Mentoring Professional Collaboration and Communication in the Physics Laboratory

Suzanne White Brahmia, Jared Canright, Yasmene El Hady, Charlotte Zimmerman
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Acknowledgements and Support

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Roadmap

• What problem motivates this work?
• What does DBER research suggest?
• What are we doing?
• Are we having any success?

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Solvay 1911 – the world's first physics conference

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Viewpoints
(Hazari & Potvin 2005)

- Perhaps there is a biological foundation.
- Perhaps, as a subject, physics just naturally appeals to its current practitioners only.
- Perhaps there is an (unintended) bias in the culture of the physics community that favors the current majority by repelling the minority.

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## Characteristics

### SES

<table>
<thead>
<tr>
<th></th>
<th>Top 20% (n&lt;sub&gt;sample&lt;/sub&gt;=98)</th>
<th>The rest (n&lt;sub&gt;sample&lt;/sub&gt;=363)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAT_M</td>
<td>710</td>
<td>670</td>
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<tr>
<td>FCI % pre/change</td>
<td>65/+9</td>
<td>42/+9</td>
</tr>
<tr>
<td>Math Reasoning % pre/change</td>
<td>51/+4</td>
<td>43/-2</td>
</tr>
<tr>
<td>CLASS Problem Solving (Gen) % pre/change</td>
<td>71/-2</td>
<td>62/-10</td>
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<tr>
<td>CLASS Personal Interest % pre/change</td>
<td>73/0</td>
<td>65/-9</td>
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<td>Average of the Median MHI High School</td>
<td>$Q$</td>
<td>$0.9*Q$</td>
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<td>$&lt; .015$</td>
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<td>Schoolwork culture</td>
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<td>Top 1%</td>
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<td>Work is developing one’s intellectual powers; students invent ways to measure and calculate in math class.</td>
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**NJ school math and socioeconomics (J. Anyon 1980)**

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"The biggest obstacle to success is NOT limitation with math skills or knowing the definition of density…**It's the institutional suppression of thinking.**"

- Richard Steinberg 2011

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Most physics students, and especially students from low SES high schools, struggle to assimilate the habits of mind we model.

Many leave our courses with even less expert-like quantitative attitudes and habits than when they started.
Roadmap

- What problem motivates this work?
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Transmission mechanisms of cultural norms
(adapted from Hazari & Potvin 2005)

- **Pedagogically**: through instructional practices, conveying what it means to do physics
- **Socially**: encouraging/discouraging through the structure, interactions, and treatment in the physics community

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Target characteristics of physicists

- **Physics Identity**: Physics identity is important characteristics of all successful students. Reward and praise are essential to its development. *(Potvin & Hazari 2013, Hazari et al. 2010, Stout et al. 2012)*

  how a person is viewed by self and others, and how they want to be viewed
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how a person is viewed by self and others, and how they want to be viewed

*A strong physics identity is less likely for students from underrepresented groups (gender, race, ethnicity, socioeconomic status)*
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- **Self-efficacy**: Self-efficacy is a significant predictor of success for all students. *(Sawtelle 2011)*

  the extent or strength of one's belief in one's own ability to succeed at physics-related tasks

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First steps (Hazari & Potvin 2005)

• change the social climate towards collaboration instead of competition

• rethinking physics curriculum and culture to include broad and diverse worldviews

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Theoretical framework: community of practice
(Wegner et. al. 1998, 2002)

- is a group of people who are active practitioners.
- made up of domain, community, and practices
- provides a way for practitioners to share tips and best practices, ask questions of their colleagues, and provide support for each other.
Theoretical framework: community of practice
(Wegner et. al. 1998, 2002)

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micro aggressions and micro validations

• aggressions: brief, everyday exchanges that send (unintended) denigrating messages to certain individuals because of their group membership

• validations: just the opposite

• no one event will make or break, but the accumulation can make a difference one way or another.

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Theoretical framework: community of practice

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Theoretical framework:

- **Community**
  - Language: assume heterogeneous; gender-neutral
  - Climate: collaborative; welcoming; encouraging
  - Visibility: faculty from under-represented groups

- **Physics Domain**
  - Experimental Practices: based on research-validated curricula and methods
  - Mathematics: Develop appropriate conceptual mathematics

- **Pedagogical Practices**
  - Group Work: validated sociocultural collaborative norms
  - Student-centered: based on research-validated curricula and methods

**SELF-EFFICACY**

**PHYSICS IDENTITY**

**MICRO VALIDATIONS**
Summary: Some suggested Practices

- Group norms (code of conduct)
- Effective collaboration as a learning objective
- Authentic intellectual challenge
- Student-centered community of practice

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Laboratory courses can:

- Foster self-efficacy in physics practices
- Enrich beliefs about the scientific practice
- Model a welcoming and inclusive community
- Help students develop professionalism

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One attempt a reframing “successful” in the physics laboratory

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Context is a 200-level lab course: *Introduction to Experimentation*

- Learn to work on a team
- Ask scientific questions and design and conduct experiments to answer them
- Develop own methods for data reduction, modeling, error propagation
- Communicate through reports and presentations

- **There is no designated physics context associated with this lab**
One attempt a reframing "successful" in the physics laboratory

I. Shift in learning objectives and assessment from individual to Collective Intelligence
   • independent of the average IQ of its members
   • depends on equitable #words spoken per member, and average social intelligence of group members
     (Woolley, Chabris, Pentland, Hashmi, Malone in Science 2010)

II. Develop self-efficacy through engagement in a community of experimental physics practices

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I. Fostering CI through Community of Practice

- Dedicated lecture time throughout the course to learning about effective collaboration
- Professional communication platform (Slack)
- Student activities:
  - Code of conduct
  - Teamwork agreements
  - Group roles with scripts
- Mentoring: management and guidance
Student driven community of practice

Connected through professional communication platform

Lecture effective collaboration

Student activities and Mentoring

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<td>• Make sure all group members participate.</td>
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<td>• Watch the time spent on each step.</td>
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<td><strong>Recorder/checker</strong></td>
<td>&quot;Do we all understand this diagram?&quot;</td>
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<td>• Act as a scribe for your group.</td>
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<td>• Check that all group members are able to effectively use Slack and Zoom</td>
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<tr>
<td>• Check for understanding of all members.</td>
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<td>• Make sure all members of your group agree on plans and actions.</td>
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<td>• Make sure names are on group products.</td>
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<td><strong>Skeptic</strong></td>
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<td>• Help your group avoid coming to agreement too quickly.</td>
<td>&quot;Let's try to look at this another way.&quot;</td>
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II. Community of experimental physics practices
   • processes of experimental physics, including **student designed experiments** (Etkina et al, 2007)
   • Data reduction/modelling **constructed** through invention activities (Schwartz et al 2011, Day et. al 2010)
   • Collaborative Report writing
• Under the ISLE framework, **observational experiments** are a place for open-minded exploration and creation of a model.
Model Creation Curriculum

- Observational experiment activities are hard to design
- Anything accessible is a known phenomenon with known answers

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Model Creation Curriculum

- Observational experiment activities are hard to design
- Anything accessible is a known phenomenon with known answers
- Students are conditioned to confirm known answers in science labs
Intervention: NOMR Labs

*(Canright et al., 2020)*

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**NOMR: Novel Observations in Mixed Reality**

- Students explore fictitious physical phenomena in an immersive 3D environment
  - Hands-on
  - Experimental uncertainty present
  - "Answers" never shared
  - Phenomena consistent with known physics
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Early indications of some success:

*Measures of some effects of collaboration*

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Engagement With TAs
• Mitigates anxiety
  • related to lower success in engineering
  • correlated with being from underrepresented group
• Reward and praise are important to development of strong physics identity

Student-to-student engagement
• Sharing experiences mastering material can build self efficacy, particularly for women
  (Sawtelle, Brewe, Goertzen, Kramer, 2012)
1. Messaging activity in Slack → Student-to-student engagement
Average messaging activity per week per person

(El Hady et al., 2020)

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Average messaging activity per week per person

- Activity over 10; nearly three times the activity as the comparison intro mechanics course

- We attribute this difference to collaborative graded reports and presentation

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1. Messaging activity in Slack \( \rightarrow \) Student-to-student engagement
Average messaging activity per week per person

2. Survey Items
5-point Likert Scale questions:

<table>
<thead>
<tr>
<th>Interpreted value</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
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<tr>
<td>-2</td>
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Engagement with TAs:

- At least one TA in this class cares about how much I learn.

Student-to-student Engagement

- I have found students in this class with whom I am comfortable working.
- I feel comfortable sharing ideas with other students I’ve worked with, even if I'm not sure my ideas are fully correct.
### Engagement Item results

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<th>Intro to Experiment ± (0.09)</th>
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Early indications of some success: *Impact of science practices focus*

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Study Details

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Instructional Context:
• 100-level honors electromagnetism lab, Winter quarter 2021
• Groups of 3-4 students
• 37 students, mostly freshmen

Software: NOMR software developed in Unity in-house
Hardware: Oculus Quests lent to 1 student per group, streamed over Zoom
• Hu and Zwickl developed a student epistemology assessment consisting of four free-response questions:

### 1. Why are experiments a common part of physics classes?

1. Supplemental learning
2. Theory testing
3. Foundation of physics
4. Scientific abilities
5. Science appreciation
6. Career preparation

### 2. Why do scientists do experiments for their research?

1. Theory testing
2. Discovery
3. Theory development
4. Technology advancement

### 3. What defines a scientific theory?

1. Evidence supported
2. Explanatory and predictive power
3. Quantitative aspect

### 4. How do theory and experiment relate?

1. Experiment tests theory
2. Theory explains experiments
3. Experiment inspires theory
4. Theory guides experiment
Results

*(Canright et al., 2021)*

Compared to Hu and Zwickl and Zwickl '17, study participants:

1. See the role of instructional labs more to teach scientific abilities and less as a supplement to lecture learning

2. See experimentation in science not just as a means to test theories, but to discover and develop them

3. Have a stronger understanding of the iterative relationship between experiment and theory
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• **Socially**: encouraging/discouraging through the structure, interactions, and treatment in the physics community

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  ➢ *Creative practices of authentic science shows evidence of shifting epistemology*

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  ➢ *Student mediated community of practice shows promise of fostering engagement*

*Effective collaboration needs ongoing management. TAs need training in group management*
• The laboratory is an excellent space for broadening our message of “successful in physics.”

• Creating professional spaces in which it is normal to experience both hardship and success serves a more diverse group of students in physics.

• Mentoring students in being generous and adaptive to a variety of collaborative challenges helps prepare them for success in the workplace.

https://www.compadre.org/per/conferences/2021/

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