Open Source Technology in the Classroom

By Jesse Kasehagen
Santa Barbara Middle School
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Research Topic: Biosensors

Objective: To build a point-of-care device for a doctor’s visit

What 3 things did I learn?

1. Laboratory work is difficult, thought provoking and rewarding.

2. Many experiments involve on-the-spot troubleshooting (much like open-source technology does)

3. You don’t have to be a “rocket scientist” to actually contribute useful data to a research project.
RET II: Curriculum Basis

The Arduino

Runs any program whether on a computer, as an integrated sensor or...

A CNC

Built to run as a milling machine, explorative microscopy and autosampling
Why Open Source?

Benefits:

1. If you can *IMAGINE IT* and have the patience, you can modify any program to fit your unique needs
2. Usually free and easily downloadable
3. Peer-friendly review and sharing capabilities

Cons:

1. You have to have patience because there is virtually no technical support to call!
   Tinker but DON’T give up!
Lesson Ideas

- Introduction to circuits using a variety of sources (e.g. Little Bits and Manylabs software) to learn about them (Lessons #1).
- Build a simple graphite circuit (Lesson #2).
- Using Graphite Potentiometers (Lesson #3).
- Using a CNC machine as a platform for producing gigapixel images (Lesson #4).
- Using a CNC machine as a platform for an autosampler (Lesson #5).
Introducing Electricity and Circuits

Electricity is something students are commonly interested in...

Curiosity → Exploration → Understanding → Application
Students will get to:

Learn how circuits work!

Learn how to assemble a simple circuit - with magnets!

Lesson # 1

Little Bits Activities

Imagine and create!
ManyLabs Activities

Example of ManyLabs interactive activity

Adding a tabulation step

<table>
<thead>
<tr>
<th>Circuit</th>
<th>Button</th>
<th>Knob</th>
<th>Light</th>
<th>Tilt</th>
<th>And</th>
<th>Or</th>
<th>Not</th>
<th>+</th>
<th>&lt;30</th>
<th>&gt;30</th>
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Place a “Y” for each part “used” to complete the circuit in the table below after completing the task on the computer for each exercise:
Lesson #2
Building A Graphite Circuit

Students get to create a circuit with graphite and then test its voltage or resistance using a voltmeter or LED.

Leads of Voltmeter are closest to source:
Reading=6.15V from a 9V battery.

Leads of Voltmeter are farthest from source:
Reading = 167.9mV from a 9V battery.

Hook an LED to resistive layer (graphite) and see what happens...
Lesson #3: Using A Graphite Potentiometer

Students get to:
Perform an experiment to determine the relationship between conductivity and amount of light perceived through sheets of graphite paint with different dilutions.

2 different arduino setups:
A) computer using ManyLabs
B) simple LED readout without using a computer
Sample ManyLabs Activity:
Exploring Graphite Potentiometers
Lesson #3 ManyLabs Results:

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Undiluted</th>
<th>1:2</th>
<th>1:3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity</td>
<td>4.01</td>
<td>3.98</td>
<td>3.52</td>
</tr>
<tr>
<td>Light</td>
<td>80</td>
<td>92</td>
<td>110</td>
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</tbody>
</table>

Potentiometer measuring conductivity with of a 5V source with input values of 0-5. A higher number means less resistance. Light values of 0-780 were arbitrarily established by program. A higher number means more light detected. This graph shows a best fit line for 3 different thicknesses of shades run through the Sensor Plotting Program using ManyLabs Software. This is an inverse-relationship where the thicker the layer, the more conductive it is but less light penetration; the thinner the layer, the less conductive it is, and more light penetrates.
LED POT Readout Test

Ratio = paint:water

Undiluted

1:2

1:4
Lesson #4: **Explorable Microscopy!**

Explore great details in photographs of fossils, leaves, and cells.

**How does it work?**

1. **Focus Stacking:**
   A process taking multiple photos at different focal distances to give a higher depth of field (DOF) than a single photo.

2. **Image Mosaicing:**
   "quadrant"-grouping of lots of photos with ~30% overlap that allows stitching together of all photos in a seamless high resolution image.

Students get to...
Lesson #5: Autosampler

Students get to: Learn data collection with a complex setup with arduinos running a sensor and CNC to computer for logging data.
Thank you to:
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Extensions:

Extensions for Lesson #3

1. If you have some time, you could have students research and test different (nontoxic) spreadable materials that are conductive and they have at home (i.e., ketchup, mayonnaise, different types of mustards)- something ideally with high salt content- and set up the same lab as above to see which substance has the greatest [salt].

2. You could have students measure thickness (density?) of different conductive fabrics by establishing the same method as the procedure for graphite paint squares.

3. Measure the change in conductivity by sliding the sensor clip from one side (ground) to the other side (5V) to better understand what a potentiometer is.
Scope & Sequence?
Standards Addressed

6th Grade:

1. Develop a hypothesis.
2. Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.
3. Construct appropriate graphs from data and develop qualitative statements about the relationships between variables.
4. Communicate the steps and results from an investigation in written reports and oral presentations.
5. Recognize whether evidence is consistent with a proposed explanation.

7th Grade:

Structure and Function in Living Systems

5. The anatomy and physiology of plants and animals illustrate the complementary nature of structure and function. As a basis for understanding this concept:
   1. Students know plants and animals have levels of organization for structure and function, including cells, tissues, organs, organ systems, and the whole organism.

6. Physical principles underlie biological structures and functions. As a basis for understanding this concept:
   1. Students know that for an object to be seen, light emitted by or scattered from it must be detected by the eye.
   2. Students know light travels in straight lines if the medium it travels through does not change.
   3. Students know light can be reflected, refracted, transmitted, and absorbed by matter.

7. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:
   1. Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.
   2. Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project.
   3. Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.
   4. Construct scale models, maps, and appropriately labeled diagrams to communicate scientific knowledge (e.g., motion of Earth's plates and cell structure).
   5. Communicate the steps and results from an investigation in written reports and oral presentations.
8th Grade:

1. [x] Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:
   a. Plan and conduct a scientific investigation to test a hypothesis.
   b. Evaluate the accuracy and reproducibility of data.
   c. Distinguish between variable and controlled parameters in a test.
   d. Recognize the slope of the linear graph as the constant in the relationship $y=kx$ and apply this principle in interpreting graphs constructed from data.

2.  

3. c.

4.  

5. Electric and magnetic phenomena are related and have many practical applications. As a basis for understanding this concept:

   a. [x] Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors.

   b. Students know how to solve problems involving Ohm's law.

   c. [x] Students know any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula $\text{Power} = I^2R$ (potential difference) $\times$ $I$ (current) $= i2R$.

   d. [x] Students know the properties of transistors and the role of transistors in electric circuits.

    1. a. Students know the carbon cycle of photosynthesis and respiration and the nitrogen cycle.

    2. b. [x] Students know the global carbon cycle: the different physical and chemical forms of carbon in the atmosphere, oceans, biomass, fossil fuels, and the movement of carbon among these reservoirs.

    3. c. Students know the movement of matter among reservoirs is driven by Earth's internal and external sources of energy.

    d. * Students know the relative residence times and flow characteristics of carbon in and out of its different reservoirs.

   1. [x] Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:

      a. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.

      b. Identify and communicate sources of unavoidable experimental error.

      c. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.

      d. Formulate explanations by using logic and evidence.

      e. Solve scientific problems by using quadratic equations and simple trigonometric, exponential, and logarithmic functions.

      f. Distinguish between hypothesis and theory as scientific terms.

      g. Recognize the usefulness and limitations of models and theories as scientific representations of reality.

      d. Recognize the issues of statistical variability and the need for controlled tests.

      e. Recognize the cumulative nature of scientific evidence.

l. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.

m. Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings. Examples of issues include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in California.

n. Know that when an observation does not agree with an accepted scientific theory, the observation is sometimes mistaken or fraudulent (e.g., the Ptolemaic model of the movement of the Sun, Moon, and planets).