Statistical Analysis of Students' Performance On Research-based Inventory

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Background

- ❖ Research based assessments have been widely used within the PER (Physics Education Research) community to measure learning outcomes.
- ❖ Example: Force Concept Inventory (FCI)[1] (30-item multiple choice on Newtonian mechanics)
- ❖ IE (interactive-engagement) courses tend to yield higher FCI gains [2]
  - ❖ Normalized gain ($<g>$) $\equiv$ (%$\langle$post$\rangle$–%$\langle$pre$\rangle$)/(100–%$\langle$pre$\rangle$))
  - ❖ $<g>\sim$0.2 for traditional lectures, $<g>\sim$0.4 or IE courses
- ❖ Relatively less work has been done in primarily undergraduate institutions (PUI) and minority-serving institutions.

Study & Methodology

Goal:
- ❖ Provide evidence for the reproducibility of educational studies for a variety of student population
  - ❖ Cal Poly Pomona(CPP) is both a PUI and Hispanic serving institution
  - ❖ We are trying to replicate results from a study [3] including Loyola Marymount University (LMU) & Edward Little High School.
- ❖ Explore possible gender or racial gaps in student's performance

Data:
- ❖ Data collected in introductory physics courses (PHY131 in quarters) at CPP:
  - ❖ _Winter 2017_, _Spring 2017_, _Summer 2017_ and _Fall 2017_
- ❖ N=1311 total
- ❖ Pre and Post tests of FCI (N=700 has both pre and post score)
- ❖ Other background variables: SAT, Highschool GPA, College GPA, etc.

Research Questions

1. For our student population, what background variables would affect students' performance on the FCI?
2. Will instruction type affect student performance on the FCI?
3. What is the correlation between student FCI Gain & SAT Composite[3]?
4. Is there a gender gap in students' preparation and normalized gain?
5. Are there any differences in students' preparation and normalized gain among different ethnicities?

Discussion

- ❖ We established a linear regression model that predicts students' FCI post scores (65% of the variance).
- ❖ A hierarchical linear regression method showed the Instruction type made a statistically significant difference in students' FCI post score, although not practically significant.
- ❖ For reproducibility of educational studies, we found the size of the correlation between FCI gain & SAT score at CPP is different from the correlation found in the LMU study.

- ❖ A significant gender gap is shown from the data collected.
- ❖ Hispanic & Asian populations are similar in FCI pre and normalized gain $<g>$.
  - ❖ Gender Gap for these two groups is **INCREASED** by the end of the term
- ❖ The White population shows the largest gender gap which stays **consistent** throughout the term.

References

1. D. Hestenes, M. Wells, and G. Swackhamer, Force concept inventory, Phys. Teach. 30 (3), 141 (1992).
2. Richard Hake, Interactive-engagement versus traditional methods: A six thousand-student survey of mechanics test data for introductory physics courses, American Journal of Physics: Volume 66, Issue 1, Pages 64-74 , 1998
3. Coletta, V. P., Phillips, J. A., & Steinert, J. J. (2007). Interpreting force concept inventory scores: Normalized gain and SAT scores. Physical Review Special Topics - Physics Education Research, 3(1). doi:10.1103/physrevstper.3.010106
4. Carl Wieman and Sarah Gilbert, CBE-Life Sciences Education, Vol 13(3), pp. 552–569 (2014)

Linear Regression Model

FCI Post Correlation Table CPP 2017 Academic YR

Correlation Coefficient (R)	FCI pre N = 700	SAT Math N = 488	SAT Composite N = 488	MAT114 (Calculus grade) N = 276	Total GPA N = 617	HS GPA N = 635
FCI Post	0.80	0.50	0.52	0.15	0.20	0.22

Correlation coefficients normally range from 0-0.3 (weak), 0.4-0.6 (medium), 0.7-1.0 (strong)

Instruction type (IT):
- ❖ Devised 3-point scale for different pedagogical instructions of faculty
- ❖ Score was assigned by two faculty members, one of whom has extensive experience observing faculty
- ❖ Score was triangulated by faculty self-reported response to faculty teaching pedagogy: CWSEI Teaching Practices Inventory [4]

Does Instruction Type Impact Student FCI Post Scores?

Analysis 1 : Controlling FCI Pre

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Analysis of Variance Table

Model 1: g$`FCI Post` ~ g$`FCI Pre`
Model 2: g$`FCI Post` ~ g$`FCI Pre` + g$IT
  Res.Df   RSS Df Sum of Sq      F    Pr(>F)
1    698 11042
2    697 10840  1    202.61 13.027 0.0003289 ***
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Model 1 : FCI Post ~ FCI Pre (N = 700, R^2 = 0.6447)   Model 2 : FCI Post ~ FCI Pre + IT (N = 700, R^2 = 0.6512)

Through ANOVA analysis we conclude that by adding IT as a variable, model 2 better predicts FCI Post score.

Analysis 2 : Controlling FCI Pre + SAT Composite

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Analysis of Variance Table

Model 1: gsat$`FCI Post` ~ gsat$`FCI Pre`
Model 2: gsat$`FCI Post` ~ gsat$`FCI Pre` + gsat$IT
Model 3: gsat$`FCI Post` ~ gsat$`FCI Pre` + gsat$IT + gsat$SAT_Total
  Res.Df    RSS Df Sum of Sq      F    Pr(>F)
1    486 7758.7
2    485 7557.5  1    201.17 13.728 0.0002357 ***
3    484 7092.7  1    464.81 31.718 3.026e-08 ***
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Model 1 : FCI Post ~ FCI Pre (N = 488, R^2 = 0.6257)   Model 2 : FCI Post ~ FCI Pre + SAT Composite (N = 488, R^2 = 0.6478)

Model 3 : FCI Post ~ FCI Pre + SAT Composite + IT (N = 488, R^2 = 0.6578)

Whether adding SAT Composite as another predictor, the overall result is still consistent with Analysis 1.


FCI Normalized Gain vs SAT Composite
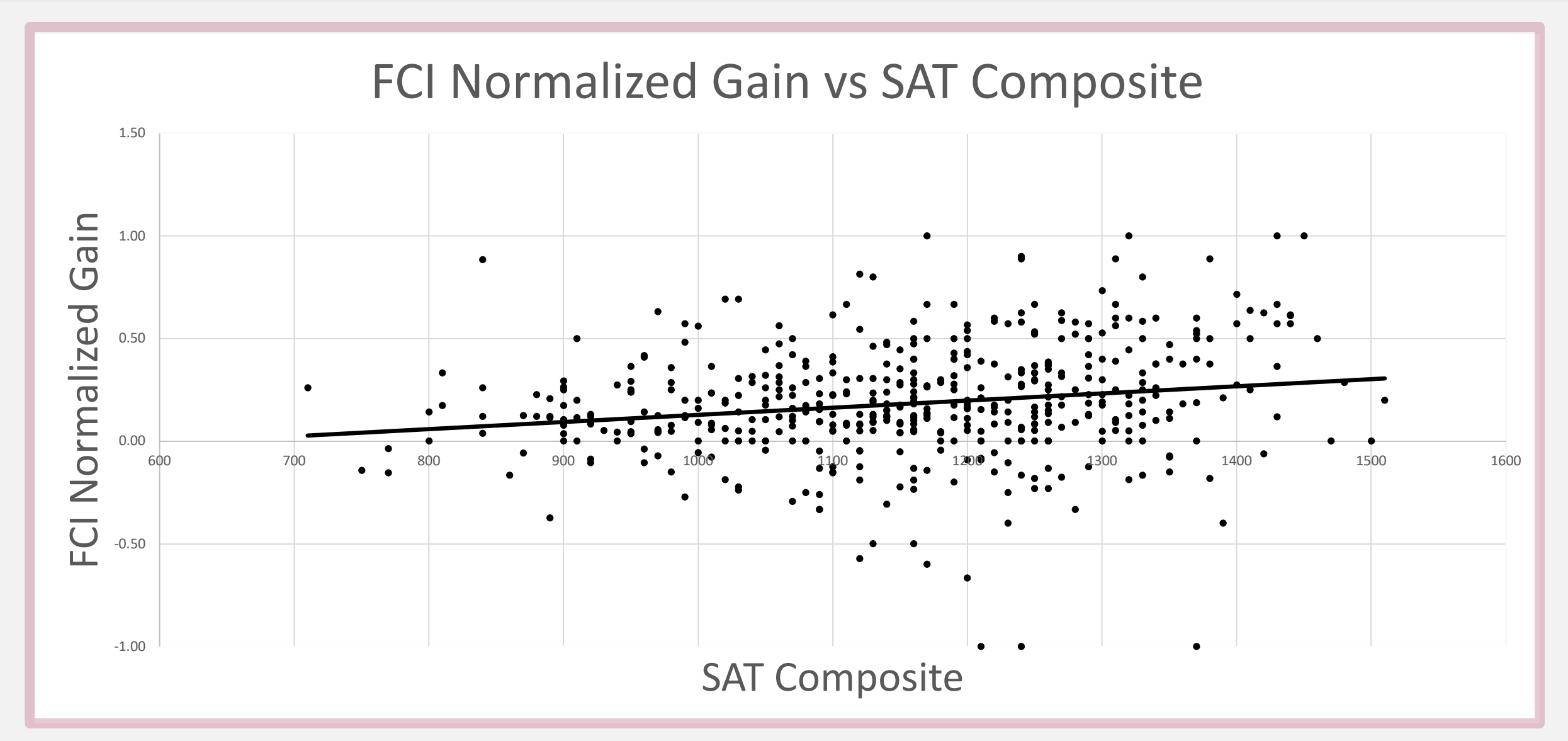
- ❖ Previous study at LMU shows a Pearson correlation coefficient of r = 0.46 (N = 292).
- ❖ Our result is: r = 0.16 (N = 456).
- ❖ This replication study indicates research findings can vary depending on populations.

Gender and Ethnicity

N	Hispanic/Latino	Asian	White	Black/ African American
Total	235	193	148	18
Male	156	138	112	17
Female	79	55	36	1

Pre-FCI Score and Normalized Gain for all Ethnic groups
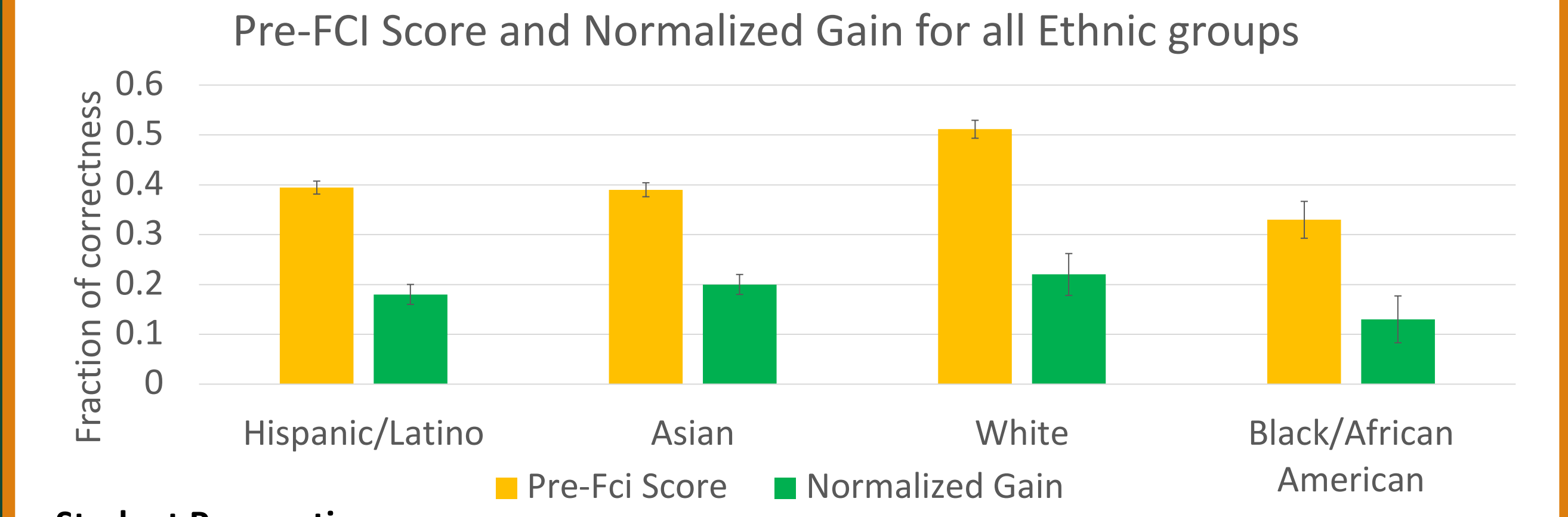
Student Preparation:
- ❖ Significant difference between White and Hispanic/Asian
- ❖ Significant difference between White and African American
- ❖ Hispanic and Asian populations are very similar.

Pre-FCI Score by Gender and Ethnicity
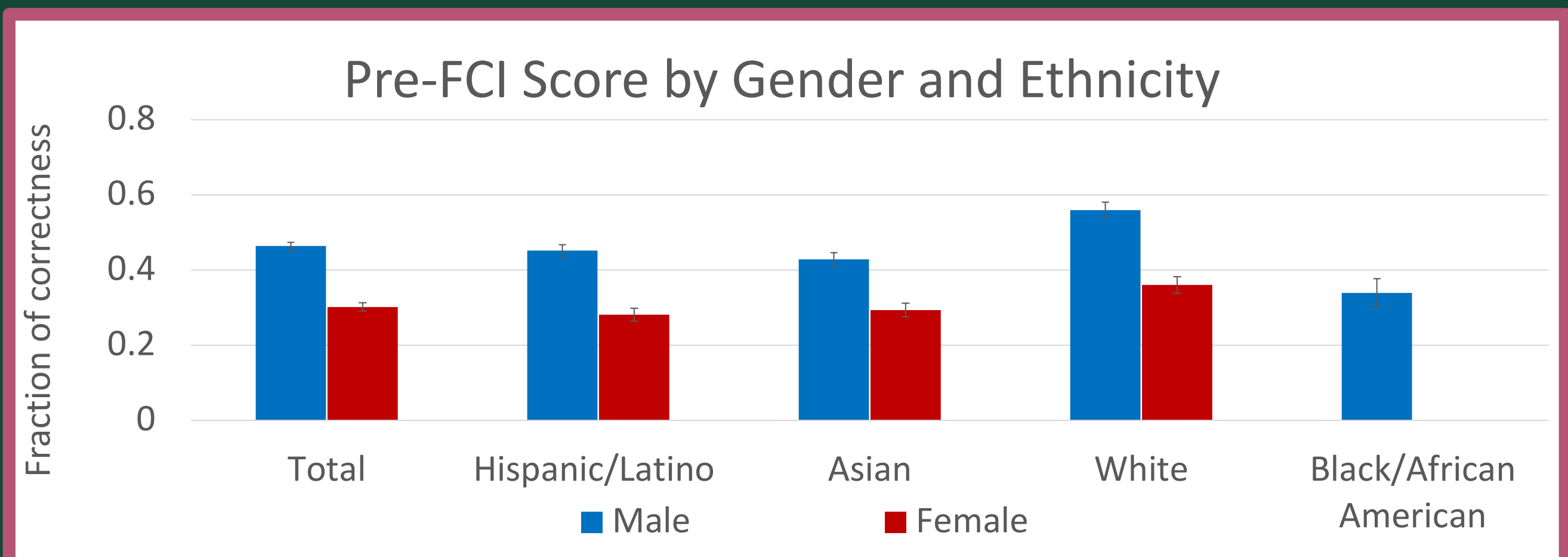
- ❖ Significant gender gap in student preparation across all groups. [p< 0.0001]
- ❖ The largest gender gap shows up in the White population.
- ❖ The largest racial gap shows up for male population.
  - ❖ Major contributor to the difference between total ethnic populations

Normalized Gain by Gender and Ethnicity
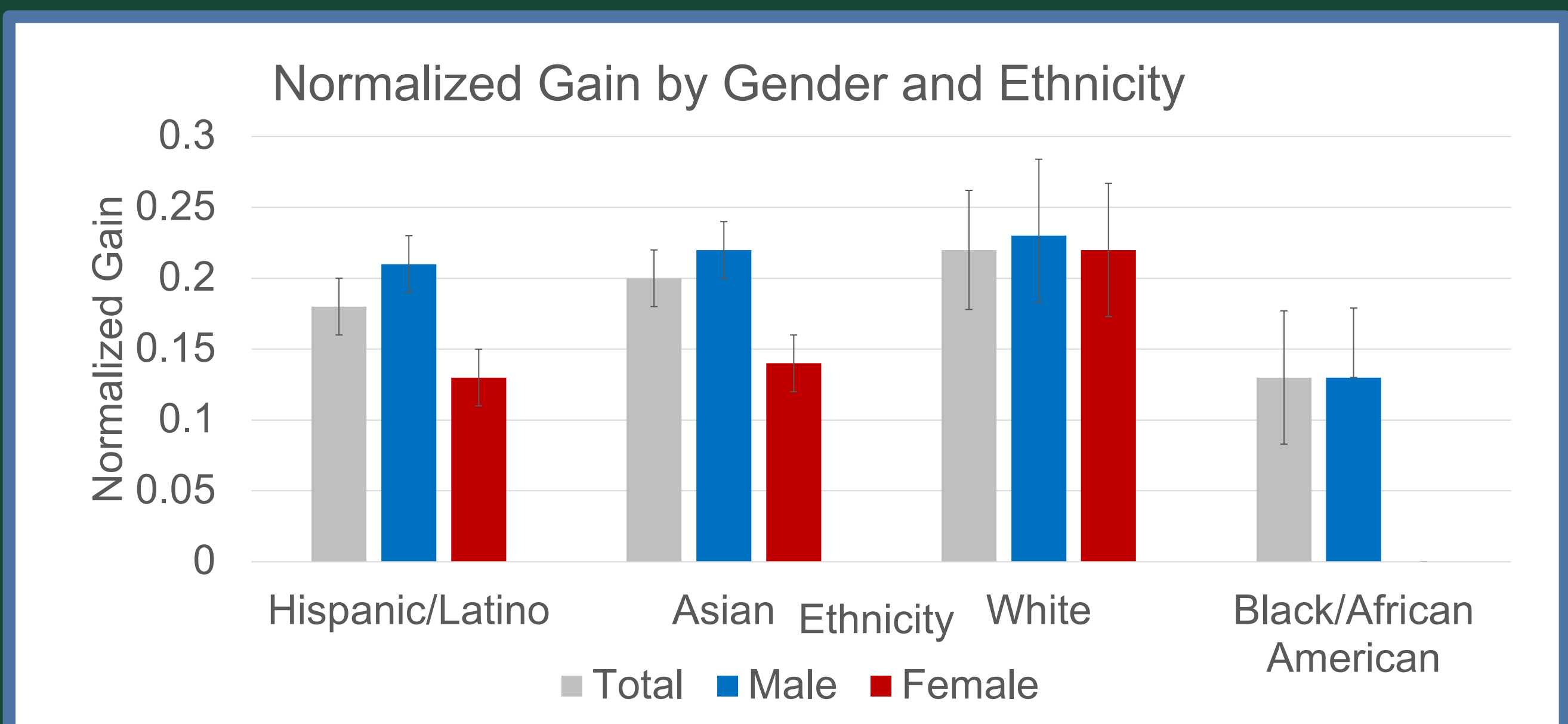
- ❖ There is a significant gender gap in $<g>$ of the FCI, only for Hispanic & Asian groups.
- ❖ The largest gender gap in $<g>$ for Asian group (3%)
- ❖ There is a racial gap in $<g>$ of the FCI, but only for females.

- ❖ It seems like gender gap was enlarged by the end of the term, for Hispanic and Asian groups.

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