Reforming Intro Physics Labs to Focus on Innovation, Creativity, and Scientific Skills

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University of Illinois

CAP Congress (June/5/2019)
Outline

Intro Physics at the U of I

Reforming the Labs

Scaling Up for 3000 Students

What we know so far
<table>
<thead>
<tr>
<th>Course</th>
<th>Code</th>
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<tr>
<td>Mechanics</td>
<td>(Phys 211)</td>
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<td>E&amp;M</td>
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<td>E&amp;M, Modern</td>
<td>(Phys 102)</td>
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What a Student Does Every Week

2 Lectures
50 minutes
300 students

1 Discussion
2 hours
24 students

1 Lab
2 hours
33-36 students
How important were ______ in helping you learn the material

<table>
<thead>
<tr>
<th></th>
<th>A (%)</th>
<th>B (%)</th>
<th>C (%)</th>
<th>D (%)</th>
<th>E (%)</th>
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<td>22.5</td>
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<td>1.2</td>
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<td>33.6</td>
<td>12.3</td>
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A: Essential, B: Very Important, C: Somewhat Important, D: Not very important, E: Useless
“Research reveals that labs are more effective when their goal is to teach experimental practices rather than to reinforce classroom instruction.”

This Agrees with PER
Our Lab Reform Trajectory

- Realize that two decades of research has validated the skills based approach (Etikna et. al.)

- Pilot a skills based approach to intro labs enabled by IOLab (100 /semester for a few years).

- Scale up to handle both intro sequences (3000 /semester).
Key Elements of Our Reform

1) Each student has an system.

2) Students explore individual pre-lab activities at home...

3) ...followed by group activities in the lab class.

4) Student write group lab reports; assessed on scientific abilities.
Brief Aside...

www.iolab.science

Show App & Repository
Technology enables new approach

- Lab 9 Materials
  1. This week’s lab handout
  2. This week’s rubric
  3. PowerPoint slides
  4. Suggestions for how to structure your report

Lab report upload link

Prelab assignments
(submitted & graded online)

In-class Instructions
(we are paperless)
Example Prelab & Lab
Physics 101, Pre-Lab 9 (Mechanics)

Build a simple pendulum using your IOLab as part of the design. Measure the period of oscillation of this pendulum using one of the IOLab sensors.

Briefly comment on whether your measured period is consistent with the prediction you get using the formula from class.

Share pictures & data with your instructor
Example student prelab submission:

“...my period was off by 2 ...”
Lab 9 in-class activity

1) Build a pendulum using your IOLab as part of the design.

2) Test the following hypothesis:
   “A pendulum has the same period regardless of the amplitude of the swing.”

Students work in teams & write & submit group lab report (PDF format)
Lab 9 Rubric

(40 points): Identifying and Minimizing Sources of Error

- Identify one or two details of your experimental setup and/or your analysis method that could impact the error in your measurement.
- If possible, use this information to improve your measurement.

(60 points): Writing a Scientific Report

The clear writing and structure of the scientific report allow a peer to understand and reproduce the investigation. Significant elements are:

- Description of experiment (including pictures and/or diagrams).
- Presentation of data and calculations (as needed).
- Concluding statement summarizing your findings.
- Readability, clear wording, good grammar, and overall effort.
1. Set up software, make any measurement (and write a lab report).

2. Test the hypothesis “The acceleration of your IOLab is the same rolling up and rolling down a ramp”.

3. Compare three hypothesis related to a hand shoving an IOLab device.

4. Design an experiment to measure $\mu_K$.

5. Design an experiment to measure the work done by a string on an IOLab device.

6. Design an experiment to measure the moment of inertia of an IOLab device.

7. Find a pattern in the way forces and distances are related in static equilibrium.

8. Find a pattern in the way the equivalent spring constant changes when springs are connected in series and parallel (SHM).

9. Test the hypothesis that the period of a pendulum is independent of its amplitude.

Understanding uncertainty a key element of all labs.

Lab Exam
1. Set up software, make two ECG measurements. Find \( \mu, \sigma \) of some quantity for 10 beats of each and compare.

2. Design an experiment to measure the brightness of a bulb as a function of voltage.

3. Design an experiment to measure the resistance of a mystery resistor.

4. Design an experiment to measure the force between a magnet and a surface vs separation. Compare two models that fit the data.

5. Design an experiment to determine the current flowing in a wire hooked up to a AA battery.

6. Design an experiment to create the biggest periodic induced current (a competition).

7. Measure the intensity transmitted through 2 polarizers as a function of angle. Find \( \theta_{1/3} \).

8. Test hypothesis that the thickness of group members hair is all the same.

9. Design your own experiment.

Understanding uncertainty a key element of all labs.
## Our Lab Reform Timeline

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Piloting
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**NSF/DUE 1712467:**
*Using IOLab to provide ISLE-style labs at scale.*
Main Challenges to Scaling Up:

- **Workload (limited TA staff)**
  - Managing & grading weekly lab reports. Consistency between TA’s, ...

- **Staffing & Training**
  - Combining pedagogy and technology make this more challenging than traditional labs.

- **Lab Room**
A Good Vibe is Really Important

A table at the back with coffee, tea, cocoa, and animal crackers

Comfy tables & chairs on wheels
TA Workload

• Prelabs are graded by FlipItPhysics on participation.

• In class, students work in groups of 3 to create a single electronic lab report per group.

• Students upload report before leaving lab room.

• Gradebook rubric feature.
Staffing & Training

• Experienced Mentor TA’s help train new TA’s.

• Learning Assistants have the perfect experience & skills

A huge success so far
Our New Learning Assistant Program

• Resources:

  • LA’s work for course credit, not money:
    o Each LA takes a pedagogy class (90 min/week; taught in Physics).
    o Each LA helps in one 2 hour lab section.
    o Each LA earns 2 hours of PHYS 398LA credit.
    o Each semester about 50 students have applied for 20 positions.

  • Returning LA’s can work as “Expert LA’s” (ELA’s)
    o Each ELA helps in one 2 hour lab section; no pedagogy class.
    o Each ELA earns 1 hour of PHYS 398ELA credit.
    o This fall 19/22 eligible LA’s applied to be ELA’s

First LA’s are all 3rd + 4th year bio majors!
So Much Data, So Little Time
(the story of this project)
Etkina & Murthy Lab Goals Survey:
“Learning to design your own experiment”

Most students are 3rd + 4th year bio majors
Lab Confidence Survey

Confidence that you can design an experiment or procedure to test a hypothesis that you came up with

Before - After Physics 101

$\Delta \mu=0.522$ #σ=6.455 $P_{MW}<.0001$

Before - After Physics 101+102

$\Delta \mu=0.737$ #σ=9.960 $P_{MW}<.0001$

(3rd + 4th year bio majors)
... I just wanted to let you know how much I look forward to coming to lab every week and appreciate what we learn every time. I learn a great deal from conducting hands-on experiments and enjoy being able to apply physics concepts we learn in class to everyday activities. I was very excited to learn the diameter of my hair and comparing it to my classmates then telling my parents about my experience. I also appreciate the structure of the labs and having the freedom to add our own ideas to them and the concept of having no completely incorrect answer as long as we can explain our results. Thank you again for making this class so enjoyable.

This student became a great LA
(didn’t do particularly well on exams – orthogonal skill)
Lessons learned so far

• Data indicates we are on the right track: Students like the new labs and their skills & confidence improve through the semester.

• Teaching this new way required additional planning:
  o Lab staff needs more training & support.
  o New Learning Assistant program.

• Less lab infrastructure is needed.
  o No expensive equipment. No weekly setup. All labs use the rooms & materials.
Collaborators
Illinois PER Group

See Katie Ansell’s Ph.D thesis