Exploring Electricity and Engineering 1 Project and Lab EDUCATOR GUIDE

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OVERVIEW AND PROJECT SEQUENCE

This document describes a series of progressive lessons that teach core engineering, scientific process and electricity concepts through student direct exploration and making.

The document is intended to be used as a framework to be modified by the instructor to match the pace, experience and maturity of the target students.

The proposed curriculum sequence of each module is built on two hands-on exercises as follows:

- **Project** – Open-ended craft project to allow students to discover the core concepts through making
  - Review and discuss observations and core concepts
- **Lab** – More structured lab project focused on scientific process and data collection.
  - Review data and discuss core concepts

Duration: 2-3 hours

KEY CONCEPTS AND STANDARDS ADDRESSED

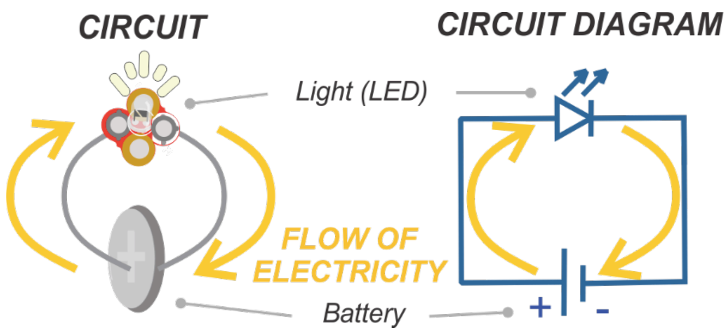
- Electricity Basics
- Conductivity
- Resistance
- Scientific Process
- Data Analysis
- Measuring Change

Next Generation Science Standards that align with this project include:

2-PS1-1	Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.
2-PS1-2	Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.
4-PS3-2	Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
4-PS3-4	Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
3-5-ETS1-2	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

CONCEPT REVIEW

What is a circuit? A circuit is a closed path through which electric current flows. The simplest circuit we can work with is a battery connected to a light. The light turns on when electricity flows from the battery, through the light and back to the battery. A common way of drawing circuits is called a circuit diagram. In a circuit diagram, a battery is shown as two parallel lines and an LED as a triangle and line with arrows representing the light.



In this circuit, the light is always on until the battery runs out of energy. When we add a switch to the circuit, we can control when the light is on or off.

LED – LED stands for Light Emitting Diode and is a semiconductor diode that emits light when a current is applied to it. LEDs convert electricity directly into light through a process called electroluminescence, which makes them much more energy efficient than incandescent bulbs, which loose energy to heat.

Direction - LEDs are diodes and conduct electricity in only one direction (forward) while blocking electricity in the other direction (reverse). This direction is indicated by the direction of the triangle in the circuit diagram and is from positive to negative.

Conventional current/flow vs. electron flow – When electricity was first discovered, it was believed that the electrical current flowed from positive to negative and this became the convention for circuit diagrams and is often described as conventional flow or conventional current. However, it is now known that electrons flow from negative to positive and that is described as electron flow. Many norms (like the direction of the diode arrow) were designed using conventional flow.

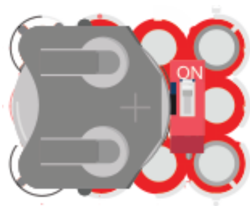
Conductive materials allow the flow of electricity. Most circuits are made with copper wire but many metals are conductors including iron, paper clips, copper tape, and aluminum foil. Liquids can be conductive when there are ionic molecules present in them. The more conductive a liquid, the higher the ionic concentration. In environmental science, this is described as Total Dissolved Solids described as PPM (parts per million).

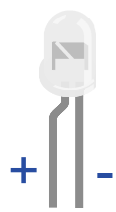
Resistance is the reciprocal of conductivity and is the measure of how difficult it is for electrical current to flow through a material. Higher resistance means less current will flow through a circuit, and low resistance means more current will flow. Resistance is most commonly measured in Ohms (Ω).

MATERIALS

This curriculum uses standard components that can be sourced from any electronics vendor. Visit http://www.lectrify.it/tpt for low cost, pre-packaged bundles that map to this curriculum. If using your own components, please be careful to match the correct battery voltage to the LED. Also, be careful to avoid shorts (crossing the positive and negative of the battery with no load (LED, resistor, etc.).

Battery: The battery will power your circuit. It stores electricity that makes your circuit light up. Lectrify battery packs have an on/off switch to help you control when your circuit is powered on. The packs are also color coded with red representing positive and white representing negative. The battery pack uses a standard 2032 battery.

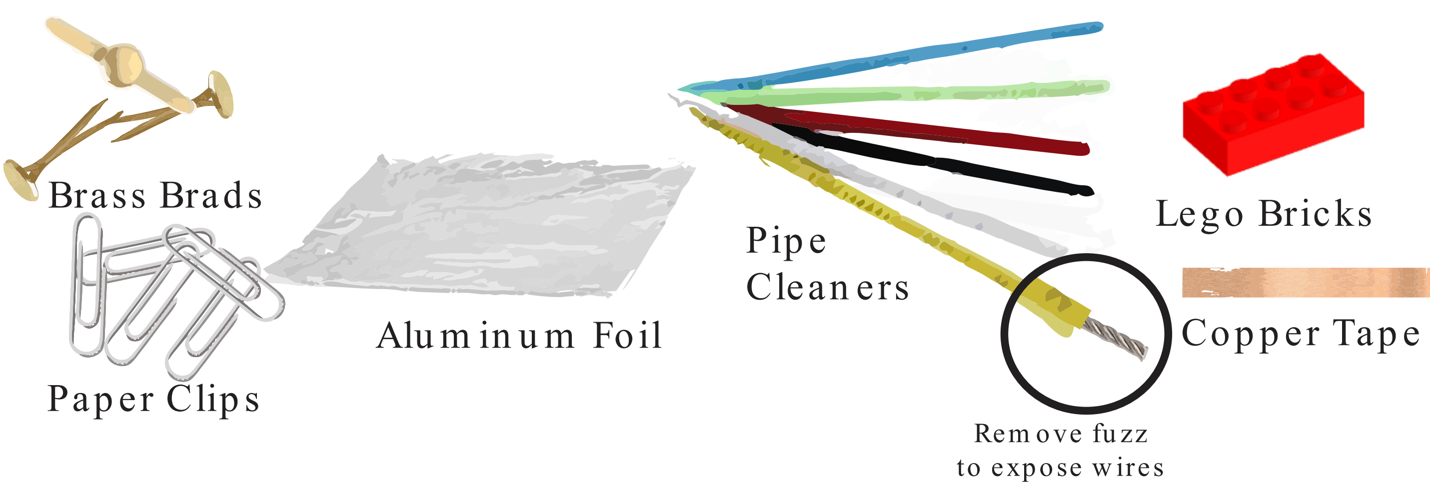




LED stands for Light Emitting Diode and they turn electricity into light. These components allow you to light up your projects. Lectrify LEDs are color coded with a positive (red) and negative (white) side. Stand alone LEDs usually have two leads with the longer one being the positive lead.

Other Materials:

The craft project requires paper clips, brass brads, pipe cleaners and optional materials such as aluminum foil, copper tape and LEGO.



The lab project requires copper tape, straws, alligator clips and material required to perform the specific lab (i.e. cups and liquids, pots of soil, etc.)

PROJECT – CIRCUIT CRAFTS

The first student project consists of building of a simple circuit with paper clips. The project will build student confidence and understanding of how a circuit works. Once students build their first circuit, they can move on to a more complex craft project that further enables them to explore how electricity is transmitted and which materials are conductive or not.

Discussion

Start by reviewing each of the components – battery, LED, paper clips.

- Describe a battery.
- Where have they used a battery before?
- What does a battery do?
- Describe an LED.
- Where have they used or seen an LED before?

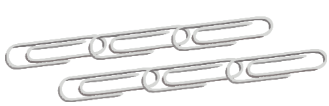
Review the basics of a circuit.

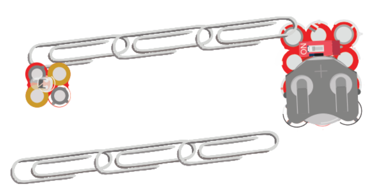
- What do you need to make a complete circuit?
- How does the electricity flow?
- What do the red and white sides of the battery/LED indicate?

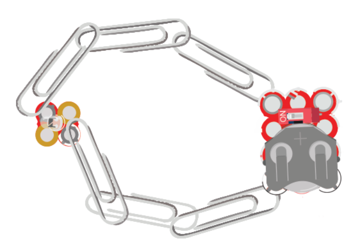
Basic Circuits with Paper Clips

In this first project, students create a paper clip circuit using a battery pack, LED and paper clips.

- Start by linking a few paper clips into two chains.
- Hook one paper clip chain to the metal red corner of the battery and LED. Then hook the other paper clip chain to the white side of the battery and LED.
- Use the on/off switch to turn the LED on.



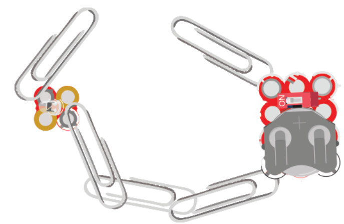




Open-ended Questions

- Did the circuits work?
- Discuss why the circuit may not have turned on for some. What was the issue? Ask students with working circuits to help troubleshoot those with non-working circuits.
- What do students notice about their circuit?
- Is the LED always on? Does it flicker? Why?
- How can they control if it's on or off?
- Can they think of another way of controlling if it's on?

Explore
Students can explore what else is conductive around the classroom. Before they begin to test, discuss which materials they think will be conductive and why? They can use their paper clip circuit as a probe to test their theories. To make the probe, unlink two of the paper clips. Now hold the two paper clip ends against any material to test conductivity.



Circuit Crafts – extension & exploration of additional materials

Once the students have explored conductivity and simple circuits, they can begin to create their own circuit crafts using pipe cleaners, paper clips, conductive tape, and LEGO…

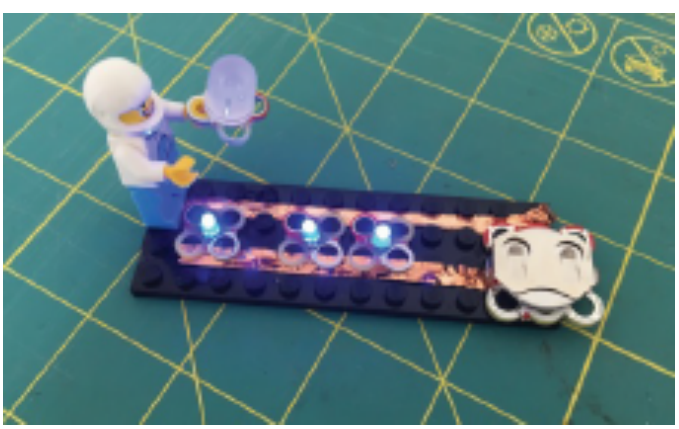
The craft project they design can be seasonal or based on a theme that maps to a current classroom lesson. Sample basic projects ideas include:

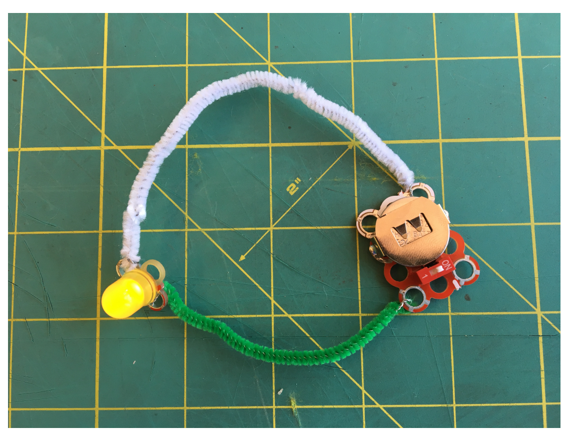
- Light up ornaments
- Decorations for locker/backpack
- Hair or sneaker accessories
- Dioramas or art pieces with light
- "Spy" communicators where the light can be used to signal others silently

More complex projects with simple logic (require more time)

- Rube Goldberg machine that lights up when activated
- Pinball machine with lights that light up when certain areas are triggered.
- Interactive game (i.e. Operation).

Plan
Before students make their circuit project, ask them to make a sketch of their plan and how it will go together. Make sure they label the components they'll use.





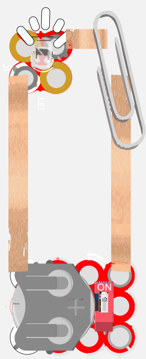
Teachable Moments:

Engineering Design is the process of coming up with a solution to a problem. The steps include brainstorming, prototyping and testing your ideas. Students engage in this as they create their projects.

What is a switch? In a circuit diagram, a switch is shown as a "door" that opens and closes the circuit. There are many different types of switches, from the light switch. Switches come in many forms and are in almost every device with electricity.

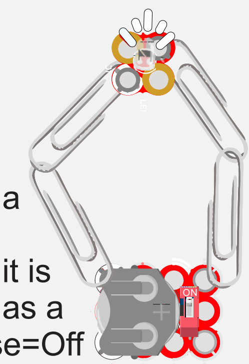
Once you understand how a switch works, you will be surprised to find how easy it is to make switch out of any conductive materials you find: Paper clip, aluminum, copper tape, etc.

Prompt: Ask students to look around the room and count how many switches can be seen from their seats.



In this circuit, the paper clip functions as the switch closing the circuit when touching both pieces of copper tape.

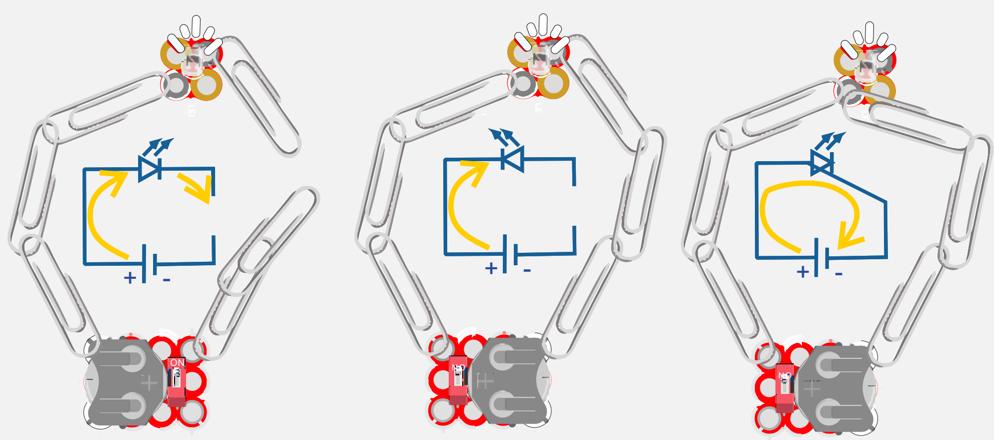
This paperclip bracelet does not look like it has a switch but the air gap between the clips when it is loose can be thought of as a switch. Tight= On, Loose=Off



Troubleshooting tips

Troubleshooting simple circuits is relatively straight forward because there are only three potential issues with the circuit.

A. Break in the Circuit – Is the circuit complete? Is there an air gap anywhere in the circuit that is not allowing electricity to flow through it? Look carefully at the circuit and push down on all the connection points to ensure good connections.
B. Polarities reversed – Remember that LEDs are like all diodes and do not allow electricity to flow through them in the wrong direction. Is the positive (red) of the battery connected to the positive (red) of the LED?
C. Short Circuit – This is not always easy to spot, but look carefully at your circuit and make sure that the electricity does not have a direct path from one side of the battery to the other.



A. Break in Circuit B. Polarities Reversed C. Short Circuit

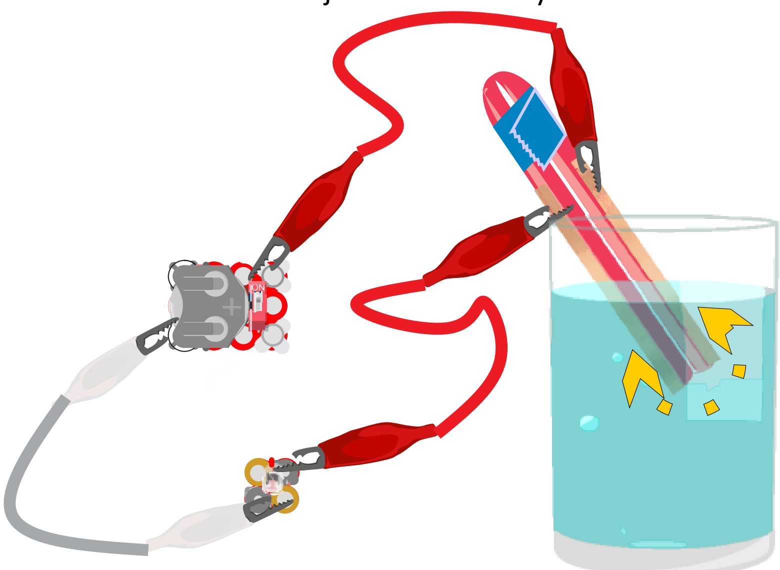
LAB: DATA GATHERING WITH CONDUCTIVITY PROBE

Now that the students have had an opportunity to explore conductivity through circuit crafts, they are ready for a more structured lab project to reinforce and provide structure to their observations and hypothesis.

This lab allows students to further appreciate the scientific process and data collection through the creation of their own measurement tool: a conductivity probe. This same probe can be used in subsequent labs with more sensitive measuring tools.

Making the Probe

What is a conductivity probe? A conductivity probe is used to measure whether something is conductive and when connected to the proper measurement tools, how conductive it is. This probe is a very basic probe that measures whether an object is sufficiently conductive for electricity to get through it to turn on the LED.



The LED will light up when the probe is immersed in a substance with enough ions to transmit electricity.

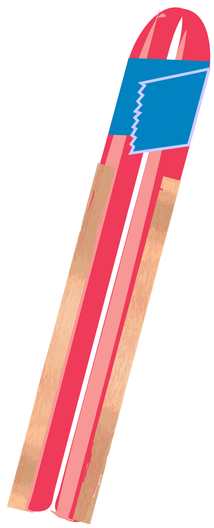
NOTE: One option is to ask the students to design their own measurement tool by discussing with them the objectives and design criteria. Some design criteria to consider include:

- Robustness – Can the tool be re-used multiple times across multiple experiments?
- Reproducibility – Can the tool produce consistent, reproducible results?
- Effectiveness – Does the tool effectively measure what you are trying to measure?

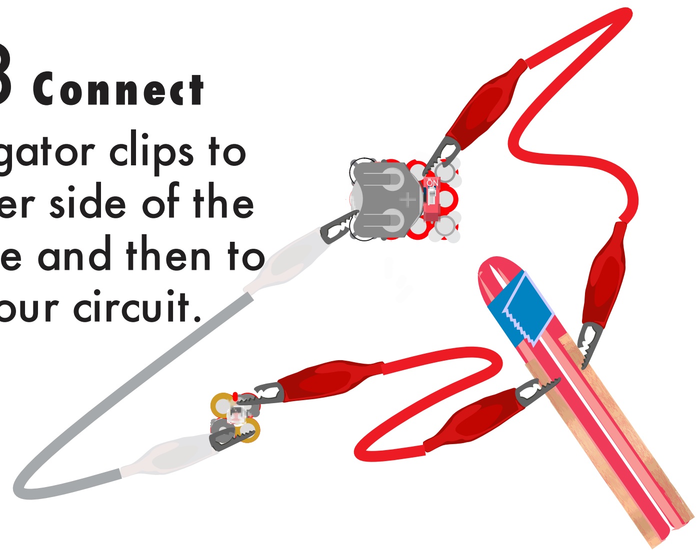
Make a Conductivity Probe

1 Cut Conductive Tape into two 3" pieces and place one each on opposite ends of the straw.

2 **Fold** straw in half keeping copper tape from touching. Keep straw folded with a piece of tape.



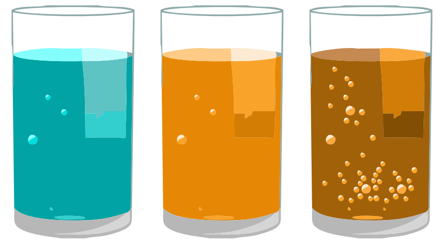
3 **Connect** alligator clips to either side of the probe and then to your circuit.



Conductivity Probe Lab

With the conductivity probe built, students can now perform a lab to explore conductivity in more depth. It is suggested that the lab be designed around a theme. Suggested themes include:

Comparing food: Use the conductivity probe to explore how conductive different common liquids are. Prepare a glass of different beverages (juices, soda, sugar free soda, low calorie beverages, sport drinks, tap water, filtered water)
Which beverages make the LED light up? Which ones do not. What conclusions can they draw based on their data?



Food Science: Explore how different titrations influence the conductivity of a liquid. Prepare samples with different levels of concentration of basic cooking materials (sugar, salt, flour, baking soda…) Using the probe, how does the conductivity change based on the material used?
What do we think that means about the relative conductivity of the food objects?

Environmental Engineering – Lets understand the differences in the water around us: Is tap water conductive, is pond water conductive, is bay water conductive? A common test for water quality is dissolved solids which measures conductivity. Dissolved solids are measured in Parts Per Million (ppm) How accurate is this probe for measuring dissolved solids?

Relative conductivity of liquids	
Reverse Osmosis Water	25-50 ppm
Domestic water	250-400 ppm
Potable water (max)	528 ppm
Sea water	28,000 ppm

Soil analysis Is different soil more conductive than others? Prepare numerous pots with different types of soil (topsoil, playground sand, beach sand, mulch). Are they conductive when dry? What happens when water is added? How much water is needed to make the soil conductive? What does that say about the differences in the soils?

It is important to emphasize the importance of documenting the students' hypothesis as well as their data gathered through experimentation. Data can be gathered in a simple table as follows:

Name	Description	Conductive? Hypothesis (Y/N)	Conductive? Experiment (Y/N)