Characterizing gaps in achievement in introductory STEM courses

An Intersectional Analysis

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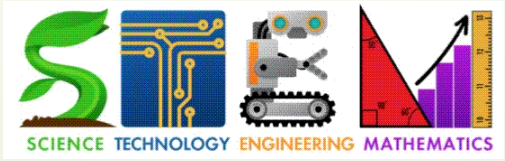
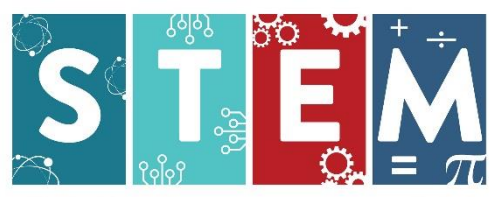
STEM as a national priority

- Attracting and keeping STEM students is important to our nation's long-term success (Executive office of the President 2012).
- The USA needs a 34% increase in the production of STEM degrees (Holdren and Lander, 2010).
- Fewer students pursue STEM majors
- The lowest retention rates among all academic disciplines (NAS 2007).
- Variation among STEM disciplines.



Students who leave STEM

- 48% of the students who start STEM majors leave (Chen and Soldier, 2013).
- Within the first two years of UG study (Center for Institutional Data Exchange Analysis 2000).
- Students who switch out are some of the most qualified students and are also disproportionately women and non-white (NAS 2007).
- African-American students are the most likely ethnic group to leave STEM majors by dropping out of college (29%) or switching to a non-STEM degree (36%) (NCES)
- Wide variety of overlapping reasons

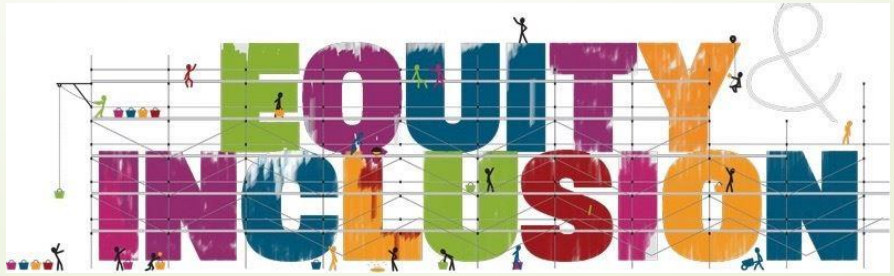


GPA matters in STEM

- Achievement is a strong predictor of retention in STEM disciplines, particularly relative to achievement in non-STEM courses(Beasley and Fischer,2012;Riegle-Crumbetal.,2012).
- Achievement gaps are mirrored by gaps in latent traits, such as a student's sense of belonging, science identity, and self-efficacy (Eddy and Brownell, 2016).
- Failure has emotional and financial impacts
- Persistent impacts of GPA:
  - Honors, awards
  - Scholarships
    - Funding – implications for students from low socioeconomic status
  - Admission to programs
    - Professional – medical, dental, etc.
    - Graduate and undergraduate
  - Employment

Achievement Gaps - Gender

- Women make up nearly 50% of the entire US workforce but only 25% of the science and engineering workforce (National Science Board, 2004)
- Some studies find Gender Achievement Gaps and others don't
- Differences that favor men have been identified in exam performance, participation in whole-class discussions, and who is viewed as most knowledgeable about course content (Eddy, Brownell, & Wenderoth, 2014; Grunspan et al., 2016)
- Even in Life Sciences where gender ratio is close to 1:1
  - Numbers do not indicate equity



Persistent Gendered Performance Difference in SM classes

- Based analysis on Matz et al. 2017;
- Six years, five research universities, 249 courses in 13 disciplines
- GPAO – grade point average in other classes (excluding the target)
  - Good predictor of performance
- Difference between performance in class vs. other classes
- GPA > GPAO = positive impact = bonus
- GPA < GPAO = negative = penalty
- Difference between women and men = Gendered Performance Difference

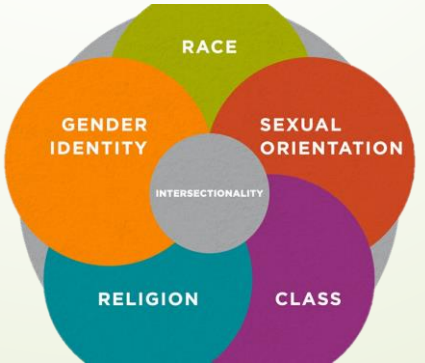
- Biology, chemistry and physics lectures = favor men
- Lab courses = more equitable
- Persistent **Gender Achievement Difference** in Intro SM classes

Achievement Gaps - Race

- Proportion of underrepresented minorities (URM) in college has increased but the proportion pursuing STEM majors has not (NCES 2017).
- **24% of African American, Latina/o, and Native American** students complete a science bachelor's degree in six years, compared to **40% of White** students (Center for Institutional Data Exchange Analysis 2000).
- URM = **25% of US workforce**; 18% of UG, **2.5% STEM majors**, 6% STEM workforce
- some traditionally underserved students' grades decline in STEM courses, but remain high in non-STEM courses
- Not about abilities – systemic inequities

Intersectional Identities

- Multiple, interacting, dimensions of identity
  - how multifaceted identities are positioned in and experience oppression
- Multiple systemic disadvantages
  - more likely to experience poor academic performance and may ultimately make the decision to leave STEM disciplines for reasons that have nothing to do with their capabilities in math and science (Gayles & Ampaw, 2016; Reyes, 2011)
- Women-of-color are virtually absent from STEM fields in the top US academic institutions (NAS 2006).



Research Questions

1. Do students in 10 Gender-Race (G-R) categories experience grade bonuses or penalties in introductory science and math classes?
2. a. What factors besides G-R influence course GPA?

2.b. After accounting for these factors, is there a G-R performance difference?

Data

- Institutional Research office provided data
- 12 semesters, including summer terms
- Between fall 2015 and spring 2019
- Introductory science and math classes (SM)
  - Science and math majors
  - Non-majors
  - Lecture and Lab courses
- The first courses encountered by SM majors,
  - Gatekeeper courses often result in high attrition rates for all students, disproportionately for URM students, (Schneider 2000; Vetter 1994).

Introductory, Gatekeeper, Courses

Table 1. Courses used in the study (n=31).				
Discipline	**Type**	**Lecture**	**Lab**	**n**
Biology	Non-majors	102	104L	2
	Majors intro sequence	240, 242	244L	3
Chemistry	Non-majors	101, 105	103L,	3
	Majors intro sequence	201, 202	207L, 208L, 209L, 210L	6
Math	Non-majors	105, 109, 190		3
	Pre-requisites for STEM	111, 180, 205		3
Physics	Non-majors	107, 111B	108L	3
	Pre-requisites for STEM	221, 222	223L, 224L	4
	Majors	298, 299	295L, 296L,	4

Gender and Race Data

- Binary gender = M or F
- 9 race categories
  - 5 used in the analyses

Code	Race
1	Non-resident alien
2	**Black/African American**
3	American Indian
4	**Asian**
5	**Hispanic**
6	**White**
7	unknown
8	**2 or more races**
9	Native Hawaiian or Pacific Islander

Student population

Total across all classes				
	Women		Men	
	n	%	n	%
Black	2493	**5.9%**	1474	**3.5%**
Asian	1476	**3.5%**	1418	**3.4%**
Hispanic	1123	**2.7%**	1023	**2.4%**
White	14384	**34.2%**	16287	**38.7%**
2 or more	1246	**3.0%**	1168	**2.8%**
		49%		**51%**

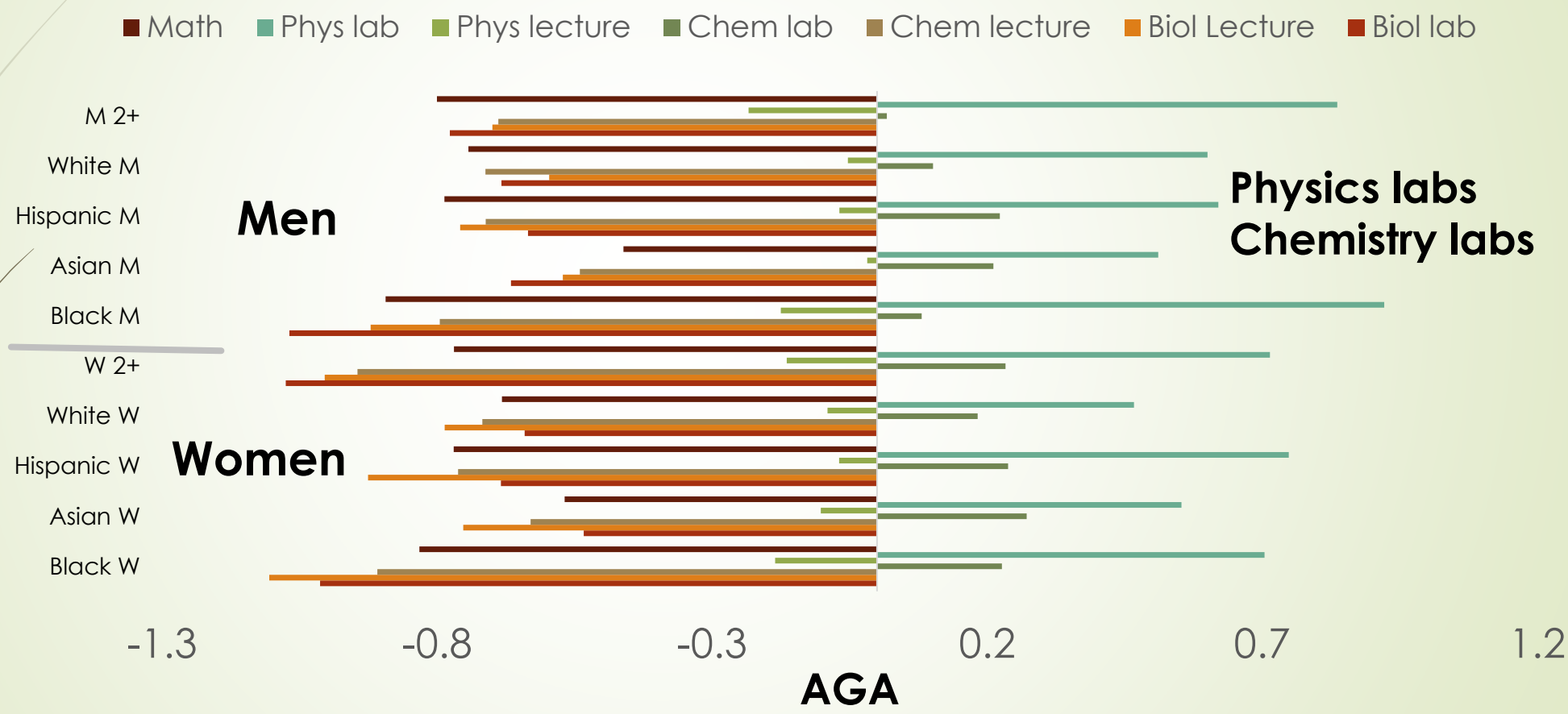
Q1, Bonus or Penalty: Methods

- Following Matz et al. 2017
- **Grade anomaly** = Grade in class – grade in other classes (excluding the target class)
- **GPA – GPAO**
- Relative performance

+ Positive Grade "bonus"

- Negative Grade penalty

Mostly grade penalties; lecture > lab



-PENALTY

+BONUS

AGA – Average Grade Anomaly – Lecture > Lab

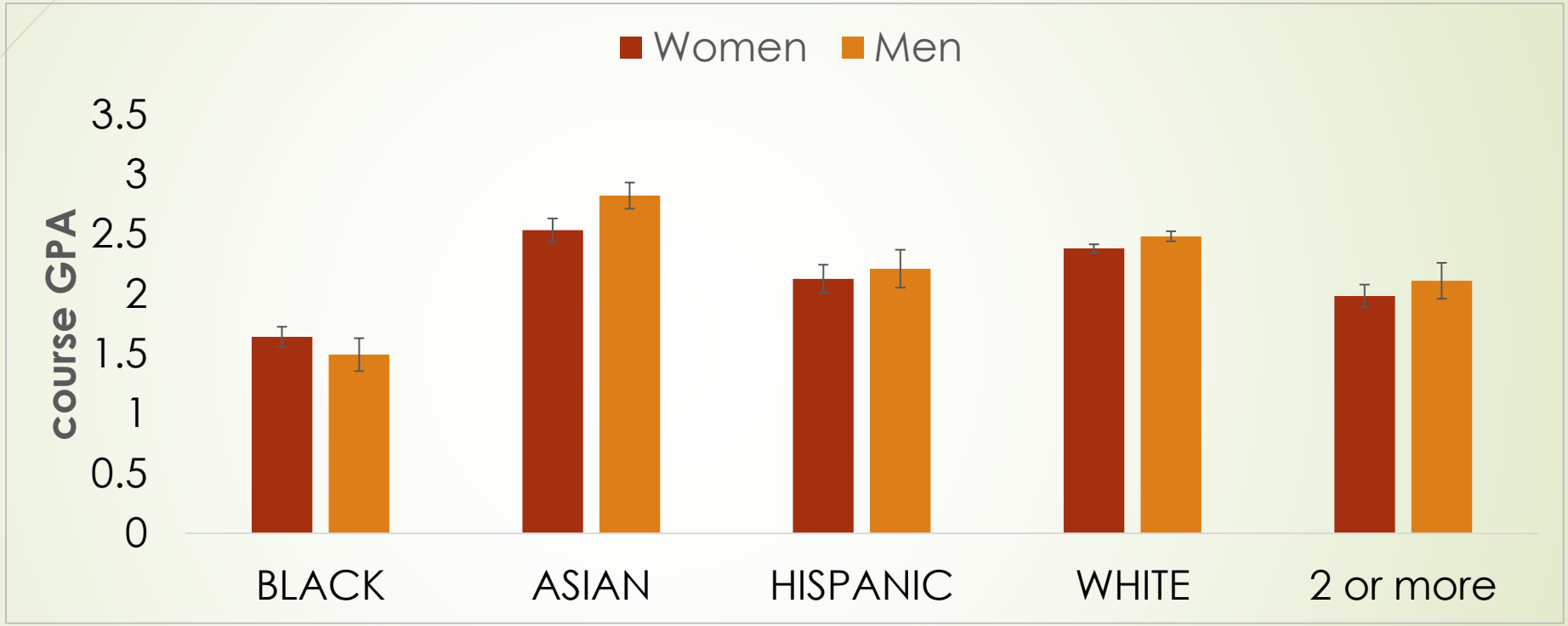
		BIOLOGY					CHEMISTRY									MATH						PHYSICS										
					LABS							LABS												LABS									
		1102	2404	2402	1044	2444	1015	1005	2001	2012	1037	2078	2089	2090	2101	1059	1090	1098	1081	1015	2065	1107	1181	1082233	2242344	2295	2296	2212	2222	2298	2299	Total n
Women	Black	N	N	N		N	N	N	N	N		N				N	N	N	N	N	N	**N**						N		N	N	19
	Asian	N	N	N		N	N	N	N	N						N	N	N	N	N	N							N		N	N	17
	Hispanic	N	N	N		N	N	N	N	N						N	N	N	N	N	N	**N**	**N**					N		N	N	19
	White	N	N	N		N	N	N	N	N						N	N	N	N	N	N	**N**	**N**					N	N	N	N	20
	2 or more	N	N	N		N	N	N	N	N						N	N	N	N	N	N	**N**	**N**					N	N	N	N	20
Men	Black	N	N	N	N	N	N	N	N	N						N	N	N	N	N	N	**N**	**N**					N		N	N	20
	Asian	N	N	N		N	N	N	N	N						N		N	N	N	N							N		N		15
	Hispanic	N	N	N		N	N	N	N	N						N	N	N	N	N	N	**N**						N	N	N	N	19
	White	N	N	N		N	N	N	N	N						N	N	N	N	N	N	**N**						N		N		17
	2 or more	N	N	N		N	N	N	N	N					N	N	N	N	N	N	N		**N**					N		N	N	19

N = grade penalty; Blank = neutral or grade bonus

Gender x Race differences in grade anomalies

		BIOLOGY					CHEMISTRY									MATH						PHYSICS										
					LABS						LABS												B	LABS									
		1 0 2	2 4 0	2 4 2	1 0 4	2 4 4	1 0 1	1 0 5	2 0 1	2 0 2	1 0 3	2 0 7	2 0 8	2 0 9	2 1 0	1 0 5	1 0 9	1 0 9	1 8 0	1 1 5	2 1 0	1 0 7	1 1	1 0 8	2 2 3	2 2 4	2 9 5	2 9 6	2 2 1	2 2 2	2 9 8	2 9 9	Total n
Women	Black	N	N	N		N	N	N	N	N	N				N	N	N	N	N	N	N							N		N	N	19
	Asian	N	N	N		N	N	N	N	N					N	N	N	N	N	N								N		N	N	17
	Hispanic	N	N	N		N	N	N	N	N					N	N	N	N	N	N	N	N						N		N	N	19
	White	N	N	N		N	N	N	N	N					N	N	N	N	N	N	N	N						N	N	N	N	20
	2 or more	N	N	N		N	N	N	N	N					N	N	N	N	N	N	N	N						N	N	N	N	20
Men	Black	N	N	N	N	N	N	N	N	N					N	N	N	N	N	N	N	N						N		N	N	20
	Asian	N	N	N		N	N	N	N	N					N		N	N	N	N								N		N		15
	Hispanic	N	N	N		N	N	N	N	N					N	N	N	N	N	N	N							N	N	N	N	19
	White	N	N	N		N	N	N	N	N					N	N	N	N	N	N	N							N		N		17
	2 or more	N	N	N		N	N	N	N	N				N	N	N	N	N	N	N		N						N		N	N	19

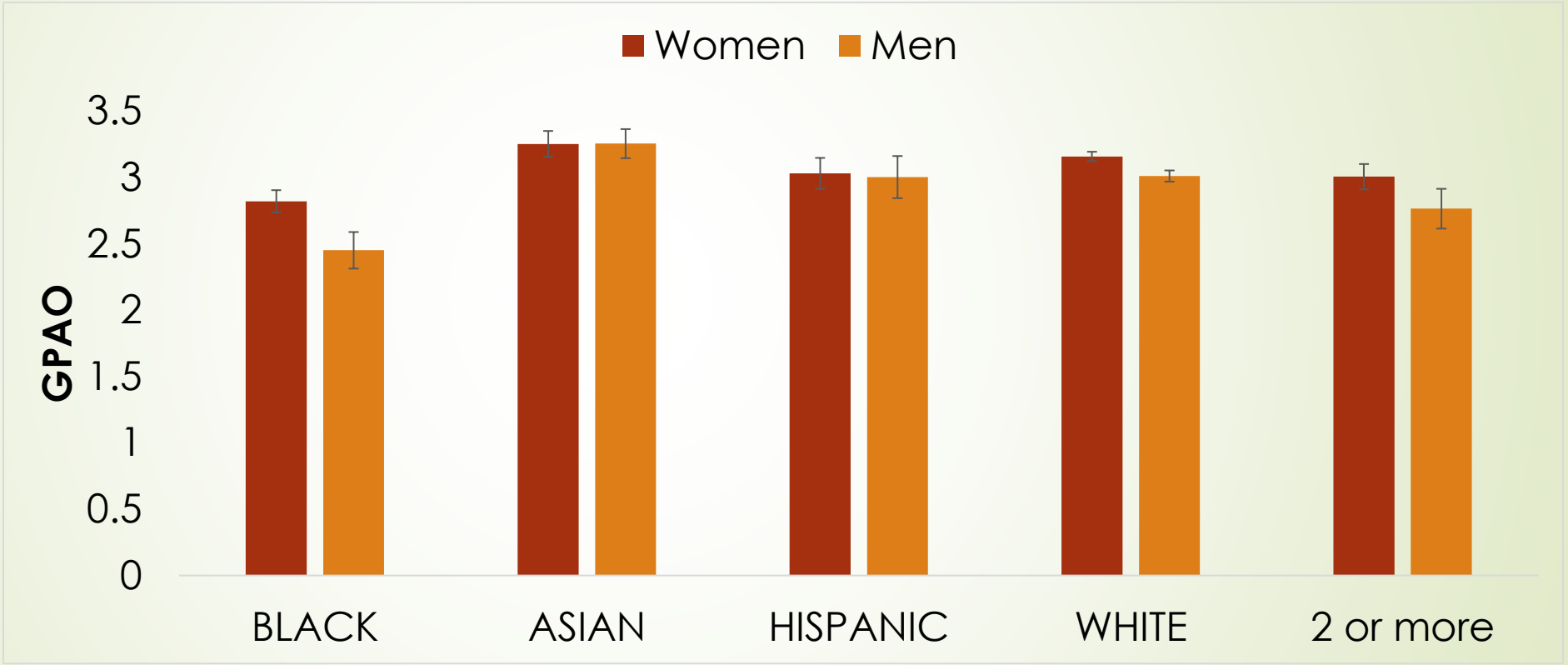
Course GPA – First Semester Biology



Men > Women (mean = 2.24, 2.13)

Asian men – highest
Black men – lowest

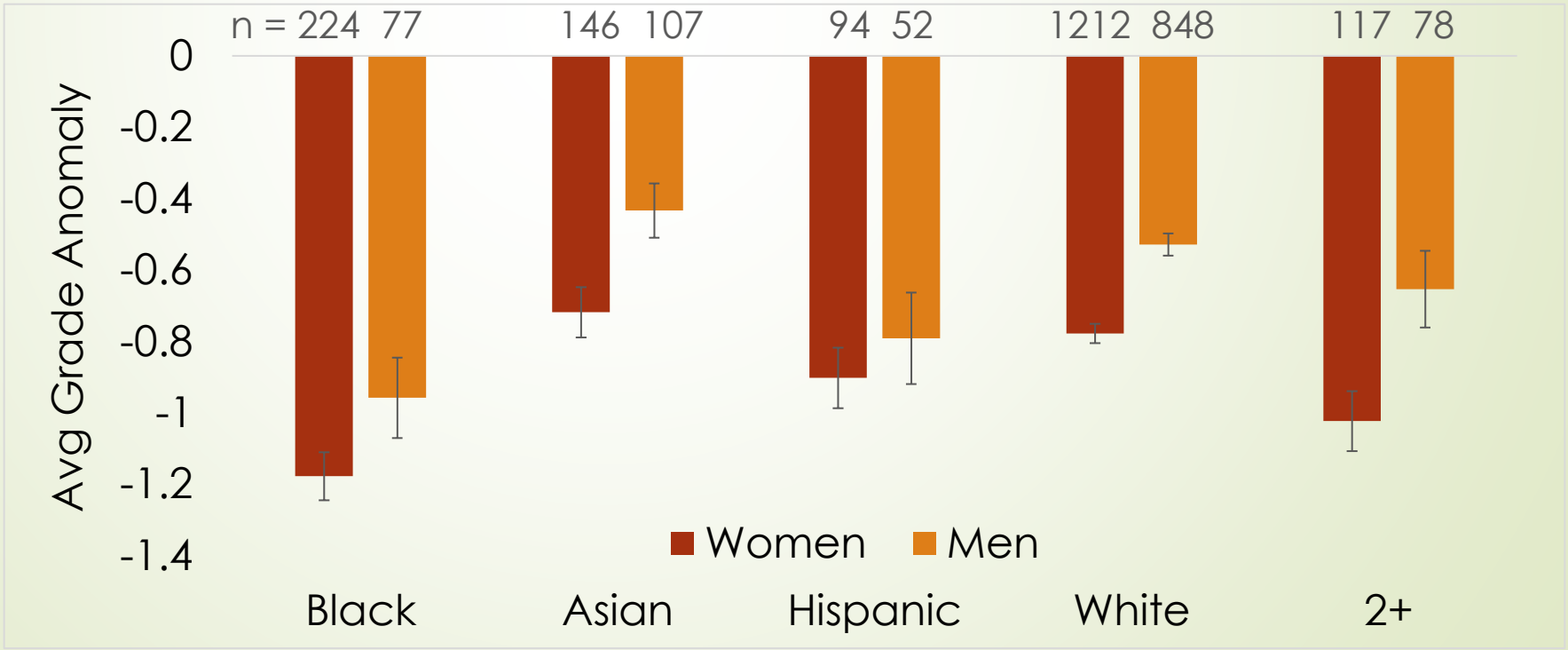
GPAO - better performance in other classes



Women > = Men (mean= 3.05, 2.89)

AGA, Biology

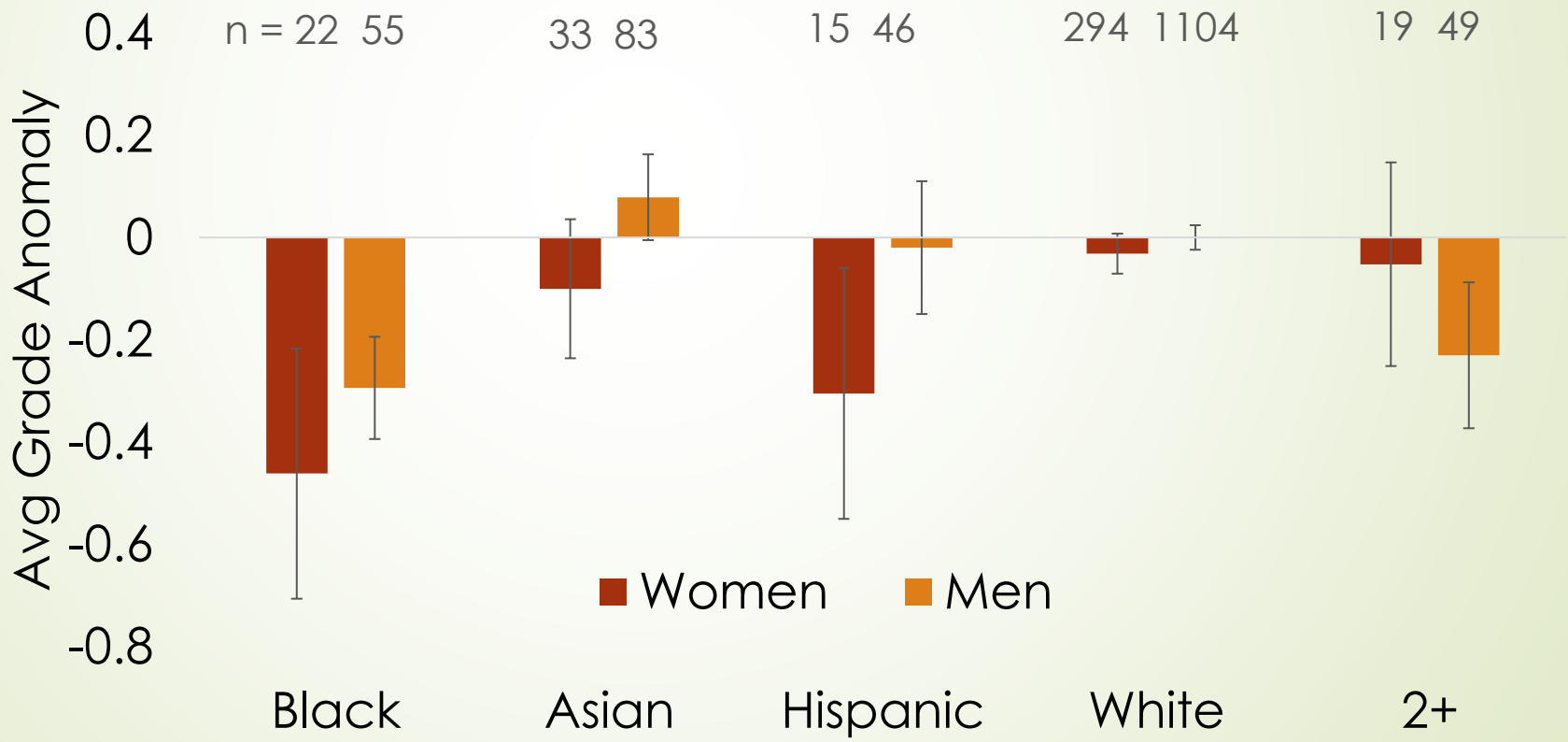
- All students experience grade penalty
- Women penalty (-0.91) > men's (-0.67)*;
- Black women (-1.17) > White Women (-0.78)*
- Asian men and white men, least penalty
- Black women, women of 2+ races, greatest penalty



Similar pattern in physics

Second semester, calculus-based Physics

- Women greater penalty than men; Black women, greatest penalty



Gender and Race Achievement Differences

- **Achievement Difference** = difference in AGA
  - relative to expectations
- **Gender**
  - Women AGA – Men AGA = Gender Difference
  - **+Positive – favors women**;
- **Race**
  - Underrepresented minority populations = URM = Black, Hispanic, 2+ races
  - Majority group = non-URM = White, Asian
  - URM AGA – Non AGA = Race Difference
  - **+Positive – favors URM**

Achievement Differences

- Women and URM – negative in majority of classes
- Different experiences for Gender and Race

Gender W - M	
BIOL-240	-0.28
BIOL-242	-0.12
PHYS-299	-0.06
PHYS-298	-0.05
PHYS-222	-0.03
PHYS-221	-0.02
CHEM-201	-0.01
CHEM-202	0.03
MATH-180	0.07
MATH-111	0.08
MATH-205	0.13

Mean = -0.02

Race U - N	
BIOL-240	-0.32
PHYS-299	-0.21
CHEM-202	-0.2
MATH-205	-0.2
MATH-180	-0.19
CHEM-201	-0.16
BIOL-242	-0.15
PHYS-298	-0.12
PHYS-221	-0.1
MATH-111	-0.1
PHYS-222	0.1

Mean = -0.15

Women from URM groups = multiple negative dimensions

Intersectional Experience

Q1: Do students experience grade bonuses or penalties in introductory science and math classes?

- Most students experience penalties in all SM classes
- Lecture penalties worse than lab
- Varies by course
  - Biology lecture classes stand out as greatest penalties
- Women and URM experience greater penalties and lower bonuses than men and non-URM students

Question 2a: What other factors influence course GPA?

- General Linear Model
  - By course
  - Majors lecture courses
  - Course GPA = dependent variable
  - Math score, English score, GPAO, Term = covariates
  - Gender-Race
- Model Selection
  - Best model for explaining course GPA

Question 2b:

After accounting for other influential variables, does Gender-Race negatively impact course grade?

- Generate parameter estimates (regression coefficients) for Gender-Race categories for the best model
- Negative coefficient = penalty for that G-R category student

Best models to explain course GPA

- For all majors lecture courses, the best models included:
  - Gender-Race
  - GPAO
  - Math ACT subscore
  - Term – control for variation across terms/classes

Course GPA = Gender-Race + GPAO + Math ACT + Term

Example: Biology lecture

- Variables from best model are useful in predicting course GPA

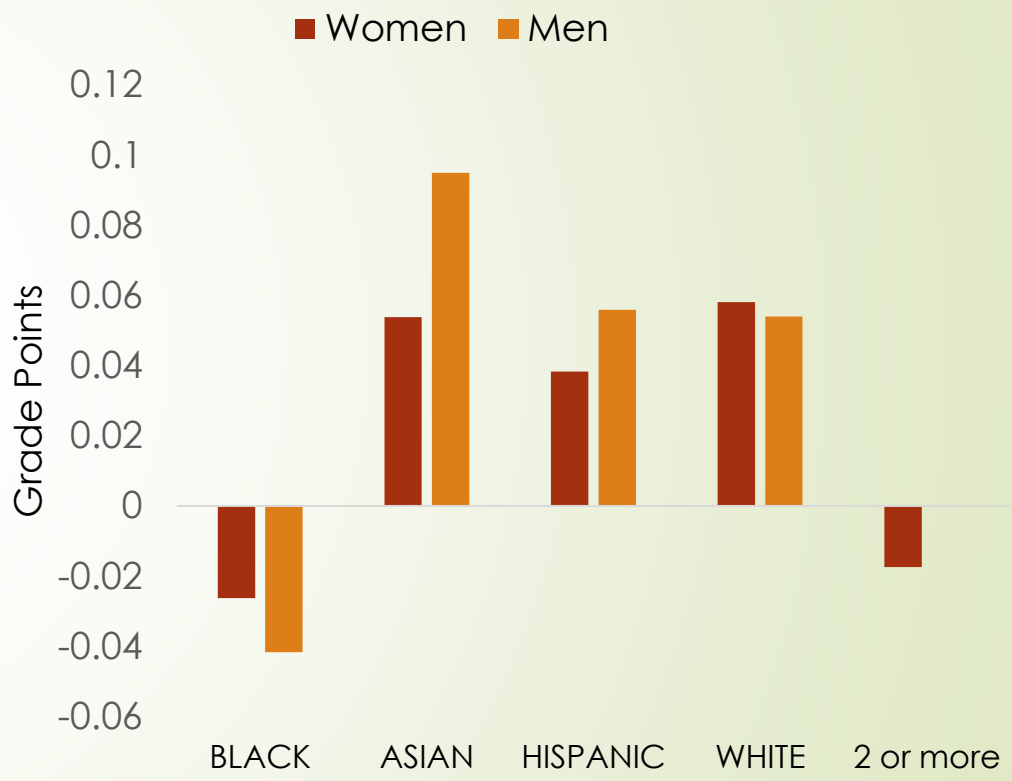
Variable	df	F	P	Partial Eta-Square
Gen - Race	9	11.02	<.0001	0.0019
Math	1	1535.27	<.0001	0.0291
GPAO	1	24180.1	<.0001	0.3203
Term	13	67.73	<.0001	0.0169

- Smaller effect of sex-race compared to other variables
- GPAO has very high predictive ability

Coefficients

- Negative = negative impact on course GPA
- Gender-Race

  - G-R performance difference
    - Black women
    - Women from 2+races
    - Black men



Q2: After accounting for other factors that influence course GPA, is there a G-R performance difference?

- GPA is predicted by GPAO, math ACT, term
- Black women, women from 2+ races, Black men experience penalties

Implications and Actions

- Identify courses with achievement gaps
- Known pedagogical remedies
- The weed out climate = competitiveness, large courses, differential treatment, grading on a curve, and lack of faculty involvement; (Koebler, 2012; Reyes, 2011).
  - stronger in STEM disciplines compared to other fields
- Eliminate grading on a curve, encourage cooperation (Epstein 2006).
- Increase course structure (Freeman et al. 2011)
- CUREs, research experiences, cultural connections (Estrada et al. 2016)

Implications beyond

- Achievement is related to other factors that discourage persistence:
  - Stereotyping, social stigma, lack of supportive networks, notions of competence, science identity (Fries-Britt 1998; Treisman 1985; Estrada et al. 2016).
- Underrepresentation impacts culture of science
  - URM scientists are more likely than non-URMs to study issues specific to minority communities (Nichols 1997).
  - Racial, gendered ‘‘culture of science’’ may inhibit the development of URM research scientists, and who ultimately becomes a scientist (Estrada et al. 2016)
- Overall climate of the university and academic culture

Thanks!

- Nick Ullrich, Becky Patterson, Shari Barrow and Bob Goldstein in Institutional Research
- BLUE/Explorance for faculty grant

bluenotes group

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Model Selection

- Several methods for model selection, each use different measures
  - LASSO – used by Matz et al. 2017
  - Backward Elimination
  - Stepwise
- Model stability
  - Bootstrapping – resampling with replacement
    - Randomly created data set
    - Run model 500 times
    - Proportion of runs that produce the same model (selection frequency)
    - Compare across methods
- Backward elimination had higher stability

Chemistry lab – first semester