Society's educational debts in chemistry, biology, and physics across race, gender, and class

Ben Van Dusen, Iowa State University, School of Education

What am I about?

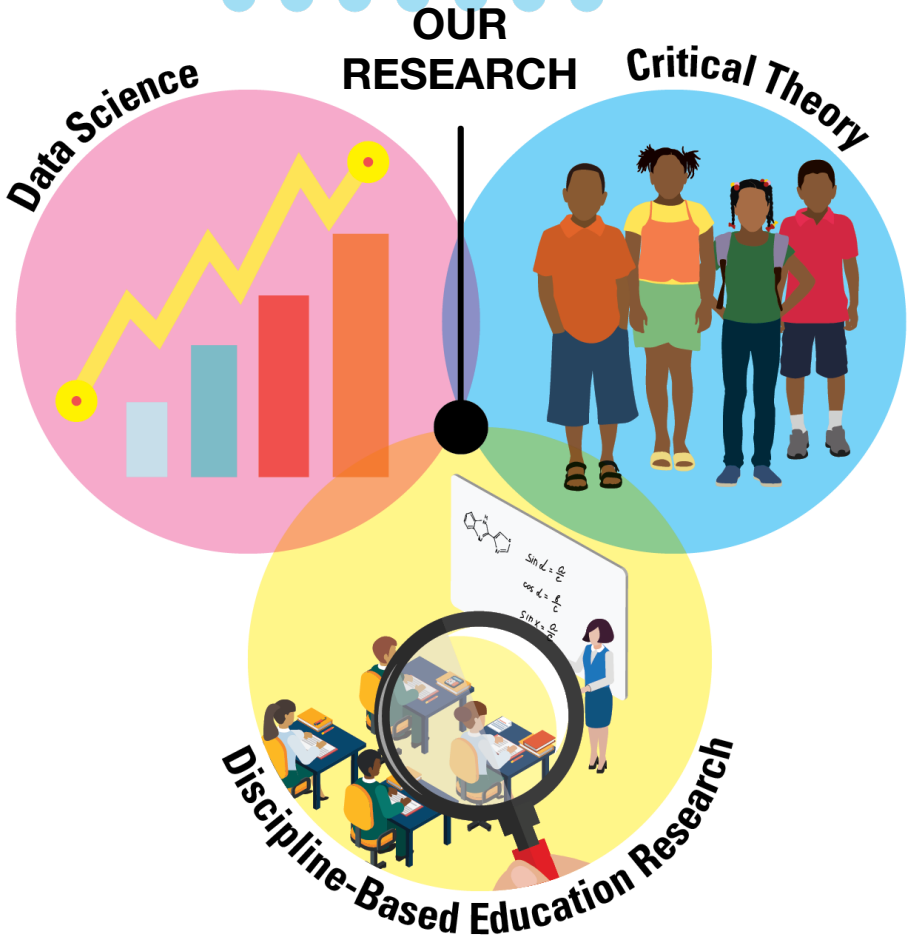
- Former high school physics teacher
- Discipline-based education researcher (DBER)
- Critical quantitative scholar (Stage, 2007)
  - Affinity for numbers and statistics
  - Inequity is a central issue in our society and my research
- Director of LASSO

Stage, F. K. (2007). Answering critical questions using quantitative data. *New directions for institutional research*, 133(5-16).

STEMEquity

What is this talk about?

- Part 1. Introduce and apply an emergent conceptual framework
- Part 2. Answer research questions about inequities in science student outcomes
- Part 3. Offer a tool to potentially ameliorate these inequities



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Part 1

Introduce and apply an emergent conceptual framework

Strategic positivism (Wyly, 2009)

- Positivist epis… …epressive political idec…
  - e.g., Fishe… …arson (correlati… …ugenics movemer…
  - Led many… …ethods
- Strategic po…
  - We must…
  - Statistics tell a compelling story

What is strategic positivism?

Wyly, E. (2009). Strategic positivism. *The Professional Geographer*, 61(3), 310-322.

Zuberi, T., & Bonilla-Silva, E. (Eds.). (2008). *White logic, white methods: Racism and methodology*. Rowman & Littlefield Publishers.

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Quantitative Critical Race Theory (QuantCrit)

- Grounded in Critical Race Theory
  - Historically used qualitative methods
- Focusses on race and racism
  - We expand on this to encompass other forms of oppression
- Offers tenets to inform research decisions (Gillborn *et al.*, 2018)

Gillborn, D., Warmington, P., & Demack, S. (2018). QuantCrit: Education, policy,'Big Data' and principles for a critical race theory of statistics. *Race ethnicity and education*, 21(2), 158-179.

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Tenets of QuantCrit

1. Centrality of oppression
   - Racism and other forms of oppression exist throughout our society
   - Researchers must explicitly challenge existing power structures
2. Data and methods are not neutral
   - All methods introduce biases
   - Researchers should be conscientious and transparent
3. Data cannot speak for itself
   - When left to speak for themselves, findings will be interpreted through the dominant perspective
   - Such interpretations reinforce existing deficit narratives about minoritized groups

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Tenets of QuantCrit

4. Categories are neither natural nor inherent
   - Social identities are socially constructed and fluid
   - People are put into categories -> turned into variables -> can lead to improper interpretation
5. Taking an intersectional perspective
   - Inequalities are generated by numerous interlocking systems of privilege and oppression such as racism, classism, and sexism
   - Pushes back against the “additive approach” of disadvantages
6. Valuing narrative and counter-narrative
   - Voice and insight are vital to eschew racist assumptions, interpretations, logics, etc.
   - Include marginalized and oppressed insights

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Why focus on theory?

- As an emergent theoretical perspective, there is a lack of guidance on how to employ QuantCrit (Castillo & Babb, 2023)
  - This is something that our group thinks a lot about.
- I will highlight the connections between the tenets and this research project.
- This does not define how critical quantitative research is done. This is how WE have figured out how to do critical quantitative research (so far).
  - Some of this is already dated… (Van Dusen *et al.*, in press)

Castillo, W., & Babb, N. (2023). Transforming the future of quantitative educational research: a systematic review of enacting quantCrit. *Race Ethnicity and Education*, 1-21.

Van Dusen, B., & Nissen, J. (In press). Comparing the efficacy of fixed effect and MAIHDA models in predicting outcomes for intersectional social strata. *Sociology of Education.*

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Where does theory inform the research

- Positionality statement
- Data collection
- Defining key terms
- Research questions
- Determining data quality
- Addressing missing data
- Visualizing data
- Model specification
- Bayesian priors
- Interpreting uncertainty in models
- Interpreting findings

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Today's research!

- A QuantCrit analysis of society's educational debts in chemistry, biology, and physics across race, gender, and class
- Research Team: Ben Van Dusen, Jayson Nissen, & Odis Johnson
- Positionality:
  - Continuing-generation, White, cis-gendered, man, w/PhD in education
  - First-generation, White, cis-gendered, man, w/PhD in physics
  - First-generation, cis-gender, gay, Black male, w/ PhD in Education and Social Policy

Valuing narrative and counter narrative

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Data collection

NSF awards # 1928596, 1525338, 2141847, 2322015

- Learning About STEM Student Outcomes (LASSO) platform (Van Dusen, 2018; Nissen et al., 2022)
  - Online assessment platform for low-stakes research-based assessments
  - Automates administration, scoring, and analysis of pre-post assessments
  - Supports STEM instructors developing and using evidence-based practices
  - Creates a large-scale anonymized database for education research
    - 80,000+ students, 1,750+ courses, 130+ institutions
- LASSO users are not "normal"
  - Most use collaborative learning
  - Many use Learning Assistants (LAs)

Data and methods are not neutral

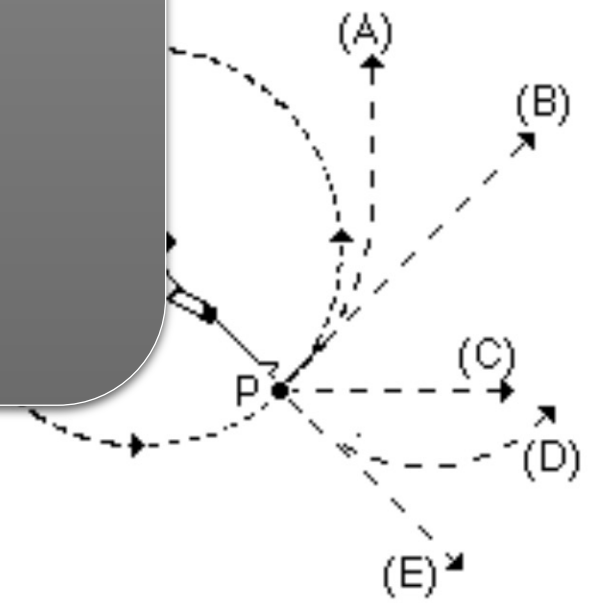
Van Dusen, Ben. "LASSO: A new tool to support instructors and researchers." *PhED newsletter* (2018).
Nissen, J. M., Many Horses, I. H., Dusen, B. V., Jariwala, M., & Close, E. (2022). Providing Context for Identifying Effective Introductory Mechanics Courses. *The Physics Teacher*, 60(3), 179-182.

Data collection

- Research-based assessments
  - Chemistr… Robinson, 2002)
  - Biology… ment (She *et al.*, 201…
  - Physics…

What are research-based assessments?

1. Heat can best…
   A) Ene…
   B) Fric…
   C) A re…
   D) The …
   E) A substance that makes objects feel warm.



Data collection

- Student-level data (pretest, posttest, social identifiers)
- Course-level data (e.g., most use collaborative learning)

Discipline	Students	Courses	Institutions
Physics	5,955	171	30
Biology	8,305	97	11
Chemistry	4,576	37	12
Total	**18,791**	**305**	**44**

Society's educational debts

Centrality of oppression

Data cannot speak for itself

Ladson-Billings, 2006; 2007

Society's educational debts

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Ladson-Billings, 2006; 2007

Society's educational debts

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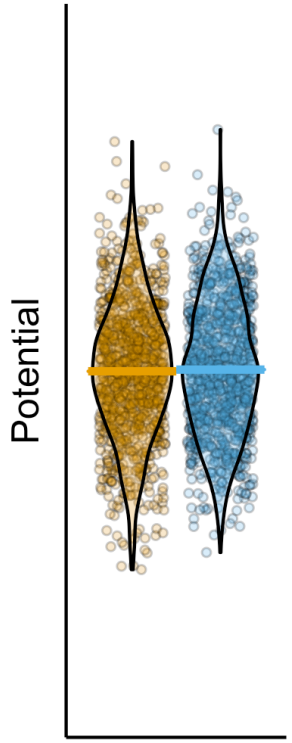

Ladson-Billings, 2006; 2007

Group Advantaged Marginalized

Society's educational debts

Centrality of oppression

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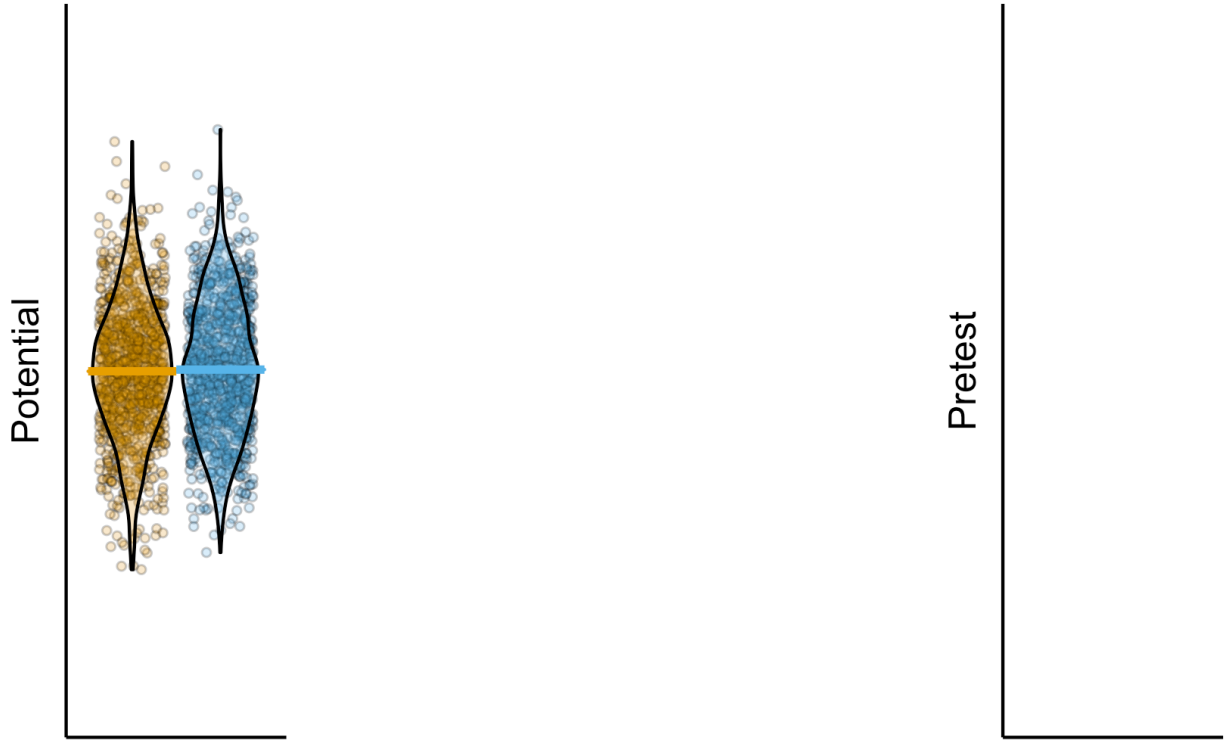

Ladson-Billings, 2006; 2007

Society's educational debts

Centrality of oppression

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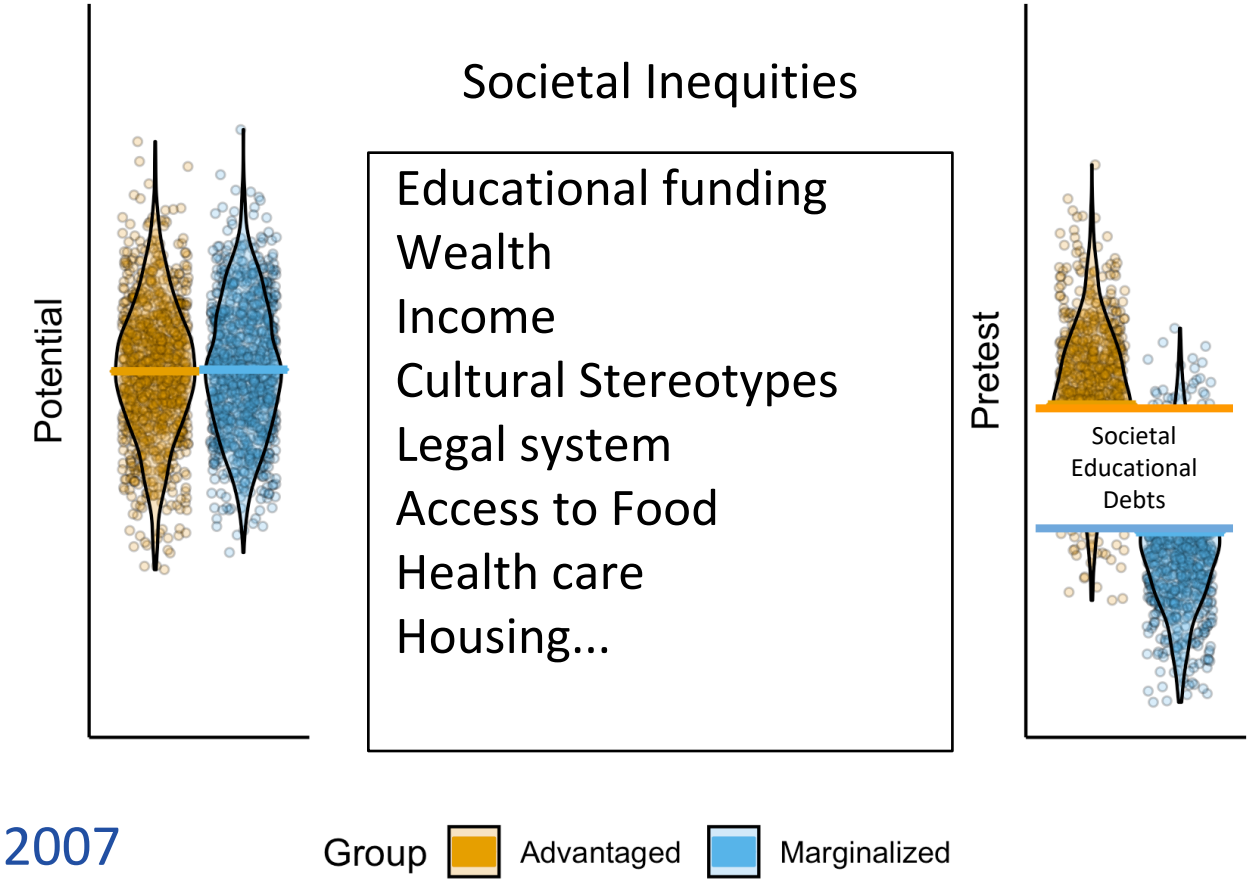

Ladson-Billings, 2006; 2007

Society's educational debts

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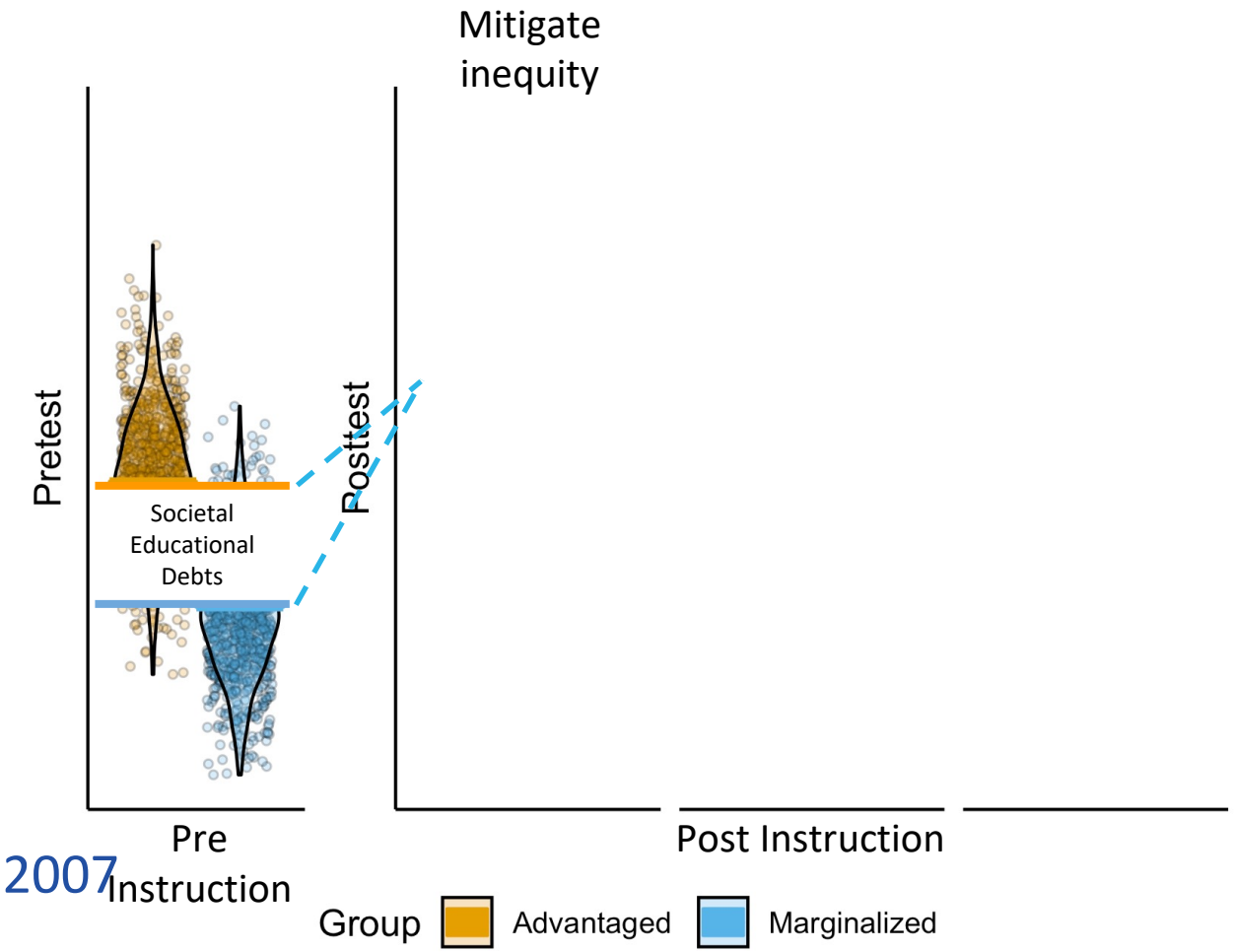

Ladson-Billings, 2006; 2007

Society's educational debts

Centrality of oppression

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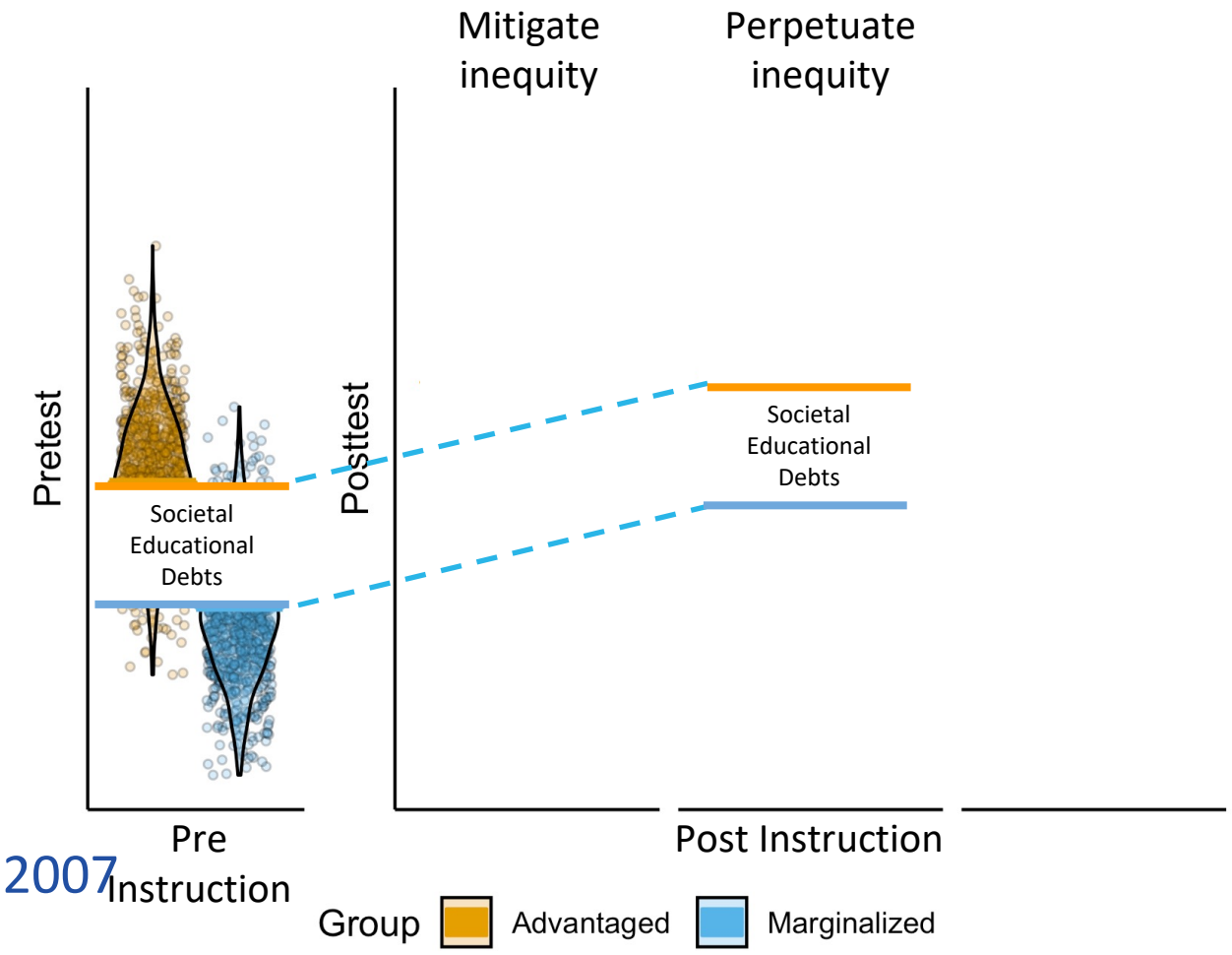

Ladson-Billings, 2006; 2007

Society's educational debts

Centrality of oppression

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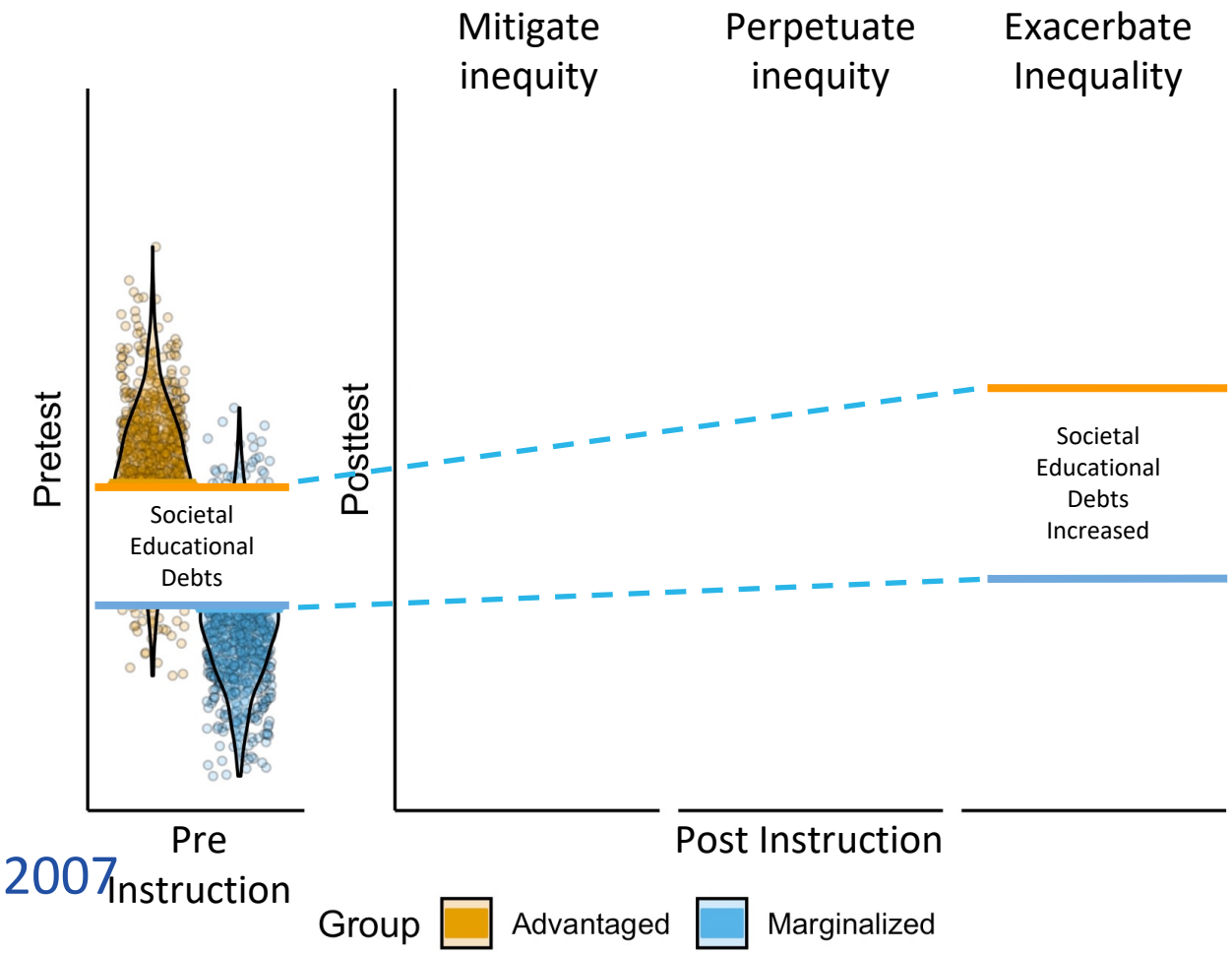

Ladson-Billings, 2006; 2007

Society's educational debts

Centrality of oppression

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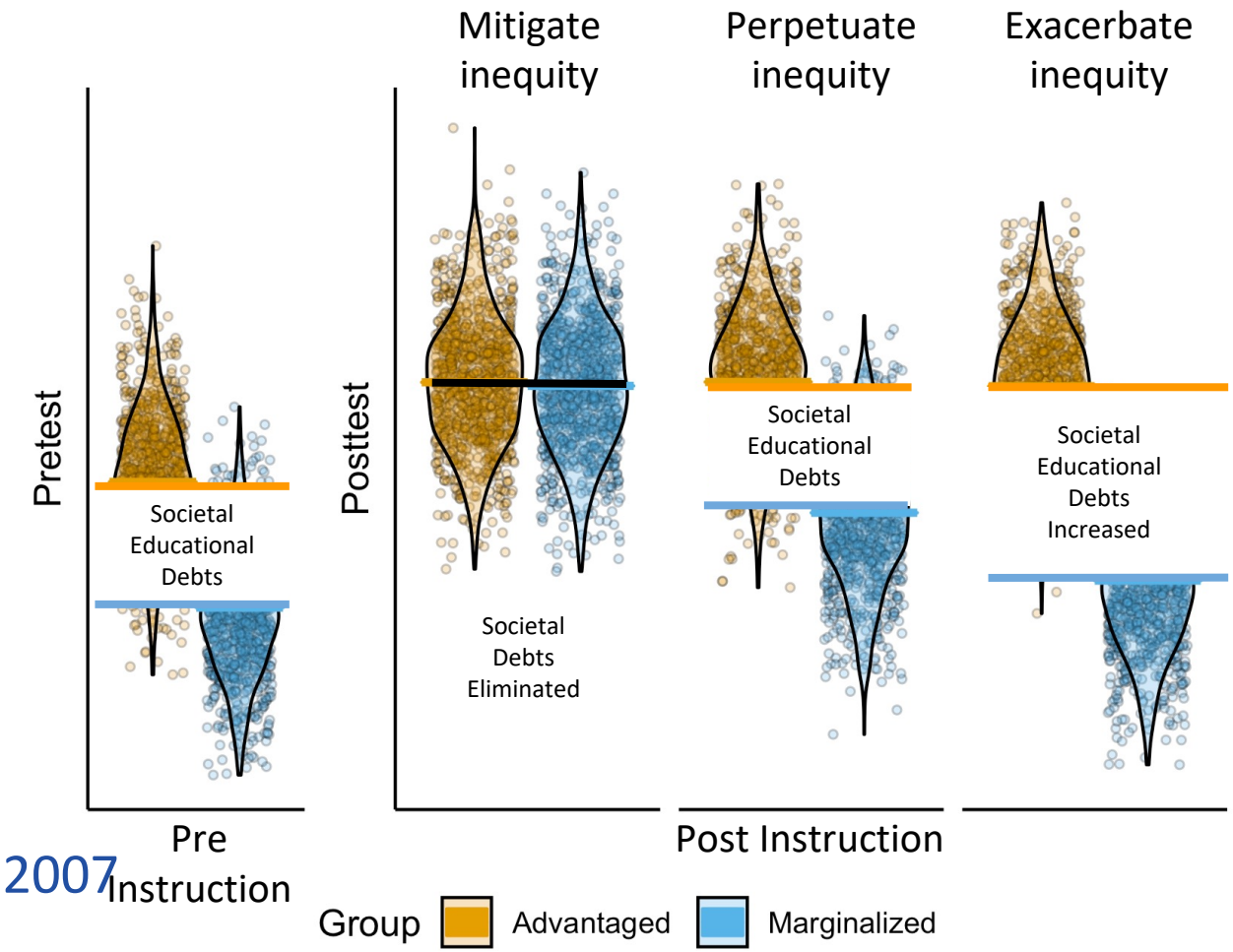


Ladson-Billings, 2006; 2007

Research questions

1. How large are underrepresented minorities' gaps in sc[illegible]e knowledge?

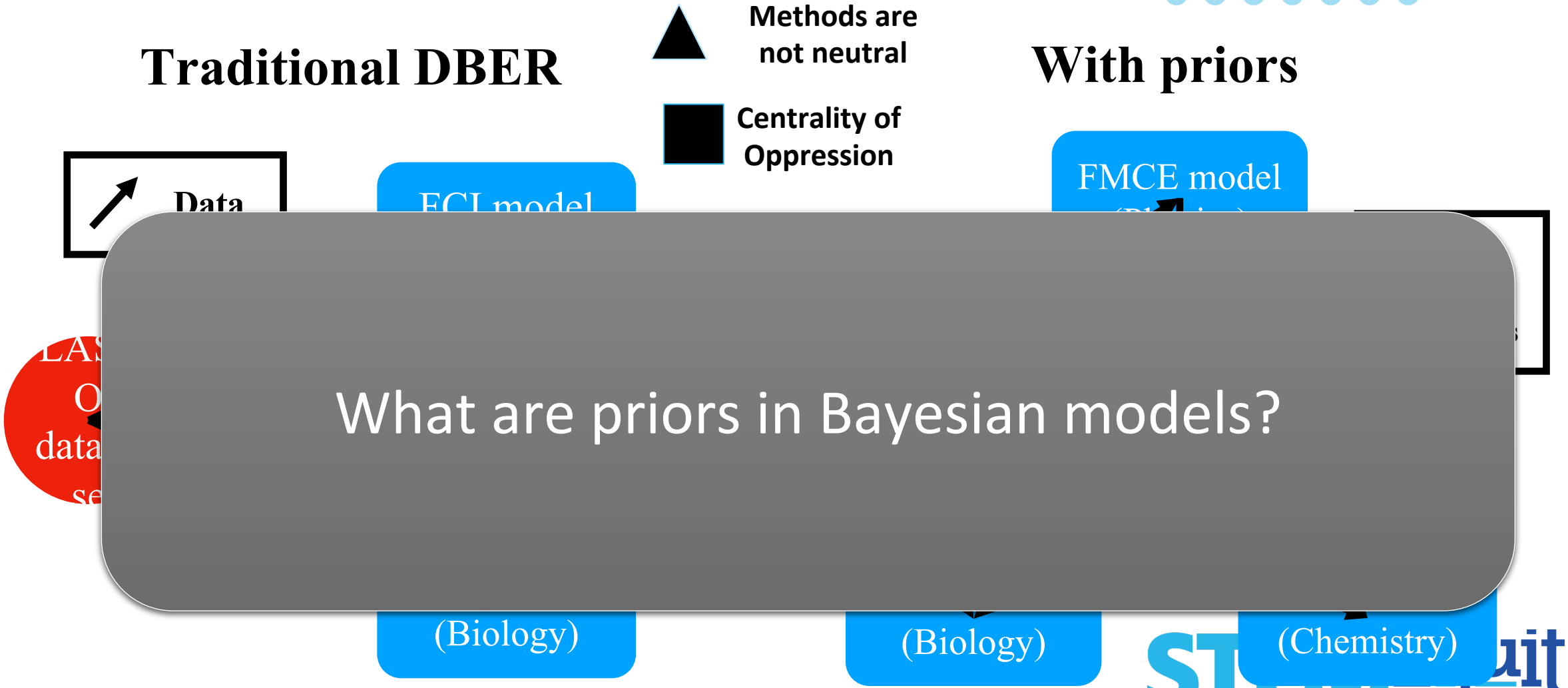
1. How much educational debt does society owe students due to racism, sexism, and classism before taking introductory college science courses?
2. To what extent do introductory college science courses mitigate, perpetuate, or exacerbate society's educational debts?

Centrality of Oppression

Data cannot speak for itself

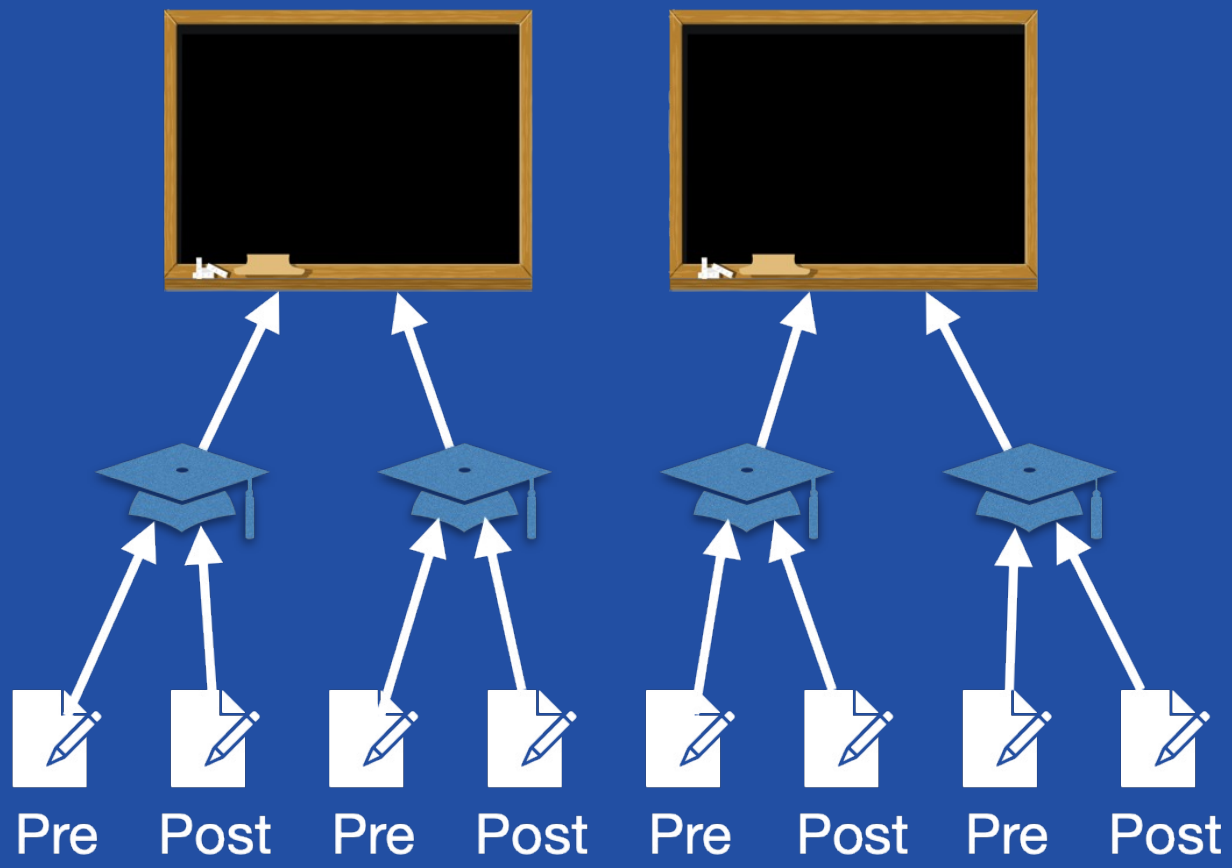
STEMEquity

Bayesian models



What are priors in Bayesian models?

Hierarchical linear model (Van Dusen & Nissen, 2018)



- Bayesian Hierarchical Linear Model
  - Level 1: test
  - Level 2: Student
  - Level 3: Course

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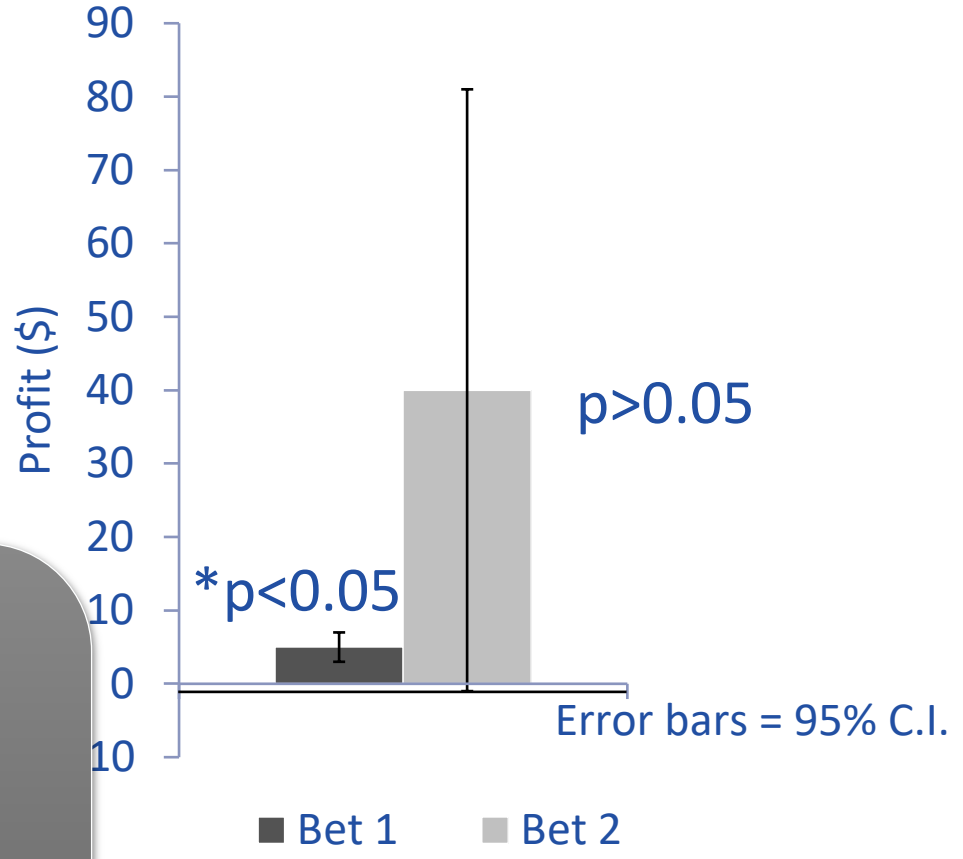
Model uncertainty

Bet 1

Bet 2



Which bet should I take?

d beyond

STEMEquity

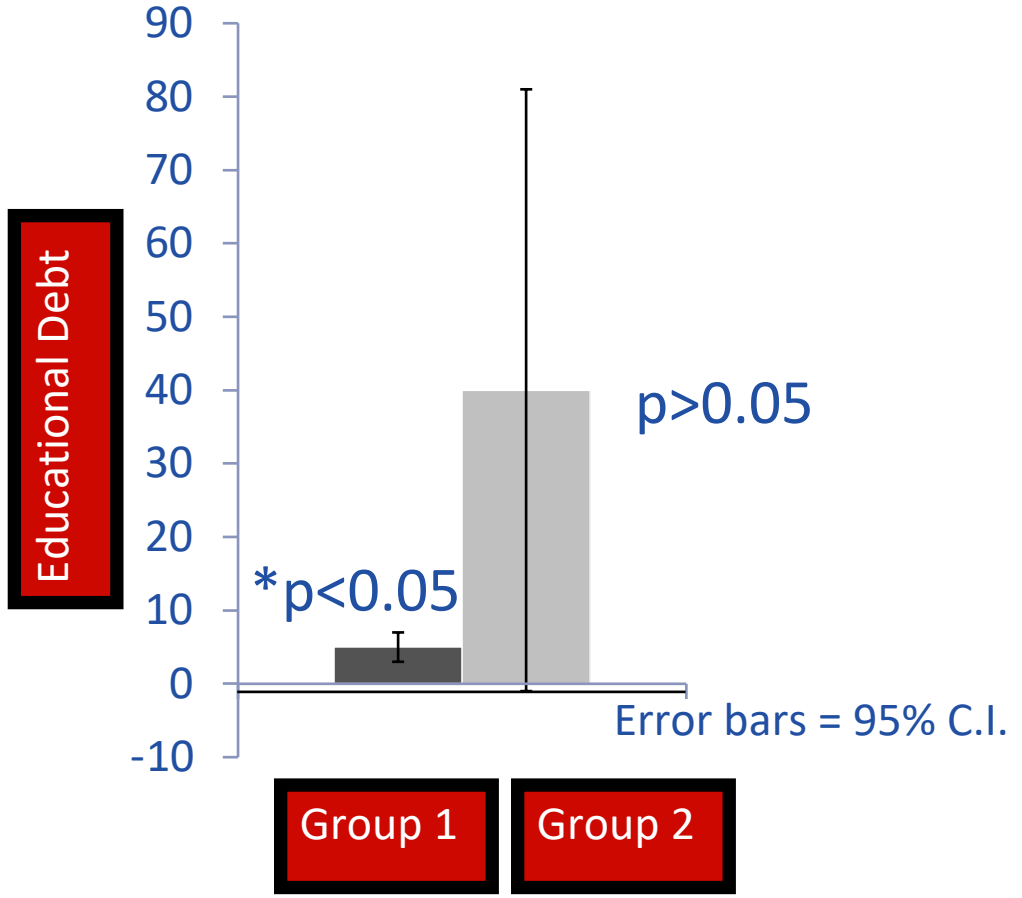
Model uncertainty

Methods are not neutral

- P-value go-no-go test is even worse for equity research
- Sample size dependence
  - Values aggregation over diversity
- Can obscure inequalities
  - Claim a meaningful difference is zero
- We take a more bayesian-like approach to interpreting uncertainty

Intersectionality

Data cannot speak for itself

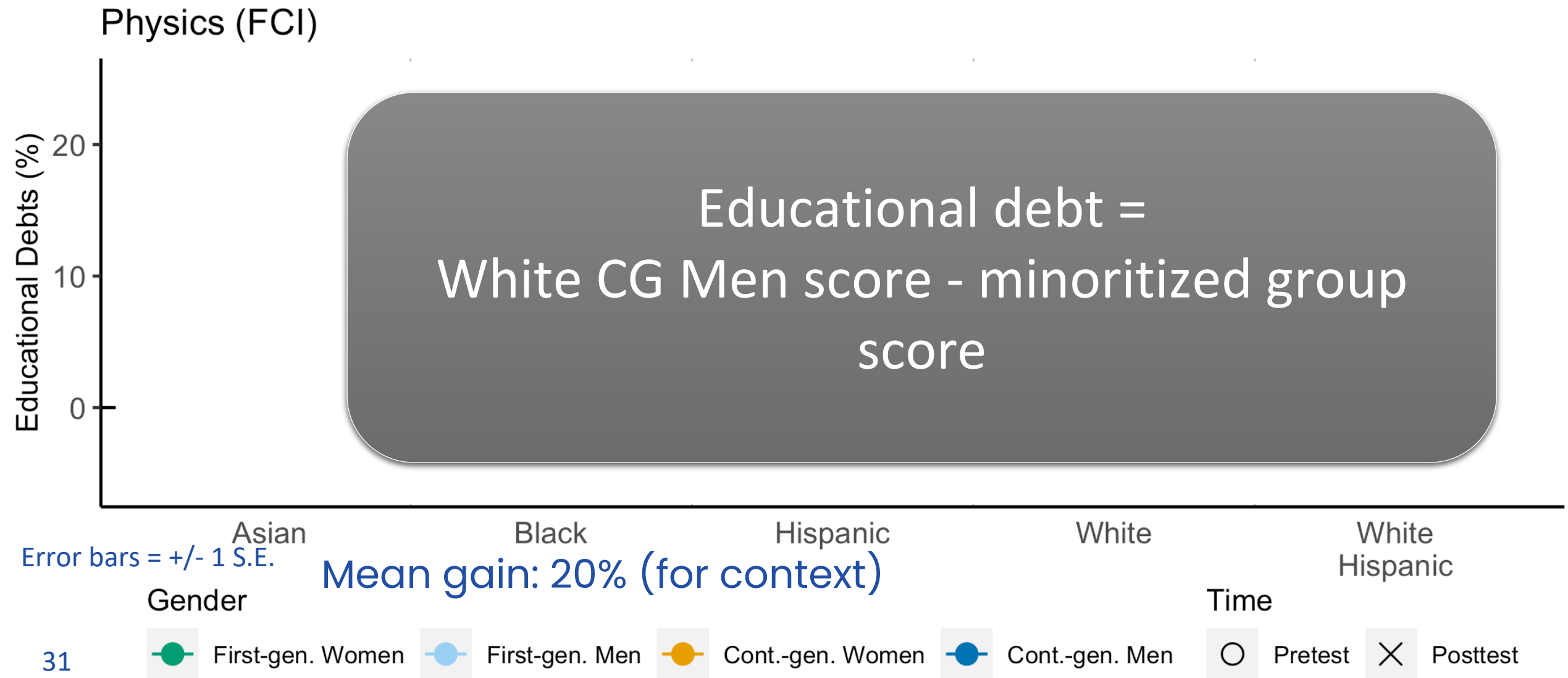


Part 2

Answer research questions about inequities in science student outcomes

Findings – Physics

Data cannot speak for itself



Findings – Physics

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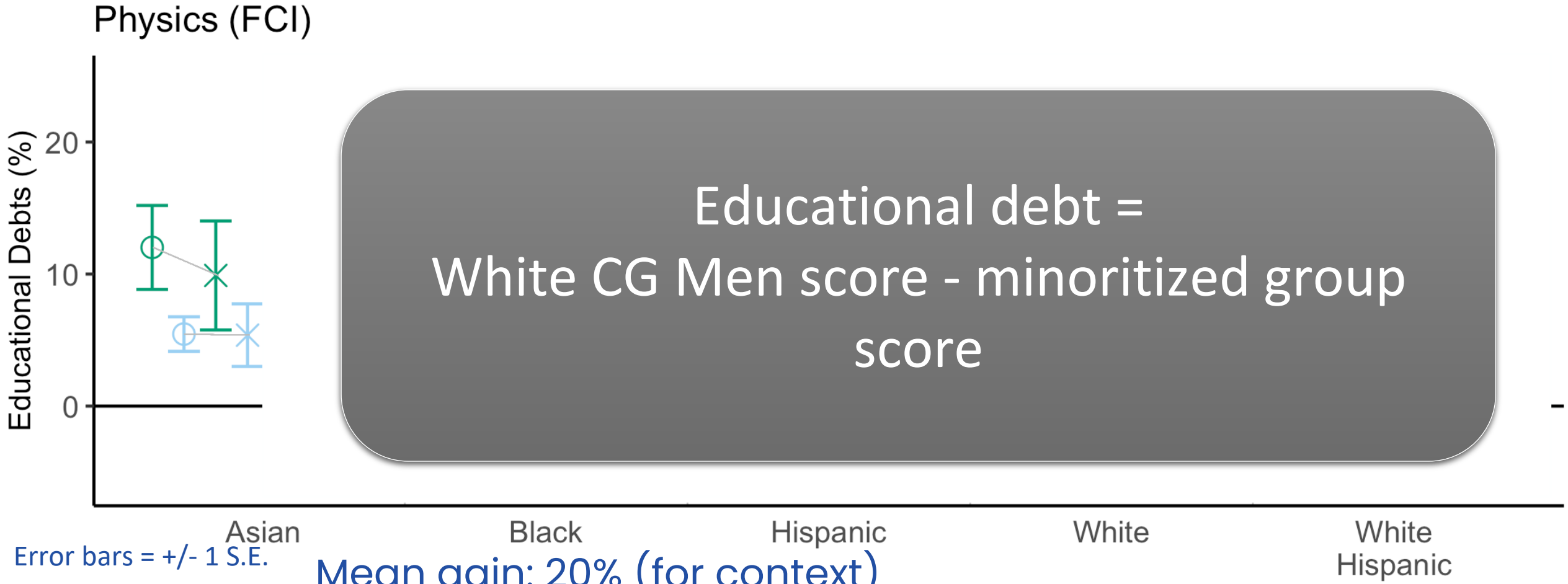


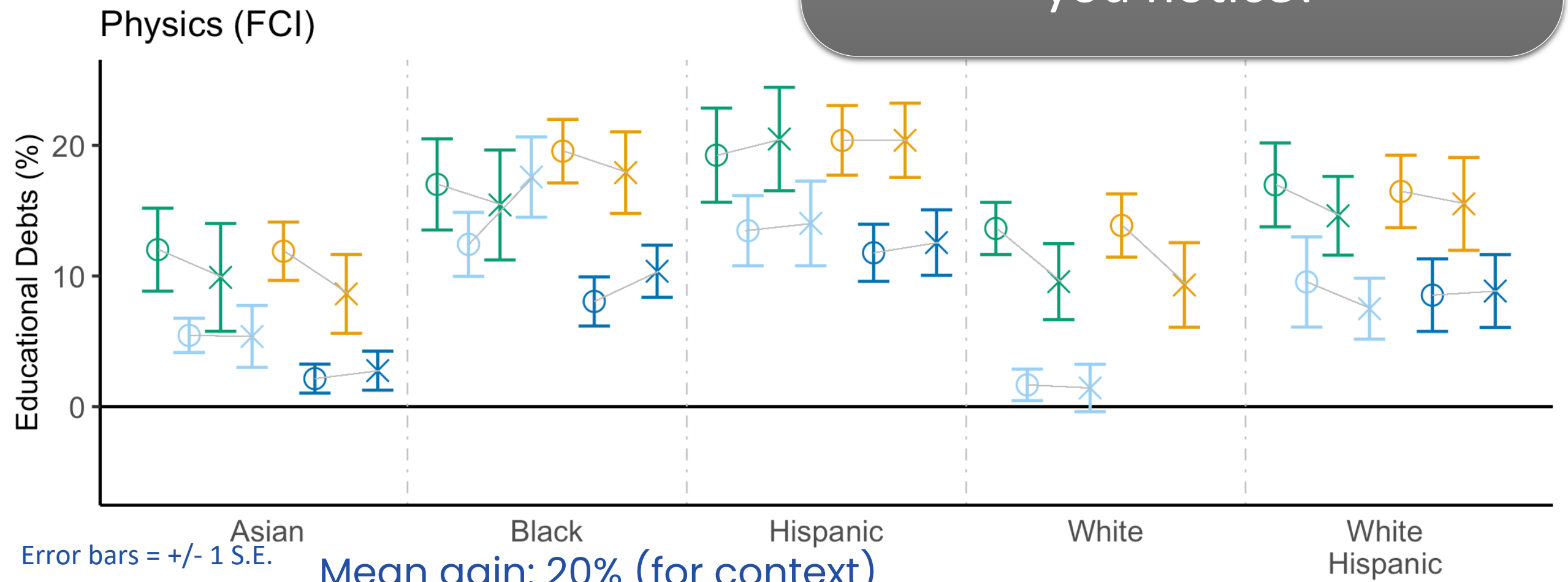
Educational debt =
White CG Men score - minoritized group score

Error bars = +/- 1 S.E.

Mean gain: 20% (for context)

Findings – Physics

Talk to a neighbor, what do you notice?



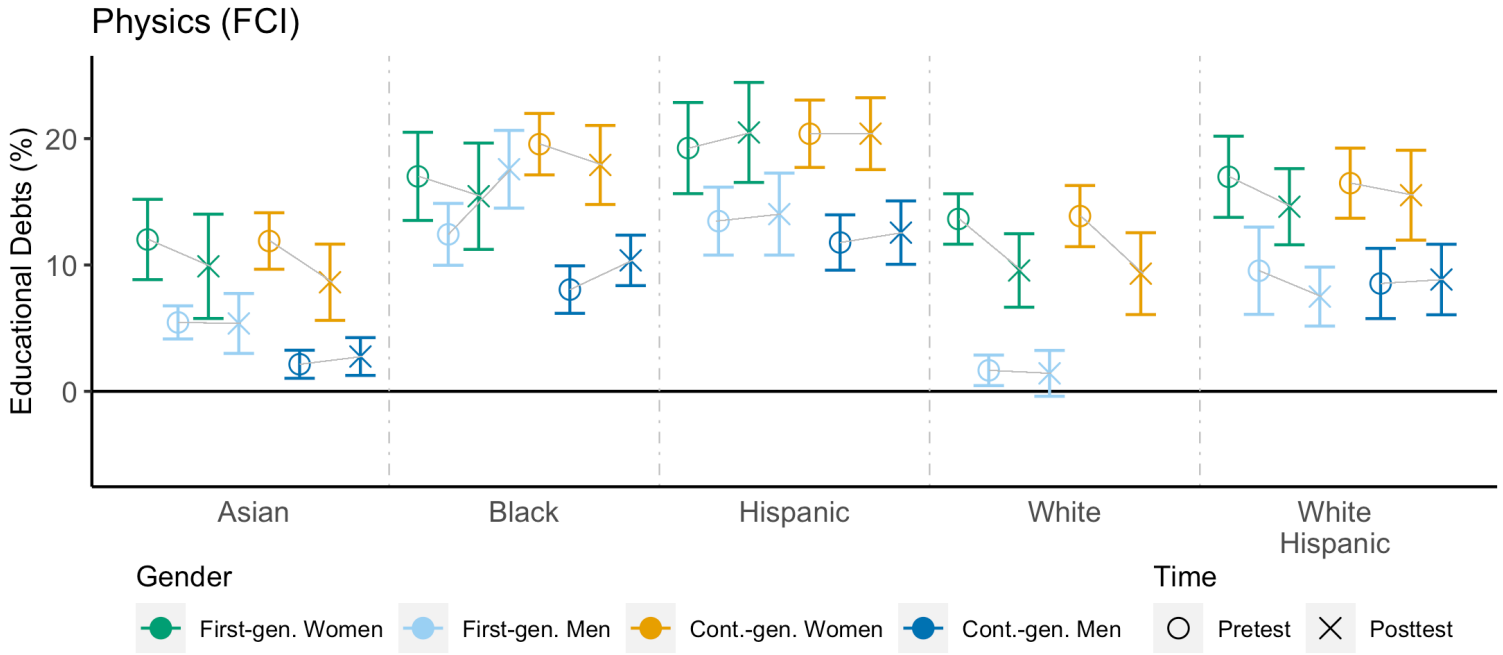
Error bars = +/- 1 S.E.

Mean gain: 20% (for context)

Findings - Physics

Data cannot speak for itself

- Mean gain: 20% (for context)
- Pre-existing educational debts
  - Range: 1%-20%
  - Mean: 12% (~2/3 sem.)
- Perpetuated educational debts
  - E.D. increase for 7 of 19 groups
  - Mean change: -0.6%

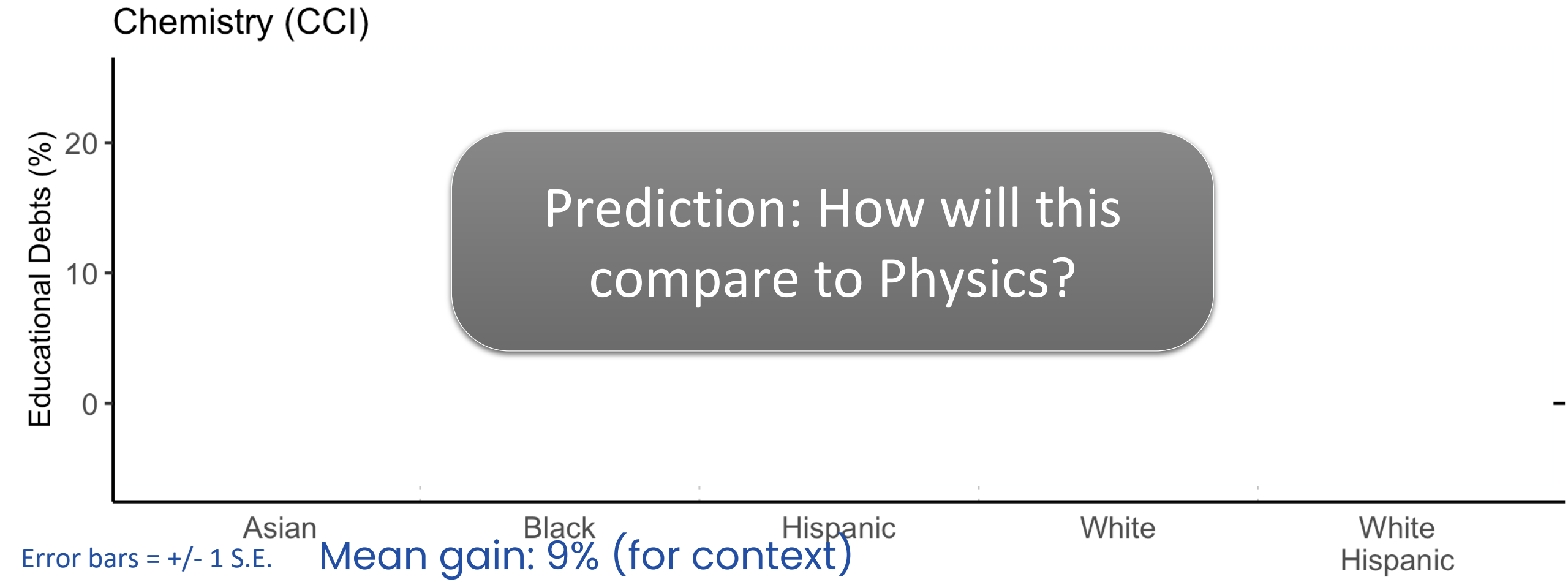


Error bars = +/- 1 s.e.

STEMEquity

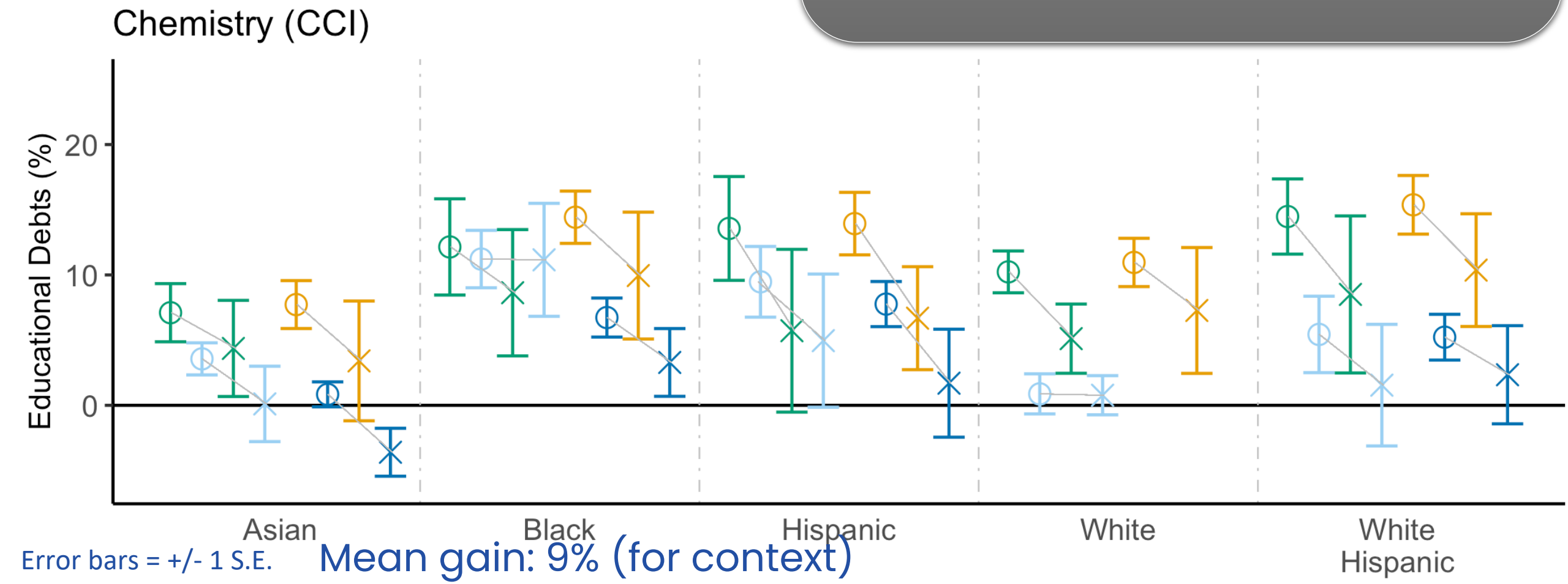
Findings - Chemistry

Data cannot speak for itself



Findings - Chemistr

Talk to a neighbor, what do you notice?



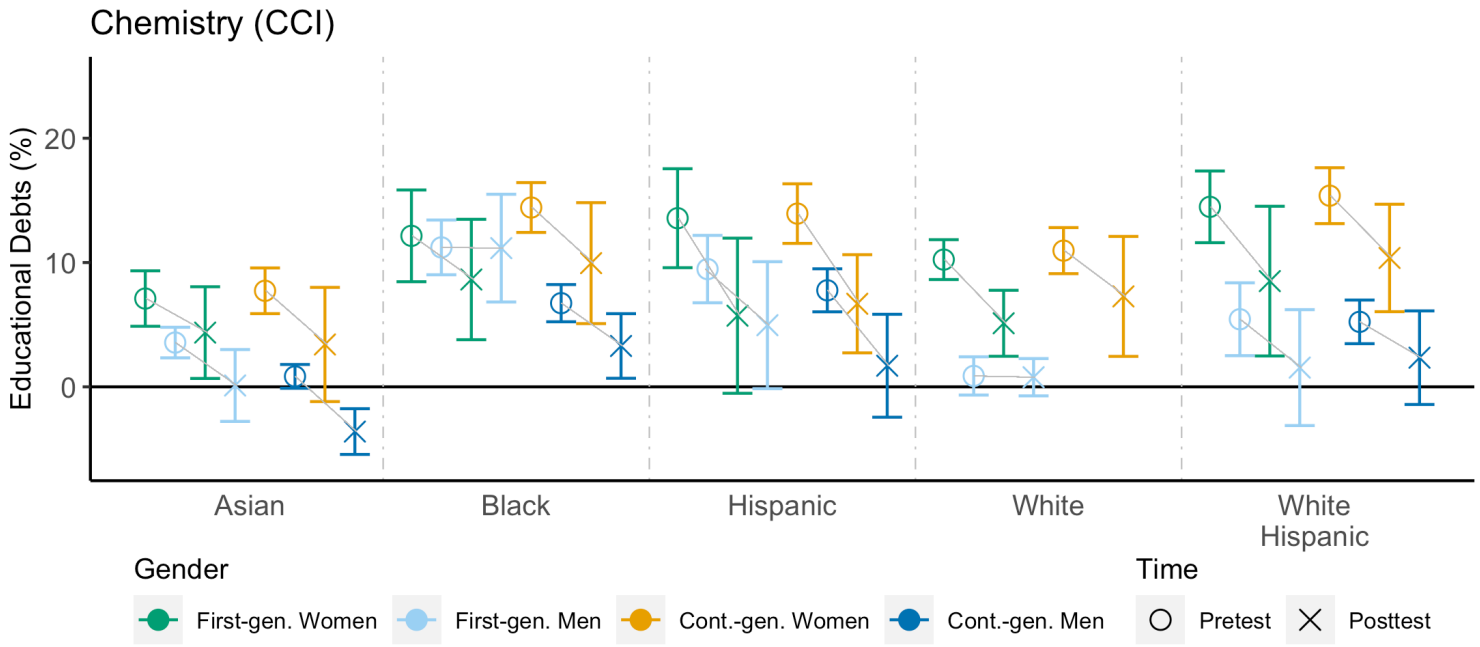
Error bars = +/- 1 S.E.

Mean gain: 9% (for context)

Findings - Chemistry

Data cannot speak for itself

- Mean gain: 9% (for context)
- Pre-existing educational debts
  - Range: 1%-15%
  - Mean: 9% (~1 sem. learning)
- Mitigated educational debts
  - E.D. increase for 0 of 19 groups
  - Mean change: -4.1%

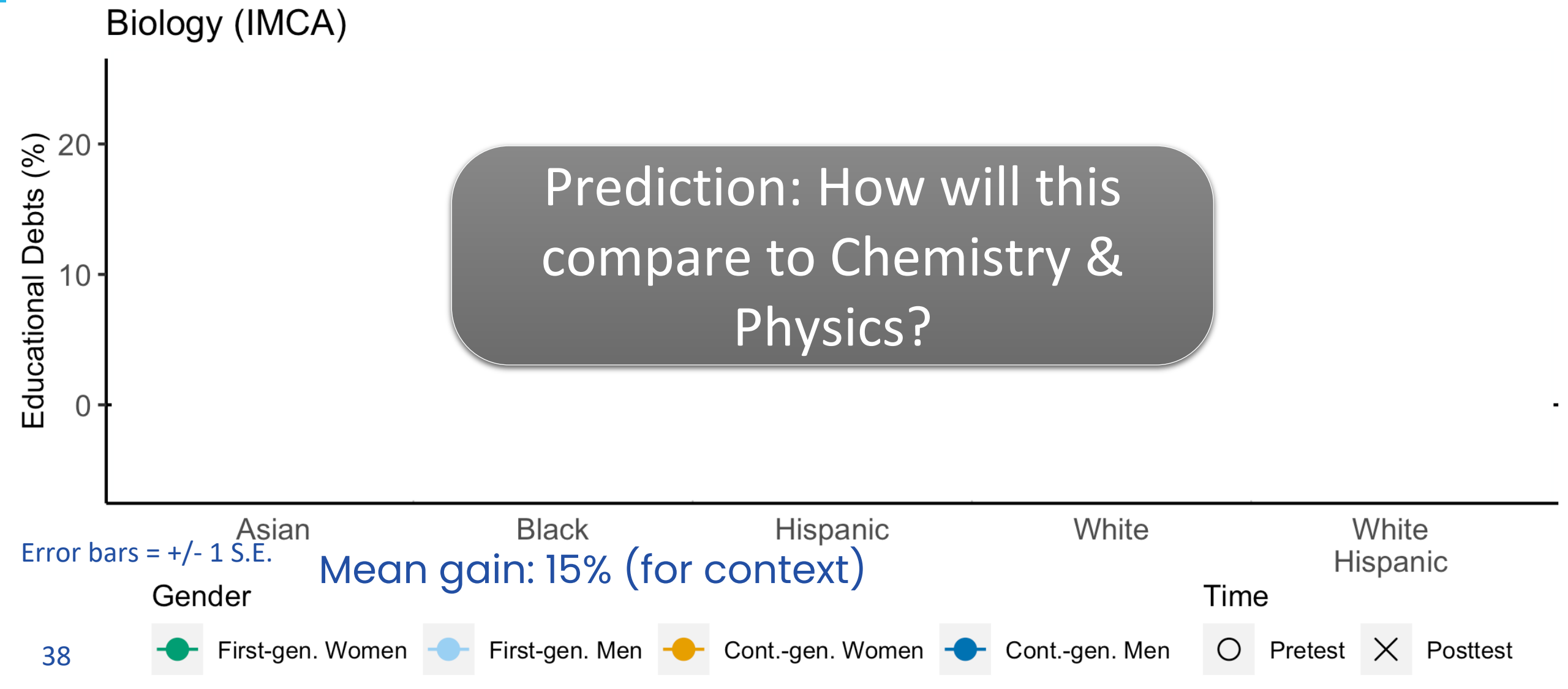


Error bars = +/- 1 S.E.

STEMEquity

Findings – Biology

Data cannot speak for itself

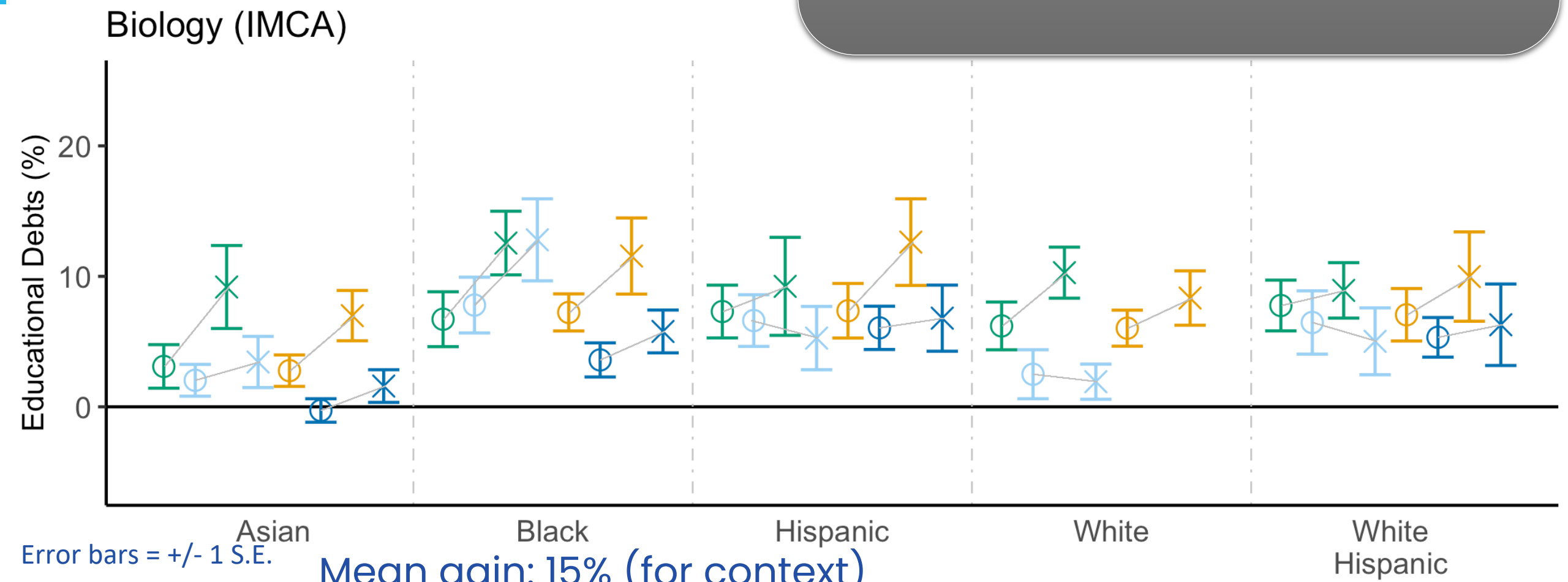


Prediction: How will this compare to Chemistry & Physics?

Mean gain: 15% (for context)

Findings – Biology

What do you notice?



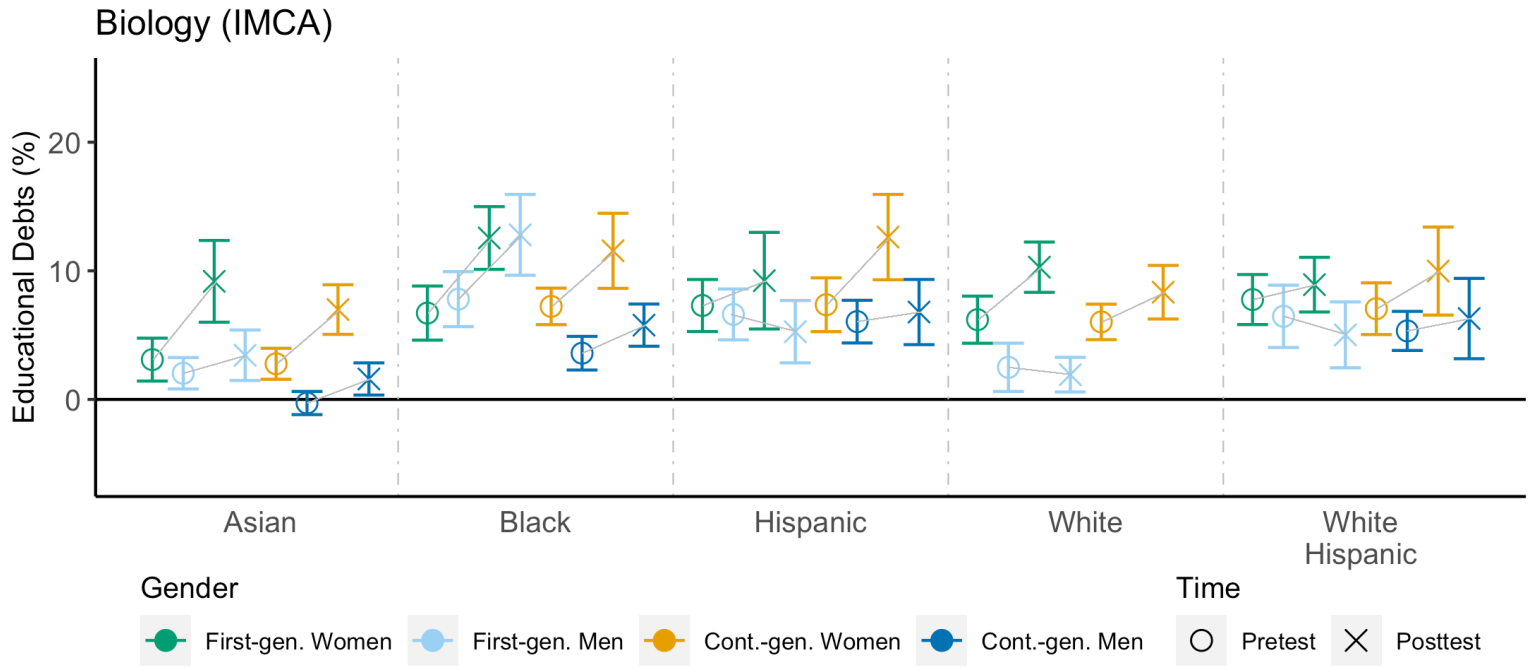
Error bars = +/- 1 S.E.

Mean gain: 15% (for context)

Findings - Biology

Data cannot speak for itself

- Mean gain: 15% (for context)
- Pre-existing educational debts
  - Range: 0%-7.8%
  - Mean: 5.3% (~1/3 sem.)
- Exacerbated educational debts
  - E.D. increase for 16 of 19 groups
  - Mean change: 2.5%



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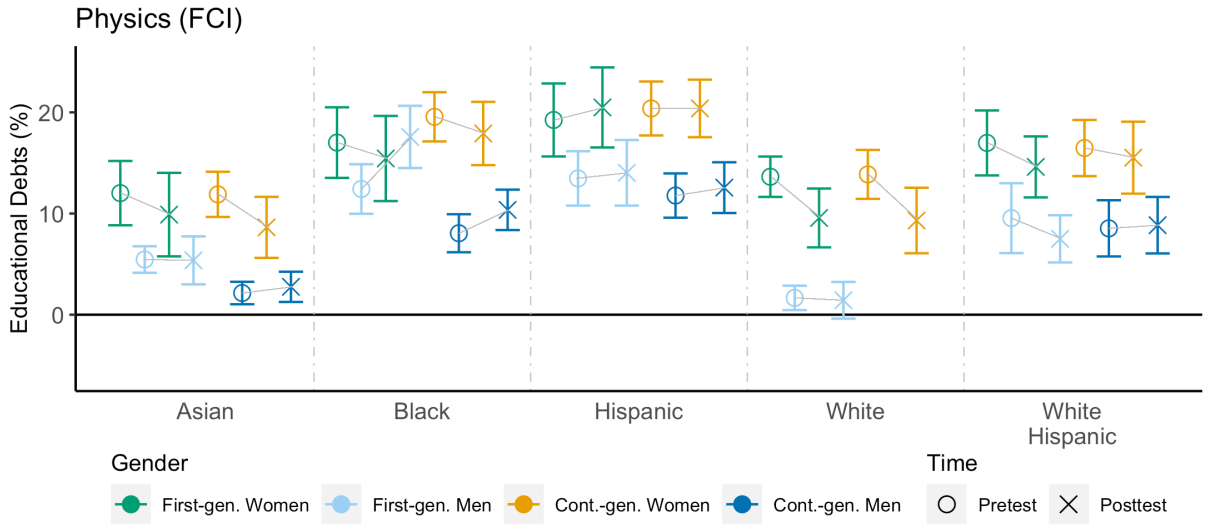
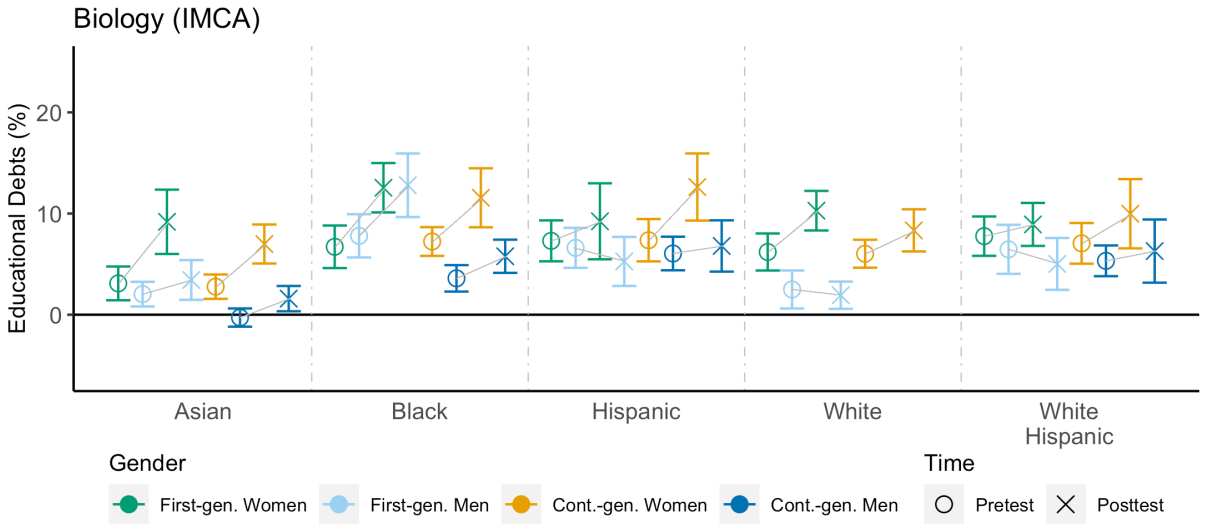
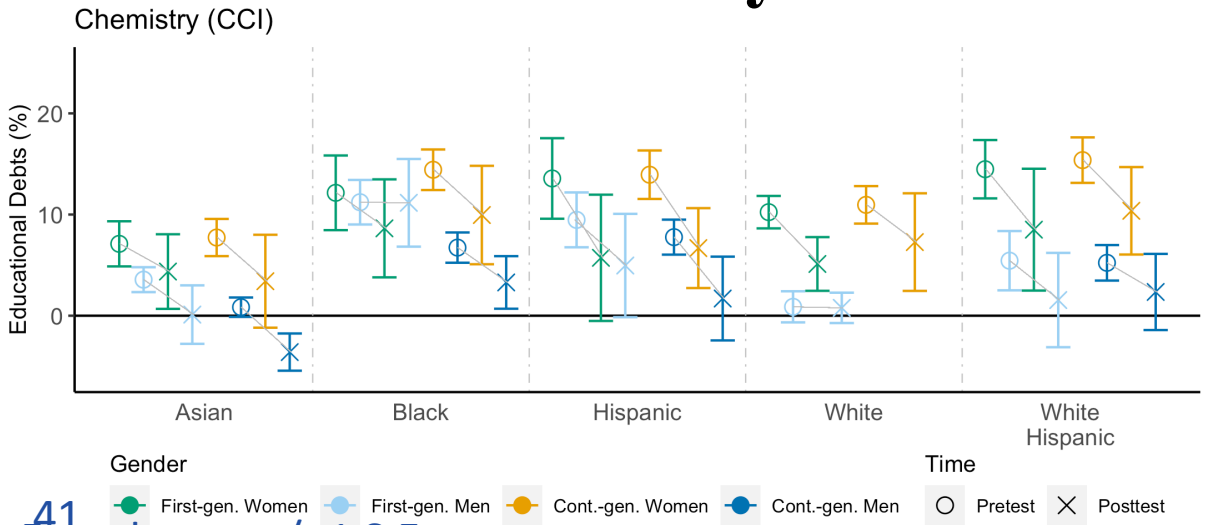
Physics



Biology



Chemistry



Error bars = +/- 1 S.E.

- Homogeneity
  - Largest debts owed to Black and Hispanic women and first-generation Black men
- Heterogeneity
  - Biology -> starts low but exacerbates educational debts
  - Chemistry -> starts high but mitigates educational debts

STEMEquity

Discussion

- Racist, sexist, and classist power structures impact science spaces
- Using collaborative learning is not enough
  - Although LAs can help with DFW rates (Van Dusen & Nissen, 2020)
- Equitable gender representation is not enough
- Universities, departments, and instructors must work to repay society's education debts or become complicit in them

Van Dusen, B., & Nissen, J. (2020). Associations between learning assistants, passing introductory physics, and equity: A qua

Part 3

Offer a tool to potentially ameliorate these inequities

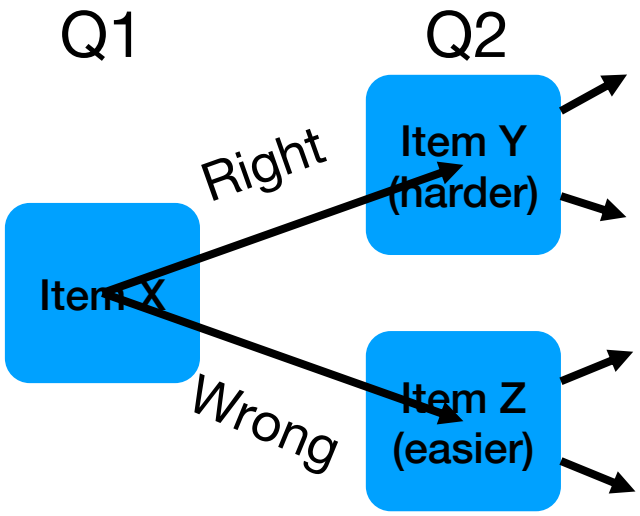
STEMEquity

A way to broaden participation?

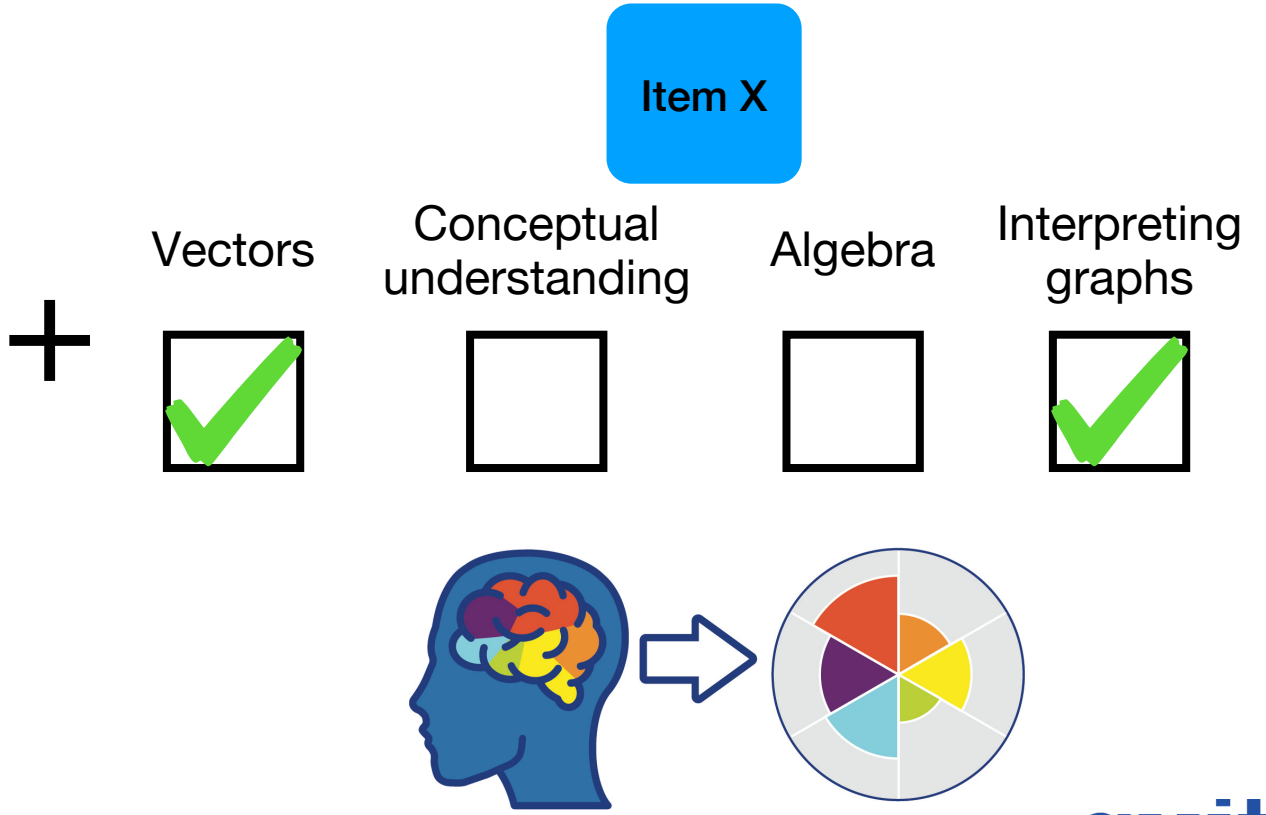
- Pre-existing educational debts are not evenly distributed across skills and content areas (Buncher *et al.*, under review)
  - E.D. on Newton's 1st and 2nd law
  - No E.D. on Newton's 3rd law and superposition of forces
- Teaching the "average" student is often teaching to White continuing generation men
  - May skip covering critical underlying skills
  - Exacerbate inequity

Solution: Cognitive Diagnostic

Adaptive difficulty

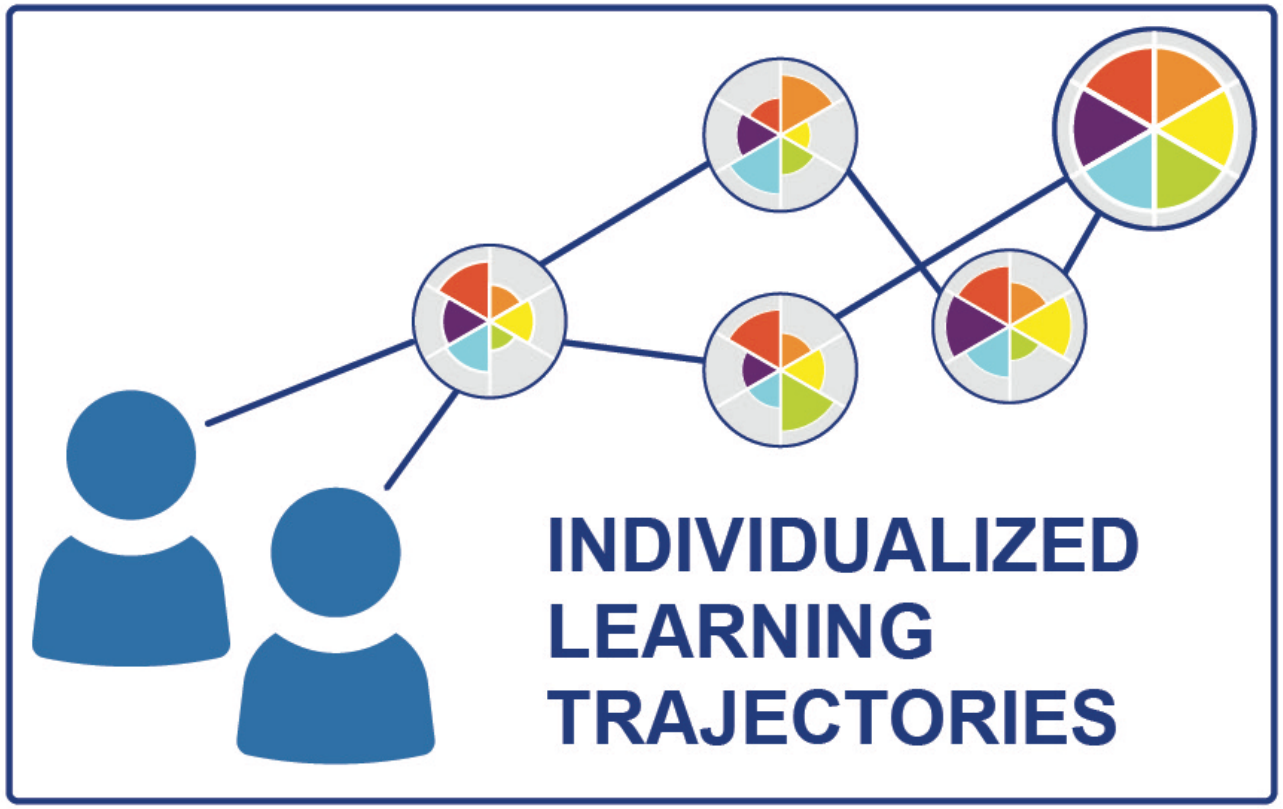


Skill-level Mastery Analysis



Solution: Cognitive Diagnostic

- Better support students with diverse backgrounds
- Launching Sp '24 (NSF # 2141847)
  - Introductory college physics
  - Offers interactive reports
  - Equity focussed reports
- Future development (NSF #2322015)
  - Chemistry, biology, & math
  - K-16 grades



Thank you

- Questions?

Ben Van Dusen
bvd@iastate.edu
www.lassoeducation.org