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

Mats Selen
University of Illinois

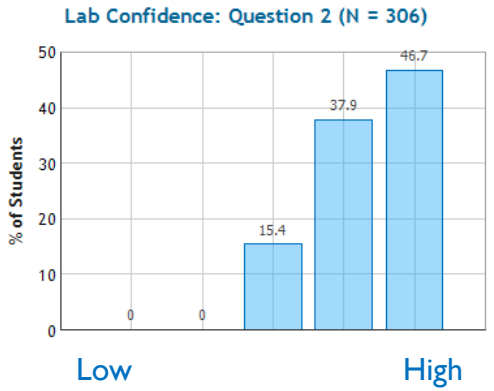
Outline

Intro Physics at the U of I

Reforming the Labs

Scaling Up for 3000 Students

What we know so far



Intro Physics at UIUC (Spring 2019)

Fall

Mechanics	(Phys 211)	1099
E&M	(Phys 212)	675
Stat. Mech.	(Phys 213)	544
Quantum	(Phys 214)	547

Now

Mechanics, Heat	(Phys 101)	299
E&M, Modern	(Phys 102)	358

What a Student Does Every Week

2 Lectures

50 minutes

300 students

FlipItPhysics

iClicker

1 Discussion

2 hours

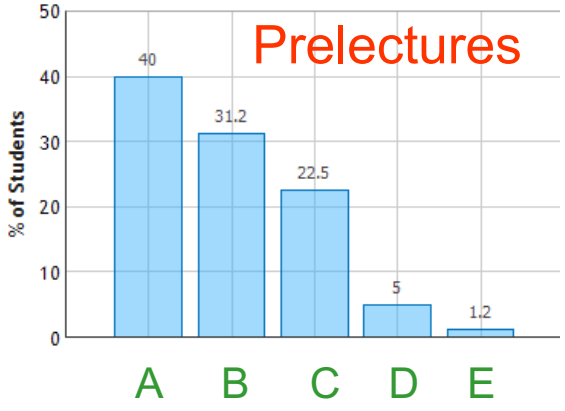
24 students

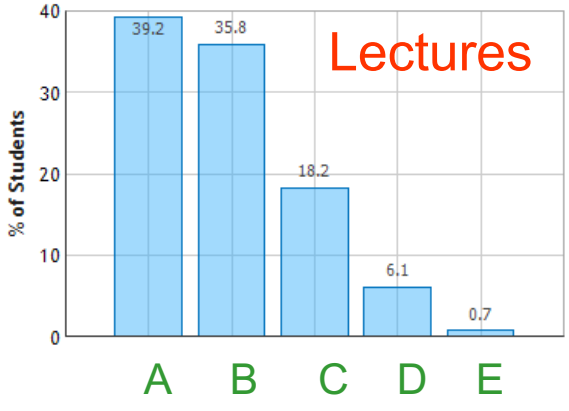
1 Lab

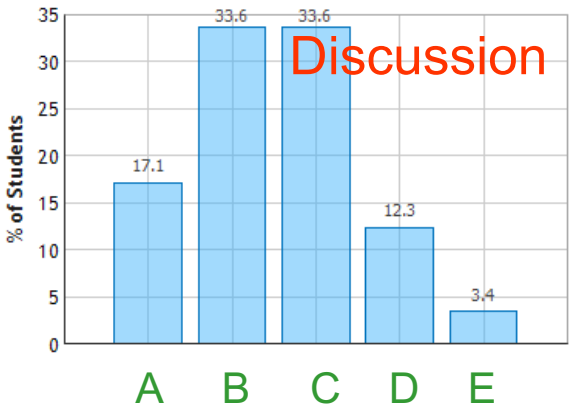
2 hours

33-36 students

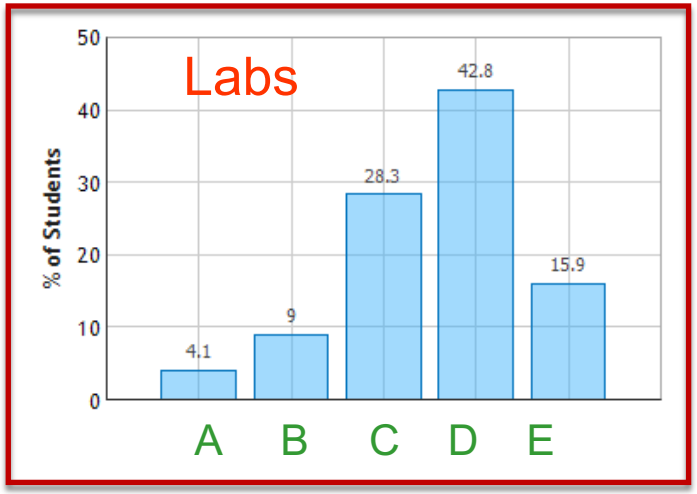
How important were _____ in helping you learn the material







A: Essential, B: Very Important, C: Somewhat Important, D: Not very important, E: Useless



This Agrees with PER

"Research reveals that labs are more effective when their goal is to teach experimental practices rather than to reinforce classroom instruction."

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

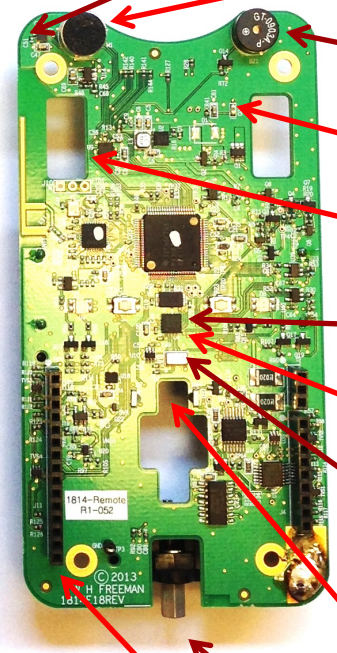
1) Each student has an  system.

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…



Magnetometer
Microphone
Buzzer
Light Intensity
Accelerometer
Gyroscope
Temperature
Atmospheric Pressure
Wheel Encoder (r,v,a)
Force Probe
Expansion Headers

www.iolab.science

Show App & Repository

Technology enables new approach

Physics 101 Lab (Spring 2019)

https://www.flipitphysics.com/Course?enrollmentID=348143

Bookmarks

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

– IOLab Pre-la

1. Lab 1: Ge
2. Lab 2: Mo
3. Lab 3: Th
4. Lab 4: Me
5. Lab 5: Wo
6. Lab 6: Mo
7. Lab 7: Static Equilibrium (omitted for Spring 2019)
8. Lab 8: Springs in Series and Parallel
9. Lab 9: Motion of a Pendulum
   - Prelab - Motion Of A Pendulum — Due: Apr. 10 at 8:00 AM
10. Lab Practical Exam - Part 1
11. Fall 2019 LA Application (optional)

Bittle, Sarah

(45 days ago)

Materials

Lab report upload link

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

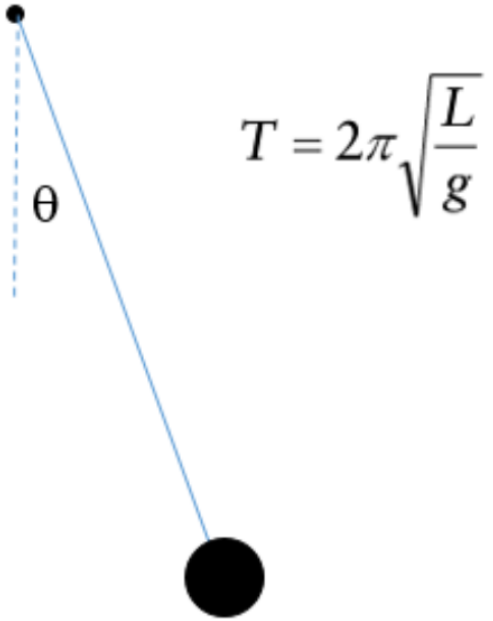
Prelab assignments
(submitted & graded online)

In-class Instructions
(we are paperless)

Example Prelab & Lab

Physics 101, Pre-Lab 9 (Mechanics)

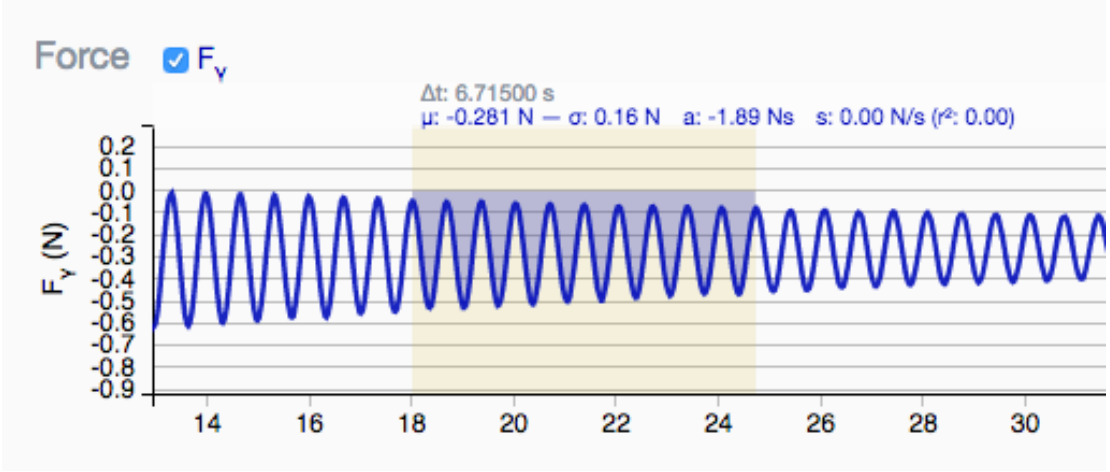
Build a simple pendulum using your IOLab as part of the design. Measure the period of oscillation of this pendulum using one of the IOLab sensors.



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.

Example report

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 μ_K.

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

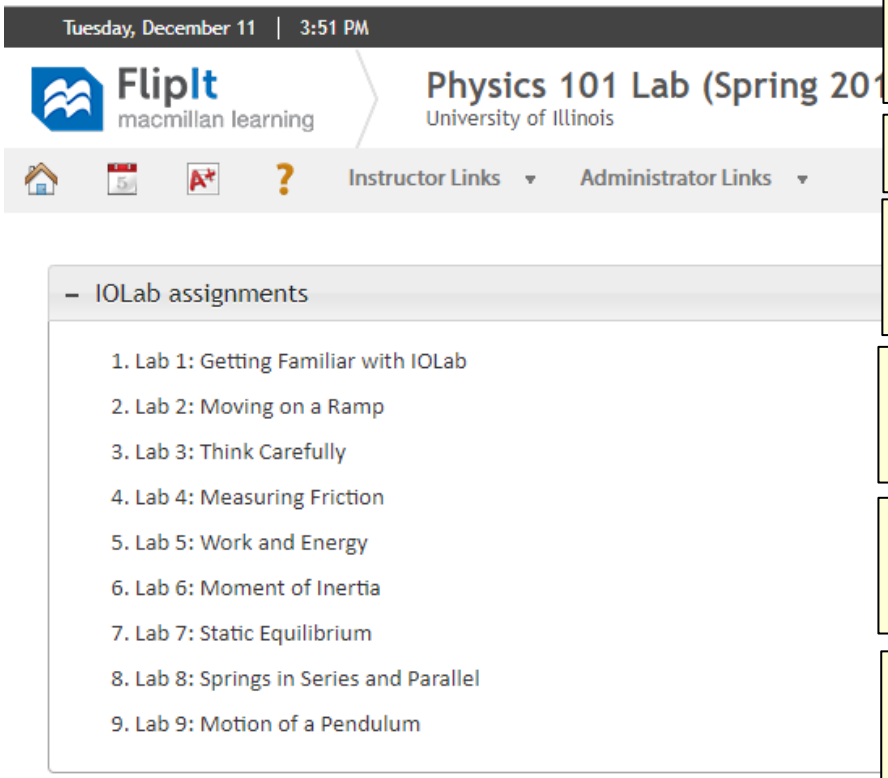
6. Design an experiment to measure the moment of inertia of an IOLab device.

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.

Lab Exam



Understanding uncertainty a key element of all labs.

1. Set up software, make two ECG measurements. Find μ, σ 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).

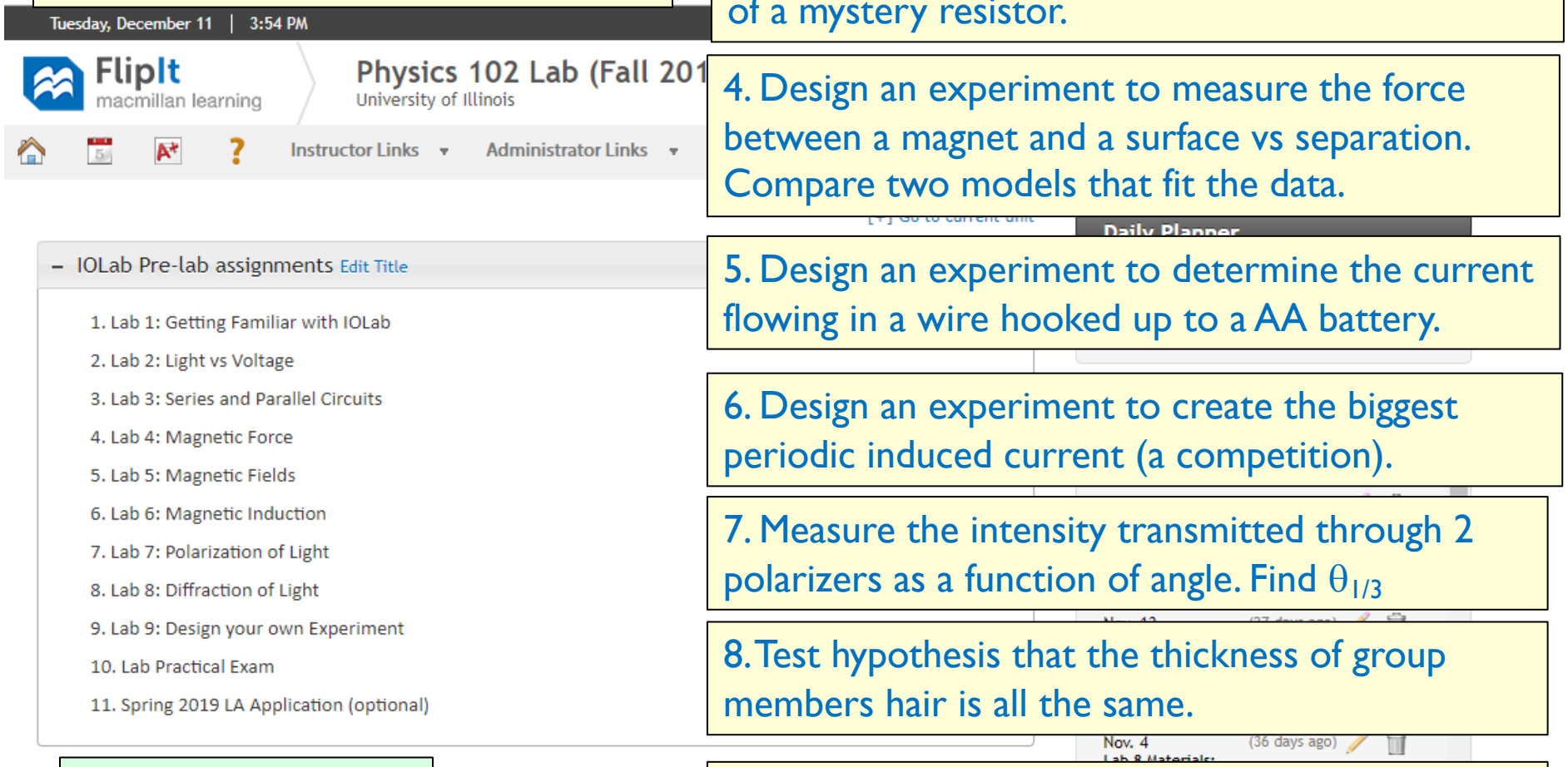
7. Measure the intensity transmitted through 2 polarizers as a function of angle. Find $\theta_{1/3}$

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

9. Design your own experiment.

Lab Exam

Understanding uncertainty a key element of all labs.



Our Lab Reform Timeline

Piloting

	Alg Mech	Alg E&M	Calc Mech	Calc E&M
Fall ’15	417	200	**28** / 842	1110
Spring ’16	310	331	**93** / 1203	797
Fall ’16	368	201	**172** 803	1122
Spring ’17	**63** / 316	329	**99** / 1147	734
Fall ’17	**90** / 355	221	782	1019

Our Lab Reform Timeline

Piloting

Scaling Up

	Alg Mech	Alg E&M	Calc Mech	Calc E&M
Fall '15	417	200	**28** / 842	1110
Spring '16	310	331	**93** / 1203	797
Fall '16	368	201	**172** 803	1122
Spring '17	**63** / 316	329	**99** / 1147	734
Fall '17	**90** / 355	221	782	1019
Spring '18	**all 360**	-	-	-
Fall '18	**all 380**	**all 230**	-	-
Spring '19	**all 300**	**all 360**	-	-
Fall '19	**all**	**all**	**all**	-
Spring '20	**all**	**all**	**all**	-
Fall '20	**all**	**all**	**all**	**all**

NSF/DUE 1712467:
Using IOLab to provide ISLE-style labs at scale.

Main Challenges to Scaling Up:

90 → 350 → 650 → 1400 → 3000

- 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

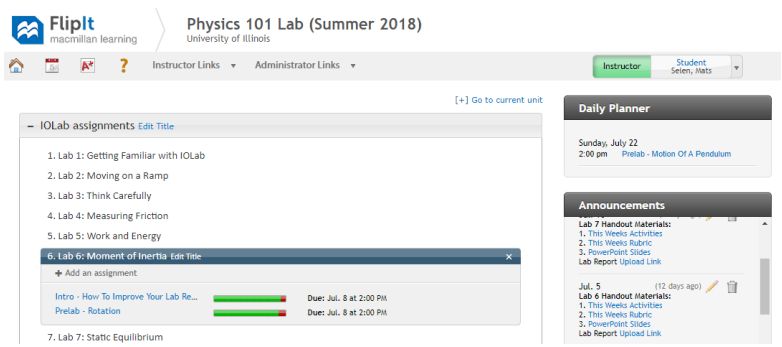
A Good Vibe is Really Important

Comfy tables & chairs on wheels

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

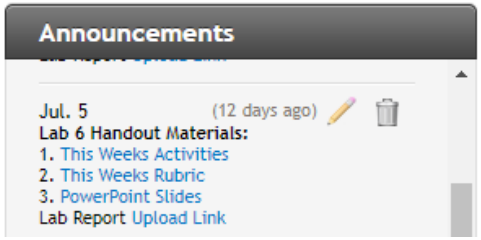
TA Workload

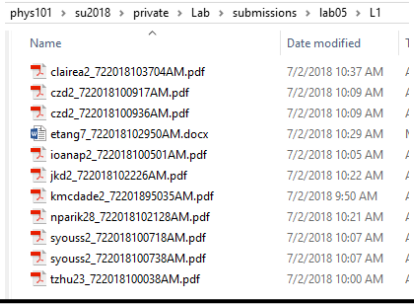
- Prelabs are graded by FlipItPhysics on participation.



- 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.

Question #	Omitted 0%	Attempted 33%	Partial Mastery 67%	Near mastery 100%	Comments to student
Q#2 **Points worth: 30 Constructing a Measurement**	The explanation for the procedure used to measure the physical quantity is omitted or sufficiently unclear that it cannot be identified.	The explanation for the procedure used to measure the physical quantity describes how the measurement procedure works using equations and physics concepts. The description is incomplete, or the design does not measure the desired quantity.	The explanation for the procedure used to measure the physical quantity describes how the measurement procedure works using equations and physics concepts. The description is mostly clear, and the design is close to measuring the desired quantity.	**The explanation for the procedure used to measure the physical quantity describes clearly and nearly completely how the measurement procedure works using equations and physics concepts. The design measures the desired quantity.**	The description of the physics is a little unclear: how does the non-slip condition lead to the statement "KE and PE are equal"?

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:

learningassistantalliance.org

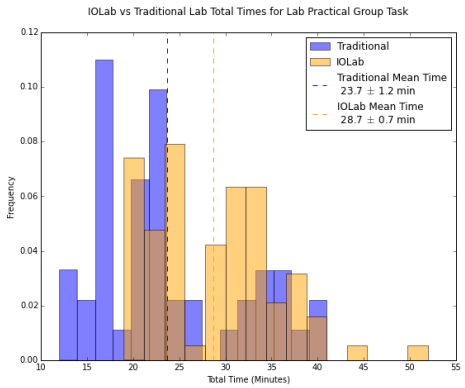
- LA's work for course credit, not money:
  - Each LA takes a pedagogy class (90 min/week; taught in Physics).
  - Each LA helps in one 2 hour lab section.
  - Each LA earns 2 hours of PHYS 398LA credit.
  - Each semester about 50 students have applied for 20 positions.

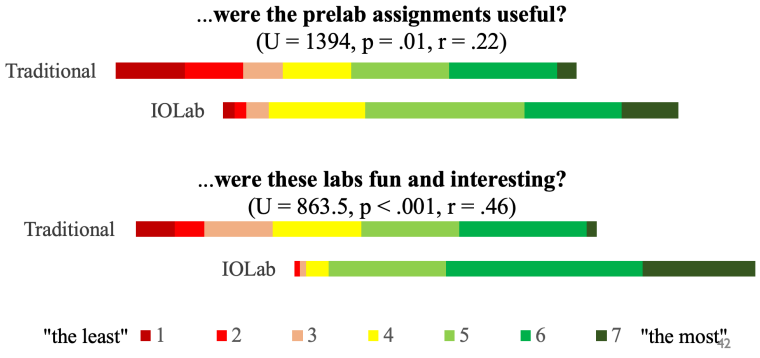
- Returning LA's can work as "Expert LA's" (ELA's)
  - Each ELA helps in one 2 hour lab section; no pedagogy class.
  - Each ELA earns 1 hour of PHYS 398ELA credit.
  - This fall 19/22 eligible LA's applied to be ELA's

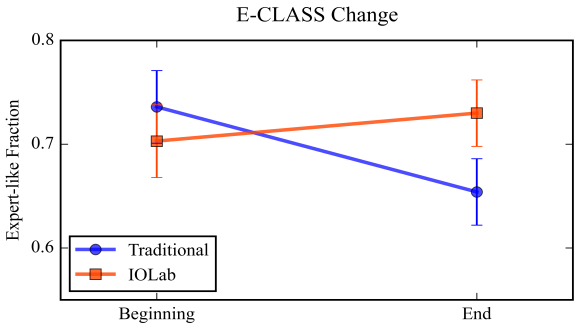
First LA's are all 3^{rd} + 4^{th} year bio majors !

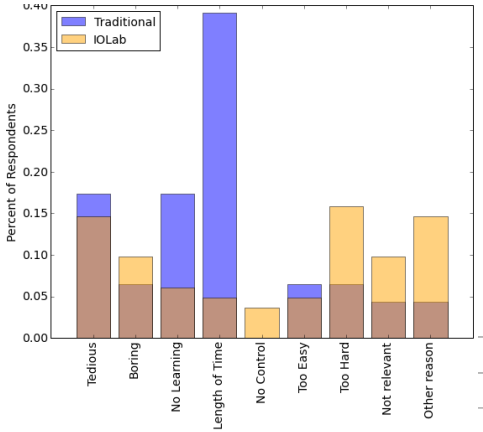
So Much Data, So Little Time

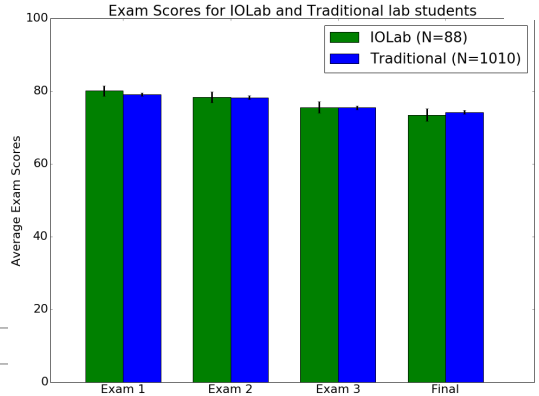
(the story of this project)

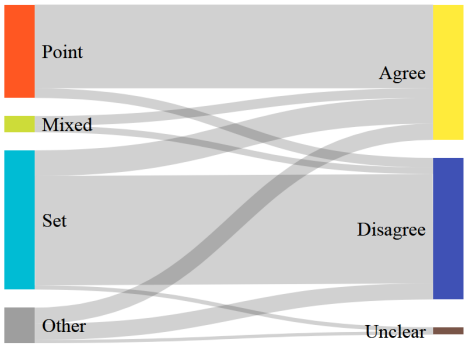


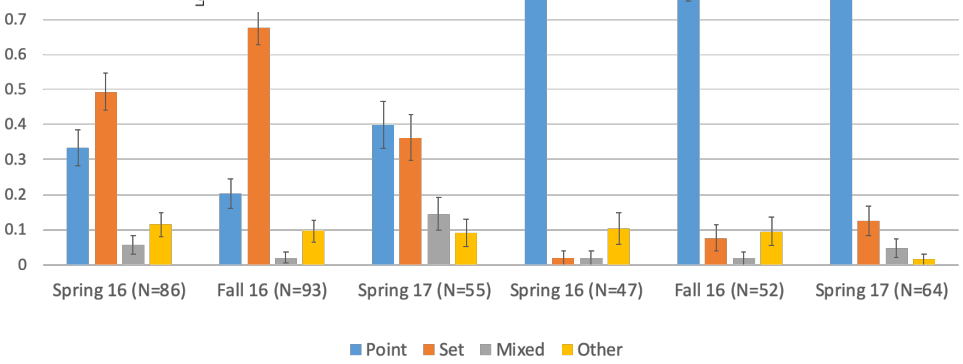


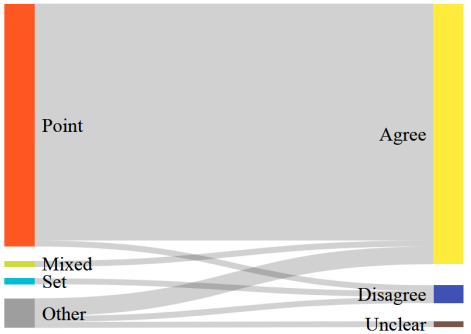






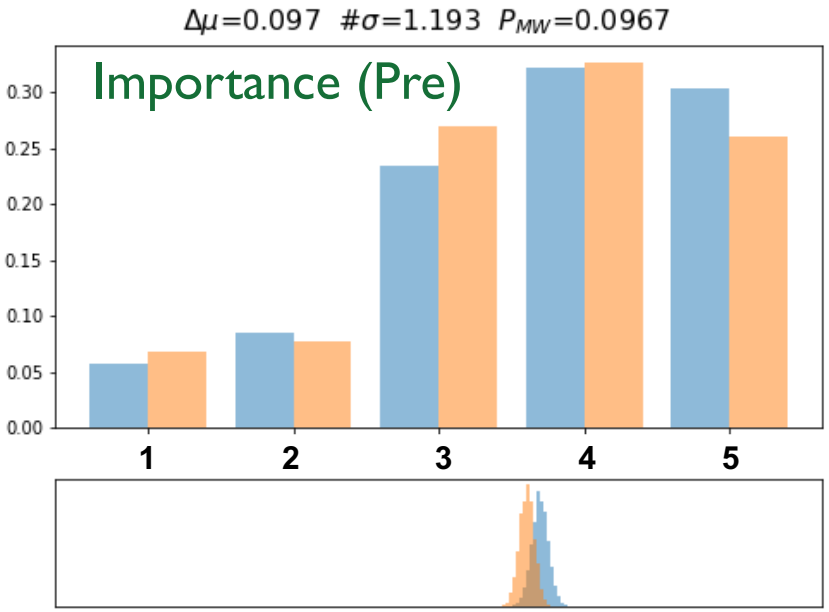


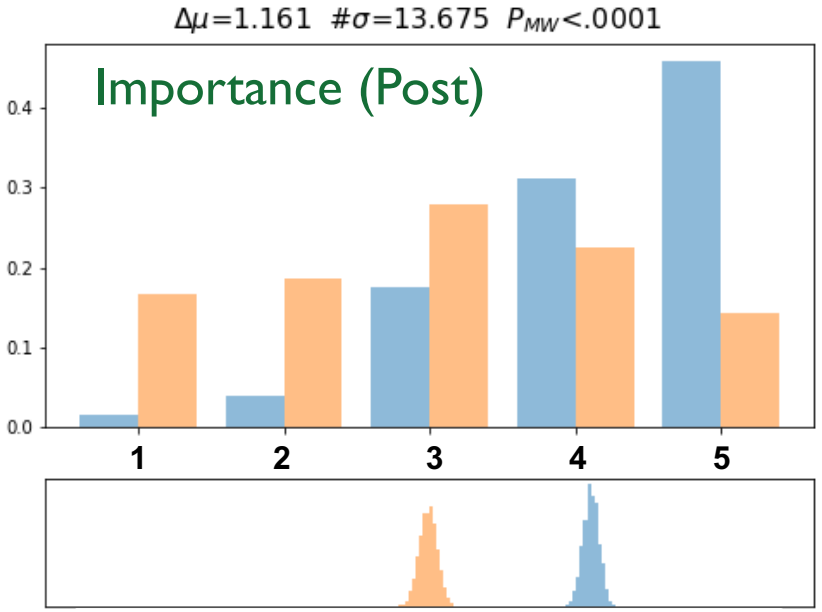


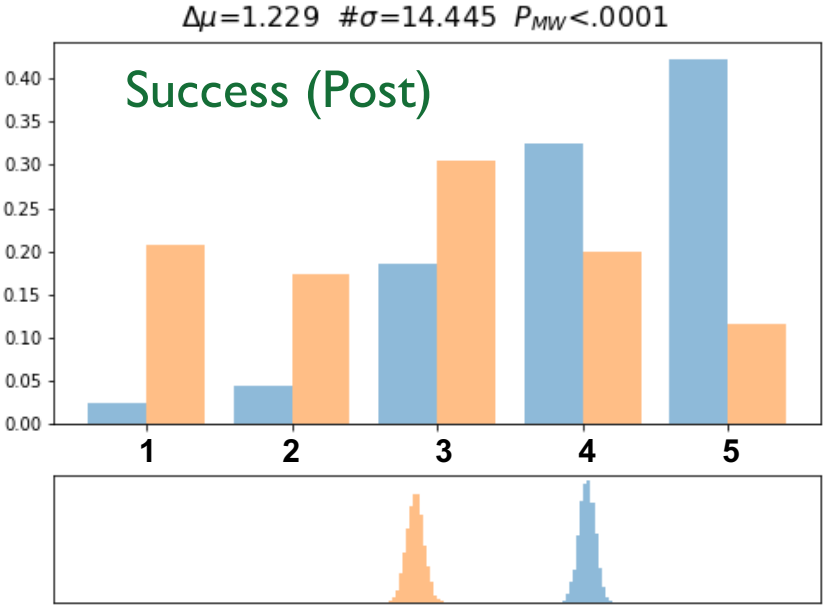


Etkina & Murthy Lab Goals Survey:

"Learning to design your own experiment"







Reformed

Traditional

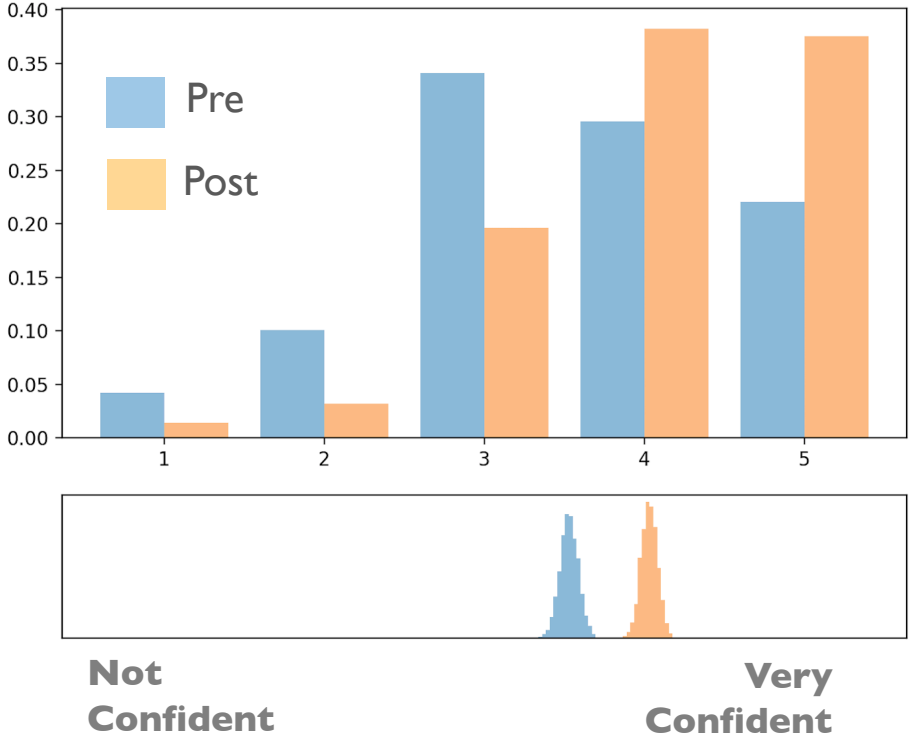
Most students are
3rd + 4th year bio majors

Lab Confidence Survey

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

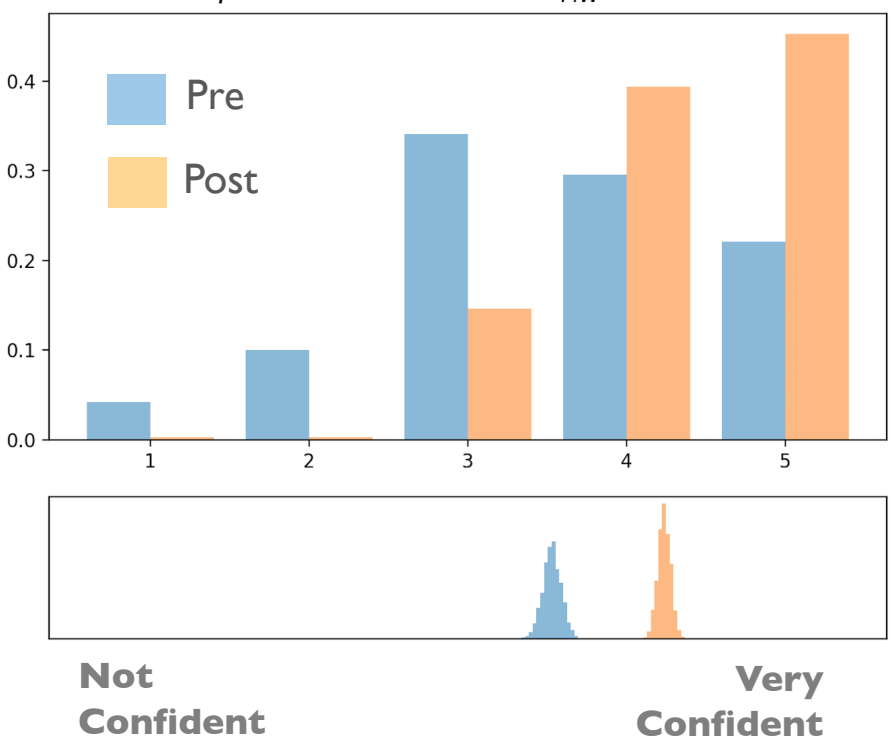
Before - After Physics 101

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



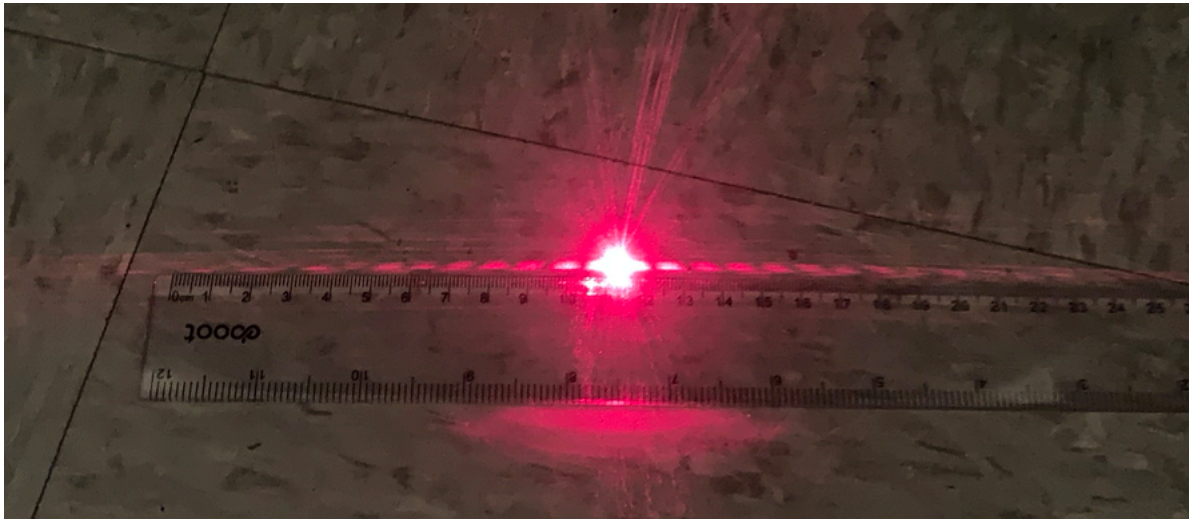
Before - After Physics 101+102

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



(3rd + 4th year bio majors)

Unsolicited email



... 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:
  - Lab staff needs more training & support.
  - New Learning Assistant program.

- Less lab infrastructure is needed.
  - No expensive equipment. No weekly setup.
    All labs use the rooms & materials.

Collaborators

SFU

Brock University

THE UNIVERSITY OF UTAH

Hope COLLEGE

UMASS

UPPSALA UNIVERSITET

1855

UNE

MILLIKIN UNIVERSITY 1901

SCHOOL OF MINES 1874 COLORADO

Wildcats

Duke

TASIS

ASU

MichiganTech

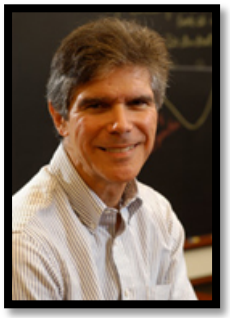
STATE

UNIVERSITY of GUELPH

Physics Education Research

Illinois PER Group


Gary


Jose


Tim


Morten


Mats

See Katie Ansell's Ph.D thesis


Katie


Bill


Brianne


Jason


Devyn


Gabe


Sam


Muxin