

Innovation and Creativity in Intro Physics Labs



APS Four Corners (10/12/2018)

Mats Selen

Talk Outline

Intro Physics at the U of I
(5 minutes)



Our new approach to labs,
mixed with some after
dinner experiments
(40 minutes)

Don't Panic: Lots of slides but mostly pictures

Intro Physics at Illinois (Fall 2018)

Calculus Based:

Mechanics

(Phys 211)

745

E&M

(Phys 212)

1023

Stat. Mech.

(Phys 213)

510

Quantum

(Phys 214)

461

Next Year

Algebra Based:

Mechanics, Heat

(Phys 101)

381

E&M, Modern

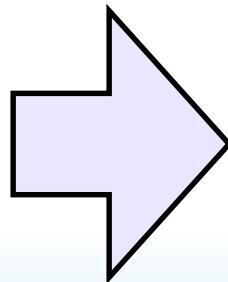
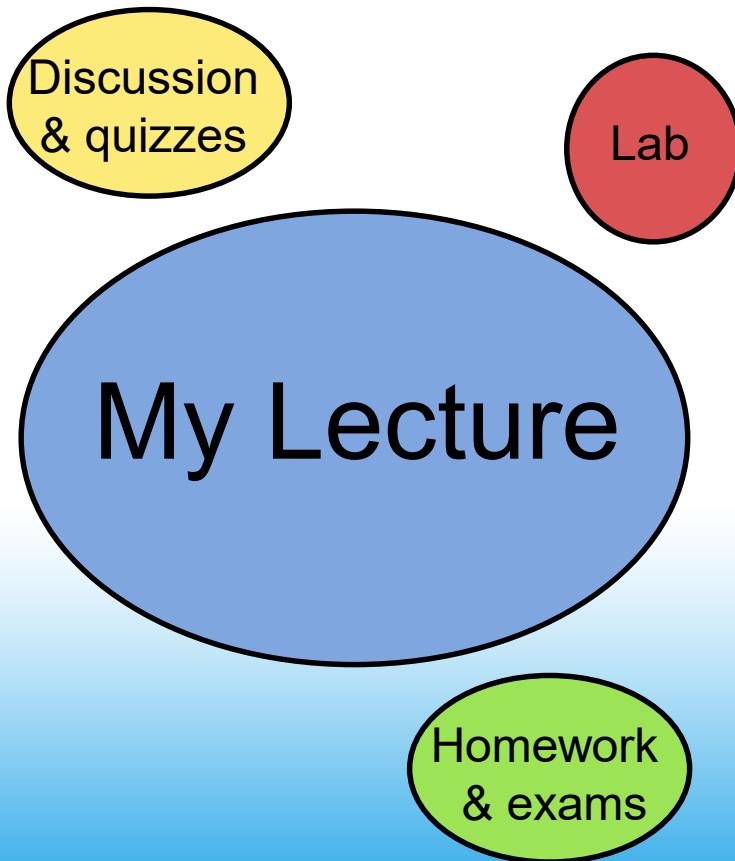
(Phys 102)

225

New Labs

Now

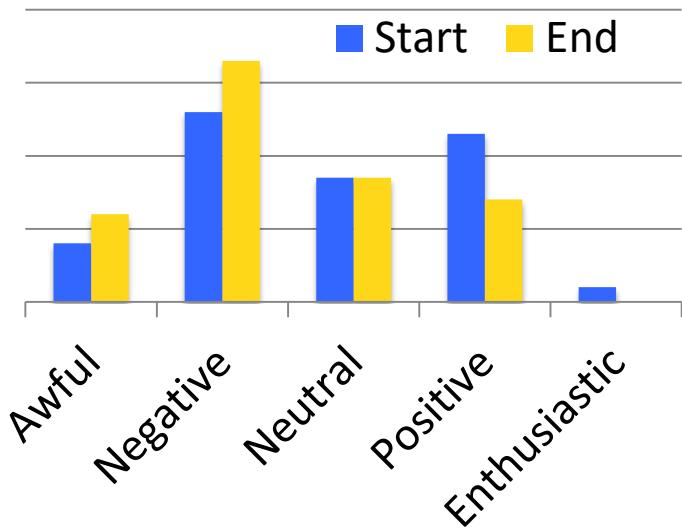
20 years ago



Our Course

Dept. Ownership
Team Teaching

Before (1995)



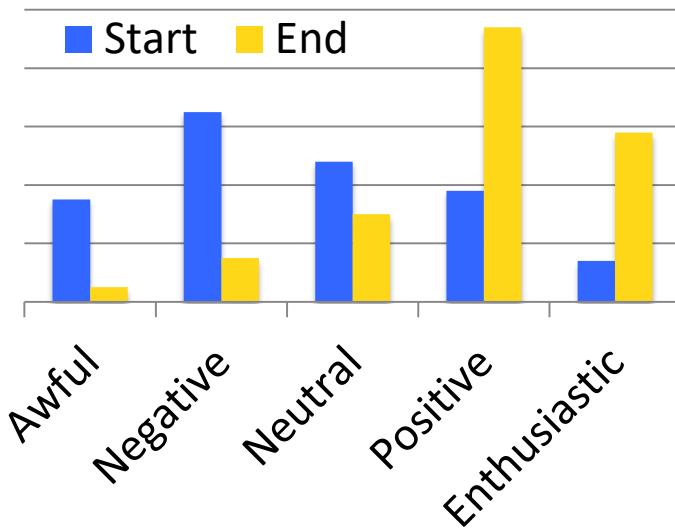
Before (Spring 95)

Total Physics TAs = 77

"Excellent" = 15

$19 \pm 5\%$

After (2001)



After (Spring 01)

Total Physics TAs = 75

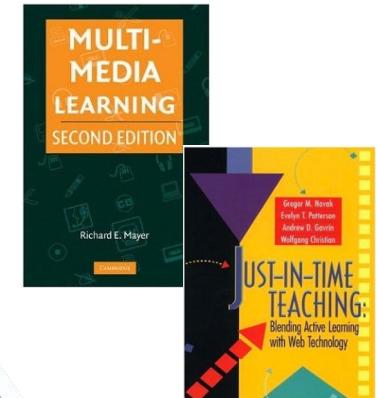
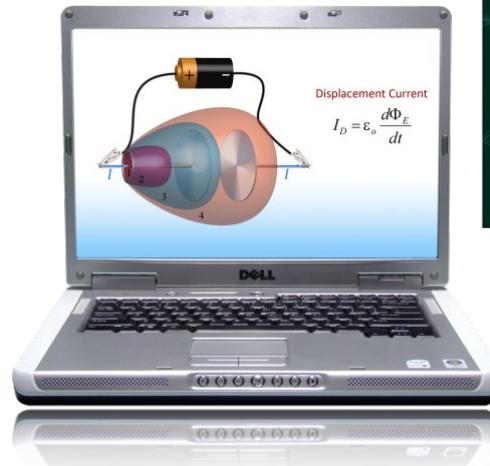
"Excellent" = 58

$77 \pm 6\%$

The impact of good organization and infrastructure

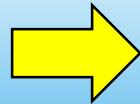
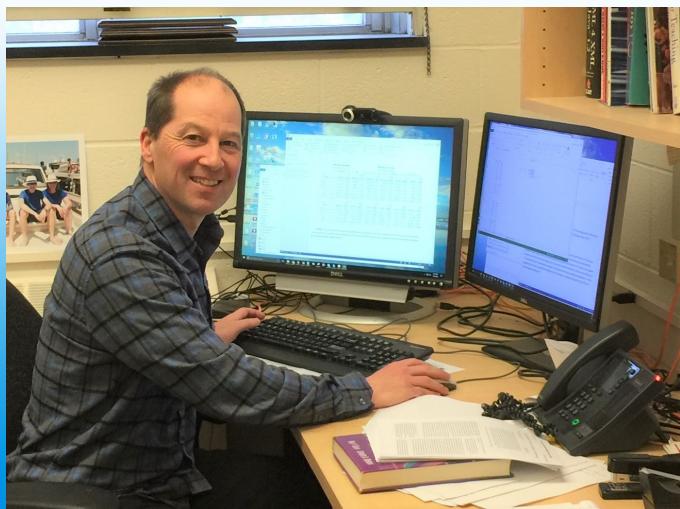
10 years ago

Students do online
Pre-Lectures & Checkpoints
before coming to class



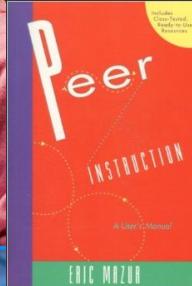
Monday Night

Tuesday Morning

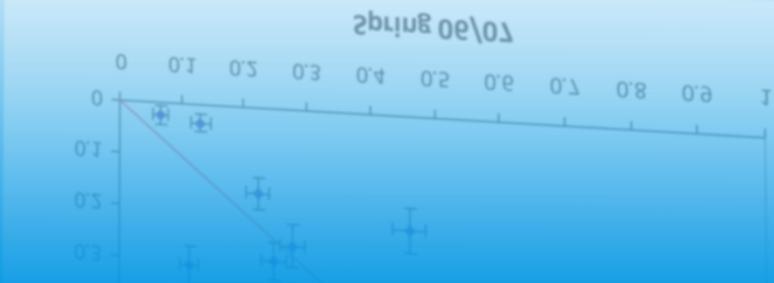
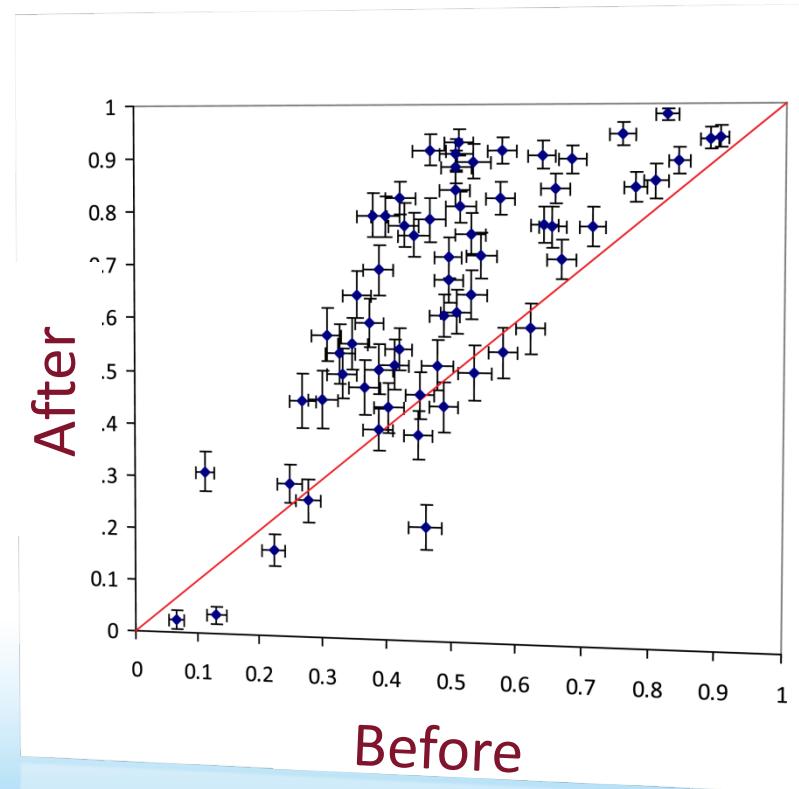


Instructor
prepares
for class

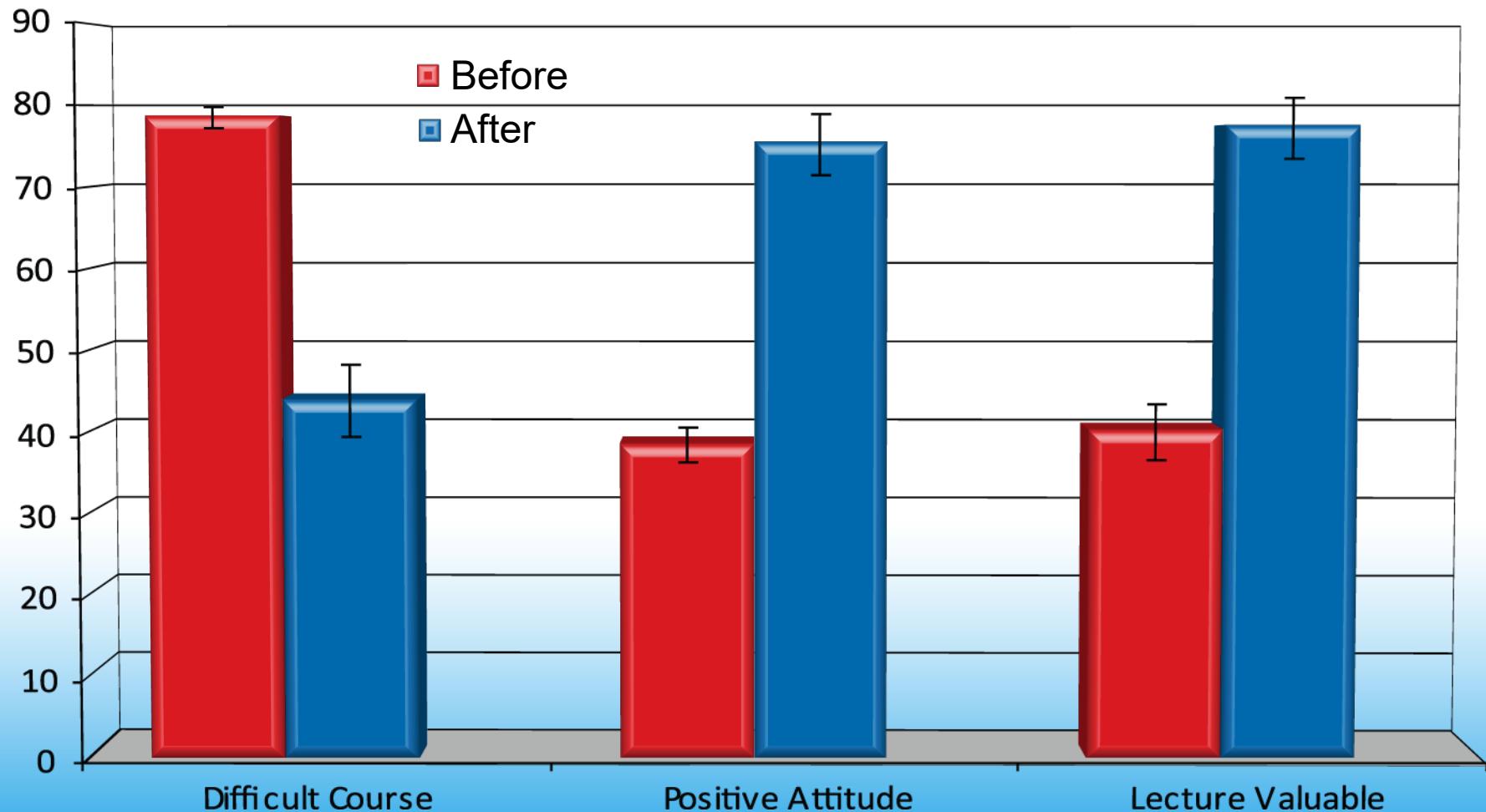
Active Classroom



Concept knowledge



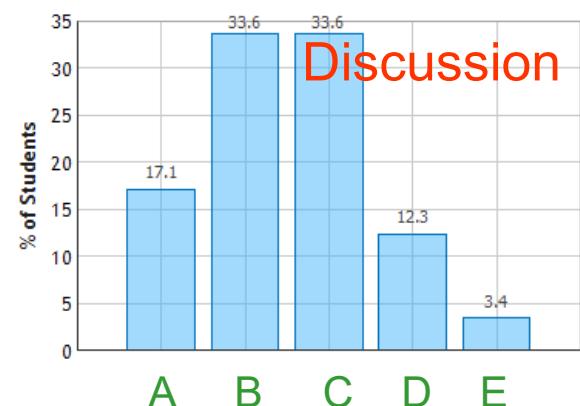
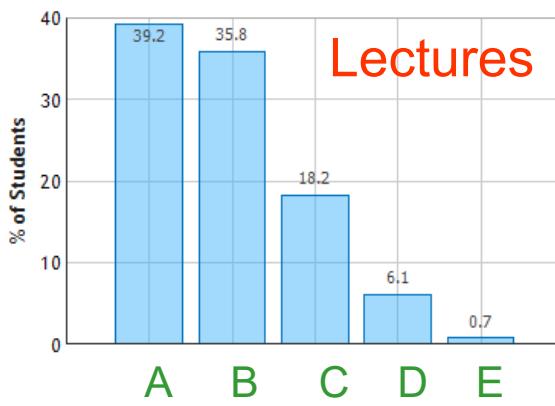
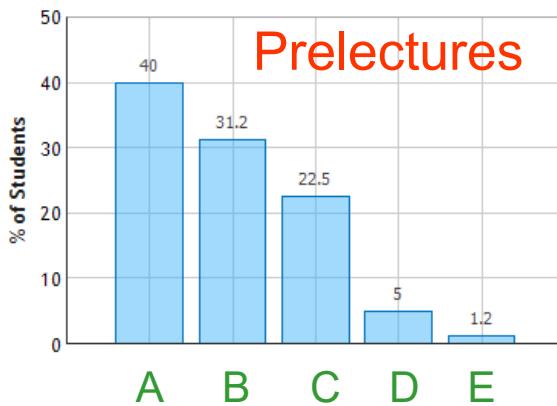
Student Perception of Course



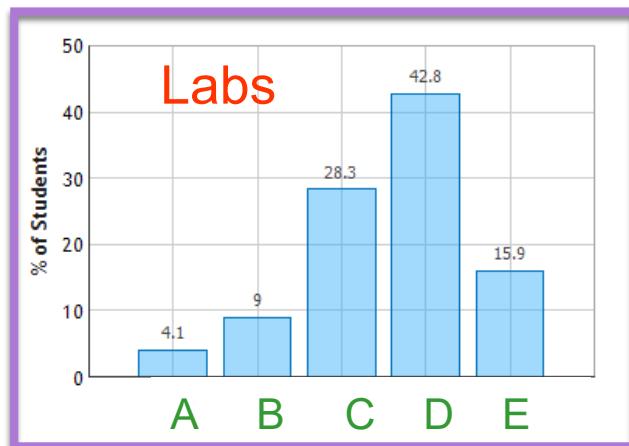
The impact of good pedagogy & technology

The elephant in the room...

How important were _____ in helping you learn the material



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



Past 20 years



Reinforce concepts. Very “cookbook”.



Introductory physics labs: WE CAN DO BETTER

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

Natasha G. Holmes
and Carl E. Wieman

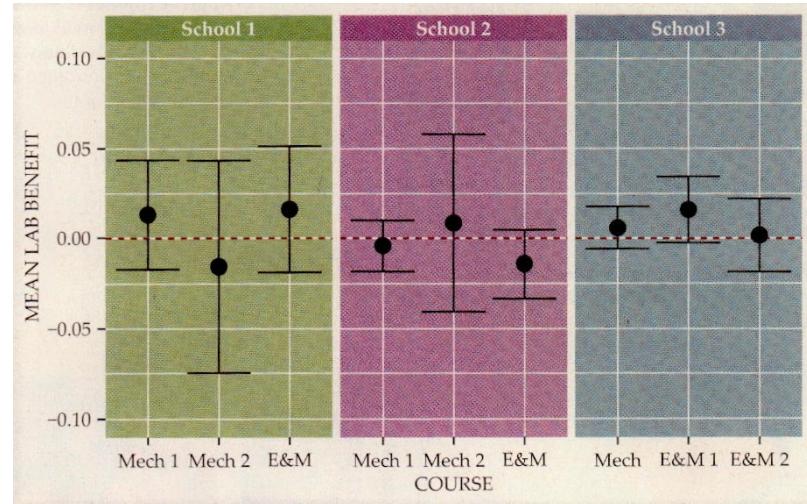
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Research reveals that labs are more effective when their goal is to teach experimental practices rather than to reinforce classroom instruction.

We and others have recently been examining how effective labs are at achieving various goals. What we've found is that traditional labs fall way short of achieving a frequent goal. The work in real life. To see whether that was true, we took advantage of courses in which the lab component was optional. This way, we could compare content mastery of the students w

PHYSICS TODAY

January 2018



...and research shows us a better way

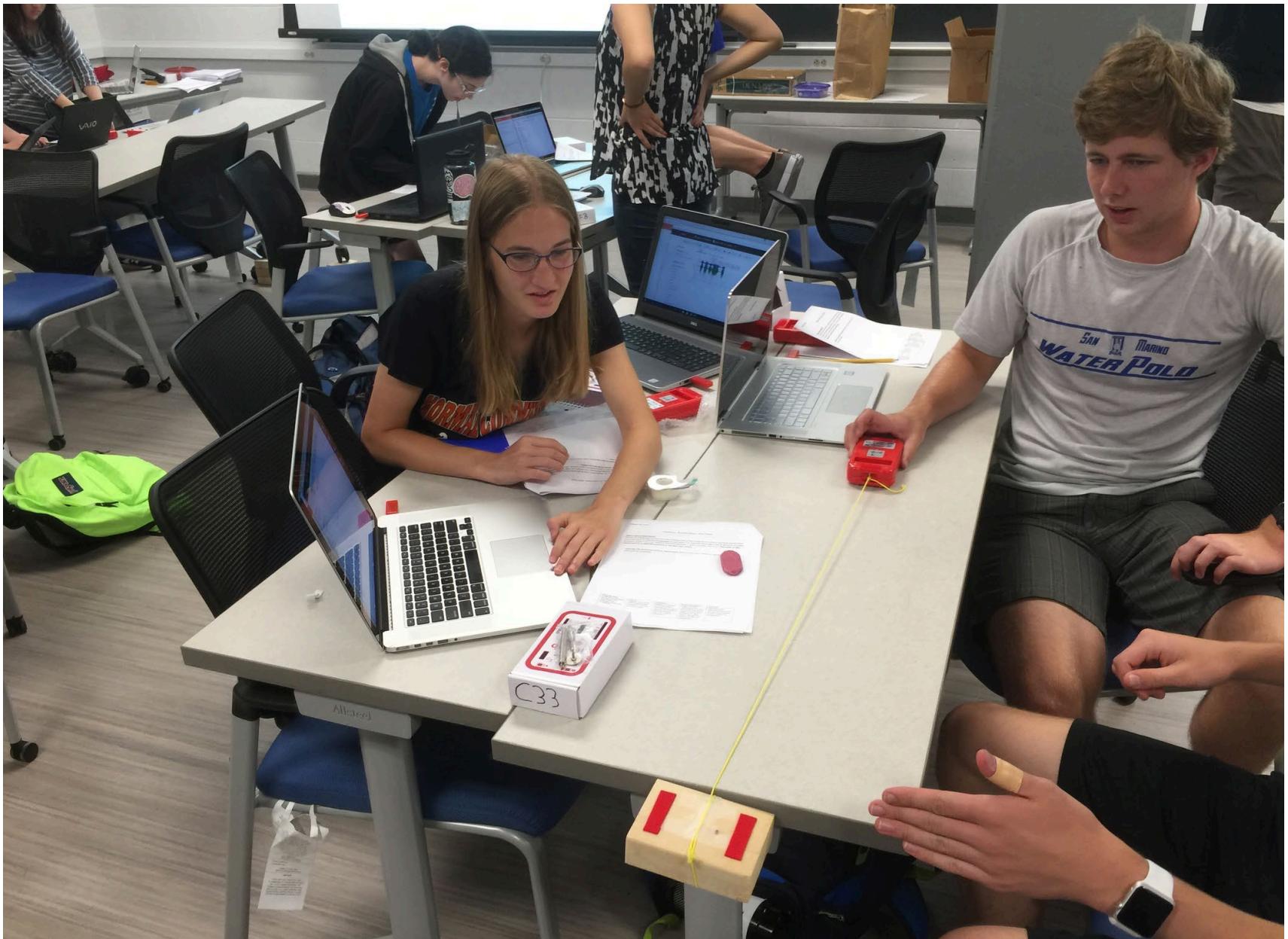


“Learning within a discipline should resemble the practice of that discipline.”

Eugenia Etkina

Think of a few words that describe the most important skills of a physicist.

Critical Thinking, Creative Problem Solving, Confidence

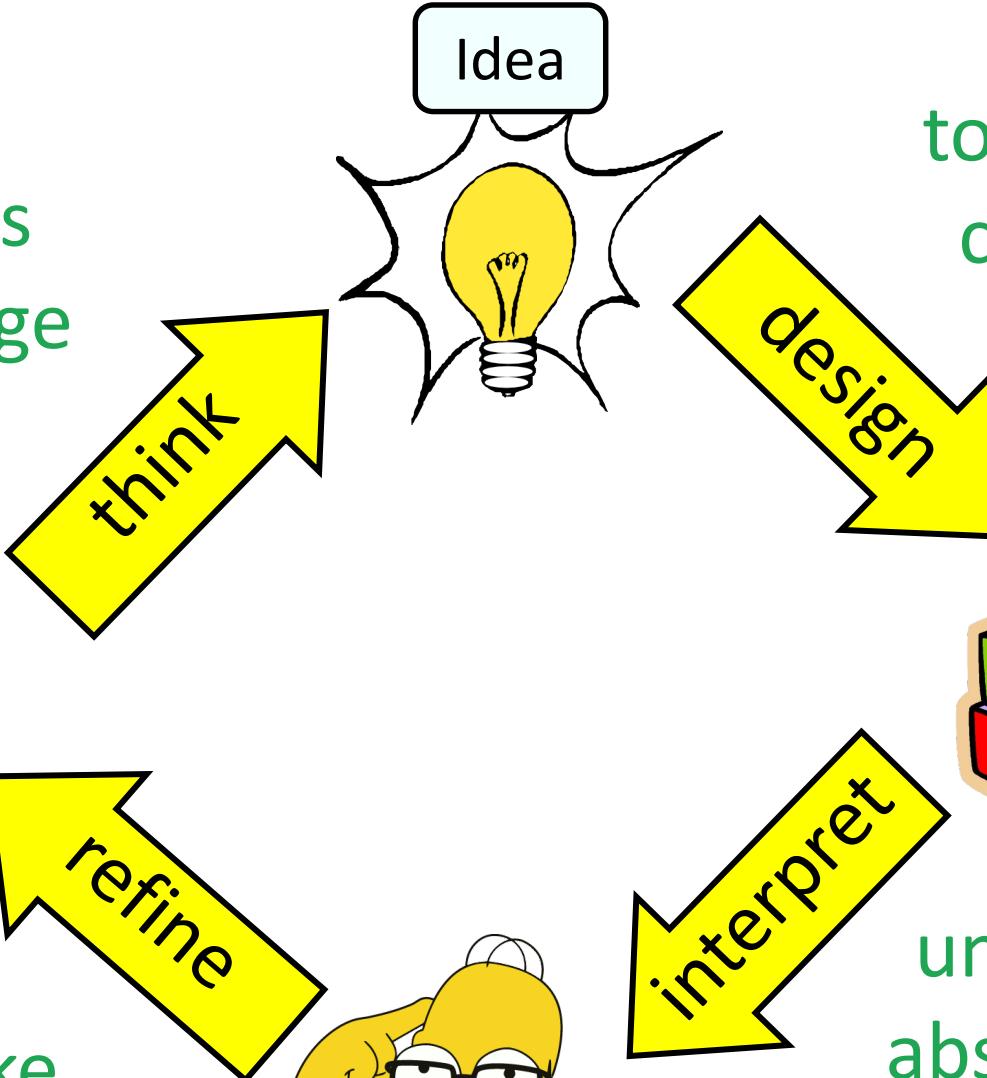


previous
knowledge

!?

make
sense

Idea

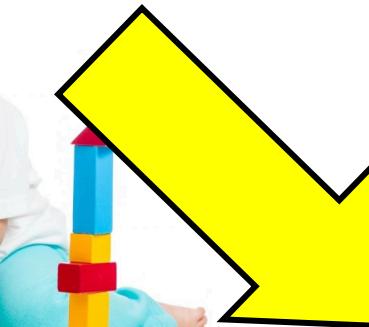


tools & skills,
confidence

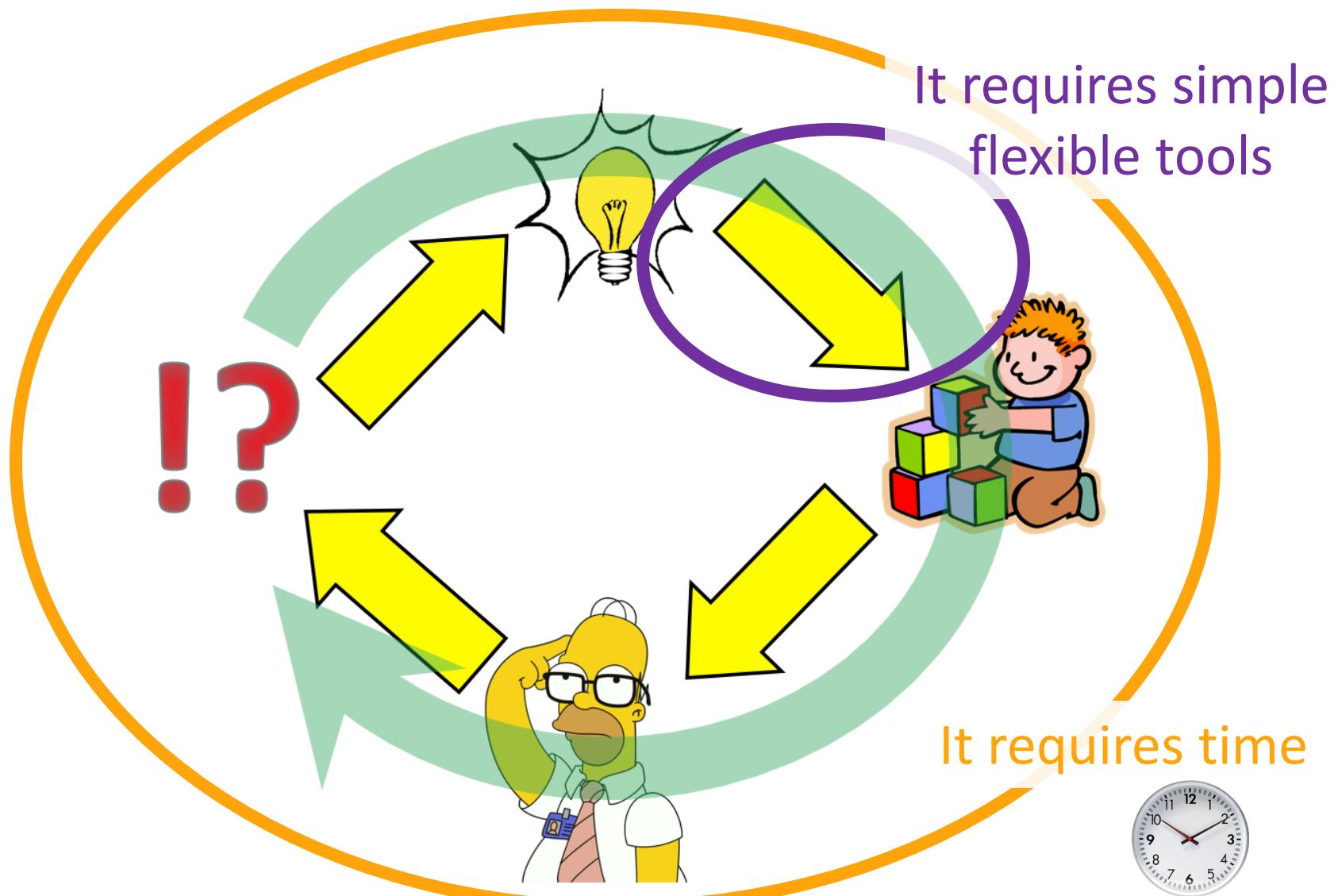
understand
abstract data

Assess

Test



Why don't we teach intro labs this way ?



Our Approach

1) Everyone has a simple flexible tool

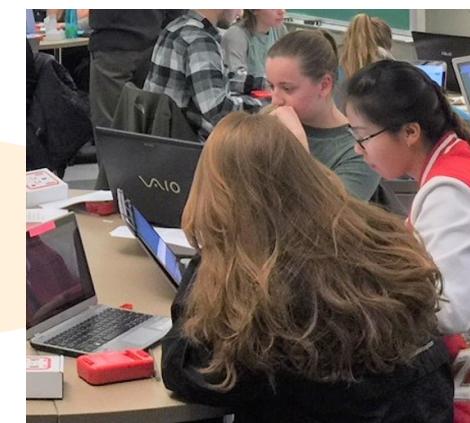


2) Students explore individual pre-lab activities at home...

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



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

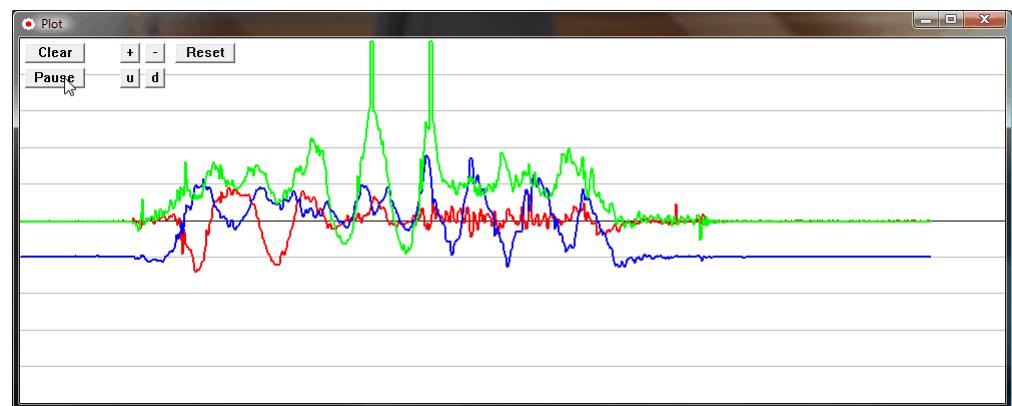
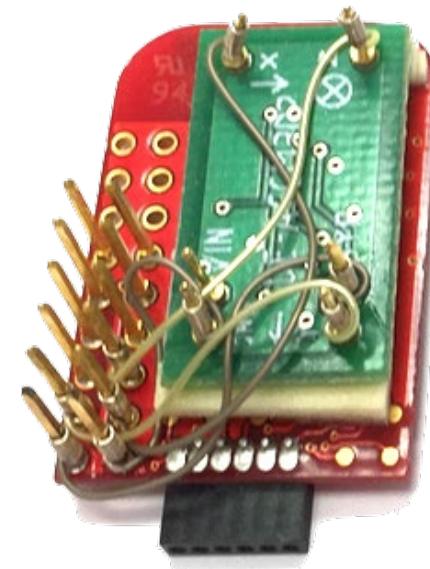


Which brings us to this...

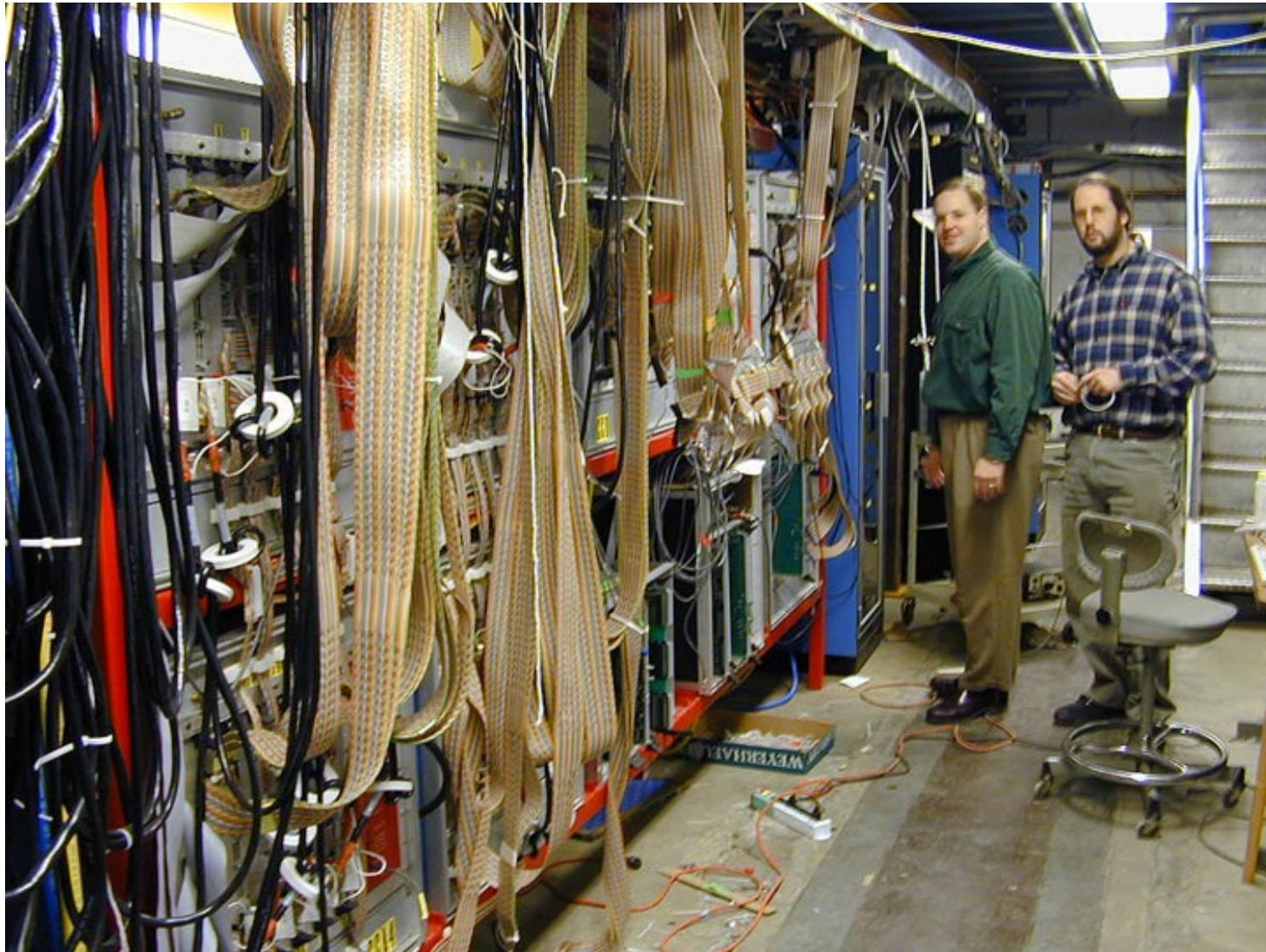


Inexpensive, simple, highly capable
wireless data acquisition hardware

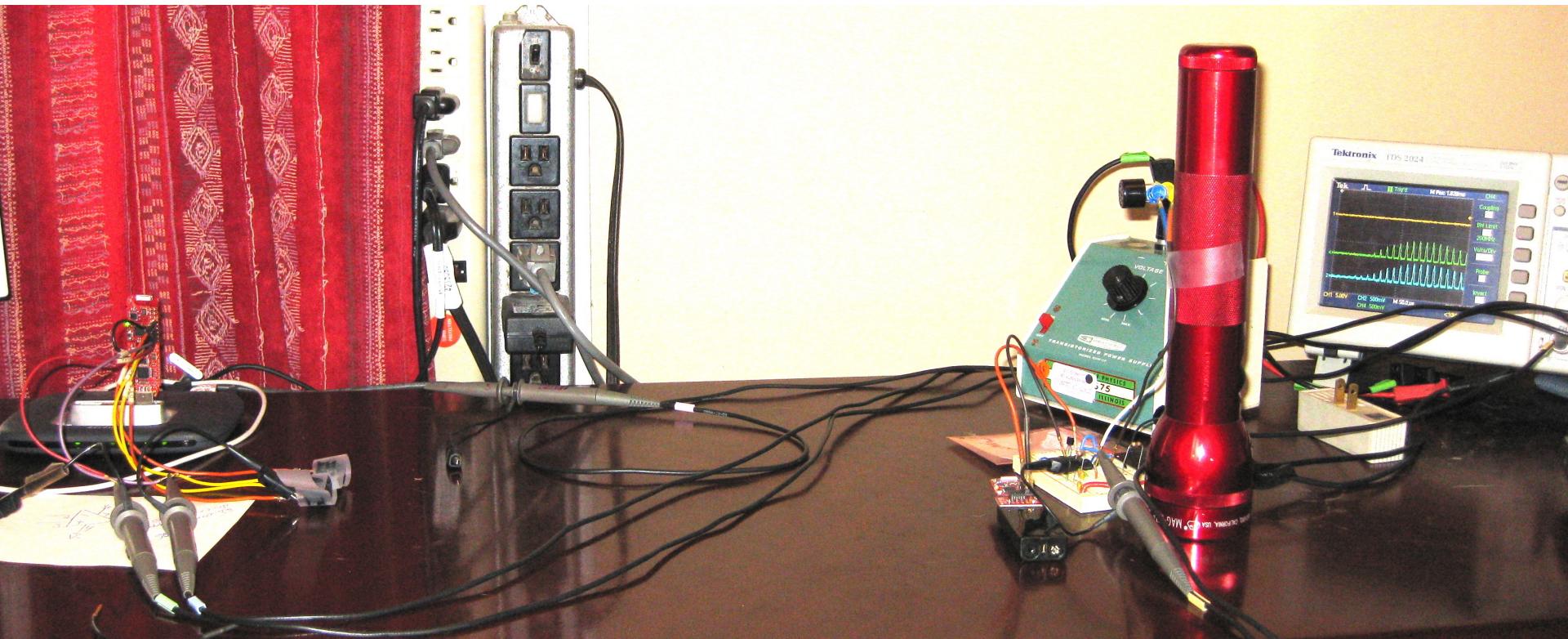
\$49 idea in 2009



ASIDE: Research Feeds Teaching



Spring 2010 was a perfect storm of luck





Spring 2010 – first crude device



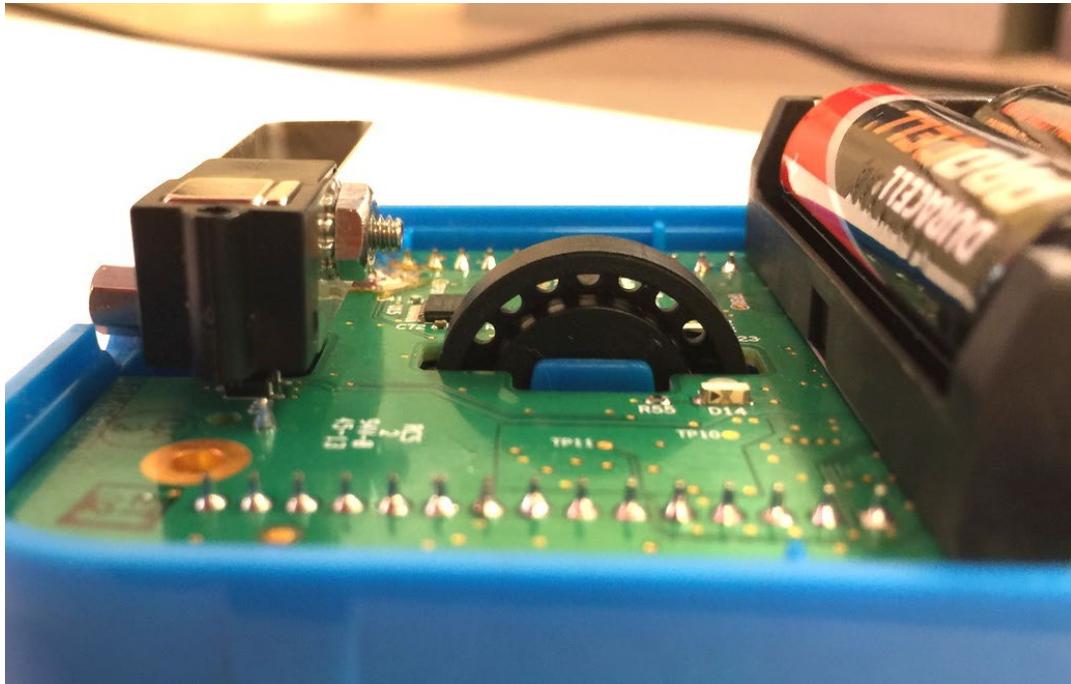
Fall 2010 – 30 prototypes





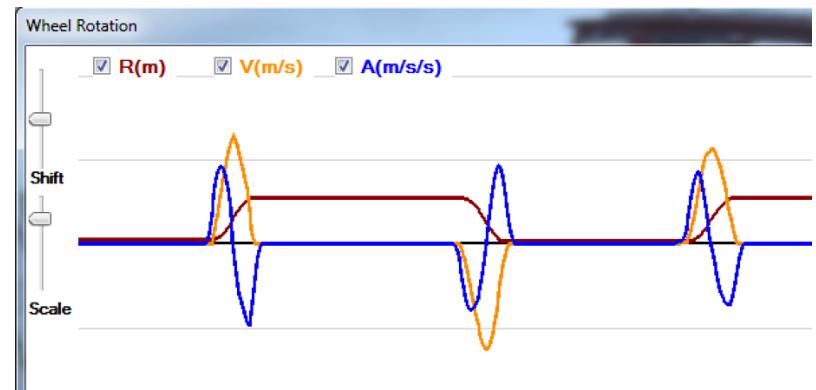
Fall 2010 Clinical Study

Added wheels



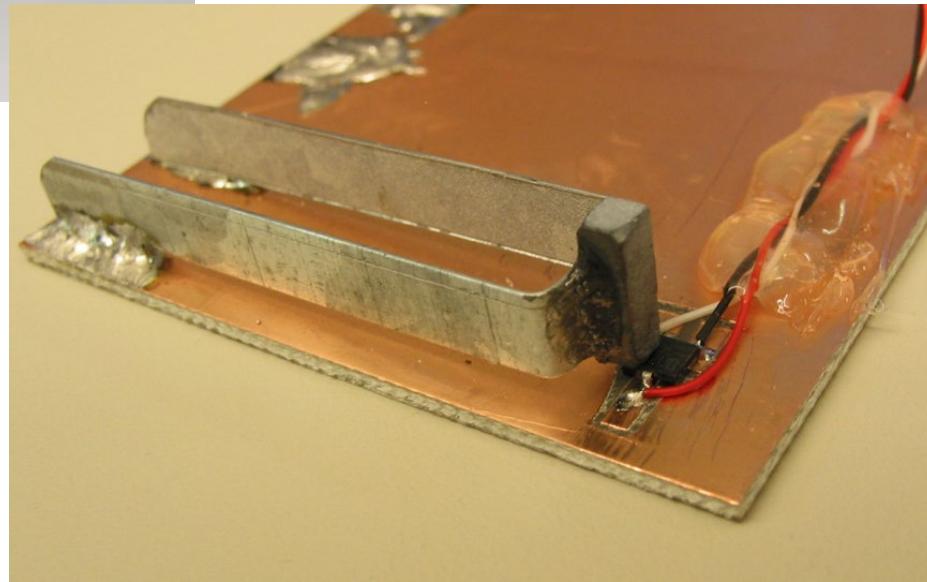
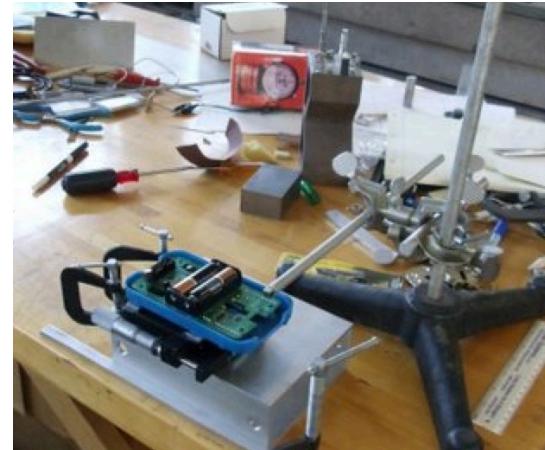
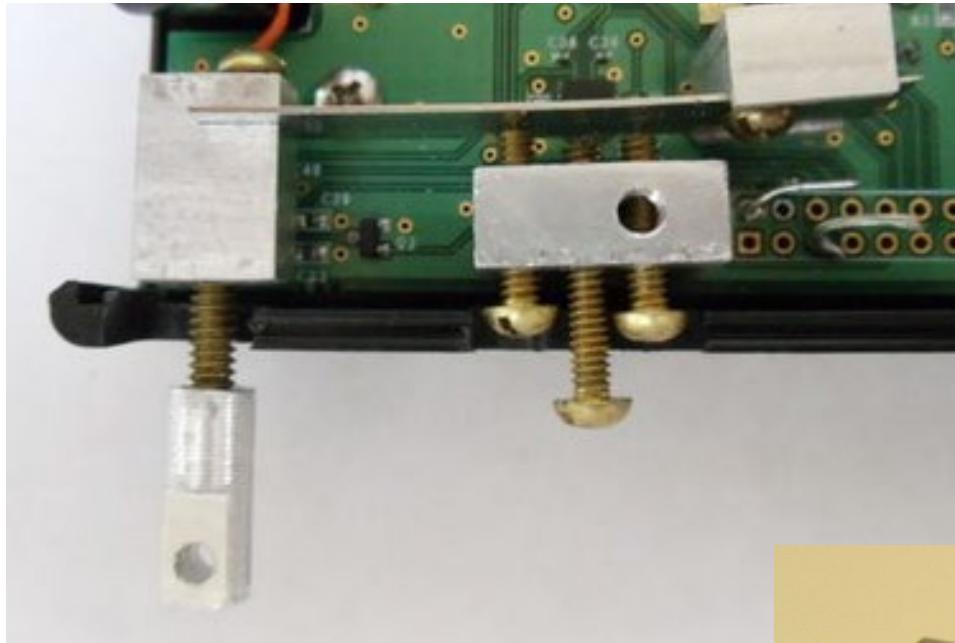
Measures velocity

$$a = dv/dt$$
$$dx = vdt$$



1 mm resolution

Lee Holloway's Force Probe

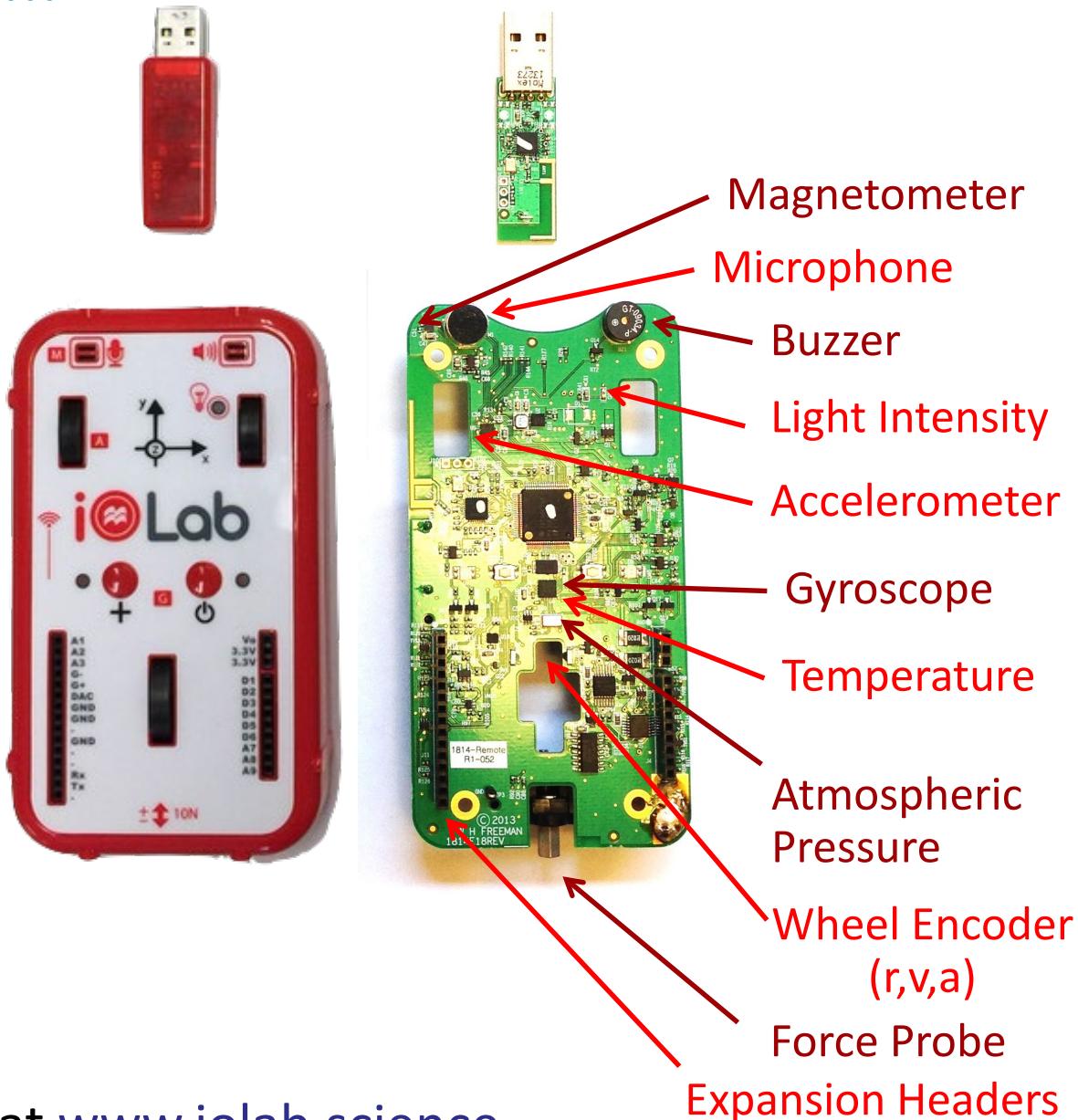


Spring 2013

(made 70 prototypes)



Fast forward...



Docs & software at www.iolab.science

Lets Play

1) Quick Orientation

Wheel, F vs a, SHM, ...



The same activities work for majors, non-majors, CC, High School, ...

2) This week in Physics 101 & 102

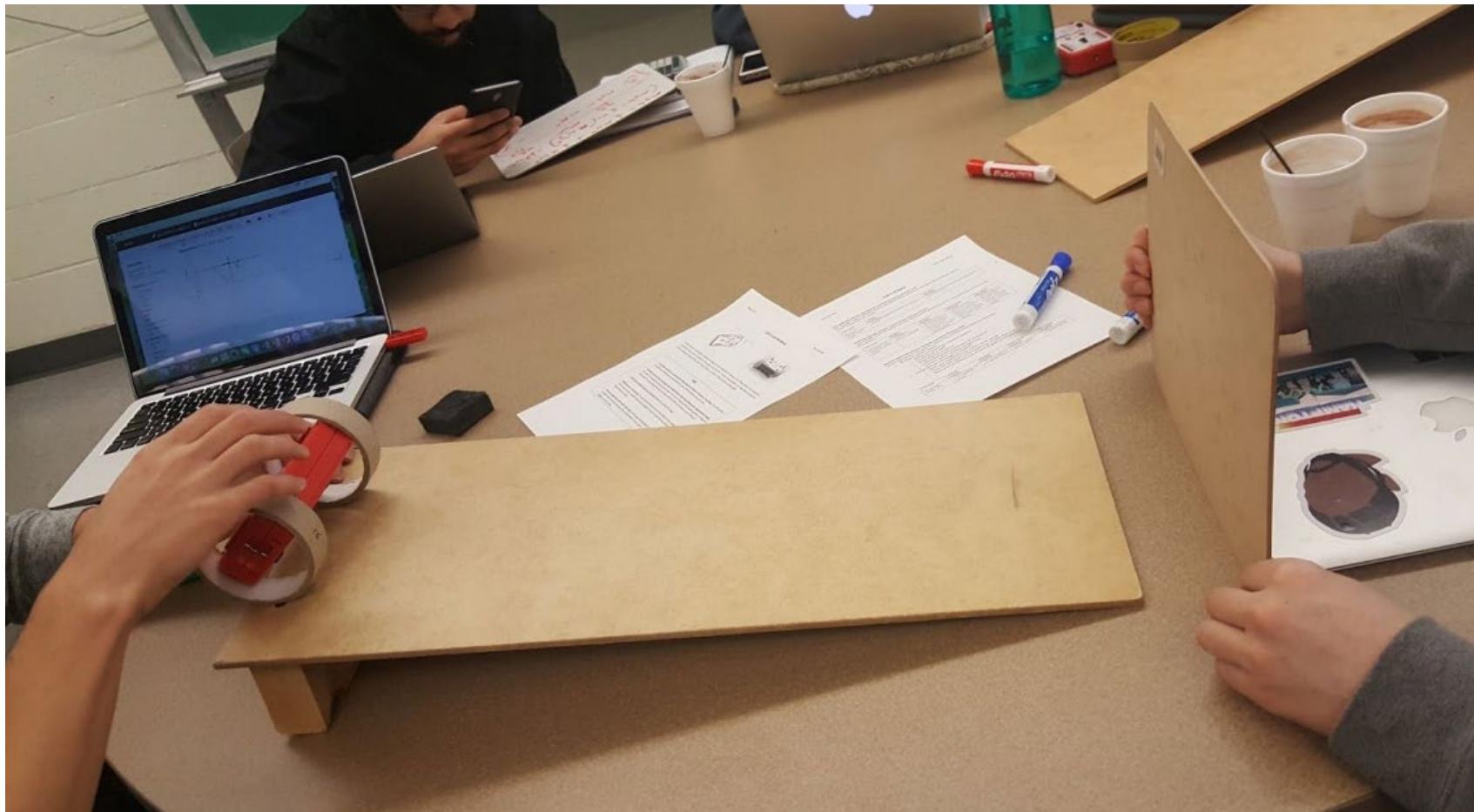
101 (Mechanics): Moment of Inertia.

102 (E&M): Calculate current in wire by measuring B

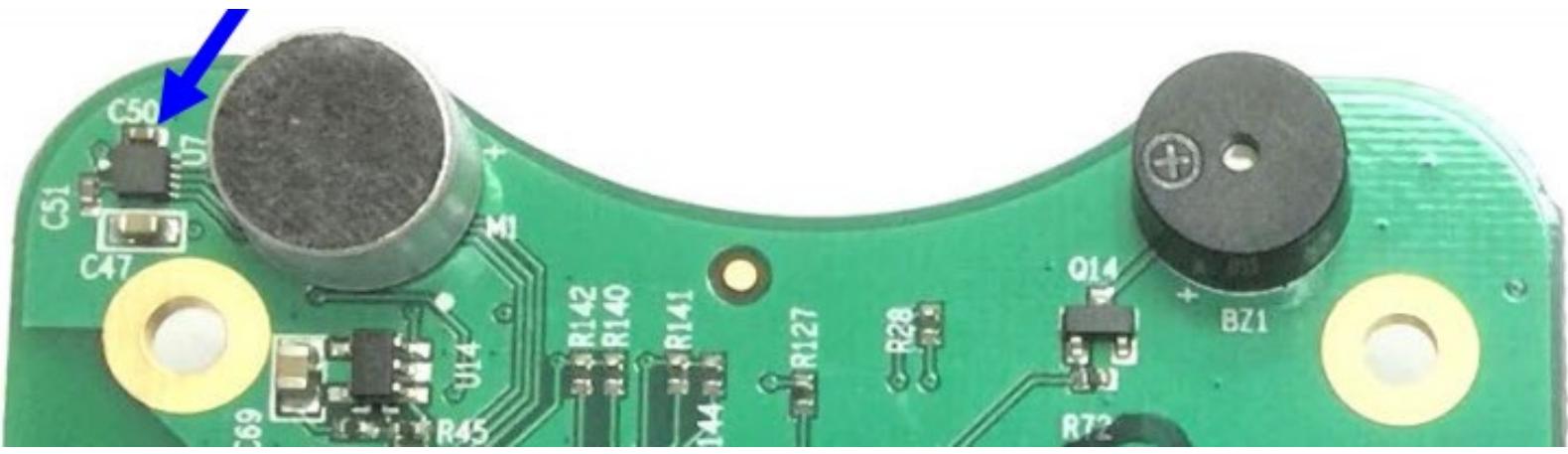
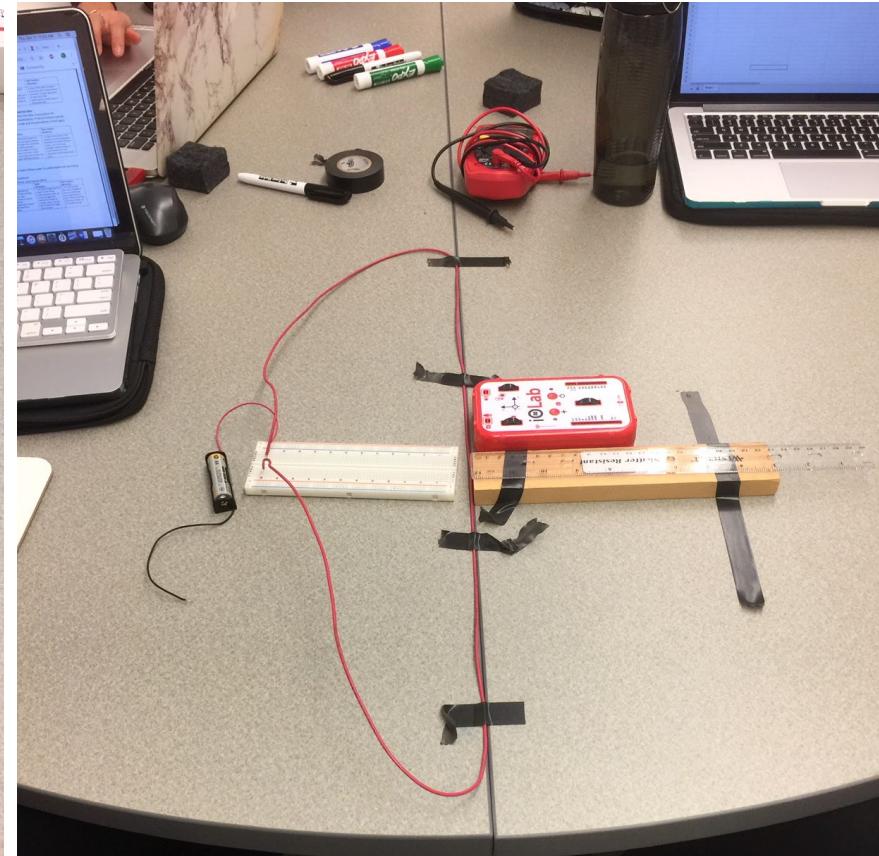
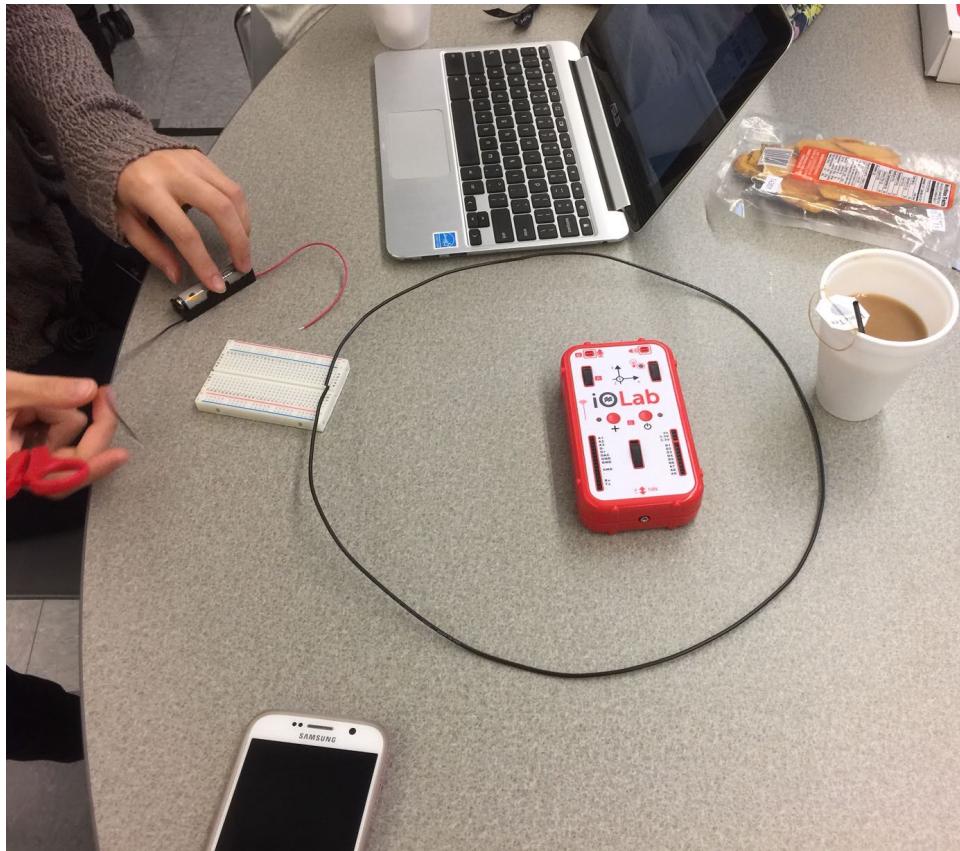
3) Some things we didn't think of right away

Quick Orientation

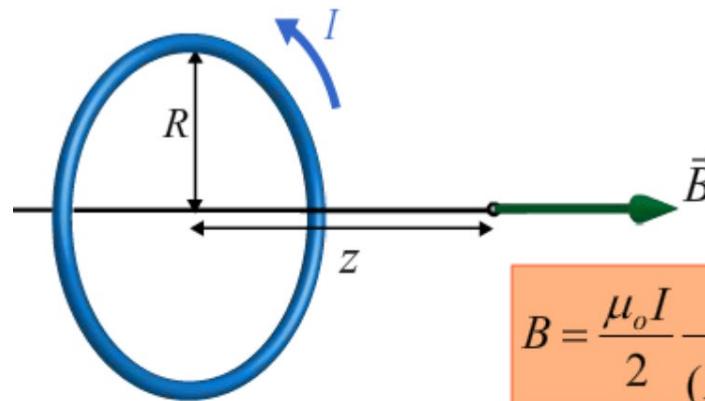
Moment of Inertia (several ways)



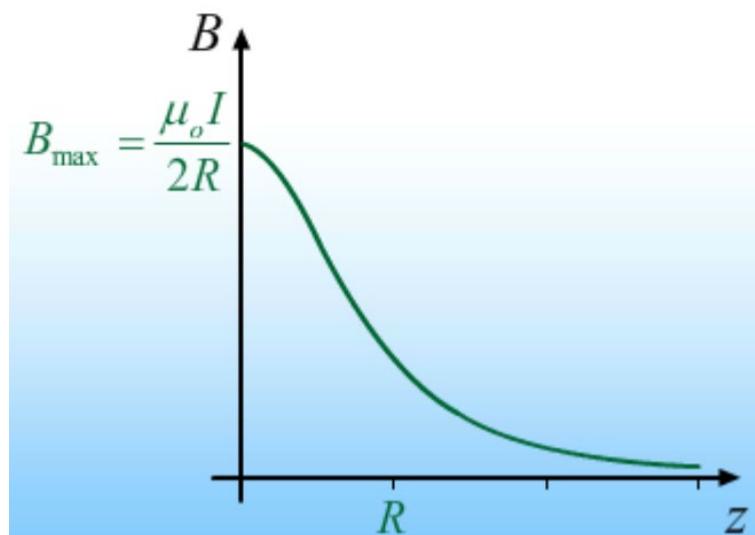
Calculate current in wire by measuring B (2 ways)



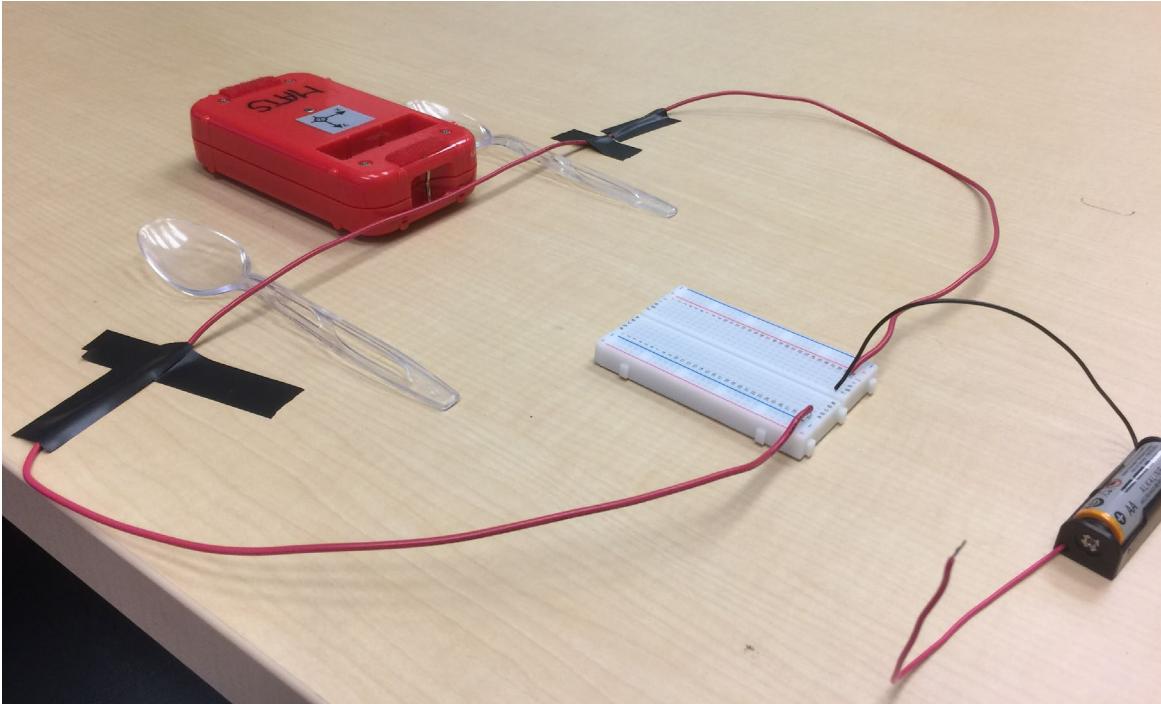
Using a Current Loop



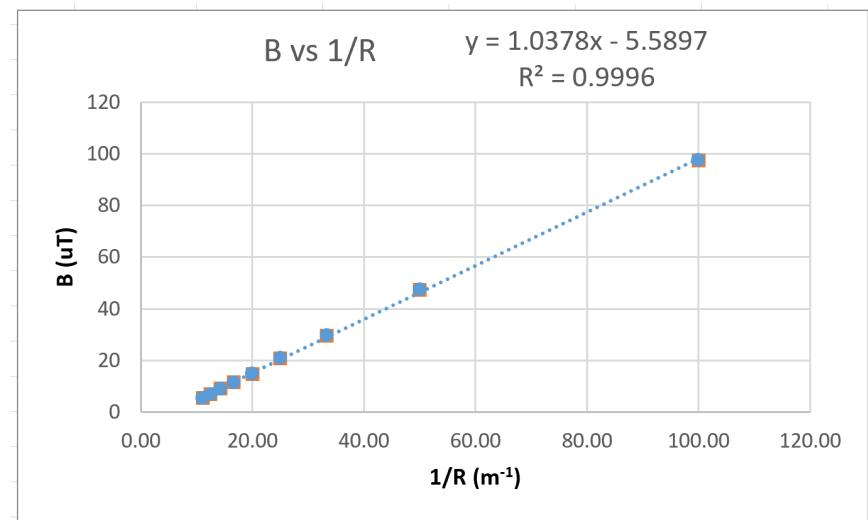
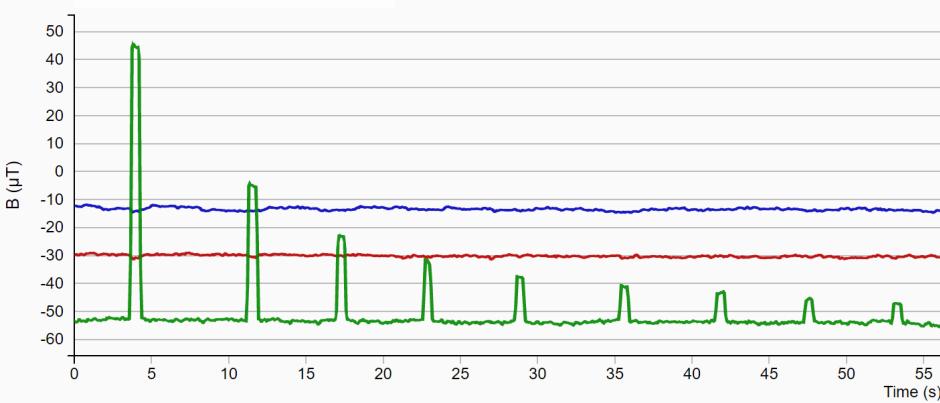
$$B = \frac{\mu_o I}{2} \frac{R^2}{(R^2 + z^2)^{3/2}}$$



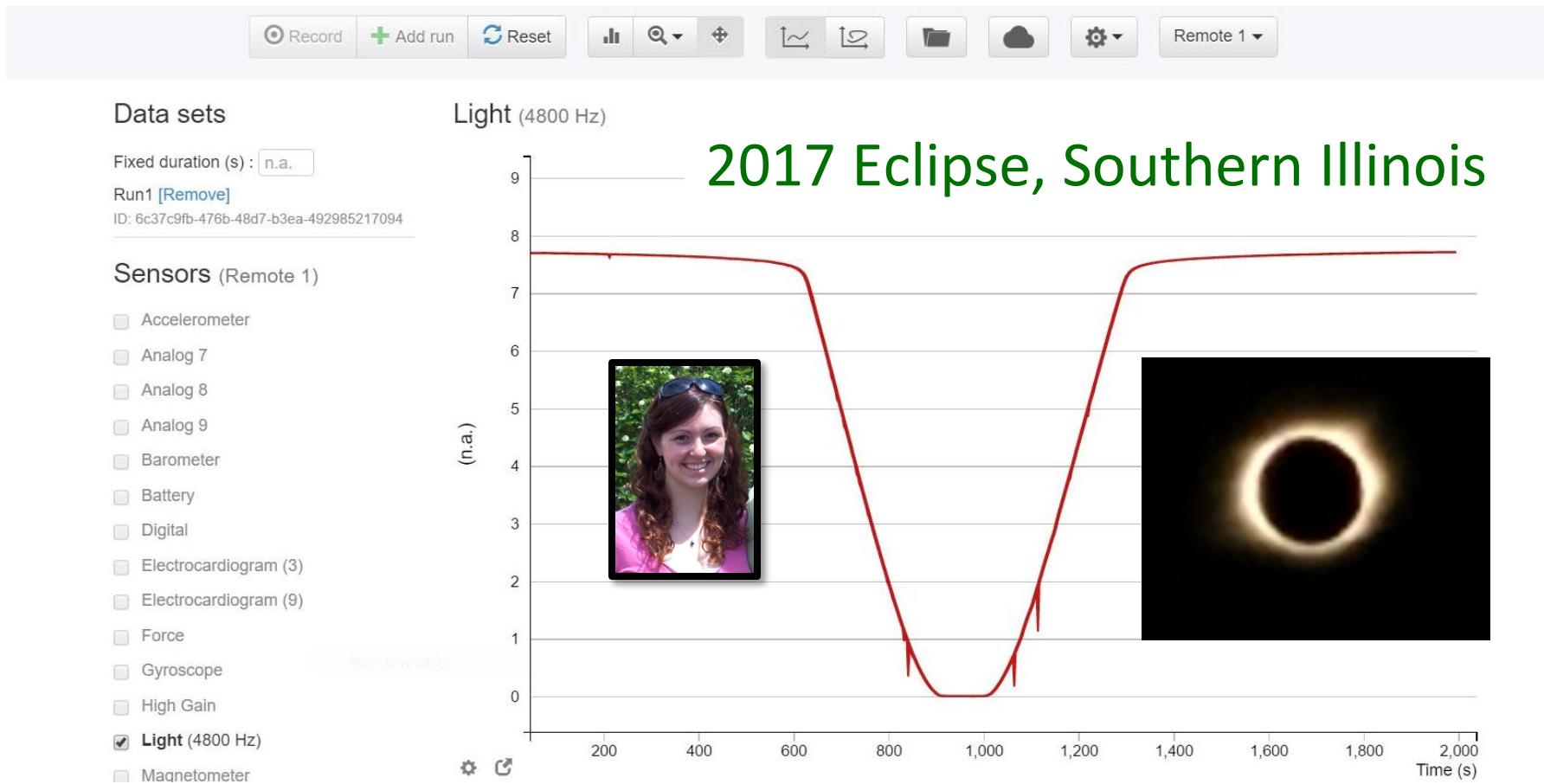
Doing the other experiment carefully:



$$B = \frac{\mu_0 I}{2\pi r}$$



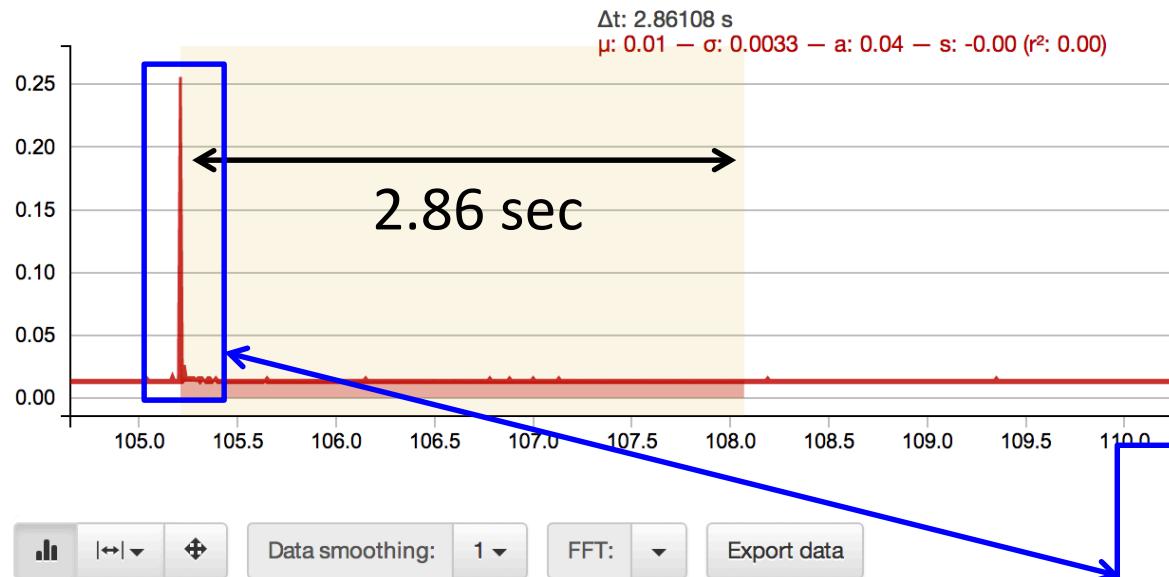
Science happens everywhere



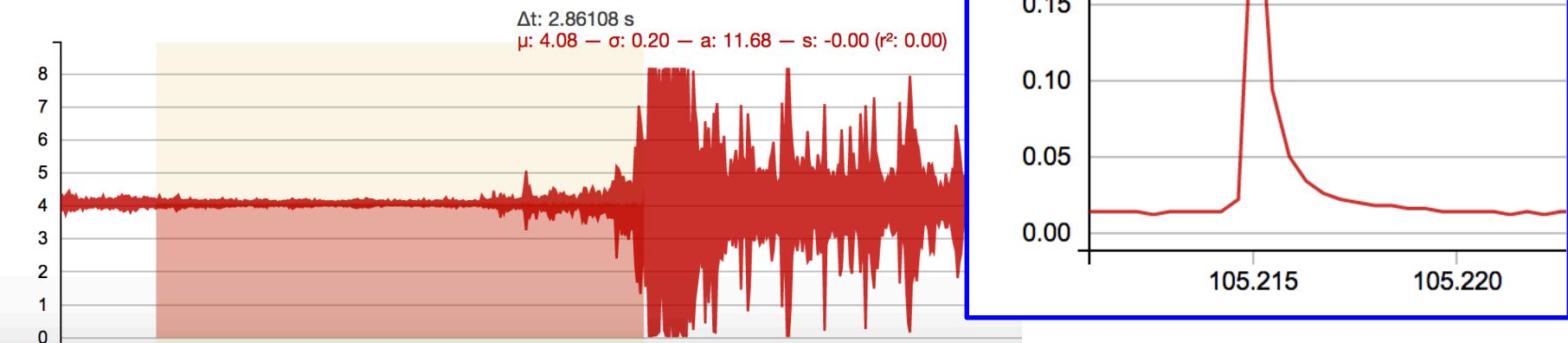
Speed of Sound

Lightning & Thunder

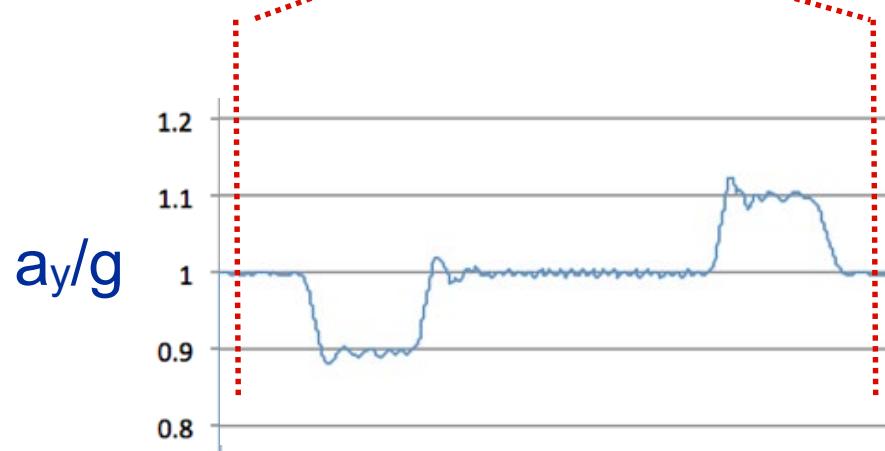
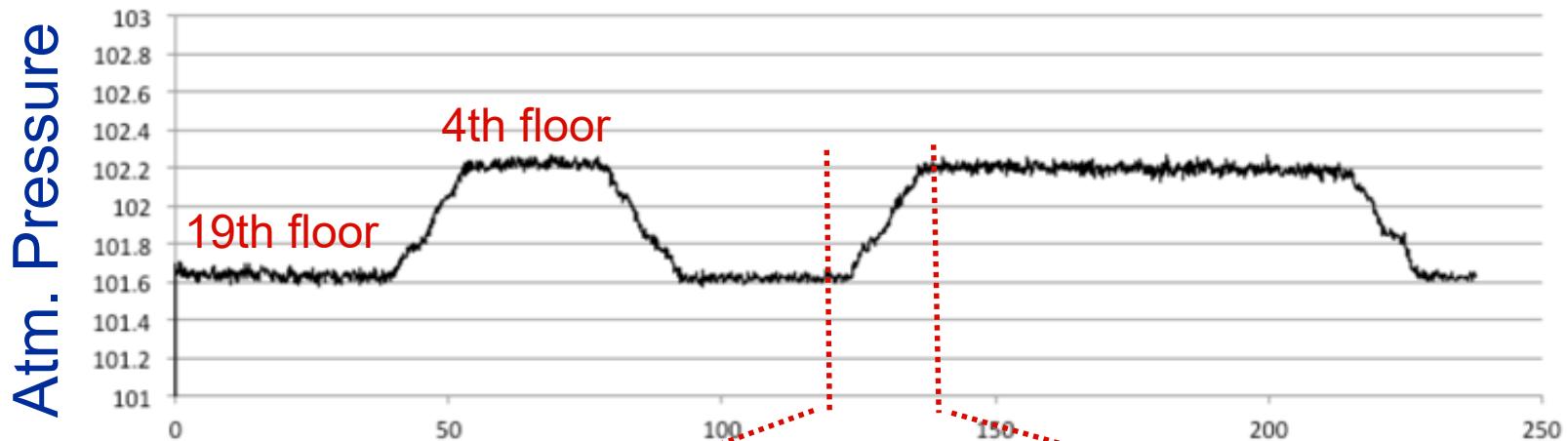
Light 2400 Hz



Microphone 2400 Hz



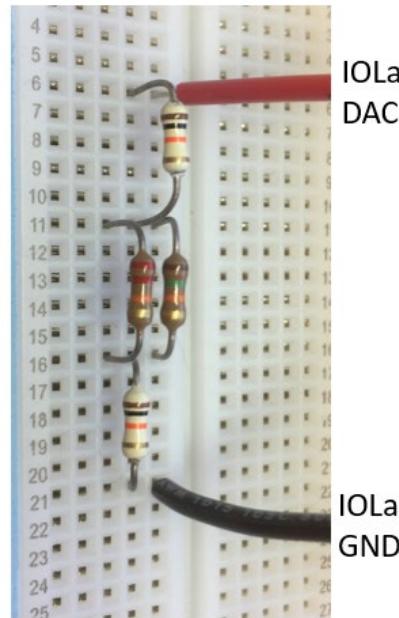
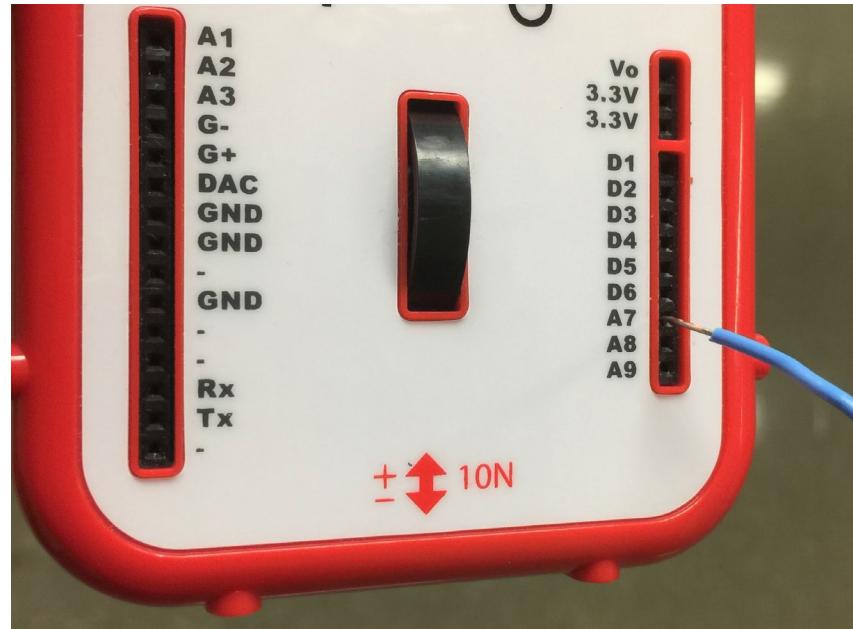
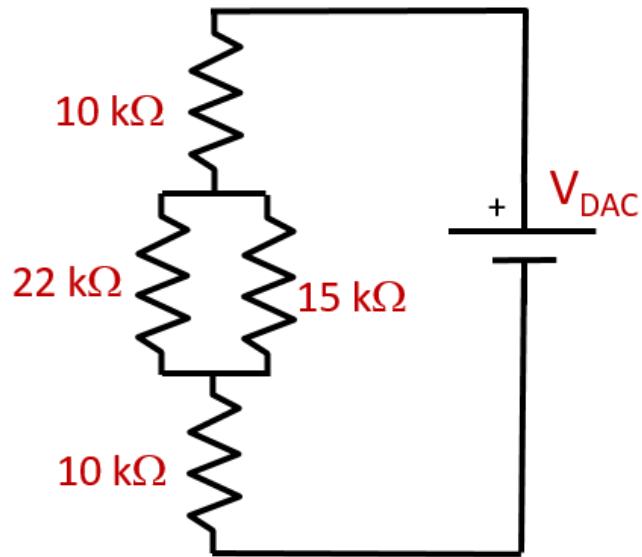
Science happens everywhere



AAPT Hotel Elevator

Ziploc Bag

Analog inputs & outputs are great for circuit labs



ECG Plugin



RA
Right Arm

LA
Left Arm

C1 C3 C6

RL
Right Leg
(2 electrodes)

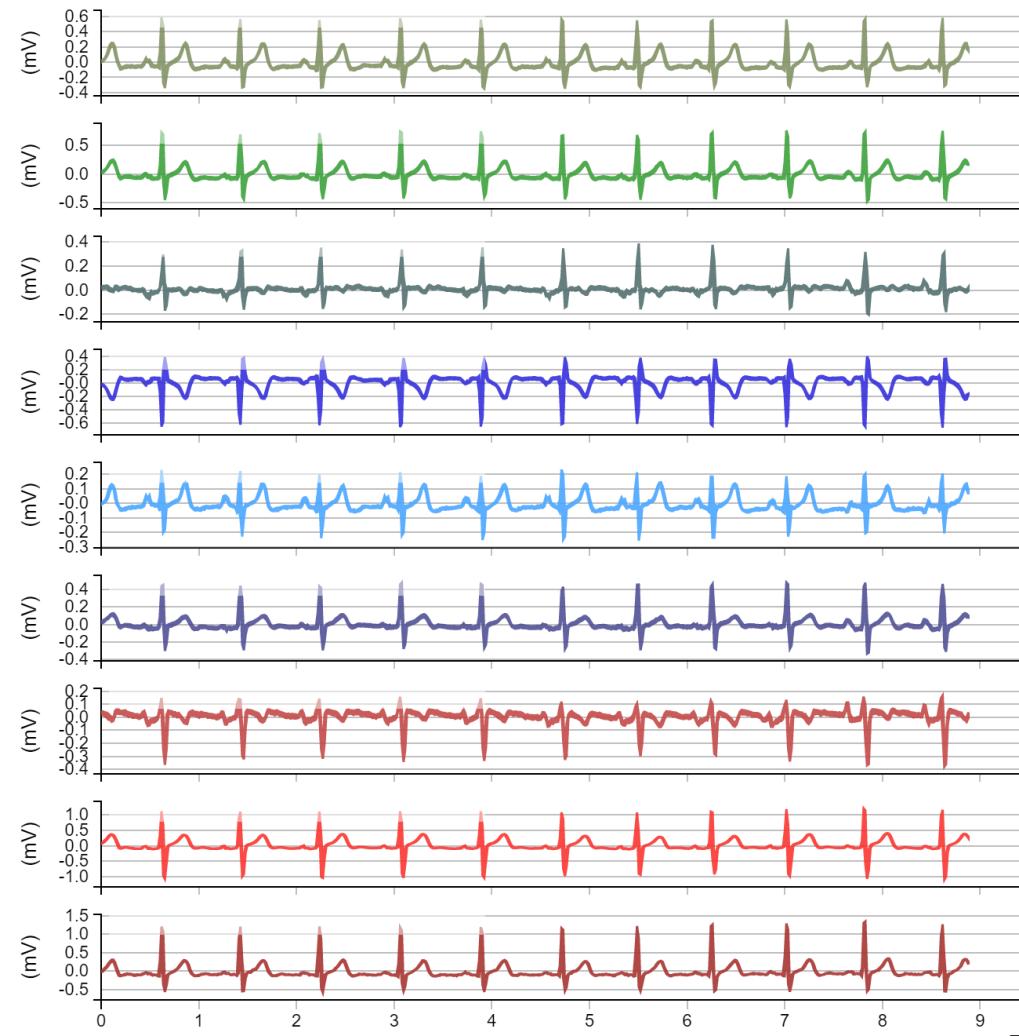
LL
Left Leg

Developed and assessed in collaboration with UIUC electrophysiology experts, UIUC Med School, and DIA

Clinical study published in Cho et al. BMC Res Notes (2015) 8:342



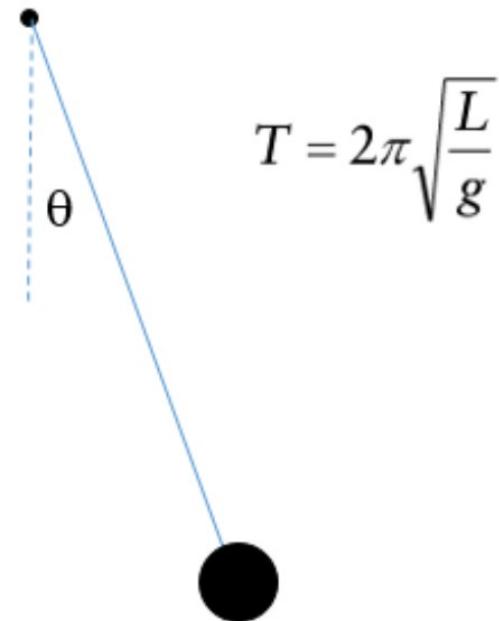
Electrocardiogram (9) I II III aVR aVL aVF V1 V2 V3 V4 V5 V6



Dorm-room Pre-Lab 9

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.

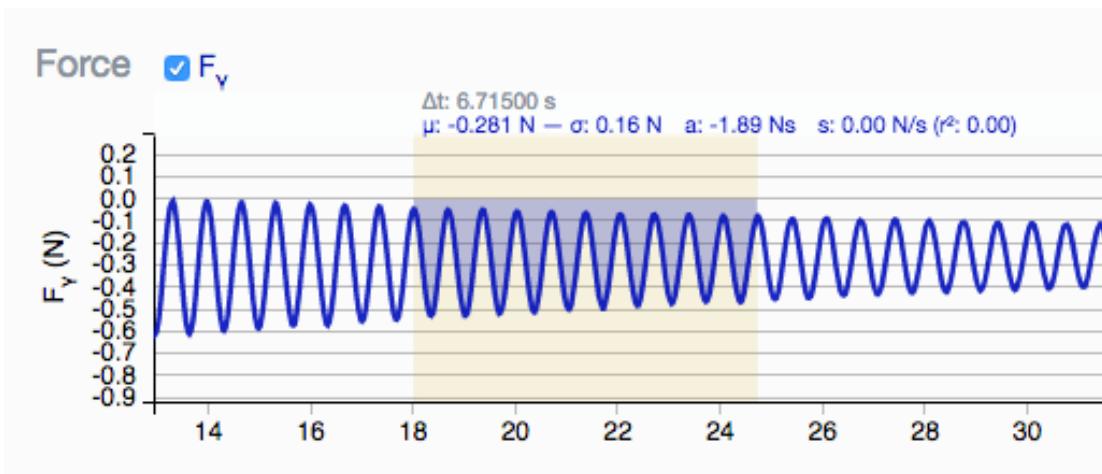
Briefly comment on whether your measured period is consistent with the prediction you get using the formula from class.



$$T = 2\pi \sqrt{\frac{L}{g}}$$

Share pictures & data with your instructor

Example prelab picture, data, and comment:



“...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:

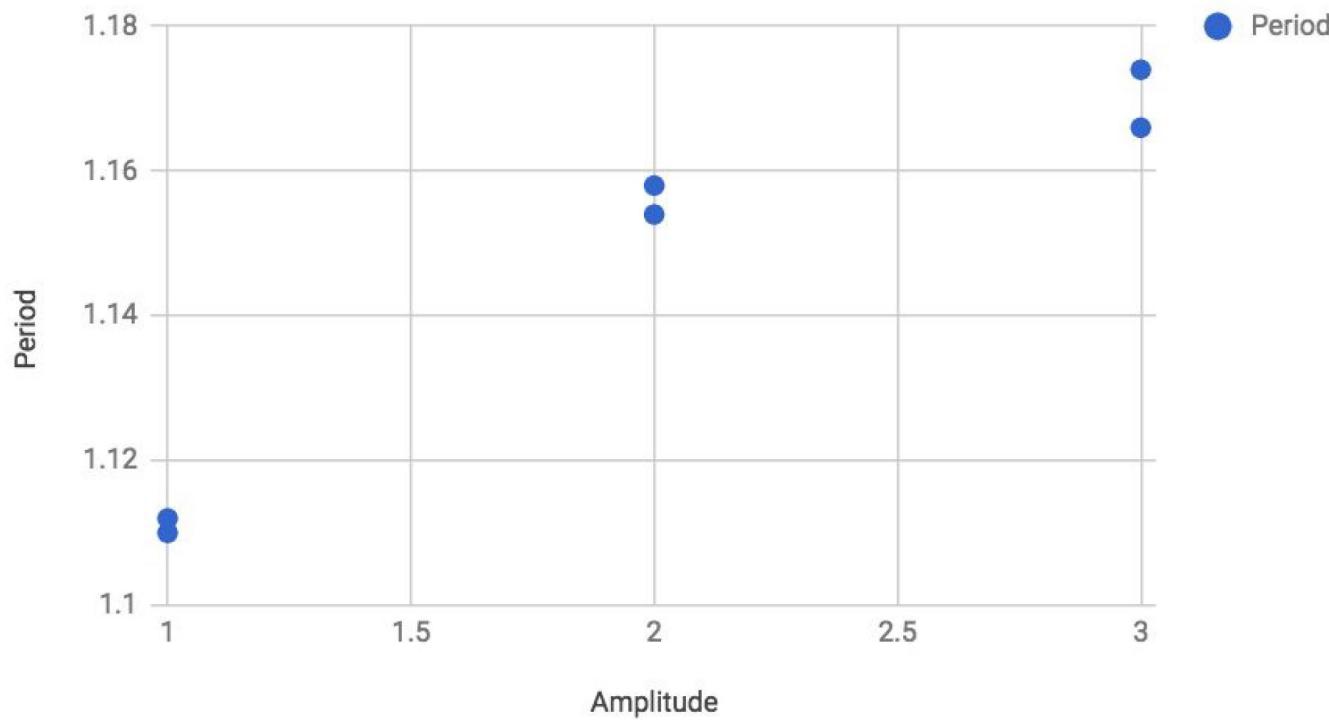
“A pendulum has the same period regardless of the amplitude of the swing.”



Students work in teams
& write group report.

Groups write lab reports in class (3-10 pages) ...

Period vs. Amplitude

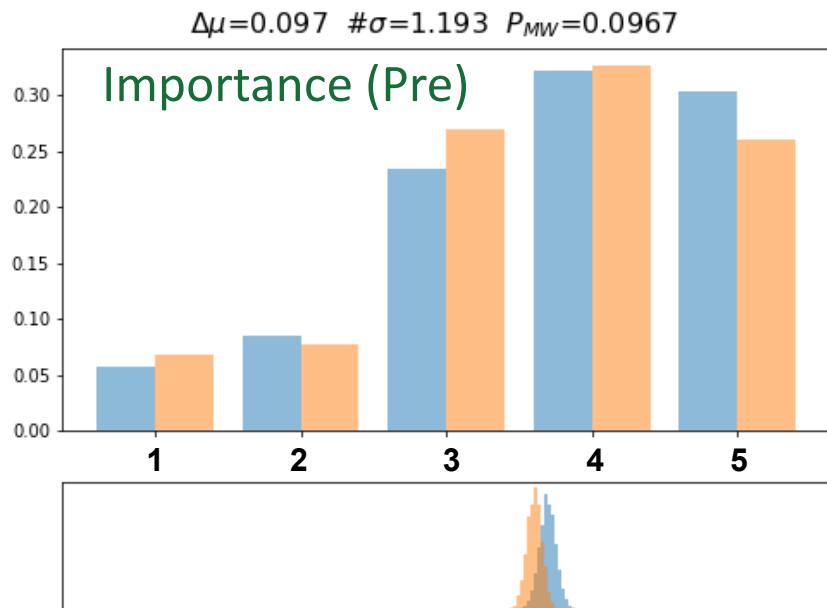


Analysis:

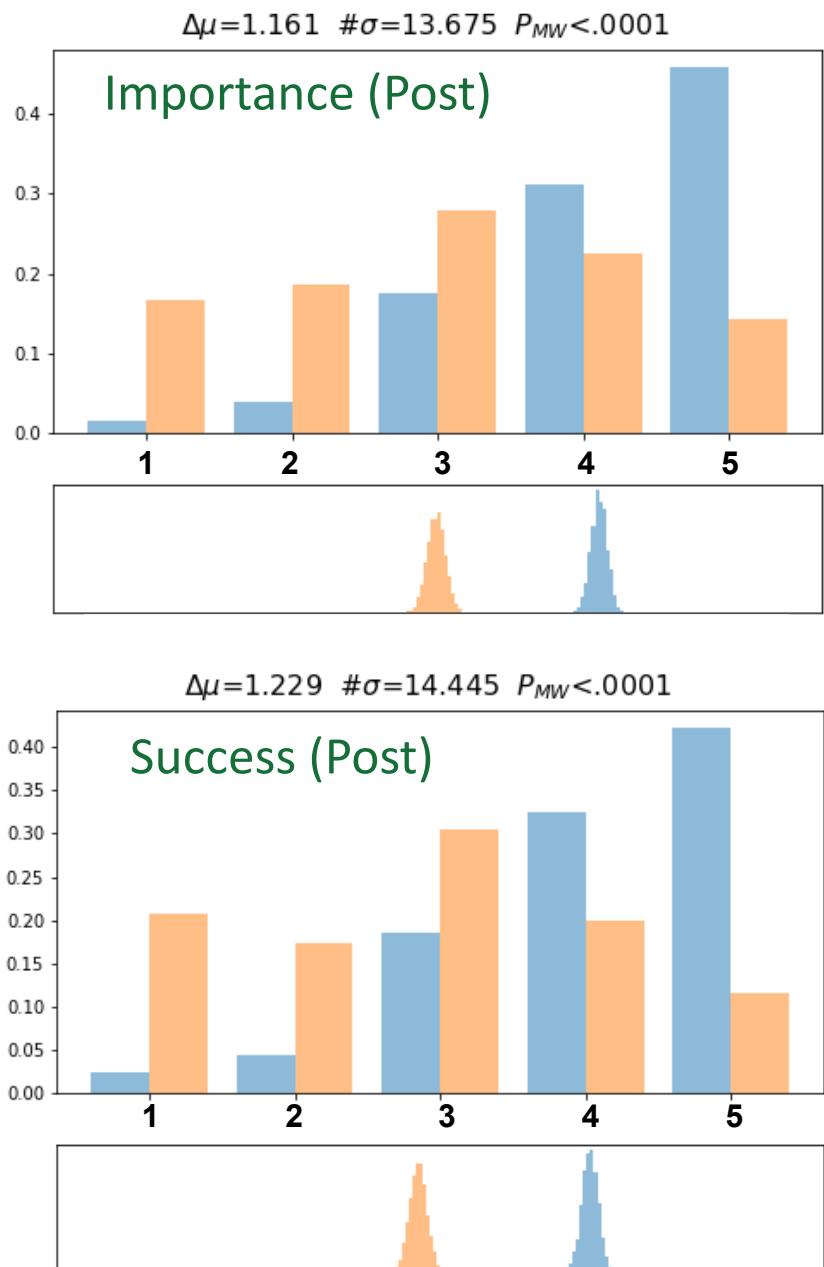
Given the data collected in the lab, it is not possible to say that a pendulum has the same period regardless of the amplitude of the swing. When looking at the data as well as the uncertainty associated with the data points, the uncertainty values do not overlap and so it is not possible to say that these numbers could be the same. The uncertainty was collected by doing each amplitude multiple times in order to make sure that the period was as accurate as

Lab Goals Survey:

“Learning to design your own experiment”



■ Reformed
■ Traditional



Collaborators

(source of the best ideas)



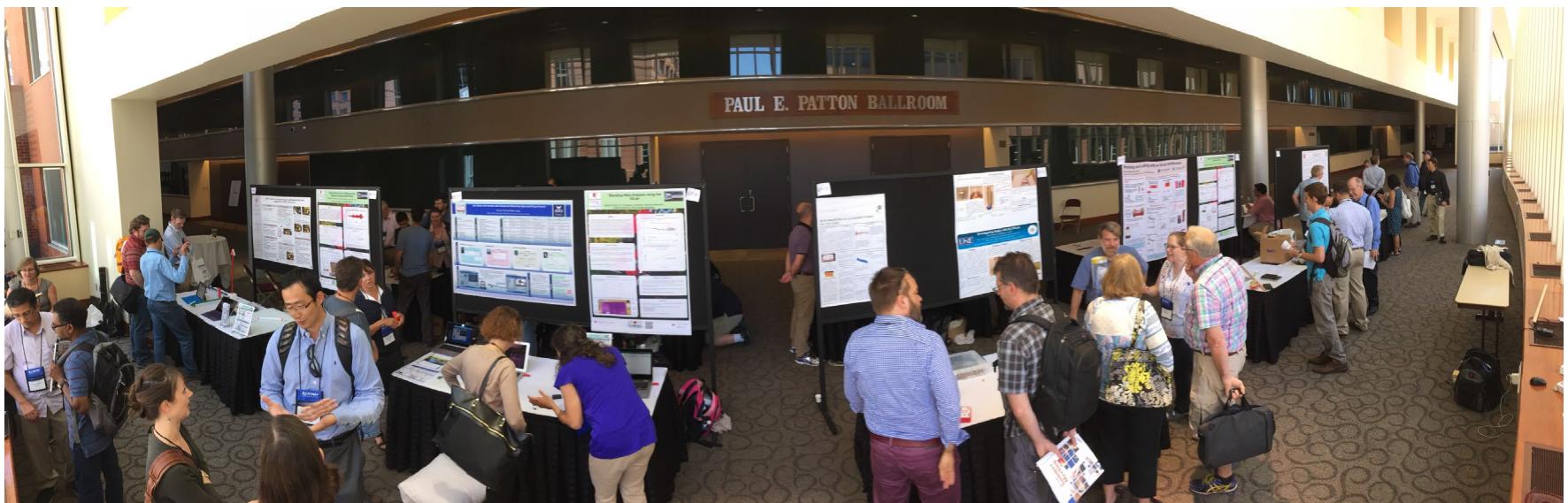
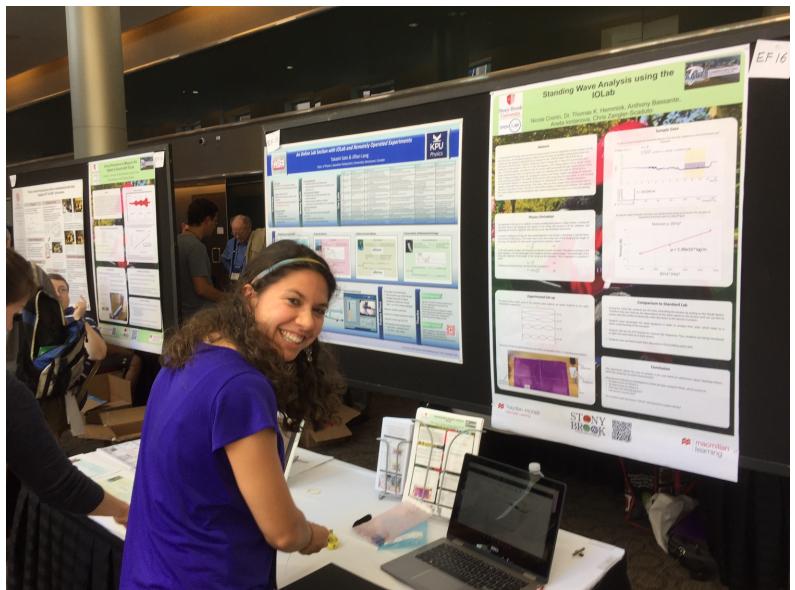
UPPSALA
UNIVERSITET



Michigan Tech



28 IOLab abstracts at 2017 AAPT summer meeting

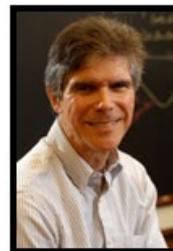


Takeaway:

- Learning is an active enterprise; keeping students engaged is key.
- Technology is useless without good pedagogy and good content.



Gary



Jose



Tim



Morten



Mats



Katie



Bill



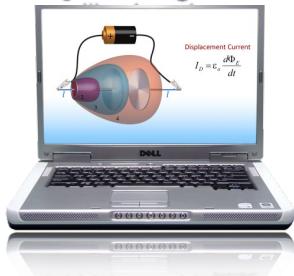
Brianne



Jason



FlipItPhysics



Devyn



Gabe



Sam



Muxin

iClicker