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Evaluating Scientific Practices in Intro Physics Labs

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Collaborators

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Stanford University
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Ruqayya Toorawa
What should labs be doing?

What are labs doing?

How do we know?
What should labs be doing?

What are labs doing?

How do we know?
Recommendations for the Undergraduate Physics Laboratory Curriculum (2014)
Where is content?
Labs found to provide no measurable added-value to reinforcing physics content beyond what is provided by lecture and tutorials

Wieman & Holmes (2015) *Am J Phys*
Holmes, Olsen, Thomas, Wieman (2017) *Phys. Rev. PER*

Labs that aim to reinforce content found to make student attitudes/beliefs about experimental physics more novice-like


Plus NGSS, AP practice, Phys 21, etc.
What should labs be doing?

What are labs doing?

How do we know?
What should labs be doing?

What are labs doing?

How do we know?
Physics Lab Inventory of Critical thinking
Physics Lab Inventory of Critical thinking

PLIC
What do you mean "critical thinking"?
Quantitative critical thinking

The process through which you make decisions and decide what to believe

Especially related to “believing” evidence, data, models, etc.
“Critical thinking” encompasses all of this
The PLIC: aim

- Assess critical thinking in an efficient, standardized way
- Useable by instructors in different courses at any institution
Generating a closed-response survey

Free response (v1, v2, ...)

Interviews + written responses

Refine questions

Use common responses to generate closed-response options
Generating a closed-response survey

Free response (v1, v2, ...)

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Closed response (v1, v2, ...)

Refine questions
Generating a closed-response survey

Free response (v1, v2, ...)

Interviews + written responses

Refine questions

Use common responses to generate closed-response options

Closed response (v1, v2, ...)

Interviews + written- + closed-answer responses

Refine questions & options

Remove rarely selection options

Statistical analysis (validity, reliability, etc.)
The PLIC: structure

- Case studies of two groups completing a mass on a spring experiment
- Closed response, choose many, Likert-like
Two fictional groups

Group 1

- Measure 10 repeated trials
- Measure 5 periods at a time
- Use 2 masses
- Calculate $k$ in each case and compare

Students described “evaluating a model” as finding $k$
Two fictional groups

**Group 1**
- Measure 10 repeated trials
- Measure 5 periods at a time
- Use 2 masses
- Calculate \( k \) in each case and compare

Students described “evaluating a model” as finding \( k \)

**Group 2**
- Measure two repeated trials
- Measure 5 periods at a time
- Use 10 different masses
- Plot, linearize, find \( k \)

Residuals graph included – trend motivates need for intercept
Which group did better?

Experts say Group 2, because:
- Extended limits (More masses)
- Analysis (Fitting, trying different models)
Which group did better?

3 intro physics courses at post-test
Which group did better?

3 intro physics courses at post-test

Course A: n=245
Course B: n=85
Course C: n=191

Group 1  Group 2  Both
Which group did better?

3 intro physics courses at post-test

Lab aimed to teach critical thinking

<table>
<thead>
<tr>
<th>Course</th>
<th>Fraction of students</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>B</td>
<td>0.7</td>
<td>0.5</td>
<td>0.2</td>
<td>0.0</td>
</tr>
<tr>
<td>C</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
</tr>
</tbody>
</table>

n=245, n=85, n=191

Lab aimed to teach critical thinking

Group 1  Group 2  Both

Course A n=245  Course B n=85  Course C n=191
Why?
Student Reasoning behind "What group do you think did a better job testing the model?"

Course A
n = 246

Course B
n = 48

Course C
n = 194

Fraction of Students

Tested the limits of the experiment
Collected more data
Collected better quality data
Response Options
Analyzed data better
Presented their work better

Group 1 did better
Group 2 did better
Both did equal
Student Reasoning behind "What group do you think did a better job testing the model?"

Course A
n = 246

Course B
n = 48

Course C
n = 194

Fraction of Students

- Tested the limits of the experiment
- Collected more data
- Collected better quality data
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Response Options

Group 1 did better
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Student Reasoning behind "What group do you think did a better job testing the model?"

Course A
n = 246

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Course C
n = 194

Fraction of Students

- Tested the limits of the experiment
- Collected more data
- Collected better quality data
- Analyzed data better
- Presented their work better

Didn't limit # options
Student Reasoning behind "What group do you think did a better job testing the model?"

- **Course A**: n = 246
  - Preferred Group 2 except for amount of data
  - Cared about all options
  - Preferred Group 1
  - Cared most about data quality & amount

- **Course B**: n = 48
  - Preferred Group 2 except for amount of data
  - Cared about all options

- **Course C**: n = 194
  - Preferred Group 1
  - Cared most about data quality & amount
What does this tell us?

• Traditional lab instruction aligns with Group 1 methods
  • Focus on data quality and quantity:
    • Comparing parameter to “true” value and taking lots of trials
• Critical thinking instruction aligns with Group 2 methods
  • Focus on range of investigation and quality of analysis
    • Need to limit number of options to differentiate ideas
    • (all options are reasonable, some more expert than others)
• …
Interested in using the PLIC? Contact me! ngholmes@cornell.edu

We’re also looking for more expert responses!

Poster session: PST2D36
Tues 5:45-6:30pm
The Physics Lab
Inventory of Critical Thinking (K.N. Quinn)

Thank you!