Amsterdam University College

Constraints in Physics Lab Courses

the Good, the Bad, and the Pandemic

Forrest Bradbury — Amsterdam University College (NL)

Co-author:
Freek Pols — Delft University of Technology (NL)

- Background
- Motivations
- Challenge
- Choices
- Structure
- Results

What am I doing at an APS March Meeting?

Serendipitously pandemic resilient lab course:

- Flipped teaching
- Open inquiries
- Maker tools

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AUC

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Additional Project Team Members:
Paul Vlaanderen — University of Amsterdam (NL)
Jasper Homminga — University Twente (NL)

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Jan Koetsier — Amsterdam University College (NL)

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Setting: Amsterdam University College

- Small liberal arts & sciences college
- ~100 “science” majors per year
- Limited lab course offerings
- No in-house laboratories

Goals:

- Serve multi-disciplinary science students
- Experience research cycle

Constraints in & of science labs

“Doing science” involves constraints:

- Constraining other variables & environmental noise
- Constraints of tools (precision, accuracy, sampling rate, time)
- Constraints of mathematical models

Giving lab courses involves constraints:

- Class-room space
- Limited (functioning) equipment
- Limited contact time

My path to "open inquiry" (doing science)

•Background
•Motivations
•Challenge
•Choices
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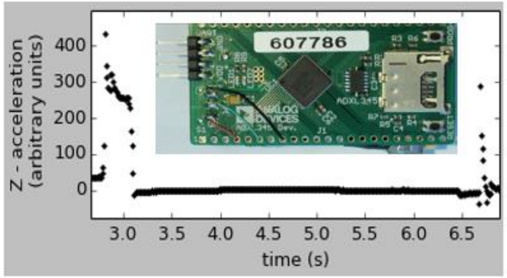
•Results

<u>Rocket project in classical mechanics</u>

"Three dimensional project":

- Theory
- Numerical simulation
- Experiment



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My path to “open inquiry” (doing science)

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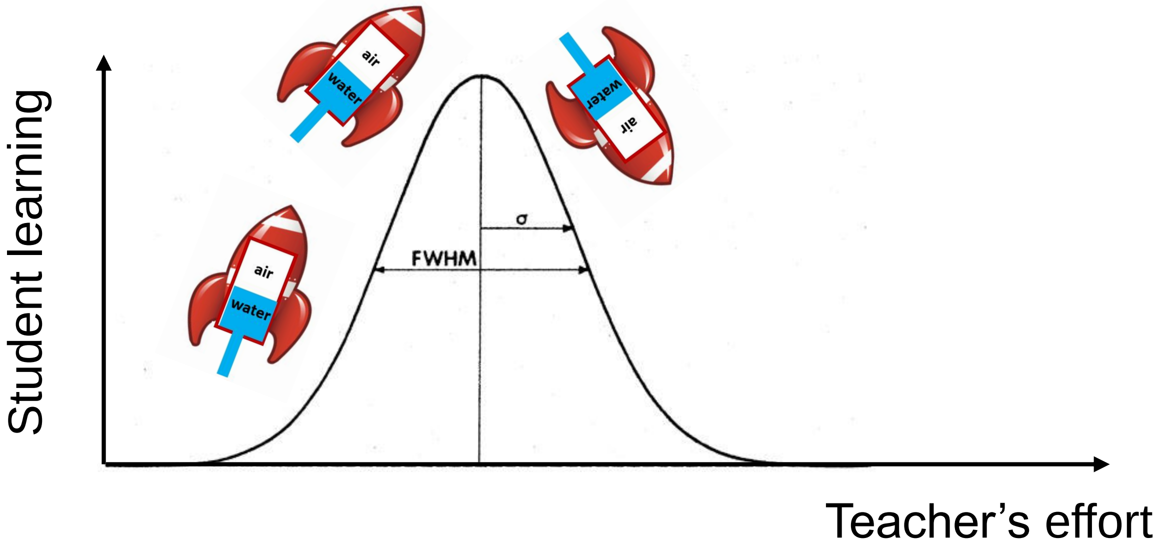

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Learning goals of science labs?

- Background
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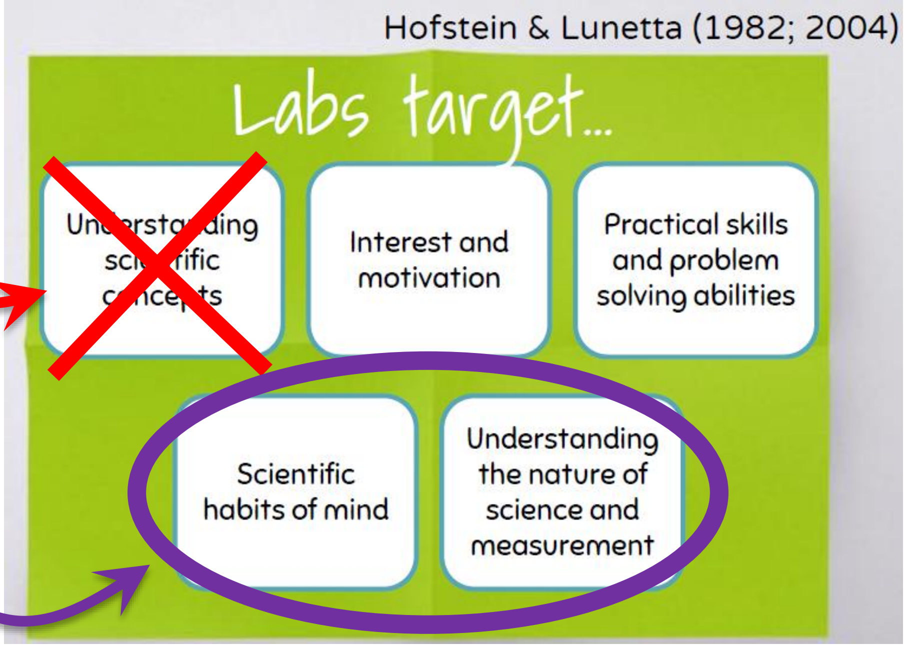
- Not effective
- Open inquiry is advantageous



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Slide from Cornell Professor Holmes' AAPT New Faculty Workshop presentation, 2017
Learning goals: Hofstein & Lunetta, Rev. Educ. Res. 52(2), 201–217, 1982 and Sci Ed 88:28–54, 2004
Ineffectiveness: Holmes, Olsen, Thomas & Wieman, Phys. Rev. Phys. Educ. Res. 13, 010129, 2017
Open inquiry: Wilcox & Lewandowski, Phys. Rev. Phys. Educ. Res. 12, 020132, 2016

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Learning goals of science labs?

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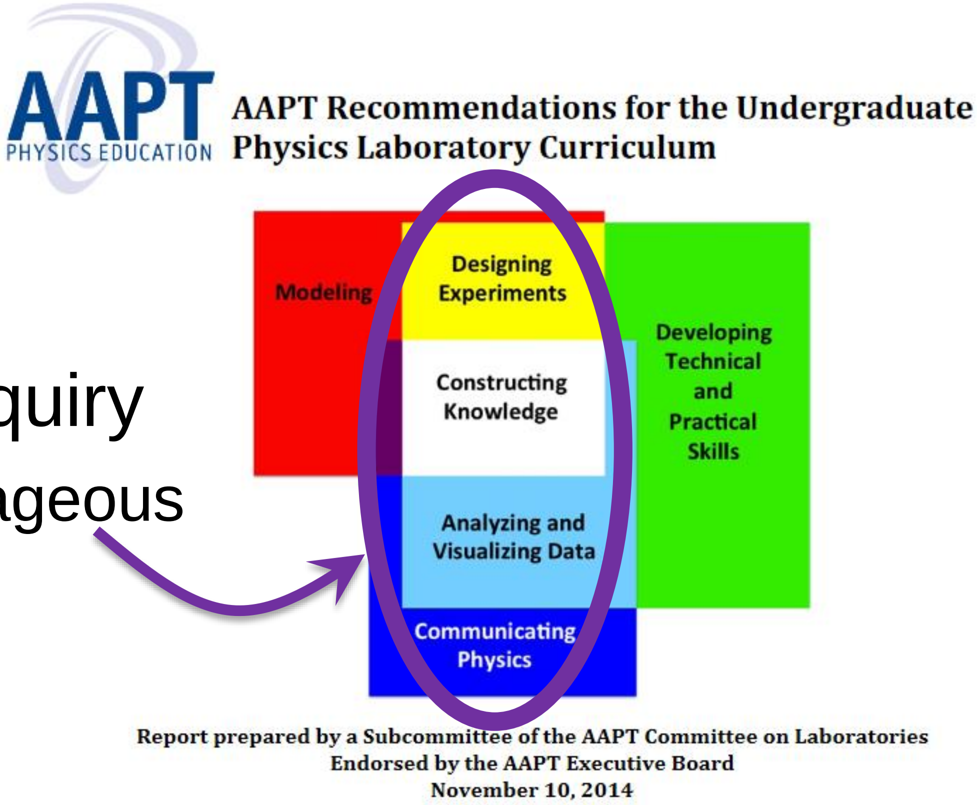
- Open inquiry is advantageous



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Empirical scientific inquiry is …

- Background
- Motivations
- Challenge
- Choices
- Structure
- Results

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Cognitive Task Analysis Elements

1. Establishing research goals
2. Defining criteria for suitable evidence
3. Determining feasibility of experiment
4. Experimental design
5. Construction and testing of apparatus/code
6. Analyzing data
7. Evaluating results and analyzing implications
8. Presenting the work

Holmes & Wieman, Phys. Rev. Phys. Educ. Res. 12, 020103 (2016).

Empirical scientific inquiry is …

- Background
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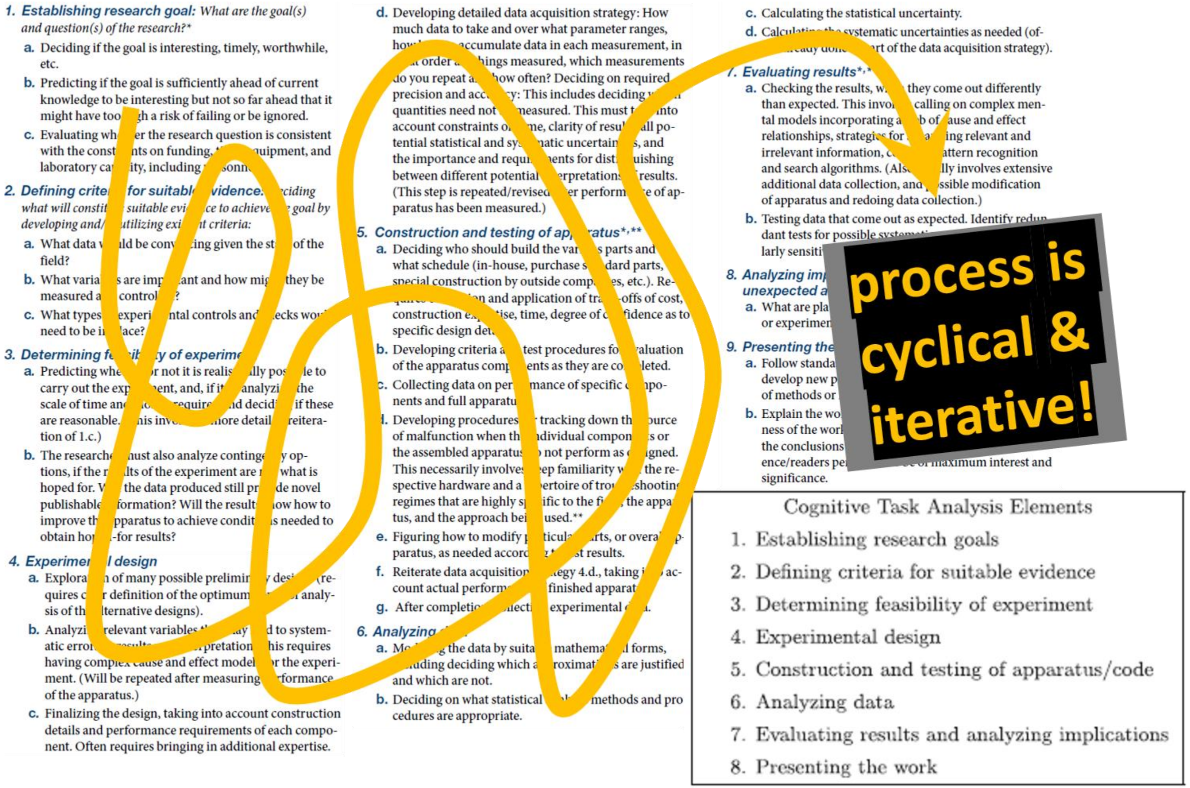

How to guide students in doing science?

Holmes & Wieman, Phys. Rev. Phys. Educ. Res. 12, 020103 (2016).

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Choice for enabling open inquries:

- Background
- Motivations
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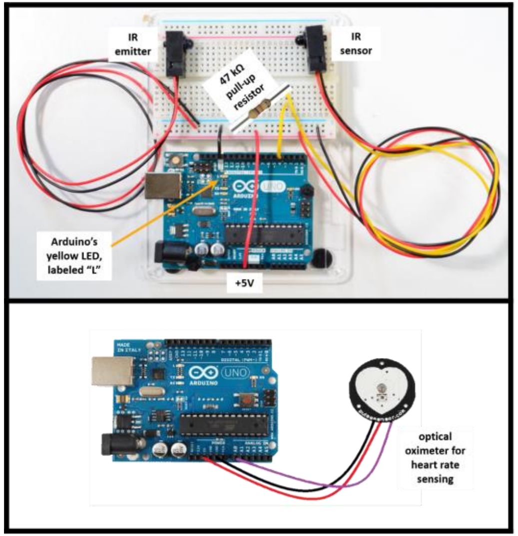
work at home using sensors controlled by Arduino Unos:



- safe
- cheap
- large choice of modern sensors

(many based on solid-state and MEMS technologies)

Large choice of modern sensors!

(many based on solid-state and MEMS technologies)

- •Background
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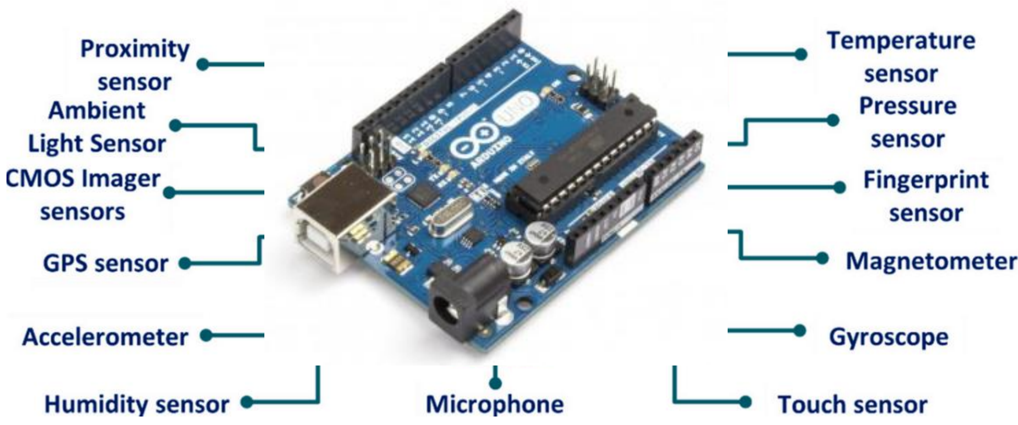
many more options with microcontrollers, including:

- Ultrasound sonar
- IR break beam
- Soil moisture sensor
- Gas sensors
- Geiger counter board
- Heart rate sensor
- Skin conductance sensor
- EMG/EKG board with amplifying electronics
- etc…



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Open inquries and student agency:

- Background
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- Epistemic agency (define research questions)
- Decision making agency (design experiments)

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Timeline of AUC's Maker Lab course

- Background
- Motivations
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- Structure
- Results

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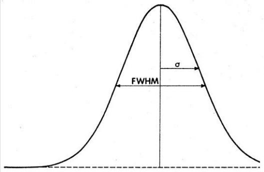
skills training



1st open inquiry
@home

go/no go
midway
final presentation

2nd open inquiry
@home

go/no go
midway
final presentation

course flips

Timeline of AUC's Maker Lab course

- Background
- Motivations
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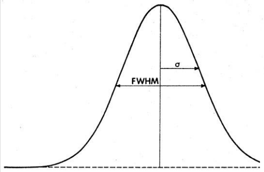
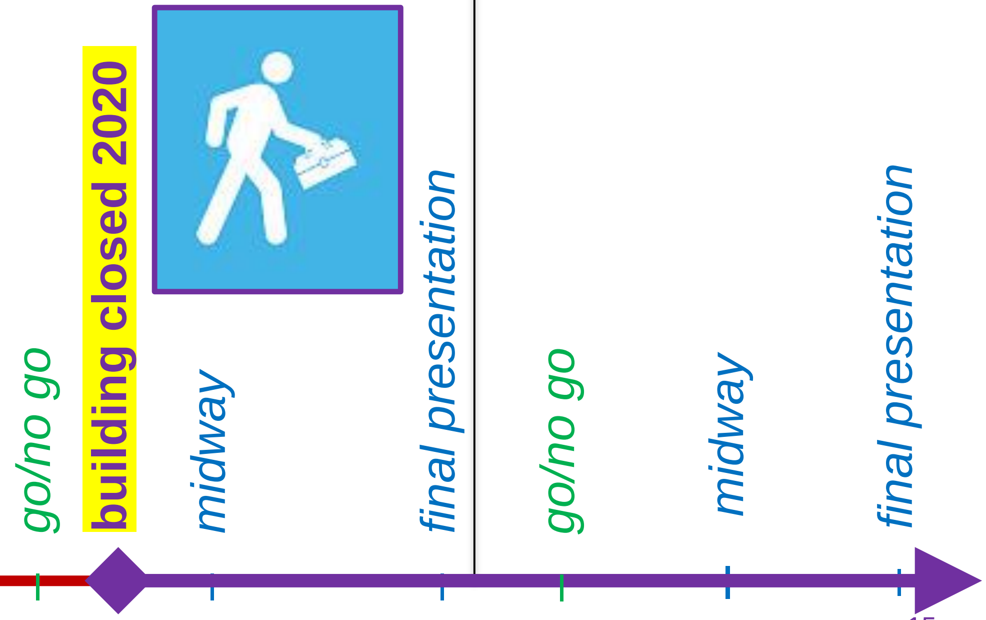
- **Structure**
- Results

skills training | 1st open inquiry @home | 2nd open inquiry @home





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Timeline of AUC's Maker Lab course

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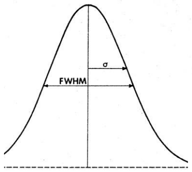
fully remote 2021

skills training
@home



1st open inquiry
@home

go/no go
midway
final presentation

2nd open inquiry
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go/no go
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Results

- Background
- Motivations
- Challenge
- Choices
- Structure
- Results

- *Student ownership & responsibility*
  - *Control over entire cycle, instructors cannot take the reigns*
  - *Authentic training in science communications*
- *Pandemic resilience*
  - *Flipped teaching, open inquiries, and Maker tools and their synergies and interdependencies*
- *Focus on science and sense-making*
  - *Individualized help with more difficult parts of research process*
  - *"Instructor" transformed into "Supervisor"*

Learning goals of science labs?

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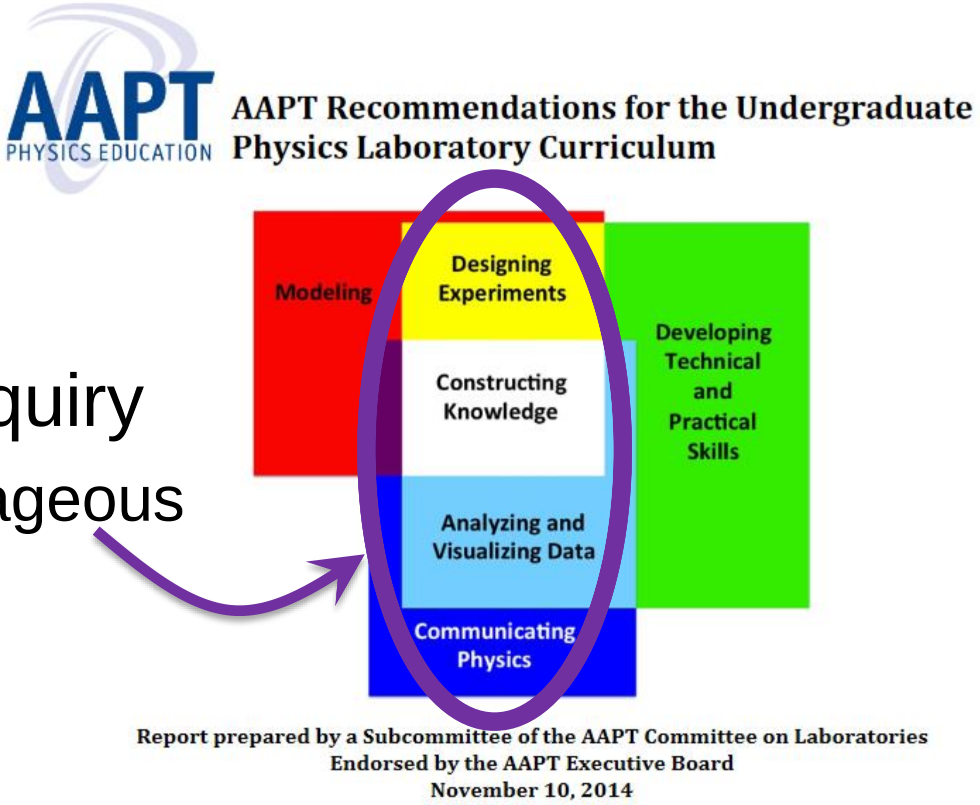
- Open inquiry
  is advantageous



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“Doing science” involves constraints:

- Constraining othe
- Constraints of too
- Constraints of ma

open inquiries require students to control and utilize constraints

Giving lab courses involves constraints:

- Class-room space
- Limited (functioning) equipment
- Limited contact time

Maker tools and flipped instruction overcomes constraints

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Thanks for your attention!

Publications:

- Published article: F. R. Bradbury & C. F. J. Pols "A pandemic-resilient open-inquiry physical science lab course which leverages the Maker movement", https://ejrsme.icrsme.com/article/view/20416
- Open-source course materials: https://github.com/forrestbradbury/MakerLab

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2020 Maker Lab Open Inquiry Projects

First round of projects

- building and improving the signal processing of an Arduino theremin
- comparing water retention of alternative potting soils against those with unsustainably harvested peat-moss
- optically measuring heart rate and characterizing its post-exercise recovery to equilibrium
- measuring color fidelity of a MacBook's screen with an RGB sensor
- investigating the dependence of a photovoltaic cell's power on its illumination angle
- pushing the Arduino's sampling rate for precision sound frequency determination
- measuring local wind-speeds to determine suitable bee-habitat

Second round of projects

- comparing signatures of bicep muscle fatigue between dominant and non-dominant arms with median frequency evolution of the electromyography (EMG) power spectrum
- building and characterizing performance of a swiveling Arduino sonar radar
- comparing accelerometer measurements of a beam's fundamental oscillation frequency with the Euler-Bernoulli model
- comparing air pollution levels inside apartments on the road-side and courtyard-side of the student residence building
- investigating whether self-reported joke funniness correlates with EMG signals of facial muscles
- comparing two measurements of bread-dough rise/yeast activity: CO_2 gas sensing & volume changes via ultrasonic ranging
- studying effects of temperature on germination of cress seeds

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2021 Maker Lab Open Inquiry Projects

- Background
- Motivations
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First round of projects

- *How does music tempo influence human heart rate, and is the effect genre dependent?*
- *How does biochar influence soil moisture retention?*
- *Does the stress of challenging games have physiological correlations (heart rate & skin resistivity)?*
- *Comparing the light transmission through synthetic and natural nail polishes.*
- *Do someone's night sounds display expected sleep cycle periodicities?*
- *Do sport drinks affect muscle fatigue, as measured by median frequency of the EMG power spectrum?*
- *Do air pollution levels in several categorized locations depend on green space and/or urbanization density?*
- *How does coffee cup size/shape/material affect rate of cooling?*
- *Measuring UV radiation dependence on humidity.*
- *Comparing magnetic field distributions from differently shaped solenoids*

Second round of projects

- *Still to come!*