Evaluation of Traditional Labs as Effective Content Delivery in a High-Enrollment IPLS Course.

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Session: Developing Scientific Practices in the Laboratory
Two key studies suggested that completing labs based on a physics concept does not improve how well a student learns that concept, or reinforce conceptual content learned elsewhere.

Wieman and Holmes (2015) – no measurable difference on exam questions relating to lab topics, comparing students who took the labs and students who did not.  
  - Calculus based, physics and engineering students at Stanford.

Holmes et al (2017) - Nine different lab courses, designed to reinforce student understanding of physics content from other areas of the course, have been shown to provide no measurable added value to course performance.  
  - Three universities, nine Mechanics or E+M courses, calculus or algebra based, students from many science disciples.
Why one more?

University of Guelph – First year IPLS Courses:
• High enrollment (and growing)
  ▫ 5 courses annually, algebra-based
  ▫ 4 with enrollment ~800 – 1000 – total students 4000+ annually
Why one more?

- Common lab design and in many cases common labs
  - Almost exclusively Life Science majors
  - Not presented as traditional Mechanics, E+M courses
  - Organized around Life Science topics

A different kind of course, and big student impact with any changes.

Is there a **content reinforcement** happening here that wasn’t in previous work?
**Setting:** PHYS*1300 – Fundamentals of Physics – Fall 2017 semester
- ~900 students who did not take Grade 12 Physics in High School
- 5 labs over the course of the semester
  - Traditional “recipe” labs in scheduled lab periods
  - ~30 students per lab
- Course evaluation:
  - 10% lab completion
  - 50% quizzes in a mastery-based (multiple-attempt) system
  - 35% final exam
Study: Split into two treatments for lab 3 of 5:

- Conservation of Energy or Conservation of Momentum
- Pre-, post-, and post-post-surveys including a “light” expert opinion survey modeled after E-CLASS
  - >90% survey participation
- In all, about 8% of final grade identified as being part of the total relevant course assessment:
  - 2 questions each on final exam relating to C of E, C of M
  - One full quiz relating to C of E, C of M
No significant difference on total relevant course assessment between students who did, or did not, complete a lab on that concept.

<table>
<thead>
<tr>
<th>Lab Type</th>
<th>Did not complete</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Score</td>
<td>(Did not complete Energy lab)</td>
<td>(Completed Energy lab)</td>
</tr>
<tr>
<td>Momentum Score</td>
<td>(Did not complete Momentum lab)</td>
<td>(Completed Momentum lab)</td>
</tr>
</tbody>
</table>

![Box plots showing Energy and Momentum scores for completed and not completed labs.](image-url)
No significant difference on quiz questions between students who did, or did not, complete a lab on that concept.

(Taking retention time into account)
Students believe that **lectures are significantly more helpful** in learning course material than labs (or homework...)

<table>
<thead>
<tr>
<th>Question</th>
<th>Mean Response</th>
<th>Difference of mean response from mean lab experiments response</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>The <strong>homework assignments</strong> in PHYS*1300 are helpful in learning and understanding the course material.</td>
<td>2.26</td>
<td>0.03 ‡</td>
<td>Students weakly agree that homework assignments are helpful in learning course material. There is no statistical difference between their agreement on homework assignments and laboratory experiments.</td>
</tr>
<tr>
<td>The <strong>laboratory experiments</strong> in PHYS*1300 are helpful in learning and understanding the course material.</td>
<td>2.23</td>
<td>---</td>
<td>Students weakly agree that laboratory experiments are helpful in learning course material.</td>
</tr>
<tr>
<td>The <strong>lectures</strong> in PHYS*1300 are helpful in learning and understanding the course material.</td>
<td>1.65</td>
<td>-0.58 ***</td>
<td>Students agree strongly that lectures are useful in learning course material, and this result is highly significantly different from their agreement on either homework or labs.</td>
</tr>
</tbody>
</table>

‡ \( p > 0.05 \)  * \( p \leq 0.05 \)  ** \( p \leq 0.01 \)  *** \( p \leq 0.001 \)  
n = 673

2 Possible responses  1 (Strongly Agree)  2 (Agree)  3 (Neither Agree Nor Disagree)  4 (Disagree)  5 (Strongly Disagree)

3 Significance of difference evaluated by both t-test and Wilcoxon signed-rank test, due to questions about normality.
Students think that labs have many roles, and they agree most strongly with the idea that labs should be a physical demonstration of theoretical ideas.

- Physical demonstration of concepts
- Reinforcing concept knowledge
- Many different things
- Practical "bench" research skills
- Data analysis
- Communicating results

Fraction of students from complete survey selecting response as the primary (most important) role of laboratory exercises in introductory physics courses.

Unpaired dataset (n = 246)
Completely linked dataset (n = 105)
Some mild, unsurprising opinion shifts:

<table>
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<tr>
<th>Stronger Agreement</th>
<th>Neutral</th>
<th>Stronger Disagreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>When I encounter difficulties in the lab, my first step is to ask an expert, like the instructor.</td>
<td>△</td>
<td>□</td>
</tr>
<tr>
<td>If I don't have clear directions for analyzing data, I am not sure how to choose an appropriate analysis method.</td>
<td>△</td>
<td>□</td>
</tr>
<tr>
<td>The primary purpose of doing a physics experiment is to confirm previously known results.</td>
<td>△</td>
<td>□</td>
</tr>
<tr>
<td>When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.</td>
<td>△</td>
<td>□</td>
</tr>
<tr>
<td>Physics becomes easier if you can see a real-world demonstration of the concepts.</td>
<td>△</td>
<td>□</td>
</tr>
<tr>
<td>I expect that doing an experiment will help my understanding of physics.</td>
<td>△</td>
<td>□</td>
</tr>
<tr>
<td>Learning physics changes my ideas about how the world works.</td>
<td>△</td>
<td>□</td>
</tr>
<tr>
<td>Nearly everyone is capable of understanding physics if they work at it.</td>
<td>△</td>
<td>□</td>
</tr>
</tbody>
</table>

Week 1

- Nearly everyone is capable of understanding physics if they work at it.
-When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.
-Physics becomes easier if you can see a real-world demonstration of the concepts.
-I expect that doing an experiment will help my understanding of physics.
-Learning physics changes my ideas about how the world works.
-Nearly everyone is capable of understanding physics if they work at it.

Week 11

- The primary purpose of doing a physics experiment is to confirm previously known results.

Week 12

- If I don't have clear directions for analyzing data, I am not sure how to choose an appropriate analysis method.

Significant shift

Week 1

- Stronger Agreement
- Stronger Disagreement
- Neutral
• Wieman and Holmes (2015) and Holmes et al (2017) studies verified in a large enrollment ILPS setting.
• Labs do not appear to reinforce content and students do not appear to expect or need them to, at least primarily.
• Students believe that labs can have many roles. They believe most strongly that they should be a real world demonstration of theoretical concepts.
• After that, they are equally comfortable with labs as content reinforcement, teaching practical bench skills, and teaching data analysis.
Thank you!

Thanks to Prof. O’Meara, the TA’s, and students of PHYS*1300 last fall.
