think about how to better think about this puzzle

- Suggestions, questions?

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Appendix Slides

For further interest

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Q&A fodder:
What’s happening in physics?

Let’s revisit those hypotheses and those from the field

Social Psychological Explanations

- Gendered differences in attitudes toward science develop early, shaping female and male students' pathways from early exposure to science through their choice of career.

- This pattern appears heightened among the most mathematically and scientifically talented girls, representing a critical pool of potential 'lost' scientific talent. These girls may be less likely to believe that they are indeed scientifically talented (Lee, 1998).

- Biased attitudes about gender and science tend to be implicit, but nevertheless can shape behavior – including engagement and achievement in math (Nosek and Smyth 2011).

How ability beliefs develop

- *Socialization messages*. E.g., parents' messages have been found to have long-term effects on young adults' occupational outcomes, in particular for females (Chhin, Bleeker, & Jacobs; 2008).

- *Expectancy-task values*. When children internalize their society's expectations for their career-related achievement, they may in turn devalue and turn away from tasks related to areas in which their group is not expected to perform well (e.g., mathematics for girls) (Eccles 2011).

- *Self-assessments*. Girls' pursuit of scientific majors in college are strongly associated with self-assessments of their ability (Correll, 2001). Self-assessments are shaped by local and societal beliefs about women's abilities and career opportunities, especially in the quantitative sciences (Correll, 2004; Ridgeway & Correll, 2004; Eccles, Adler, Futterman, Goff, Kaczala, Meece, et al., 1983).

Stereotype Threat

- Definition: "the situational threat of being negatively stereotyped" (Steele 2003: 117).
  - Concern about others' social evaluation of one's abilities → avoidance of situations in which one is devalued & might meet these low expectations.
- We see it in practice for engineering and math students and academics, both among black and Latino men (McGee & Martin, 2011) and among women (Logel, et al., 2009)

- *The brain on stereotype threat*: MRI imaging used to show how stereotype threat fosters stress that <u>competes with working memory</u> performance (Bielock, 2008)
  - Experiments performed on college women taking seemingly high-stakes math tests

Science Identity

- Talented female students often identify as "not a [math/science] person," even if their grades in these subjects suggest otherwise.
- Girls seem to develop this idea at a young age.

- Path out of science careers emerges in middle school (Bae et al. 2000, pp. 52-54).
  - Gender differences in whether students 'like science' in fourth grade
    - Differences emerge in 8th grade
    - By 12th grade: 56% of boys like science vs. 48% of girls
  - Girls also have a greater tendency to report that they are not "good" at science
    - 4th grade girls report being more likely to persist in science even if given a choice and less likely to consider science a 'hard' subject
    - By 12th grade: 36% of girls say they would not take more science (as compared to 30% of boys) and 56% say science is hard (as compared to 44% of boys).

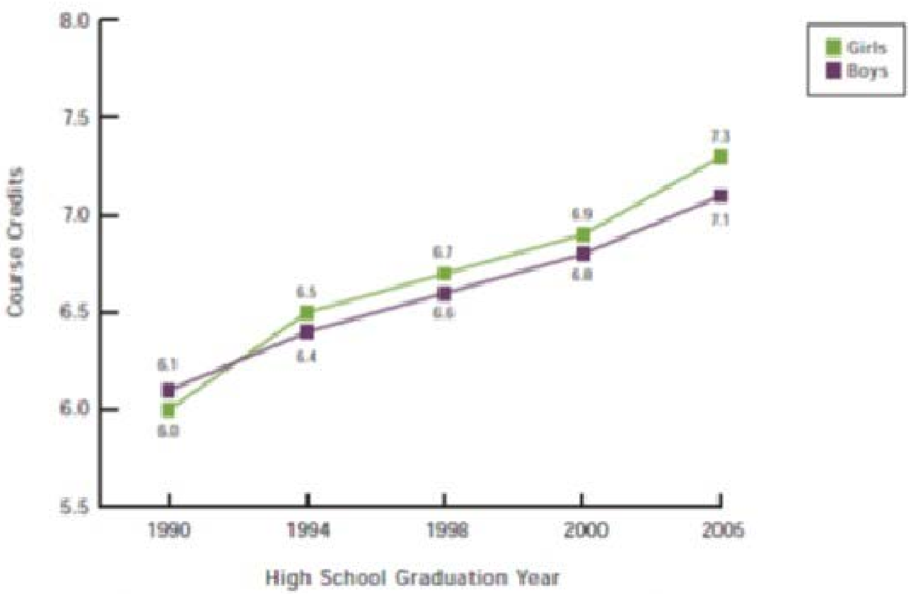
Curricular Choices in High School

- Here, students can *choose* which courses to take
  - Girls may be less inclined to pursue areas that are not associated with female success.
  - Boys have been found to enroll in more advanced secondary school physics courses than girls.

- Those girls that do enroll in more advanced math and science coursework seem to have more negative subjective orientations to math – notably, assessments of their ability and mindset towards math ability (Perez-Felkner, et al., 2012).

Math and Science Course Taking in HS

Figure 1. High School Credits Earned in Mathematics and Science, by Gender, 1990–2005



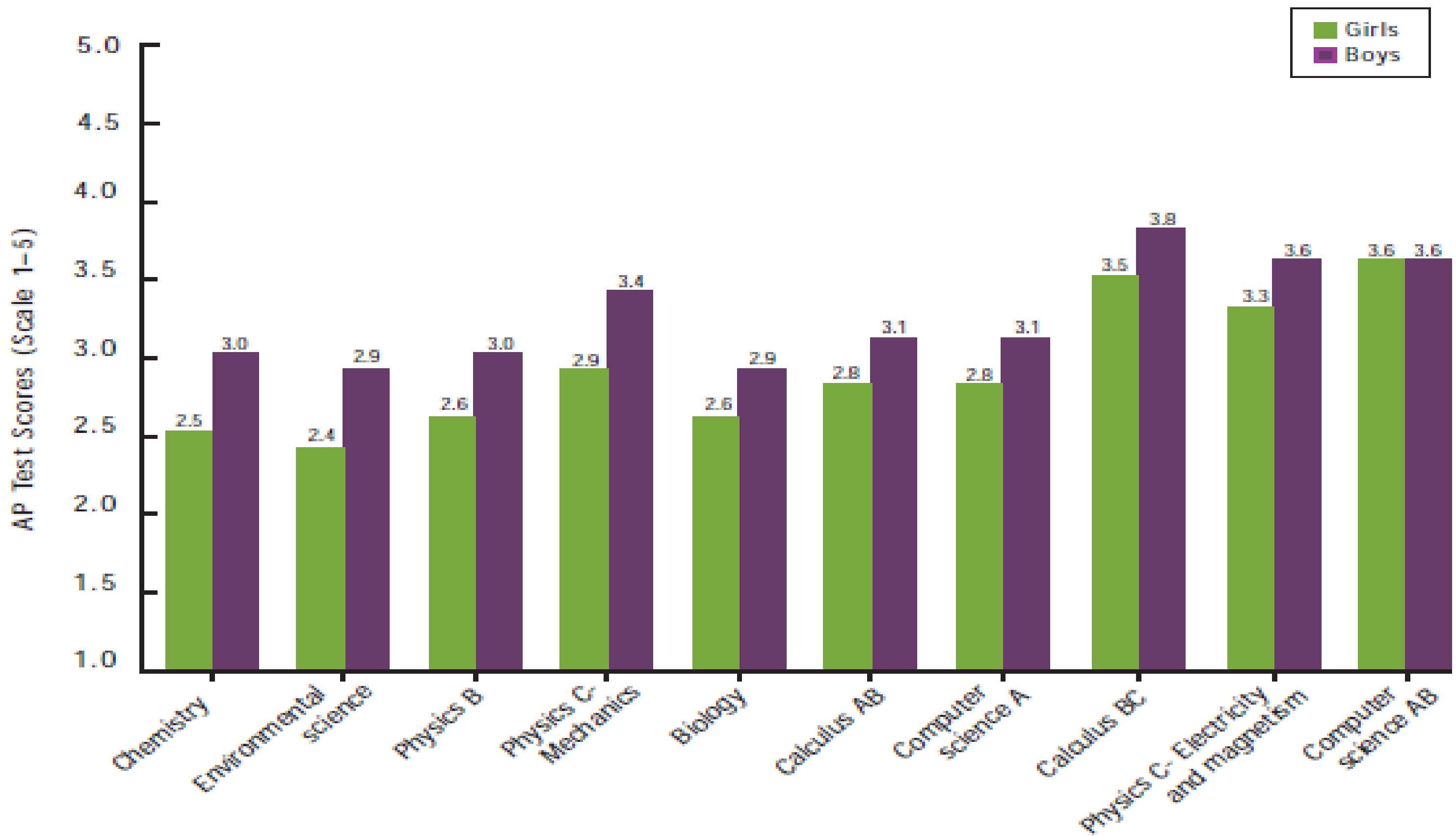
Source: U.S. Department of Education, National Center for Education Statistics, 2007, *The Nation's Report Card: America's high school graduates: Results from the 2005 NAEP High School Transcript Study*, by C. Shettle et al. (NCES 2007-467) (Washington, DC: Government Printing Office).

Rates and patterns of advanced course taking vary widely at both the individual and school levels.

- Affluent students tend to take more advanced mathematics and science coursework than their less socioeconomically advantaged peers
- High schools that serve high percentages of minority and low-income youth less commonly offer advanced math and science courses to their students (Adelman, 2006).
- Community/residential contexts influence Physics course taking rates – specifically, density of STEM-employed professionals (Riegle-Crumb & Moore, 2013)

High-Stakes Tests: Girls Underperform

Figure 4. Average Scores on Advanced Placement Tests in Mathematics and Science Subjects, by Gender, 2009



Source: Retrieved November 11, 2009, from the College Board website at www.collegeboard.com.

Social Contexts of Influence

- *Starts early*: Preschool children have stronger preference for same-sex peers and exhibit behavior more closely in line with gender stereotypes when gender is made salient (Hilliard and Liben 2010).

- Students' perceptions of the degree to which teachers and peers regard their academic potential can explain differences in their postsecondary enrollment (Perez-Felkner, 2009).

- Gender variation in academic support
  - Girls are typically perceived as "better" students, harder working and easier to discipline (Jones & Myhill, 2004; Mickelson, 1989).
  - Boys may receive less praise than girls for their overall academic performance, they appear to receive more support from parents and teachers for their interests and ambitions in STEM (Gunderson, Ramirez, Levine, & Beilock, 2012).

College Years

- In a major study of NC college students, first year grades in science courses did NOT explain the gender gap in STEM majors (Stearns, et al., 2013).
- In a qualitative study of female computer science majors, most women came to doubt their identity as computer scientists: they felt that they *did not belong*, were *"guests in a male-hosted world"*, and did not share the *"total absorption"* (an all-consuming passion for working with computers and robotics in both work time and free time) that their male peers displayed (Margolis & Fisher, 2002: 72).
- Enrolling introductory physics undergraduates in short values-affirming writing assignments meaningfully narrows the gender gap in course performance (Miyake et al. 2010).

Intrinsic vs. Extrinsic Motivation: Women Choose Lower-Paying Majors