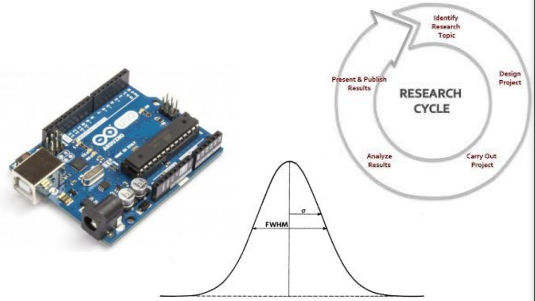
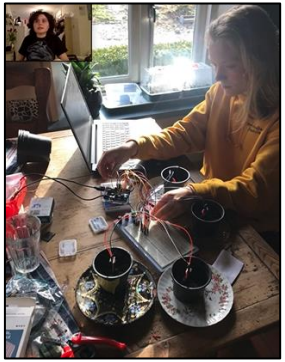
Assessing a flipped-lab course consisting of open-inquiry projects using Arduinos

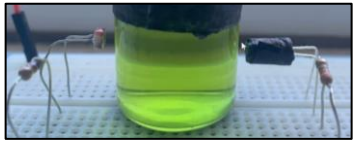
skills training

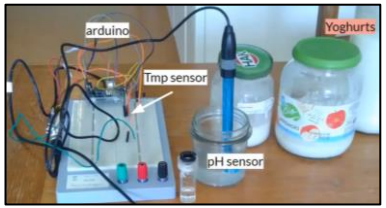


1st open inquiries



2nd open inquiries





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Assessing a flipped-lab course consisting of open-inquiry projects using Arduinos

- Course setting, goals & methods
- Course structure

- Quantitative results (partial)
- Qualitative results

- Discussion

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Course Setting, Goals & Methods

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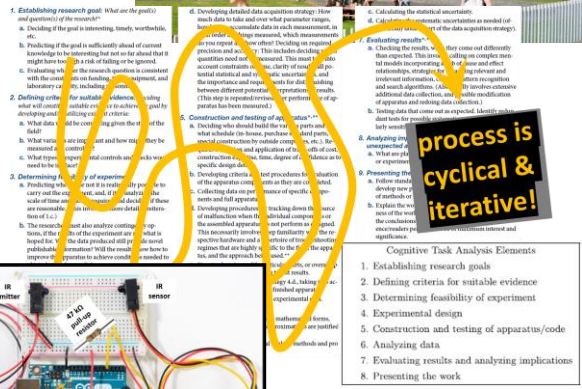
- Small liberal arts & sciences college
- Course study load = 6 ECTS (168 hours)

Main Goal

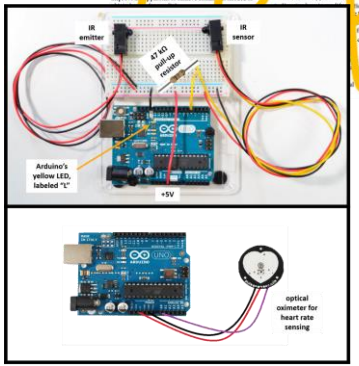
- To confront multi-disciplinary science students with the processes and complexities of *doing science*

Methods

- Open inquiry, with both epistemic and decision-making agency
- Students experiment at home using sensors controlled by Arduinos



C. Wieman, The Physics Teacher 53, p349 (2015).

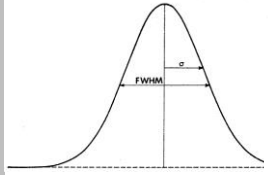


Course Structure

skills training

1st open inquiries @home

2nd open inquiries @home



course flips

go/no go — *midway* — *results in 2-slides* — *final presentation* — *go/no go* — *midway* — *results in 2-slides* — *final presentation*

Mainly synchronous class sessions with small assignments

Mainly individual team meetings to discuss projects, punctuated by synchronous class sessions for peer interaction and feedback

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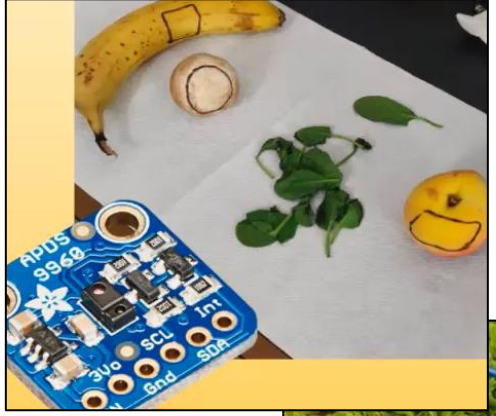

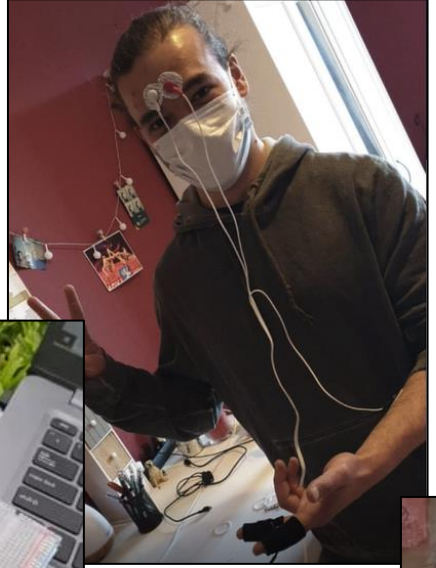

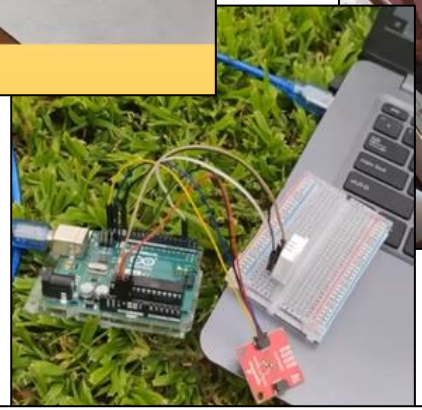

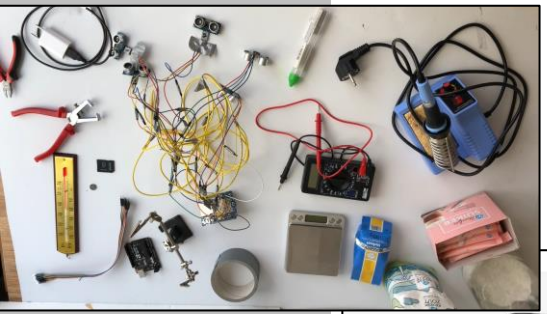

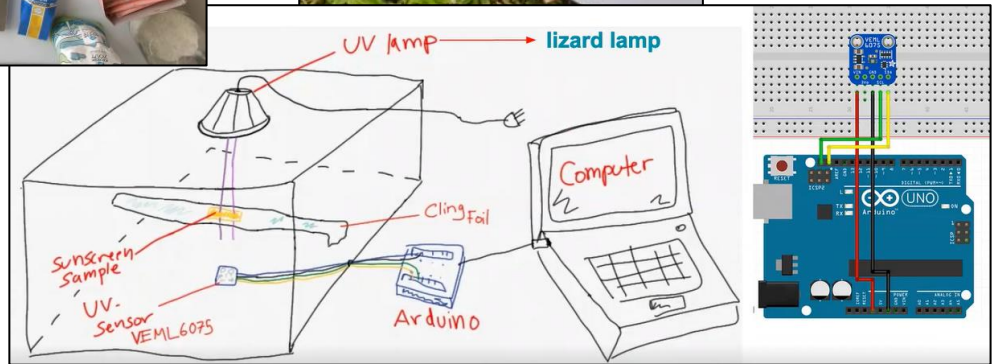

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2020 Maker Lab Open Inquiry Projects

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

BROWN INDICATES PHYSICS TOPICS

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2021 Maker Lab Open Inquiry Projects

First round of projects

- *How does biochar influence soil moisture retention?*
- *Does the stress of mathematics problems have physiological correlations (heart rate & skin resistivity)?*
- *Are air pollution levels in the city lower in green spaces?*
- *How does music tempo influence human heart rate?*
- *Comparing the light transmission through nail polishes of several colors in different price classes.*
- ~~*Do night sounds display expected sleep cycle periodicities?*~~ *Temperature dependence of noise sensor.*
- *Do sport drinks affect muscle fatigue, as measured by median frequency of the EMG power spectrum?*
- *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*

BROWN INDICATES PHYSICS TOPICS

Second round of projects

- *Geiger counter particle detection in buildings from different materials and time periods*
- *Lie detection via Galvanic Skin Resistance and Heart Rate measurement*
- *UV adsorption of sunscreen versus SPF*
- *Measuring an 8-point transmission "spectrum" for inferring absorption of chlorophyll*
- *RGB sensing for tracking ripening and rotting of fruits and vegetables*
- *Measuring heat dissipation of spherical breads*
- *Measuring formants in the human voice via Fourier analysis*
- *pH evolution of vegan yogurts*
- *Investigating gender differences in heart rate increase after jump-scares*
- *Gamers and their Galvanic Skin Resistance*

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Instructor Time Tracking

2021 Total: ~300 teaching hours for 6 ECTS course for 20 students

50% project guidance (mainly meetings w/ teams plus emailing and other asynchronous help with concepts and materials)

10% synchronous class time (lectures, discussions, and student presentations)

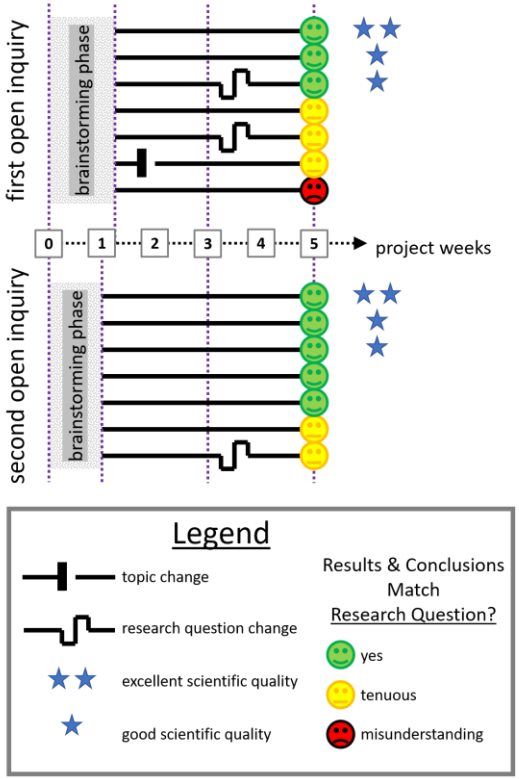
20% grading

20% other: preparation of equipment, preparation of lectures, and admin

- not including prior course development hours
- negligible teaching assistant time
- at AUC: more time spent than compensated, looking for efficiencies

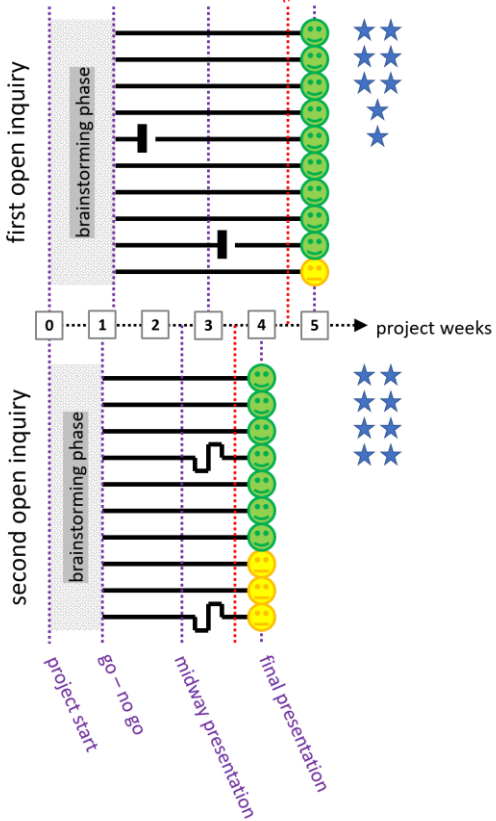
Quantitative Results

2020 cohort



2021 cohort

(new for 2021) informal two slides on results



Observations

- inquiries can and do evolve
- suggestive patterns (especially between cohorts), but no significant differences

More rigor:

- PERC poster: *"Using the **Assessment Rubric for Physics Inquiry** for open inquiries in a multi-disciplinary lab course"*
- Four minute **ARPI** intro: https://youtu.be/-cVptExBJdk

Qualitative Results – question 1

Post-course Student Interviews (first cohort - 2020)

- What was your most valuable learning outcome?

Example response, paraphrased:

the whole picture of doing an experiment, you need to look at the experiment from many different angles.

Even if you have a very specific topic and precisely defined question, you are never finished researching. There is always another question that needs to be addressed, that you still do not understand.

Qualitative Results – question 1

Post-course Student Interviews (first cohort - 2020)

- What was your most valuable learning outcome?

Many remarks about self-efficacy:

- planning & responsibility & freedom
- innovating & creating
- fun & interesting
- capable & getting to know new technologies
- problem-solving & how to tackle
- building knowledge in interest areas

Qualitative Results – question 2

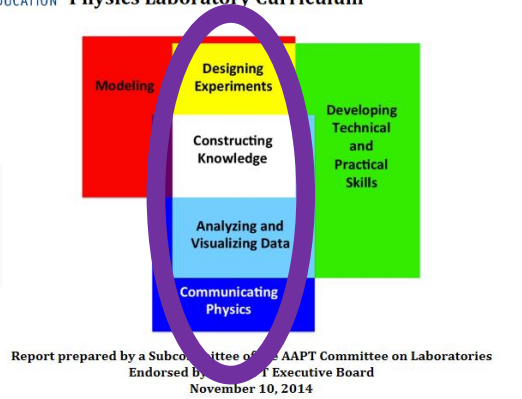
Post-course Student Interviews (first cohort - 2020)

- What would you do differently in a next inquiry?

Many remarks about scientific habits of mind:

- perform a detailed feasibility analysis
- start measurements/testing sooner
- plan more rigorously
- more research into equipment capabilities
- reflect more on research question & models
- ask for more feedback

Discussion



Pros

- Raises student self-efficacy for "doing science"
- Learning outcomes cover AAPT's central axis →
- Serves multi-disciplinary cohorts
- Utilizes 21st century skills & technologies
- Inexpensive, flexible, even pandemic resilient

Cons

- Ill-suited for training some specific technical skills/methods
- Scientific quality of *open inquiry* results often lower than for *closed inquiry*
- Significant contact time required, and use of teaching assistants is untested

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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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