How increasing equity in the science classroom can drive social change

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Significant gendered performance differences in large introductory STEM lecture courses

Grade in STEM class vs. GPA in other classes at Michigan

Women
Men

N = 627,998

Koester et al., arXiv (2016)
Under-representated minority (URM) status predicts differences in GPA.
Student participation in introductory biology

Women participate less than expected based on enrollment.

Eddy et al., CBE-LSE (2014)
student deficit model
focuses on inadequacies of individuals
• assumes some students enter college lacking the academic resources necessary to succeed in an otherwise fair learning environment.
**student deficit model**
Focuses on inadequacies of individuals
- Assumes some students enter college lacking the academic resources necessary to succeed in an otherwise fair learning environment.

**course deficit model**
Considers the negative impact of environmental conditions on student performance
- Assumes classroom practices favor certain groups of students while increasing performance disparities.

student deficit model

change student behaviors

course deficit model

change classroom microclimate
student deficit model

change student behaviors

deficit model

course deficit model

change classroom microclimate
To optimize learning while maintaining rigor, we employ evidence-based teaching (or scientific teaching) ...approach the evaluation of teaching with the critical thinking, rigor, creativity, and spirit of experimentation that defines research... (Handelsman et al., 2007)
Active learning increases student performance in science, engineering, and mathematics

Scott Freeman*, Sarah L. Eddy*, Miles McDonough*, Michelle K. Smith*, Nnadozie Okoroafor*, Hannah Jordt*, and Mary Pat Wenderoth*

A

![Diagram showing Hedges's g for different STEM disciplines]
Active learning increases student performance in science, engineering, and mathematics

Freeman et al., PNAS (2014)
Why does Active Learning Pedagogy (ALP) improve learning and performance?
Question(s):
1) Does ALP decrease the performance gap between non-URM and URM students?
2) Does ALP increase self-efficacy, and does this influence performance outcomes?
Active learning closes the achievement gap

Ballen et al., CBE-LSE (2017)
Active learning closes the achievement gap across two metrics of performance.

Ballen et al., CBE-LSE (2017)
Self-efficacy drives performance gains for URM students

NON-URM STUDENTS

Students’ science self-efficacy

Gender + Semester

Grades

Ballen et al., CBE-LSE (2017)
For URM students, the increase in science self-efficacy mediated the positive effect of active learning pedagogy on two metrics of student performance.
What else might explain the benefits of active learning pedagogy?
Some ideas...

• Multiple opportunities to engage with a topic through small group work (Spring et al. 1999)
• Increased classroom structure (Haak et al. 2011)
• Positive impact on aspects of classroom climate (Ballen et al. 2017; Eddy & Hogan 2014)
• ‘Harder to hide’ (personal obs.)
• Mixed teaching strategies (Ruiz-Primo et al. 2011)
• Mixed methods of assessment
Some ideas...

- Multiple opportunities to engage with a topic through small group work (Spring et al. 1999)
- Increased classroom structure (Haak et al. 2011)
- Positive impact on aspects of classroom climate (Ballen et al. 2017; Eddy & Hogan 2014)
- ‘Harder to hide’ (personal obs.)
- Mixed teaching strategies (Ruiz-Primo et al. 2011)
- Mixed methods of assessment
Exams: you don’t like taking ‘em, we don’t like making ‘em, grad students don’t like grading ‘em

Assessments in higher education
The Limitations of the GRE in Predicting Success in Biomedical Graduate School

GRE does not predict most measures of success in biomedical graduate school.
Patterns of Gendered Performance Difference in Introductory STEM Courses

Grade Anomalies in STEM

N = 627,998

Grades awarded to students in class, compared to those they receive in all their other classes

Koester et al., arXiv (2016)
Possible selection going on in these second year courses

None used timed examinations as important evaluative elements.

Koester et al., arXiv (2016)
The anxiety-performance link

Chang and Beilock, Curr Opin Behav Sci (2016)
Setting the scene...
What factors, other than incoming academic preparation, influence student performance on exams?
Full Mediation Model
Partial Mediation Model
Performance
Test Anxiety
Interest
ACT
The diagram represents a causal relationship among several variables:

- **ACT** (on the left) influences **Performance** on the right.
- **Test Anxiety** and **Interest** are connected to **Performance**.

The relationships are as follows:

- ACT → Performance
- Test Anxiety → Performance
- Interest → Performance

This suggests a model where ACT can have direct and indirect effects on performance through test anxiety and interest.
In our sample of **women**, incoming preparation (ACT) did not predict interest or anxiety, but both impacted exam performance.

A. Female students

- **ACT** to **Interest**: $b = -0.042$ (0.078)
- **ACT** to **Test Anxiety**: $b = -0.113$ (0.079)
- **Interest** to **Exam Performance**: $b = 0.159^*$ (0.068)
- **Test Anxiety** to **Exam Performance**: $b = -0.218^{**}$ (0.068)

Total effect = Direct Effect: $b = 0.551^{***}$ (0.064)

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Ballen et al., PLoS ONE (2017)
In our sample of men, incoming preparation (ACT) predicted anxiety, but neither anxiety nor interest impacted exam performance.
Based on these data, we may expect the following to reduce gender gaps:

- Design curricula to promote students’ interests
- Minimize risk/threat during exams
How can you minimize the sense of risk in an exam environment?
Some ideas...

• Align exam questions with homework questions
• Affirmation exercises before an exam (e.g., Cohen et al. 2006, 2009; Martens et al. 2006)
• Distribute more exams
• Distribute no exams
• Offer students the ability to drop an exam
• Lower the amount that exams account for in total course grade
• Lower the sense of risk by allowing re-take exams
Some ideas...

- Align exam questions with homework questions
- Affirmation exercises before an exam (e.g., Cohen et al. 2006, 2009; Martens et al. 2006)
- Distribute *more* exams
- Distribute *no* exams
- Offer students the ability to drop an exam
  - Lower the amount that exams account for in total course grade
  - Lower the sense of risk by allowing re-take exams
Do grading schemes cause gaps in performance?
## Summary of three case studies

<table>
<thead>
<tr>
<th>Course</th>
<th>Academic level</th>
<th>Major or nonmajors</th>
<th>Instructor identification</th>
<th>Student cohorts</th>
<th>Semester 1 (% exam)</th>
<th>Semester 2 (% exam)</th>
<th>Direction of exam % over time</th>
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</thead>
<tbody>
<tr>
<td>BIOL 1003</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; year</td>
<td>Nonmajors</td>
<td>Same both semesters</td>
<td>Different</td>
<td>Sp2016 (28)</td>
<td>Sp2017 (44)</td>
<td>Increase</td>
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<tr>
<td>BIOL 2002/2003</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; year</td>
<td>Majors</td>
<td>Same both semesters</td>
<td>Same</td>
<td>Sp2016 (22)</td>
<td>Fa2016 (42)</td>
<td>Increase</td>
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<tr>
<td>BIOL 3409</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; year</td>
<td>Majors</td>
<td>Same both semesters</td>
<td>Different</td>
<td>Sp2016 (50)</td>
<td>Fa2016 (30)</td>
<td>Decrease</td>
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<td></td>
<td>Low stakes</td>
<td>High stakes</td>
<td>Low stakes</td>
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<td>0.5</td>
<td></td>
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</tbody>
</table>

High stakes exams result in significant gender gaps. Low stakes exams do not.
student deficit model
focuses on inadequacies of individuals

course deficit model
considers the negative impact of environmental conditions on student performance
Can lowering the perception of risk reduce gaps in performance within one semester?

Stay tuned!
Increasing equity in the science classroom can drive social change because:

Grades guide self-assessments
Shape students perceptions of ability
Selection of coursework, major, career
Acknowledgements – thank you for your time!

**Active Learning**
Kelly Zamudio
Carl Wieman
Shima Salehi
Peter Lepage
Jeremy Searle
Brian Lazzaro
Amy McCune
Bob Reed

**Statistical advice**
Francoise Vermeylen

**Test anxiety**
Sehoya Cotner
Shima Salehi
Jonathan Andicoechea
Emma Goldberg
Will Harcombe
Mark Decker

**Institutional Research and Planning**
Marin Clarkberg

**Undergraduate Researchers**
Steven Wallace
Christine Lian
Olivia Treudeu
Mai Vang
Morgan Burkhart
Dahsol Lee