

# Thermal Energy Conductivity

Building a scientific instrument to investigate thermal conductivity of different materials.

**Microsoft Hacking Stem**

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# Overview for Teachers

# Hello Teachers!

In this project, your students explore the phenomenon of thermal conductivity through engaging in scientific inquiry not only through observing and measuring, but also through designing and building a scientific instrument.

## Aligned to NGSS Standard: 5-PS1-3

Make observations and measurements to identify materials based on their properties.

## 1 Learning Sequence

Duration of Activities: 2 full-length class periods.

### Activity 01:

Students explore the phenomenon of thermal conductivity by making and personalizing their own thermometer.



## Build and learn

Students build a thermometer to examine and analyze thermal conductivity. The thermometer measure the temperature of the material.

## Connect your tools

Digitize the thermometer using the Arduino Uno. Students learn essential prototyping and are guided through carrying out a scientific investigation. Students are instructed to document a hypothesis and set up their experiment. As students take measurements, they can make observations about their collection of data in real-time.

## Activity 02:

Students use their thermometer to carry out a computer-assisted lab investigation. Finally, students make graphical interpretations by analyzing and discussing visualizations of real-time data.



### Conduct experiment

Aided by the computer, students are guided through carrying out a scientific investigation. Students are instructed to document a hypothesis and set up their experiment. As students take measurements, they can make observations about their collection of data in real-time.

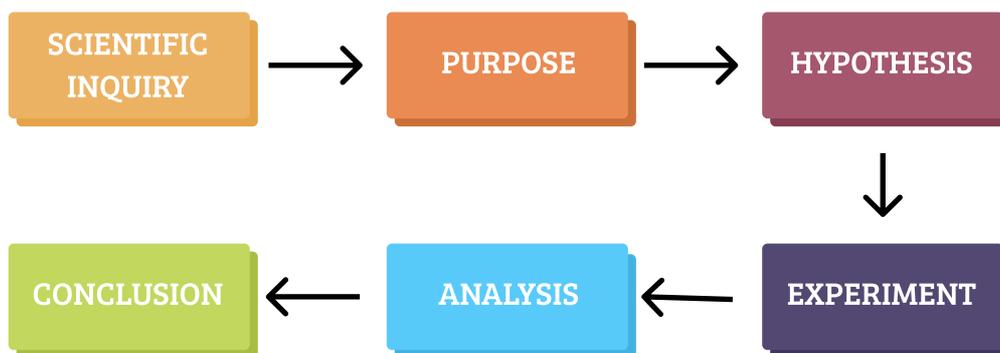
### Visualize the data

Students view data, represented in a visual format and displayed on their computer screens. Using a screen display students visualize thermal. Students identify trends and relationships among energy capacity and heat transfer variables.

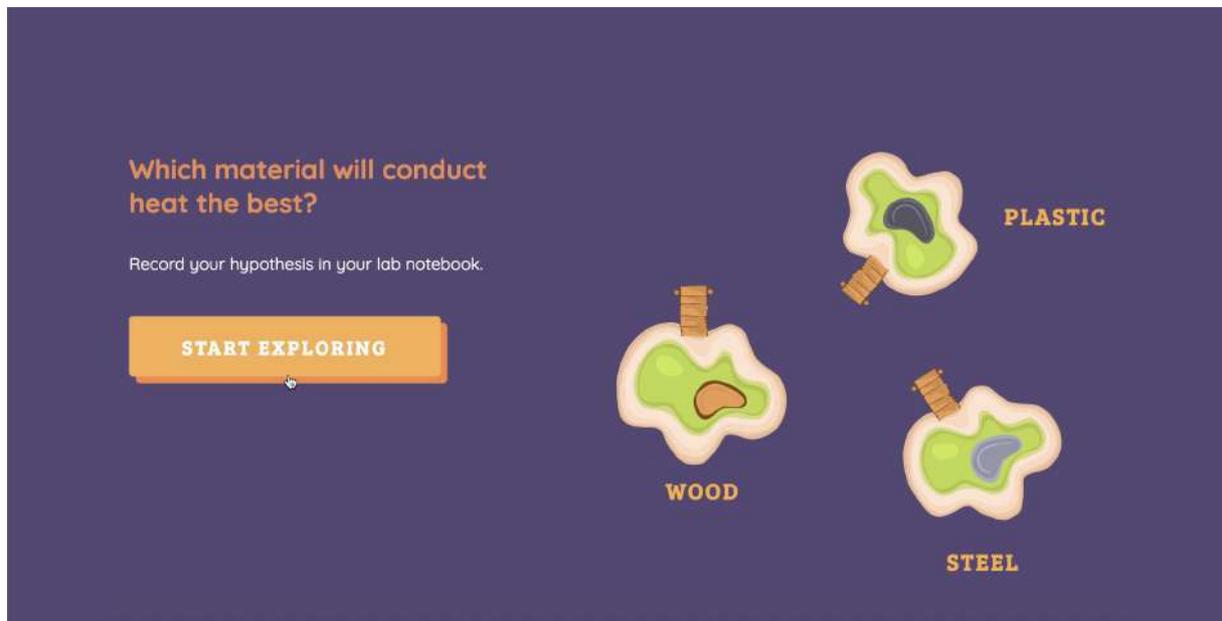
## 2 Scientific Investigation

Investigation is the dominant activity of the scientific investigation interface. The interface emphasizes conducting the experiment and making sense of data. It provides rigorous yet engaging guidance by using comic-book inspired characters that lead your students through developing and evaluating explanations.

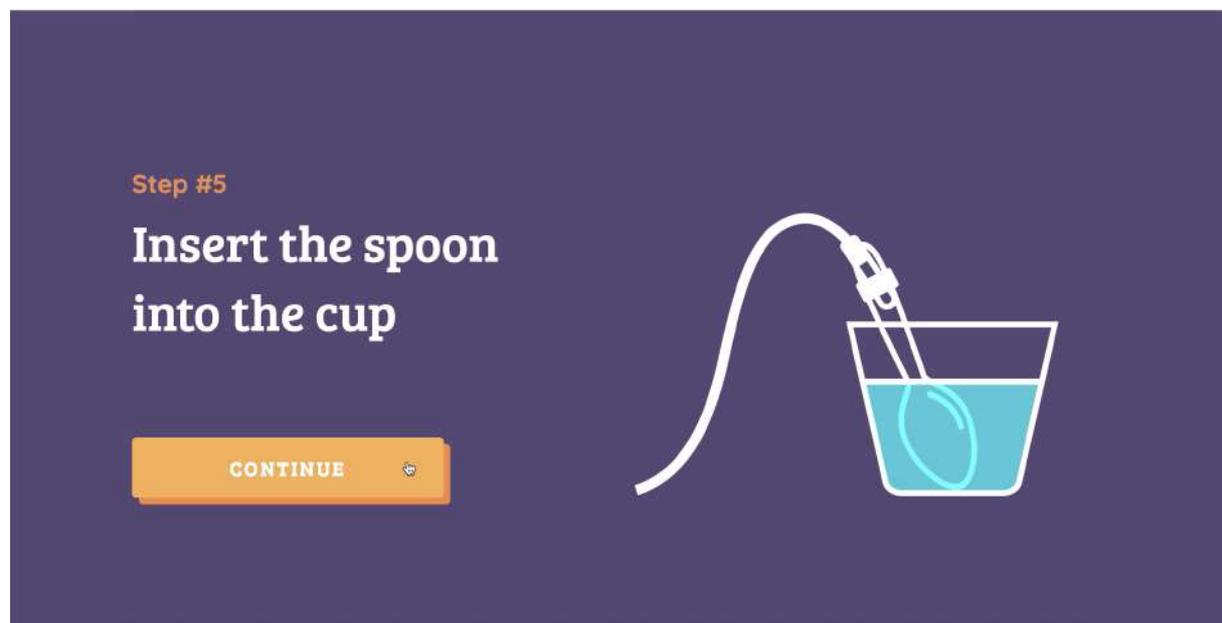
Suri and Equinox assist your students in each stage of the scientific investigation.



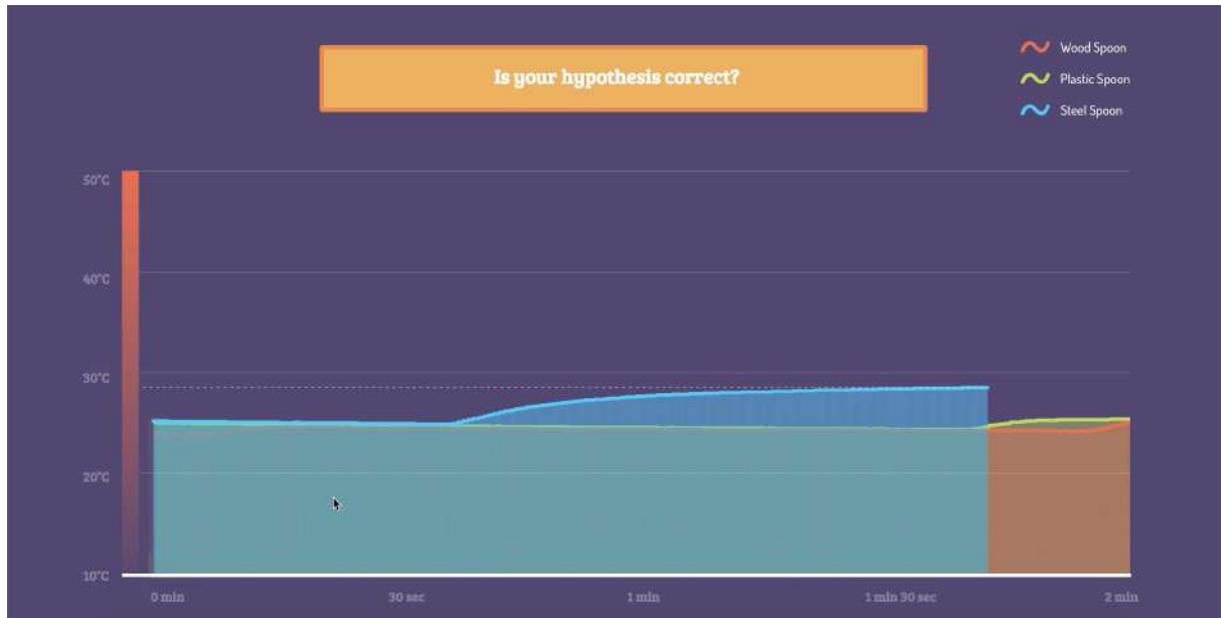
Formulate a hypothesis for the experiment. This is done in the companion lab notes provided.



Gather materials and set up the experiment. The interface also handles errors and provides a step-by-step process to the students.



The interface reads the real-time data and displays it in a easy to understand graph.



Students can analyze the data and revisit their hypothesis after the experiment is completed.

All done!

## So, which material should we use for our gloves?

Record your answer in your lab notebook.

**CONTINUE**



## Before Investigation

- Plan to conduct the experiment yourself to ensure things run smoothly.
- Print student printables **(see page 26 & 27)**
- Ensure a source of hot water is available or plan for a cold water experiment.

## Concluding Investigation

- Lead a discussion about results, here are some questions to consider:
- Is data consistent?
- Is it always going to be the case that steel conducts the most thermal energy?
- Do we see the same results each time?
- Are there any results that are outliers (too high, too low, out of range)
- Is there an upper maximum temperature?
- How could you improve the experiment to increase the certainty of your conclusion?

# Guidebook for Students

# 1 What is thermal energy?

Thermal energy is the energy that comes from heat. This heat is generated by the movement of tiny particles within an object.

# 2 Make it an experiment!

Even though we can't see those particles we can build a thermometer and make an experiment to observe how different materials conduct thermal energy.

# 3 Meet Equinox and Suri!

Equinox and Suri are twins who have the power to store an infinite amount of thermal energy.

They need your help to find the material with the highest thermal conductivity for their special glove.

Let's get started!





## 4 Things you will need

### Materials

- \*1 printed thermometer box (print on 11 X 17 paper)
- Crayons
- Colorful paper
- 5 jumper cables
- Pluggable terminal block DS-182B0 waterproof
- temperature sensors
- Spoons

### Reusables

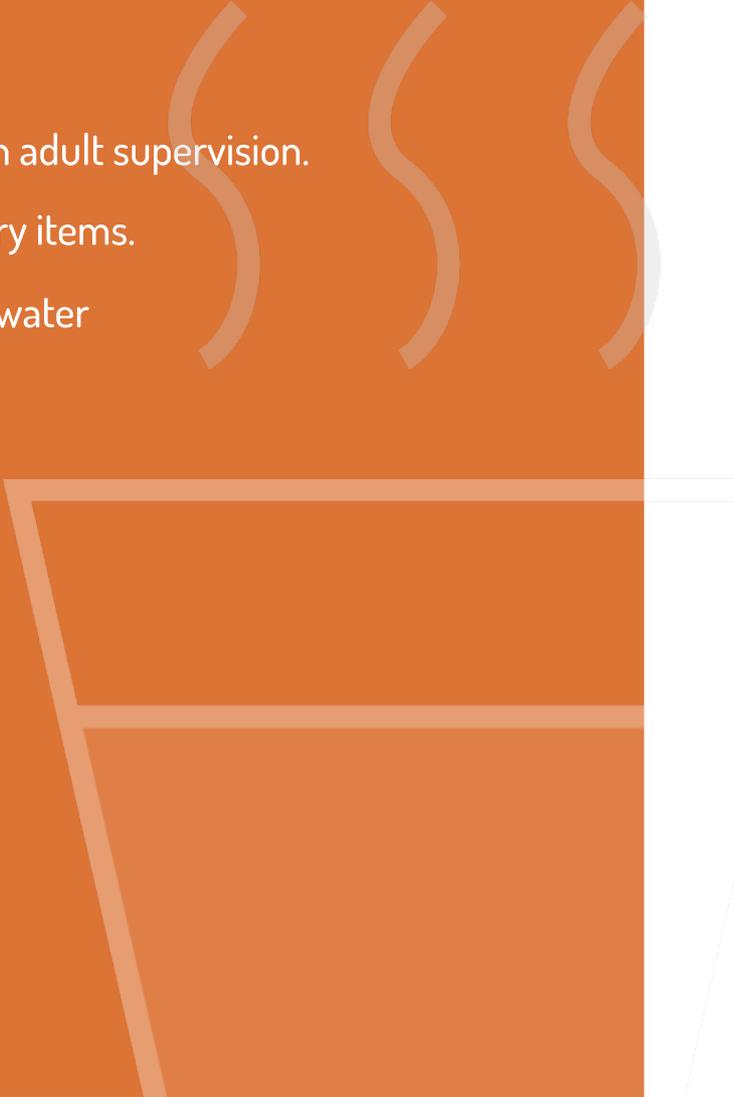
- 1 microcontroller (Arduino)
- 1 USB cable A-to-B for Arduino
- 1 breadboard
- Jump wires

### Toolkit

- Scissors
- Glue
- 2.0mm Screwdriver
- Kettle (or, other source for hot water)

# Safety guidelines

## You will be using Hot Water

- Use caution when handling hot water.
  - Avoid dangerous behavior.
  - Always conduct your experiments with adult supervision.
  - Keep the work area free of unnecessary items.
  - Keep electronics a safe distance from water
- 
- The background features decorative elements including three vertical wavy lines on the right side and a large, faint outline of a glass of water in the bottom right corner.

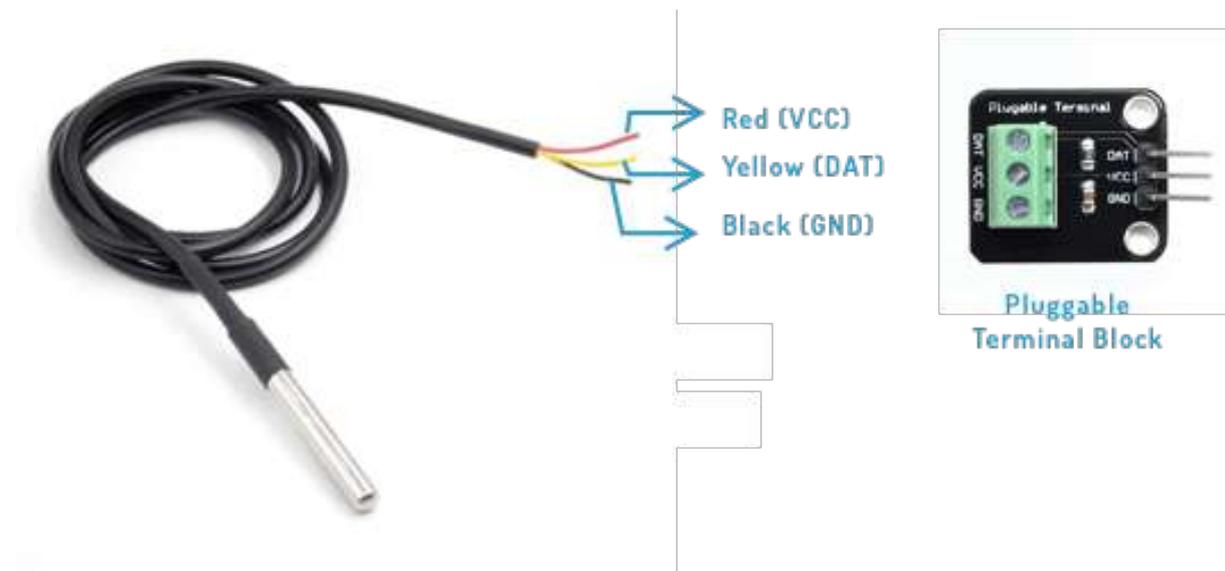
# 5 Setup your Arduino Circuit

Gather the following materials

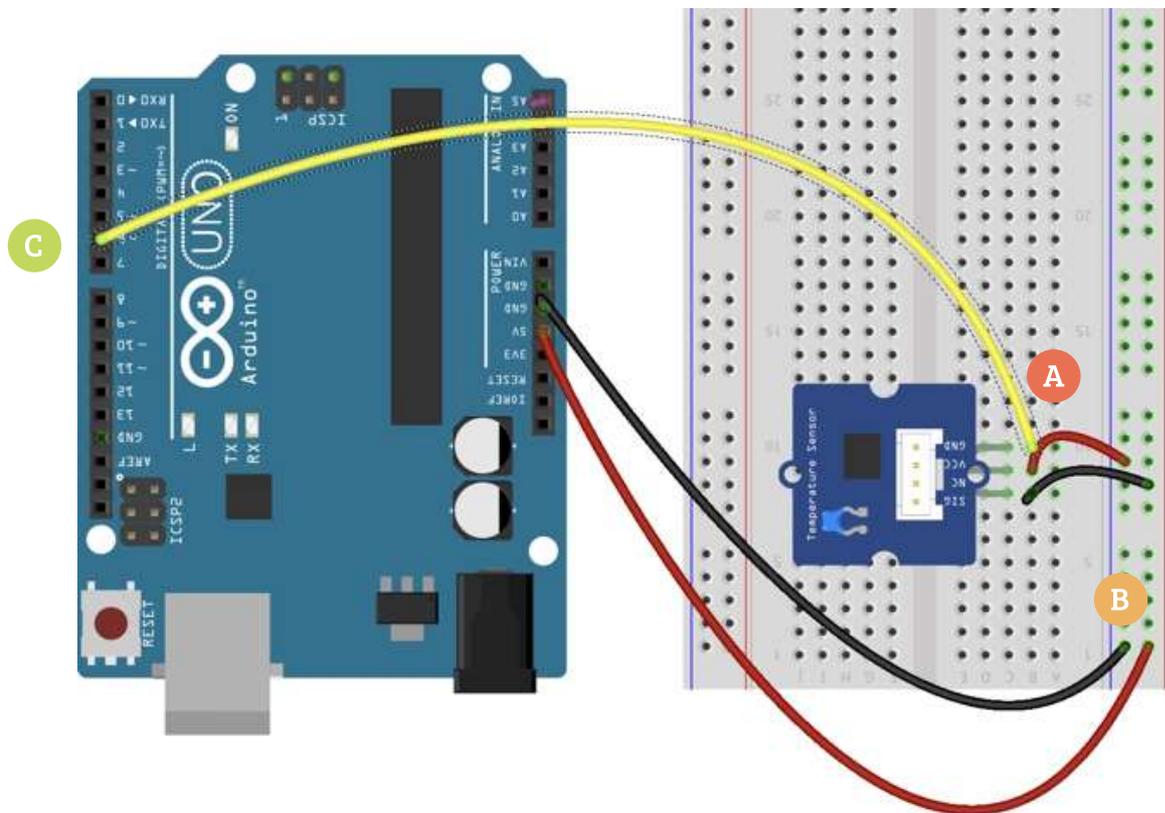


**Screw each wire into the terminal.**

Use the 2.0mm Screwdriver to attach the temperature probe to the pluggable terminal block.



## Use the diagram to plug in your wires



- A** Connect the block to the breadboard. Red wire is attached next to VCC hole. Black wire is attached next to GND hole. Yellow wire is attached next to DAT hole.
- B** Give your board some power. Connect a male to male jumper wire from 5V on the Arduino to the (+) column on your breadboard. Connect another male to male jumper wire from GND on the Arduino to the column (-) on your breadboard.
- C** Now attach the other end of the yellow wire to ~6 hole in your Arduino.



## 6 Setup your Arduino Code

**Downloads**  
Latest LTS Version: 10.15.3 (includes npm 6.4.1)

Download the Node.js source code or a pre-built installer for your platform, and start developing today.

**LTS**  
Recommended For Most Users

**Current**  
Latest Features

**Windows Installer**  
node-v10.15.3-x86.msi

**macOS Installer**  
node-v10.15.3.pkg

**Source Code**  
node-v10.15.3.tar.gz

32-bit	64-bit	
32-bit	64-bit	
64-bit		
64-bit		
64-bit		
ARMv6	ARMv7	ARMv8
node-v10.15.3.tar.gz		

Windows Installer (.msi)  
Windows Binary (.zip)  
macOS Installer (.pkg)  
macOS Binary (.tar.gz)  
Linux Binaries (x64)  
Linux Binaries (ARM)  
Source Code

Now, go to your terminal and type in the following command

If it throws an error, try using this. It would ask for your computer password

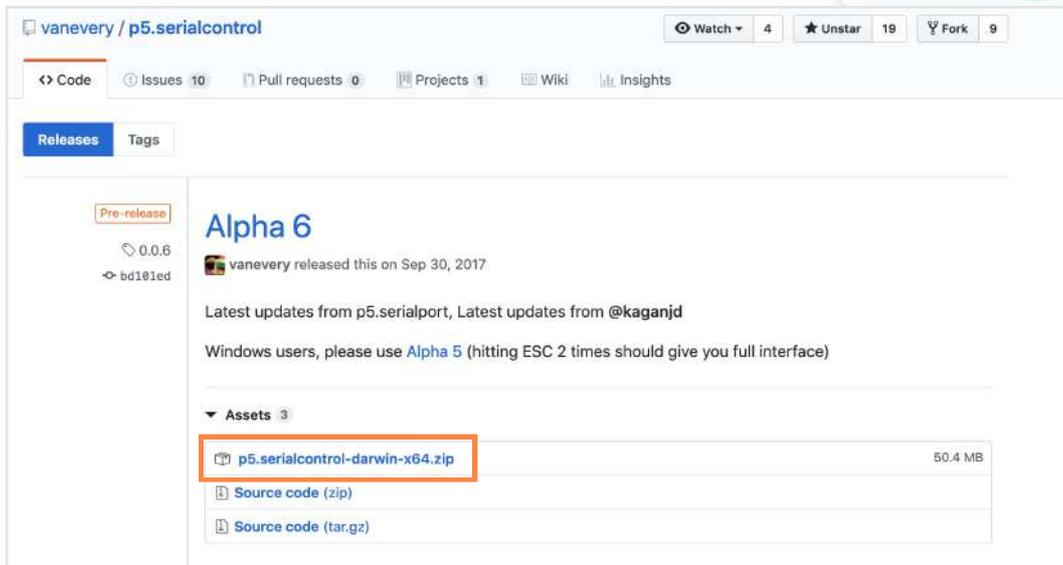
```
sudo npm install http-server -g
```

Once the command works, type in

```
http-server
```

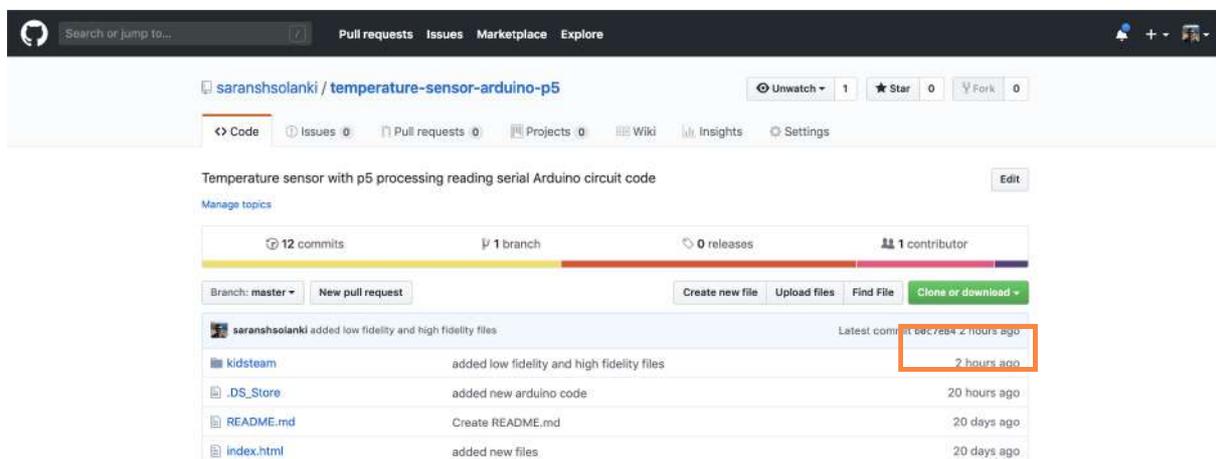
## Install P5 Serial control

This is a software which helps reading data from your thermometer. Go to <https://github.com/vanevery/p5.serialcontrol/releases/> and download file.

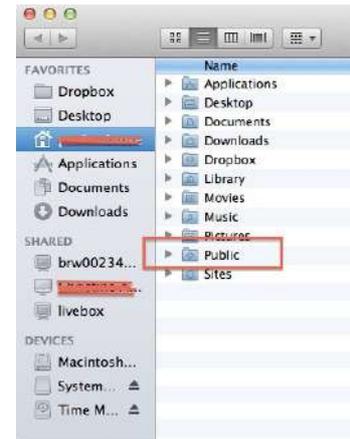


Install the downloaded software by opening it. Follow the prompts and provide any permission it asks for.

## Download the Investigating interface



Paste the code to your Public folder. Click on the desktop to get to Finder and from the File menu select New Finder Window. Click on your Home folder (the House) and in the window to the right you should see it:



## Install Arduino

Install the Arduino IDE from <https://www.arduino.cc/>. This will download a zip. Double click to install the software

A screenshot of the Arduino IDE download page. The title is 'Download the Arduino IDE'. On the left is the Arduino logo. The main text says 'ARDUINO 1.8.9' and describes it as open-source software for Windows, Mac OS X, and Linux. On the right, there are links for 'Windows installer', 'Windows ZIP file', 'Windows app', 'Mac OS X', and 'Linux' (32 bits, 64 bits, ARM 32 bits, ARM 64 bits). There are also links for 'Release Notes', 'Source Code', and 'Checksums (sha512)'.

Download the Arduino IDE

**ARDUINO 1.8.9**  
The open-source Arduino Software (IDE) makes it easy to write code and upload it to the board. It runs on Windows, Mac OS X, and Linux. The environment is written in Java and based on Processing and other open-source software.  
This software can be used with any Arduino board. Refer to the [Getting Started](#) page for Installation instructions.

**Windows** installer, for Windows XP and up  
**Windows** ZIP file for non admin install

**Windows app** Requires Win 8.1 or 10  
[Get](#)

**Mac OS X** 10.8 Mountain Lion or newer.

**Linux** 32 bits  
**Linux** 64 bits  
**Linux** ARM 32 bits  
**Linux** ARM 64 bits

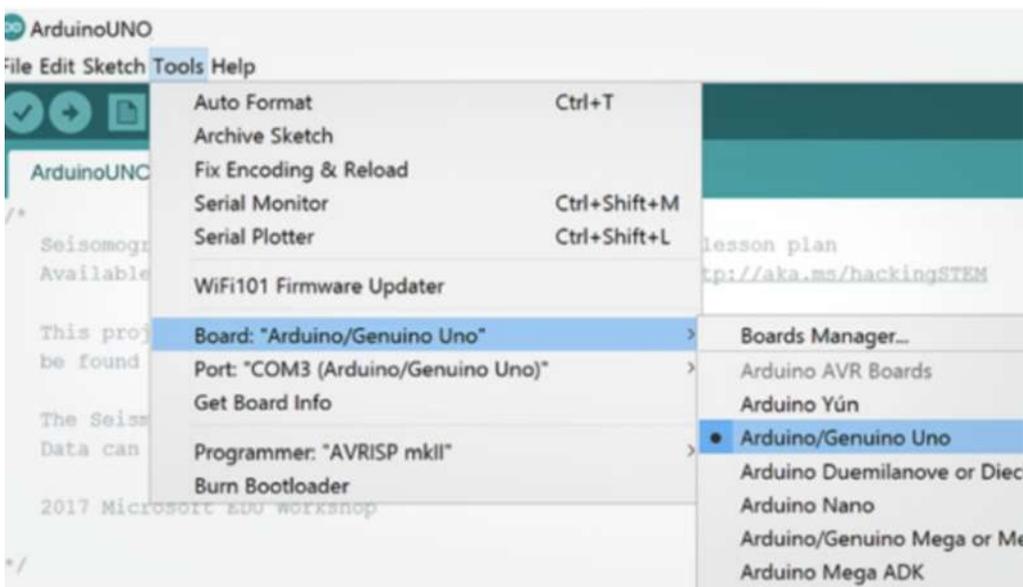
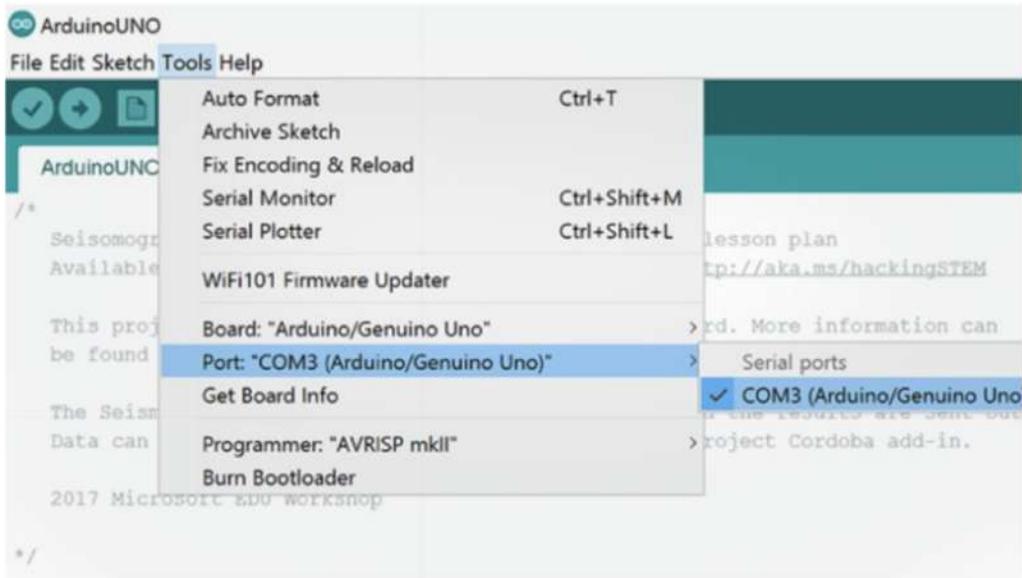
[Release Notes](#)  
[Source Code](#)  
[Checksums \(sha512\)](#)

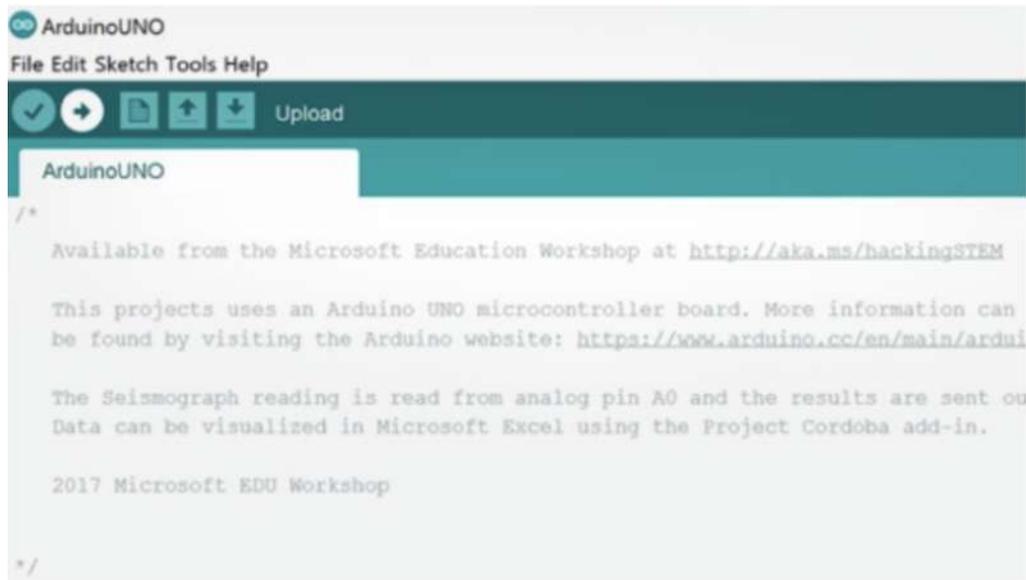
## Download the Arduino code

Go to <https://github.com/saranshsolanki/temp-sensor-arduino-p5> to download the arduino file. You will need to download the file thermometer.ino

## Setting up Arduino

Double click on the installed thermometer.ino file. Now, we need to set up your Arduino to work.

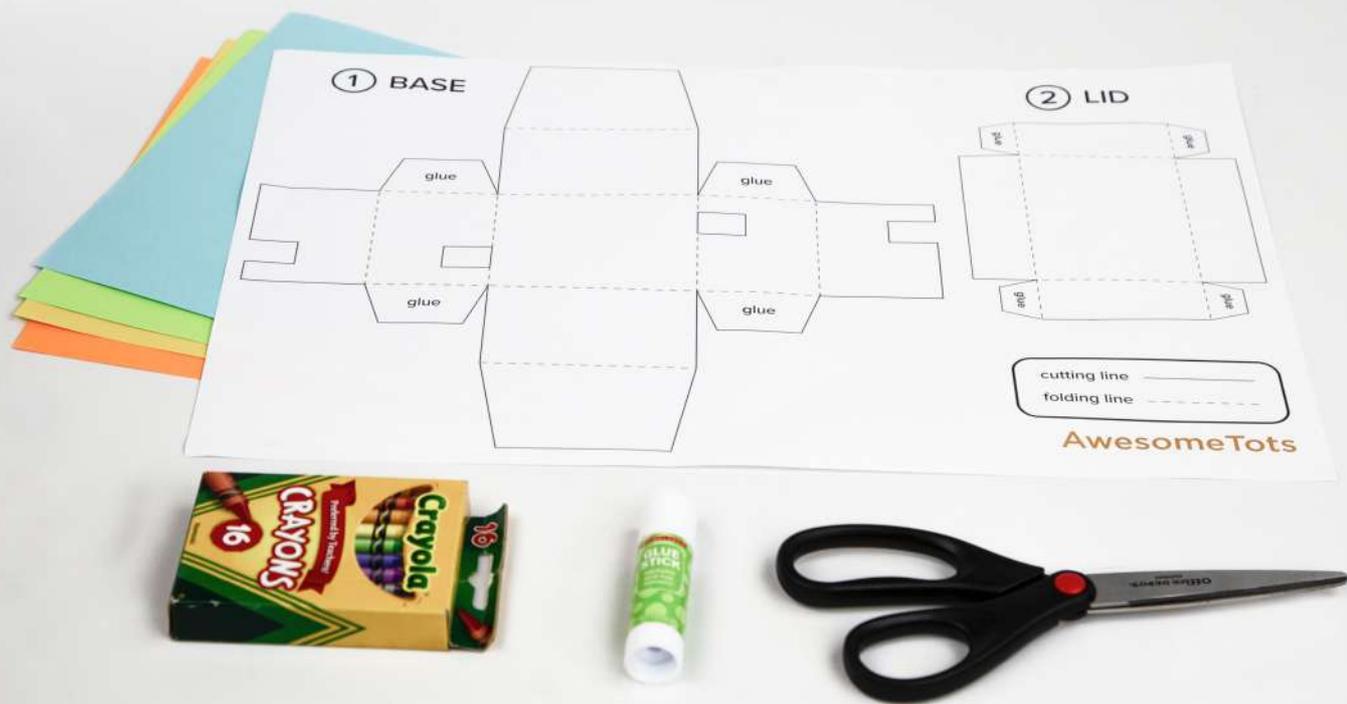




Click on the circular right arrow button to upload to Arduino.  
Now, your Arduino is all set to start the experiment.

## 7 Create a Box for your Circuit

Before starting the experiment, lets create a box for your circuit.



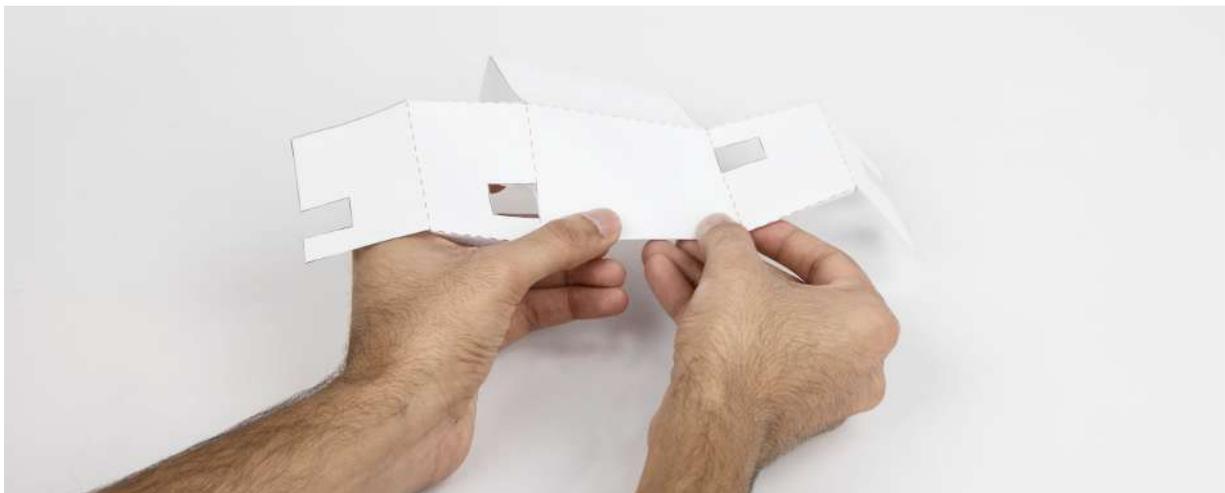
- A** Use an 11 in x 17 in sheet of paper to print out your thermometer box dieline. See page 27.



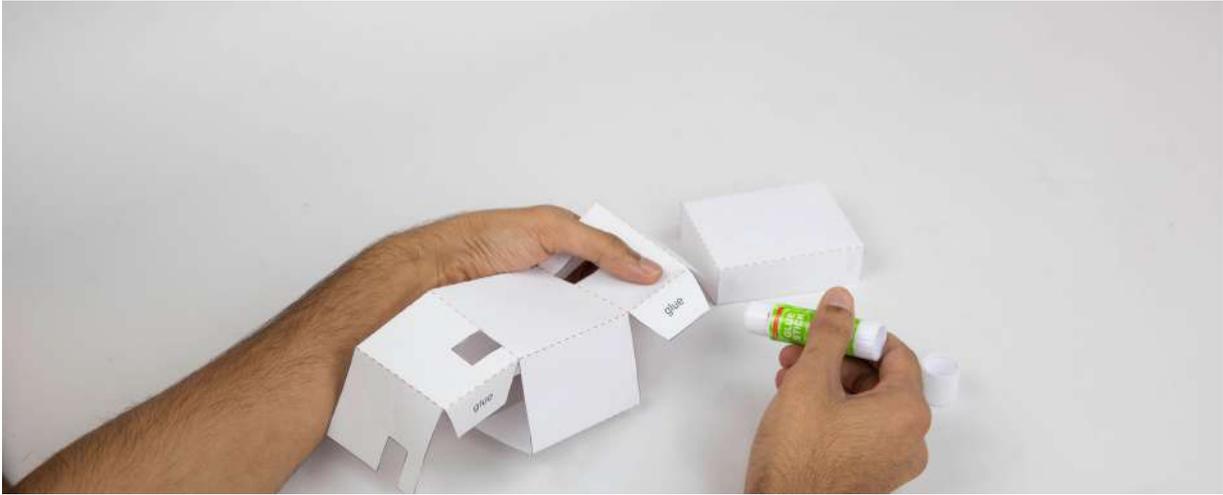
**B** Cut out both base and lid by cutting only on the solid black lines.

**Pro tip:** Cut out a rough outline first and then cut along the solid outlines.

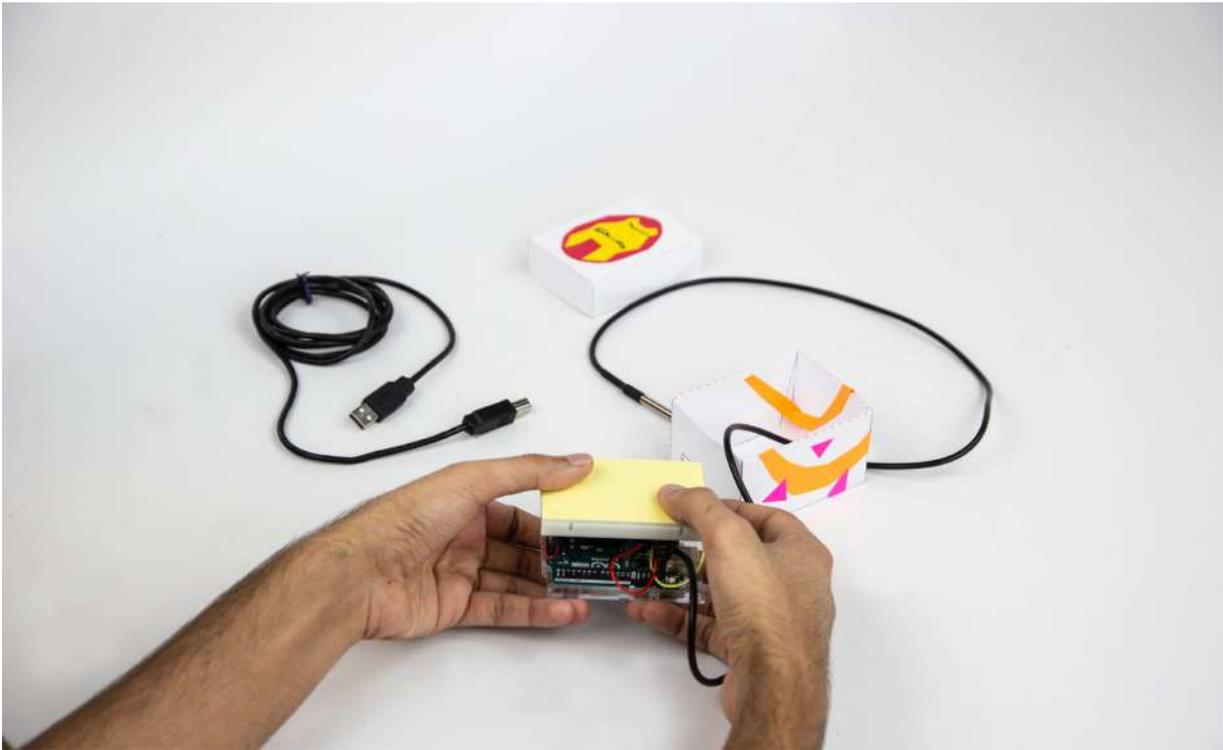
**Designer tip:** Decorate your box as you like.



**C** Fold along all the dotted lines. Make all the folds in the same direction.



- D** Apply glue to the flaps of the lid. Using the tabs on the lid of the box, tuck the smaller tab into the larger tab. Repeat this for the base of the box.



- E** Sandwich your arduino and breadboard together. Then thread your sensor through the hole of the base.



- F Fit your sandwich into the base of your box.



- G Plug the USB cord into the other side of the box. Place the lid on top of the base of your box, and you are ready to connect to your computer!

Congrats! You are all set.

Are you ready to help  
Equinox and Suri?



Go to <http://127.0.0.1:8080/main.html> to start the investigation.



**LAB NOTES**

# Investigation with Equinox and Suri

Date: \_\_\_\_\_



## 1. Which material do you think will conduct thermal energy the best?

Record your hypothesis below:

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## 2. Was your hypothesis correct or incorrect?

If correct, to what extent are you certain that your hypothesis is correct? If incorrect, what could you do to further your investigation? Record your answer below:

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# Create a Box for your Circuit

This is a scaled down version to show you the dieline.  
Please print the PDF file on a 11 in x 17 in paper.

