Designing Effective Online Laboratory Activities

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What educational goals do you have for your students in lab class?

How can you achieve (at least some of) these goals in an online setting?

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Google Doc: https://docs.google.com/document/d/1qy0S_TNn_SAydhXsoJeeNVEQMq0vuFqBrxi6b293Fk0/edit?usp=sharing

What educational goals do you have for your students in lab class?

- Measurement techniques
- Data analysis techniques
- Error analysis
- Scientific communication (oral, written)
- Displaying Data (Plots)
- Deeper understanding of lecture concepts
- Experiment Design
- Data Interpretation
- Scientific research as an iterative process
- Group Collaboration
- Literature search

Can online activities teach these skills?

Yes, for the most part. But we have to start from scratch, and many of our favorite experiments will no longer work.

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Types of Online Laboratory Activities

- Online simulations
- At-home labs (possibly with lab kits)
- Data analysis labs (students analyze data taken by someone else)
- Worksheets
- Scientific writing training
- Independent research projects
- Literature review projects
- Using online databases (e.g. museum specimens, climate data, citizen science data)
- Participating in a citizen science project
- Group projects

How to support learning and increase engagement:

Student Ownership

Scaffolding

Group Collaboration

Student Ownership

- Students are much more engaged when they feel “ownership” for their experiment.
- How can we make them feel ownership?
  - Choose the topic themselves
  - Design the experiment themselves
  - Take data themselves (at home)
  - Develop their own data analysis techniques
  - Choose an experiment where the answer is unknown

Nothing is ***less*** intellectually satisfying than following cookbook instructions to analyze data someone else has taken to obtain a pre-determined answer.

Student Ownership: Example Lab Activity

- **Week 1 (live Zoom):**
  - Students are given a problem.

Sample "Problems" for students to solve:

1. Design two experiments: one to maximize and one to minimize heat transfer to a cup of water using only cloth, paper, and aluminum foil)
2. Design an experiment to measure the latent heat of fusion of water.
3. Design two different experiments to measure the velocity of a stream of water leaking from a hole at the bottom of a milk jug.
4. Design an experiment to measure the resistivity of a wire.
5. Design an experiment that uses the apparatus shown in the video to measure the permittivity of free space.

Student Ownership: Example Lab Activity

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  - Students propose experiment to instructor, with physics explanation and relevant equations

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- **Week 2 (live Zoom)**
  - Students combine data, analyze data, make plots
  - Students write an outline for their lab report
  - Instructor approves their analysis, plots, and outline
- **Students write the lab report at home during the week**

What are students learning when they get the chance to design their own experiment?

When asked to describe key features in the design of a successful scientific experiment, students pointed to:

- Choosing experimental methods that minimize sources of bias and error
- Clear communication of experimental methods
- Careful choice of experimental materials and measuring devices
- Precise measurements
- Understanding the theoretical basis of the experiment
- Having a clear objective for the experiment
- Group collaboration and sharing of ideas

What are students learning about the role of creativity and opinion in science?

These student statements sum up most of the class's responses:

"Creativity is a crucial aspect of the scientific process, allowing scientists to:

- devise novel methods of testing hypotheses
- generate new questions regarding the operation of the world around them
- gain additional insights into the significance of the data obtained in an experiment."

"Often, a result obtained during an experiment can lead to two or more different interpretations, and different people may attribute different causes to the same observation. "

What are students learning about scientific writing?

When asked to describe how scientific writing differs from writing in other disciplines, students pointed to:

- Structured organization (Introduction, Methods, Data Analysis, etc.)
- Complicated and precise technical descriptions necessitate a straightforward and concise writing style
- Tone is professional, and avoids humor and slang
- Figures and plots provide a key role in supporting conclusions

One student said: *“I learned to write from the perspective of a researcher instead of a student.”*

Scaffolding

- Teach a skill during the first lab
- Reinforce that skill in future labs
- Create situations in which students choose to use their new skill on their own

Example Learning Goal: Students look at a data set and determine the most effective way to show the information on a plot, then make the plot.

Week 1: Teach how to make different types of plots and their purposes
First half of semester: Require specific plots to be made
Latter half of semester: Require plots to be made, with student freedom to choose the best way to display data ***(Ownership!)***

Group Collaboration

- Active Learning: students benefit from discussing scientific concepts with their peers
- Decreases the tendency to jump to an internet search
- Increases human interaction in an isolated world

Some students prefer working independently; learning to manage group members is a real-world learning experience for them.

Why Work in Teams?

- The science of learning shows that you learn better when you talk about ideas and share them with others
- This is true even if you understand the idea and are explaining the idea to someone else. Talking about it helps the person explaining and the person listening
- Different people have different skill sets and ways of approaching problems
- Builds important skills for workplace and upper division classes.
    - Decision making and problem solving skills
    - Project management and organisational skills •
    - Communication and conflict resolution skills.

Tips for Working in Teams

- Build a strong foundation
- Get organised
- Hold productive meetings
- Maintain relationships

Build A strong foundation

- Get to know your team.
- Discuss strengths and weaknesses
- Meet early and set rules
- Agree on the aims, scope, and quality of the project.

Get Organized

- Decide on a method of group communication
- Agree on who will do what
- Set early deadlines
- Plan on how to present the project as a unified work.

Hold Productive Meetings

- Make sure everyone knows the goal of the meeting
- Make sure everyone knows what to bring
- Assign roles for the meeting and SWITCH roles between meetings.
  - Have a **leader** to keep the meeting on track
  - Have a **scribe** to record decisions and people's ideas.
  - Have **gatekeeper** to make sure everyone has a chance to speak and one person doesn't dominate the conversation and work
  - Have a **timekeeper** to help the team start on time and end of time.
  - Have a **spokesperson** to share out ideas if we are in a synchronous class.

Maintain Relationships

- Resolve problems as a group
- Ensure everyone has something to contribute
- Don’t exclude others
- Address concerns as soon as they appear
- Renegotiate as needed.
- Understand the other person’s point of view.

Example Breakout Room Task

During synchronous lab time groups filled out this Google Doc.

Example: Using online databases

- Many questions in science are authentically solved with data science and using online depositories of information. You can design investigations that utilize these sources of information.

- Some examples:
  - Museum specimen data
  - Range maps
  - Climate data
  - Pollution data (e.g. nitrates, AQI, particulate matter)
  - Genetic data (e.g. genomic data)
  - Demography data
  - Public Health

- For Biology a good source to check out is https://qubeshub.org/

Example: Participating in Citizen Science Projects

- There are many citizen science projects students can participate in. Some are fully online and others require taking some kind of data and entering it into a database.
- A good resource for finding projects in all disciplines (biology, climate, physics, medicine, astronomy, etc.) is https://www.zooniverse.org/
- Participation is an authentic experience
- You can design investigations around a project

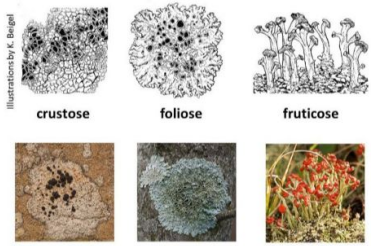
Example: EREN Lichen Citizen Science Project

- Week 1 - Synchronous session
  - Introduce lichen and their connection to air pollution
  - Explain how to perform the field research and use iNaturalist and other apps to complete the data collection
  - Have students work in teams to generate hypotheses and plan a simple study
- Week 2-3
  - Students work on their own to collect the data and upload to the database
- Week 4
  - Synchronous/Asynchronous data analysis lab
  - Students work with their group to produce a graphical abstract of their study

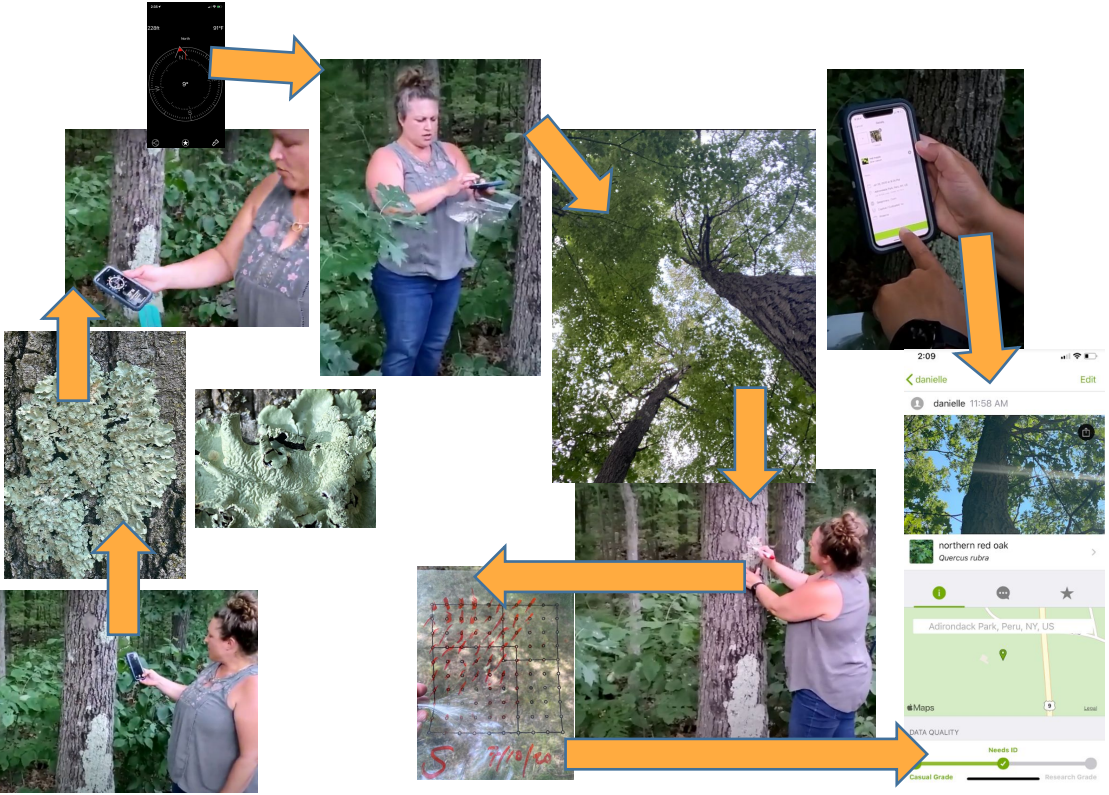
The instructor could provide data and maps or spend an additional lab period on how to generate maps in ArcGIS and/or how to graph data

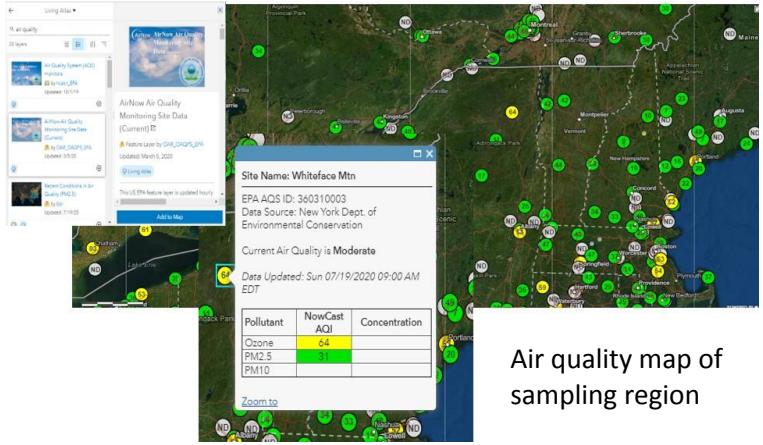
Hypothesis

Lichen abundance declines when air quality is lower

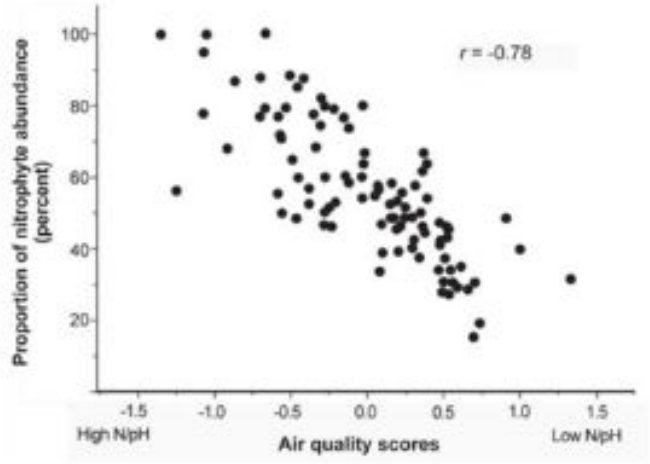


Sampling for lichen





Air quality map of sampling region



Lichen abundance declines when air quality declines

Example: Using an online climate mitigation model

- Many scientific problems are authentically solved with models (e.g. climate models). You can use the models for an authentic experience.
- One example of this is using the EN-ROADS climate mitigation/adaptation model. Students work together in groups to devise a global strategy to keep warming below 2C while:
  - Limit global warming.
  - Preserve and create a healthy economy
  - Promote equity and a just transition
  - Protect the environment
- During a synchronous lab sessions student write up their findings and share their model with the class

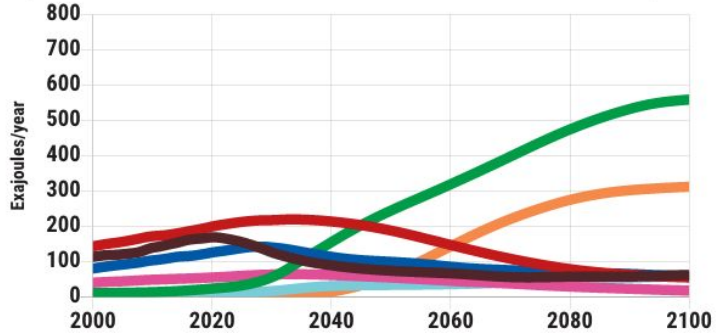
EN-ROADS

Simulation | Graphs | Language | View | Help

BETA

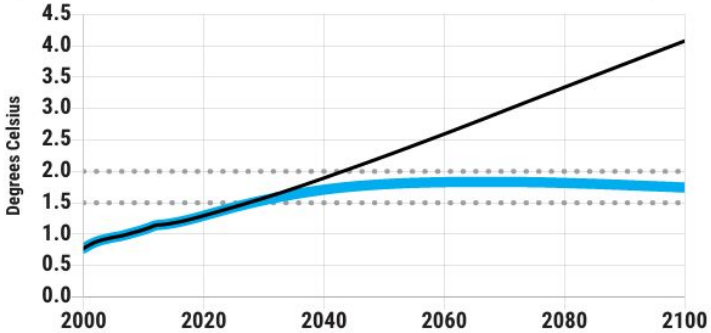
Share Your Scenario

Global Sources of Primary Energy



COAL | OIL | GAS | RENEWABLES | BIOENERGY | NUCLEAR | NEW TECH

Temperature Change



BUSINESS AS USUAL | CURRENT SCENARIO

+1.7°C

+3.1°F

Temperature Increase by 2100

Energy Supply

- Coal: highly taxed
- Renewables: highly subsidized
- Oil: highly taxed
- Nuclear: status quo
- Natural Gas: highly taxed
- New Technology: breakthrough
- Bioenergy: status quo
- Carbon Price: very high

Transport

- Energy Efficiency: increased
- Electrification: incentivized

Buildings and Industry

- Energy Efficiency: increased
- Electrification: highly incentivized

Growth

- Population: status quo
- Economic Growth: high growth

Land and Industry Emissions

- Deforestation: moderately reduced
- Methane & Other: moderately reduced

Carbon Removal

- Afforestation: medium growth
- Technological: high growth

CLIMATE INTERACTIVE

MIT MANAGEMENT Sustainability Initiative

En-ROADS Climate Ambassador Training

Combing Simulations and Physical labs at home

Typical labs in Physics 1A (Harpell) include:

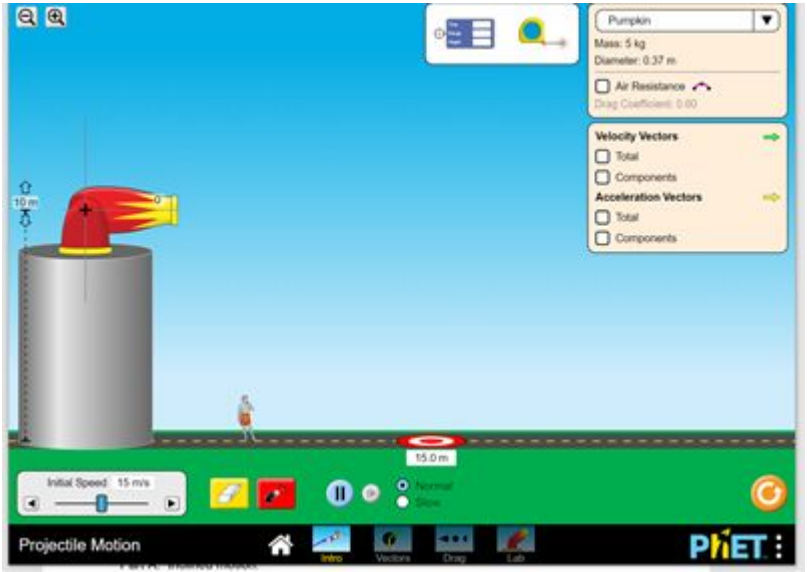
Working a series of guided problems/activities using an online simulation (typically PHET)

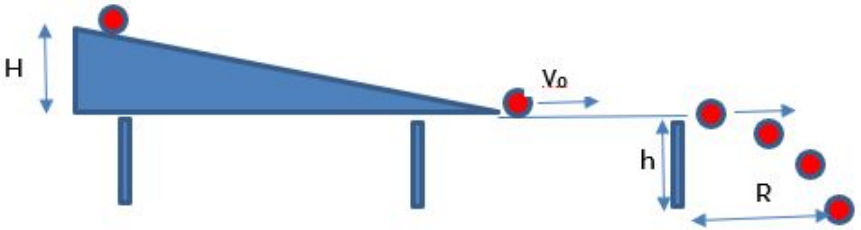
Building relatively simply apparatus from materials at home to perform an experiment related to the simulation, typically, cell phones and measuring tape provide the measuring tools necessary., Students usually work in groups using some of the organizational techniques described earlier...

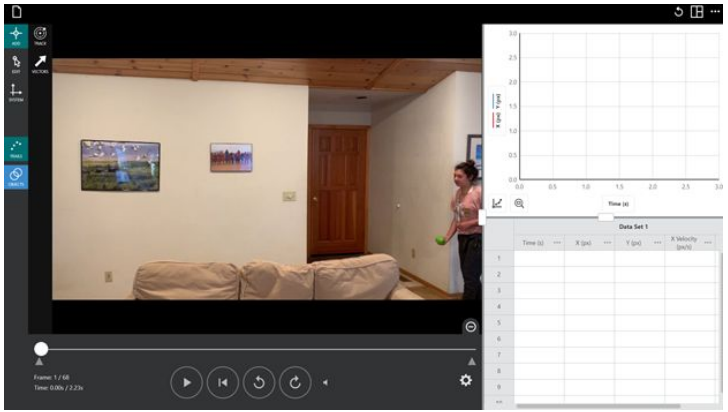
Going one step further--often by filming an experiment and analyzing the video using specialized software (typically video point)

Example of a lab: Motion in Two Dimentions

Click here for the Lab posted in Canvas







Hybrid vs completely online labs

Most of my students do four labs on campus...two at a time on two extended lab days. A lab exam is also given twice per semester.

Students come to lab rooms in groups of six or less (two rooms are used). Lectures are recorded asynchronously on lab days.

Students were given the option of working at home on the lab exam and at home versions of the experiments. They were told “it wouldn’t be that much harder at home.”

Out of 46 students, 38 came to lab, 6 worked at home, and 4 were no shows.

A few students came to multiple lab sessions to re-do the lab and make sure they understood everything! No complaints so far….

Lab exam

Assesses whether the students are genuinely working on the labs, or riding the coat-tails of lab partners. Exam exam is worth as much as 2.5 labs.

Was an eye opener for some students. Anecdotal evidence is that students are more involved in group labs!

At home lab treated like a final exam--highest level of “proctoring”

Cons: a bit stressful

Pros: Covid/zoom strategy has shifted more responsibility on learning from doing, rather than watching! Labs are key!