# SENSE YOUR SURROUNDINGS | EDUCATOR

**Module 3: Sensor Technology Series**

**Links to Next Generations Science Standards |**
**MS-ETS1-1:** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
**MS-ETS1-2:** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
**MS-ETS1-4**: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
**HS-ETS1-2**: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

**S T E M**

**Contributing Author |** Dennis (DJ) Pevey, Science Communication Fellow
**Pacing |** Several classes
**Background Needed |** Completion of Sensor Technology Series Modules 1 & 2
**Assessment |** Rubric provided
**Materials/Resources |** **Soldering may be required*

- Each group will need the following:
  - Any non-chromebook computer or laptop
  - 1 mini USB cable (http://nautl.us/2v1zbTH)
  - 1 Arduino Uno/Genuino microcontroller (http://nautl.us/2uBQw4x)
  - 1 Breadboard (http://nautl.us/2u2uWml)
  - Real Time Clock board* (http://nautl.us/2uGv9gS )
- Depending on students' experiments or projects, you may need some or all of the following materials:
  - Recommended starter sensors include:
    - Altitude / Air pressure sensors like SparkFun Alt/Pres breakout ***** (http://nautl.us/2vbuW8r)
    - Light sensors like CdS photo cell (http://nautl.us/2uGb22d)
    - Air quality sensors like the Adafruit gas sensor combo *****; refer to student-version of this module for more details (http://nautl.us/2tNuNrB)
  - Jumper wires to connect components (http://nautl.us/2vbknSS)
  - LEDs (http://nautl.us/2eRHcEl)
  - Resistors
  - MicroSD card breakout board to log data ***** (http://nautl.us/2uFWOi1)
  - MicroSD card and reader (http://nautl.us/2v2Y80O)
  - External power supply such as 9-volt battery and battery clip (http://nautl.us/2vbzFHh)
- Soldering material needs will depend on skill level of your group. Teacher discretion advised on either prepping soldered components ahead of time or supervising students on this work:
  - Soldering gun and kit (http://nautl.us/2h6AZ81)
  - Solder (http://nautl.us/2uBJLQ7 - often comes with a soldering kit)
  - Safety glasses (http://nautl.us/2vbBxQo)
  - Regular and bent header pins (http://nautl.us/2tNoIeC)
  - Soldering cleaner sponge (http://nautl.us/2h6DVSd)
  - Magnifying glass (http://nautl.us/2uGwgNA)

## Overview

In this final module of the Sensor Technology Series, students apply their STEM skills creating their own research project using data from a sensor they design and build. Student groups will collect environmental data to answer a valid research question. This module is student-directed asking groups to use the provided Resource Bank to walk through sensor platform design. It is up to you to decide what level of guidance and support to provide for your learners. Student learning is assessed through final group presentations of their findings. This document shows one example project and how to create that sensor platform. Many variations are possible with different sensors.

**Links to Common Core Standards |**
CCSS.ELA-LITERACY.RST. 6-8.3: Follow precisely a multistep procedure when carrying out experiments or performing technical tasks.

CCSS.ELA-LITERACY.RST. 6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context.

CCSS.ELA-LITERACY.RST. 9-10.7: Translate quantitative or technical information expressed in words in a text into visual form and translate information expressed visually or mathematically into words.

CCSS.ELA-LITERACY.RST. 11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media in order to address a question or solve a problem.

## Activity/Tasks

Students will:

- Determine a testable question they would like to address by collecting data using a sensor platform they build.
- Use the Resource Bank included in the student-version of the module to research project ideas, tutorials, and appropriate tools for building a sensor.
- Work as a group to complete the project.
- Present project and findings to class and/or community.

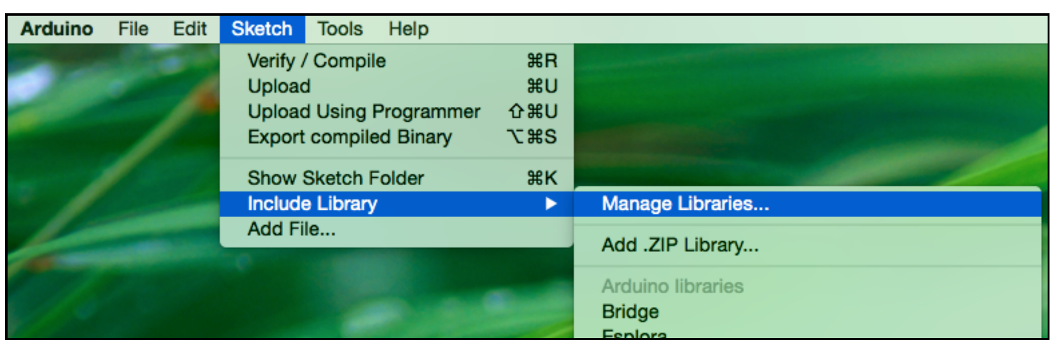
## **Educator:** Lesson Procedure/Directions

✓ **LESSON SET-UP |** This guide details one example project: building a platform using a SparkFun Altitude/Pressure sensor to collect physical data about conditions at various locations. This sensor samples local air pressure, temperature, and altitude within 30cm of accuracy. A project idea would be to have student groups build multiple identical sensor platforms and collect data from varied environments (i.e. if students live in different towns / neighborhoods or suburbs vs. rural vs cities they could compare temperature variation across locations).

✓ Follow the three procedure parts to walk through this example project. Completing the project requires all materials from page one except the photo cell and air quality sensors.

### PROCEDURE PART 1 | Downloading Libraries, Soldering and Real Time Clock

1. Open Arduino IDE and open the library manager under “Sketch”, “Include library”, “Manage Libraries…”
2. When you open the library manager, you’ll see a large list of libraries ready for one-click install. Search by product name or keyword such as “Sparkfun MPL3115A2” and install the library.





**Extensions & Adaptations**

Introductory | Student groups build the same sensor with educator guidance and work together on collecting data on a single variable like temperature across a variety of habitats to practice basic scientific, graphing and engineering skills.

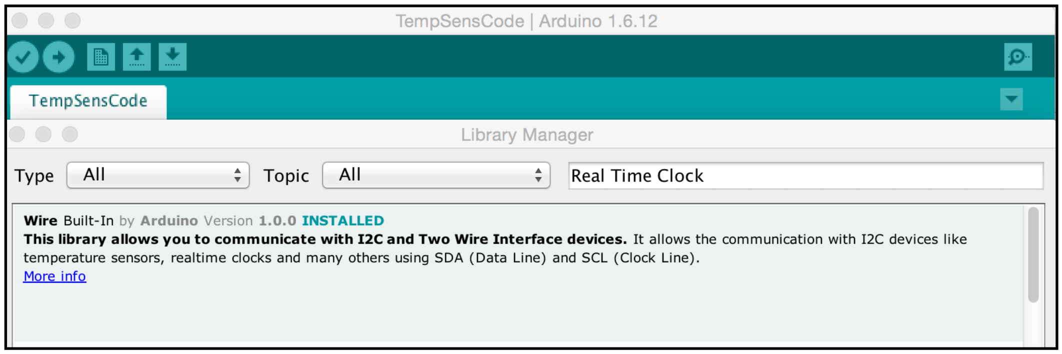
- Temperature tie ins: Urban Heat Island Effect
- Measuring Albedo

Advanced | Students execute their own research project self-directed asking for guidance as needed.

Project ideas:

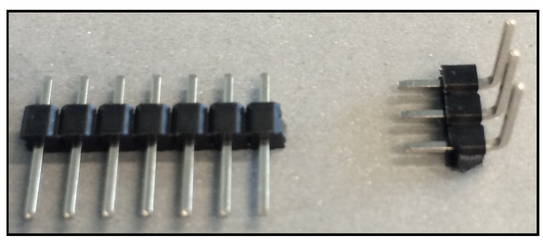
- **Pollution alarm:** build a sensor device that can activate an output (LED, Buzzer, etc.) once a certain pollution threshold is detected.
- **Air quality patrol:** build a data logging air quality sensor that can be floated in an airspace using helium balloons or a remotely controlled drone.
- **Map a pollution plume:** Use a python script and wifi-streamed data from a sensor to create a map showing the volume/ coverage/ distribution of a selected pollutant in a certain area.

3. Follow the same procedure to install the appropriate Real Time Clock library. This example uses the Built-In Arduino version. Another library which can be used is the Adafruit DS1307.




4. Check for components which need soldering. For this platform, the RTC, sensor and SD breakout board required soldering.

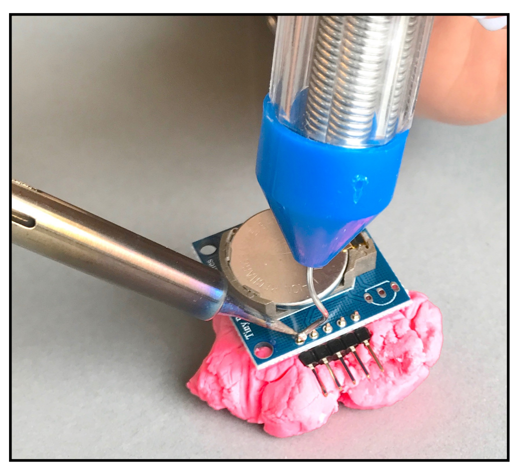
✓ Tip: Check the position of the pin holes on the components to determine how they will best be connected to the bread board - by straight header pins or bent header pins.



Regular Headers 90° Bent Headers

5. Solder components together by melting a tiny amount of solder to create a permanent connection and seal between each header pin and pin hole on the device.

The next page includes a suggested soldering setup and example video.



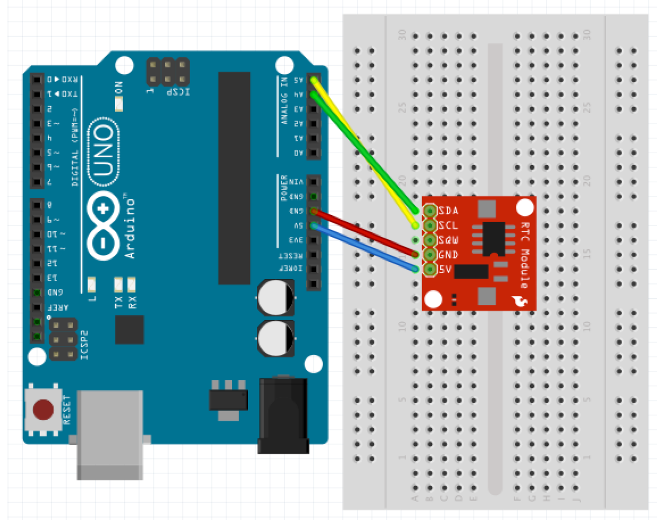
6. Soldering setup:


- ✓ Tip: Use clay to firmly hold the components together while soldering.
- ✓ Remove extra solder or fix errors by re-melting the solder and using either a soldering sucker or the solder gun to gently push excess solder off.
- ✓ Ensure solder around one pin doesn't touch the next pin - this could short the circuit!
- ✓ It may be helpful to provide pre-soldered components for student groups.
- ✓ Refer to Adafruit's Common Soldering Problems Guide as needed. https://learn.adafruit.com/adafruit-guide-excellent-soldering/common-problems

7. Video: http://nautl.us/2gxgmSA

8. Wire the Real Time Clock (RTC) to the Arduino as shown below. The RTC will assign the correct time to each data point collected by other sensors.

SCL > A5
SDA > A4
VCC > 5V
GND > GND

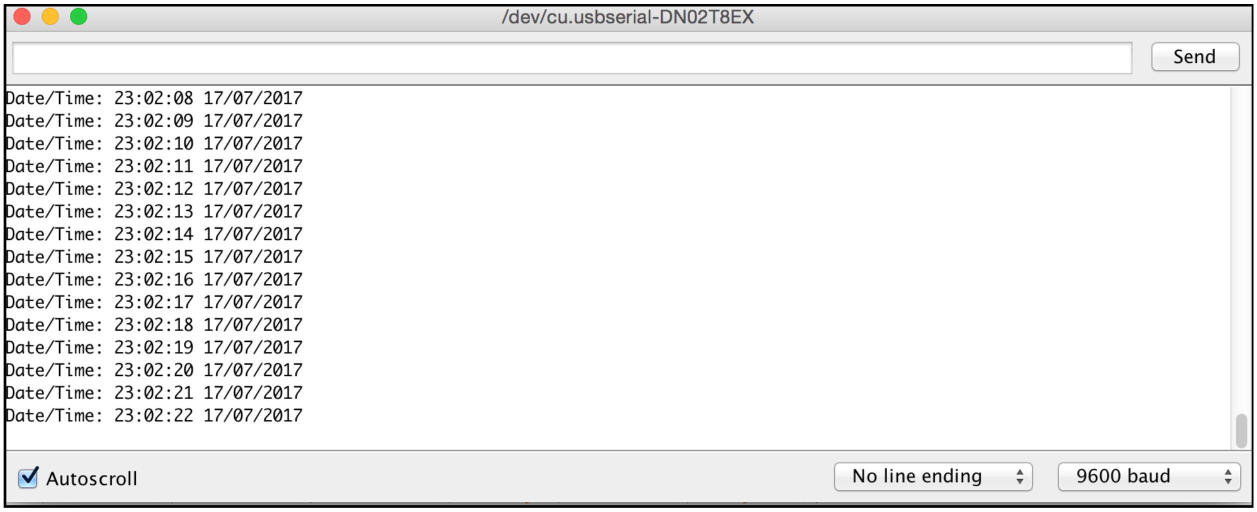



*Schematic made with fritzing.org*

9. Copy and paste the following Real Time Clock code into Arduino IDE and upload.
http://nautl.us/2w4oWL7

```
#include <RTClib.h>
#include <Wire.h>

RTC_DS1307 rtc;

char buf1[20];

void setup()
{
  Serial.begin(9600);
  Wire.begin();

  rtc.begin();
  rtc.adjust(DateTime(F(__DATE__),F(__TIME__)));

}

void loop()
{
  DateTime now = rtc.now();

  sprintf(buf1, "%02d:%02d:%02d %02d/%02d/%02d",  now.hour(), now.minute(),
now.second(), now.day(), now.month(), now.year());

  Serial.print(F("Date/Time: "));
  Serial.println(buf1);

  delay(1000);
}
```

10. Open the serial monitor to check that the time is accurate. At the bottom of the window select 9600 Baud from the dropdown. This option sets the data to a 24-hour clock so data collected over long time periods is easy to monitor.

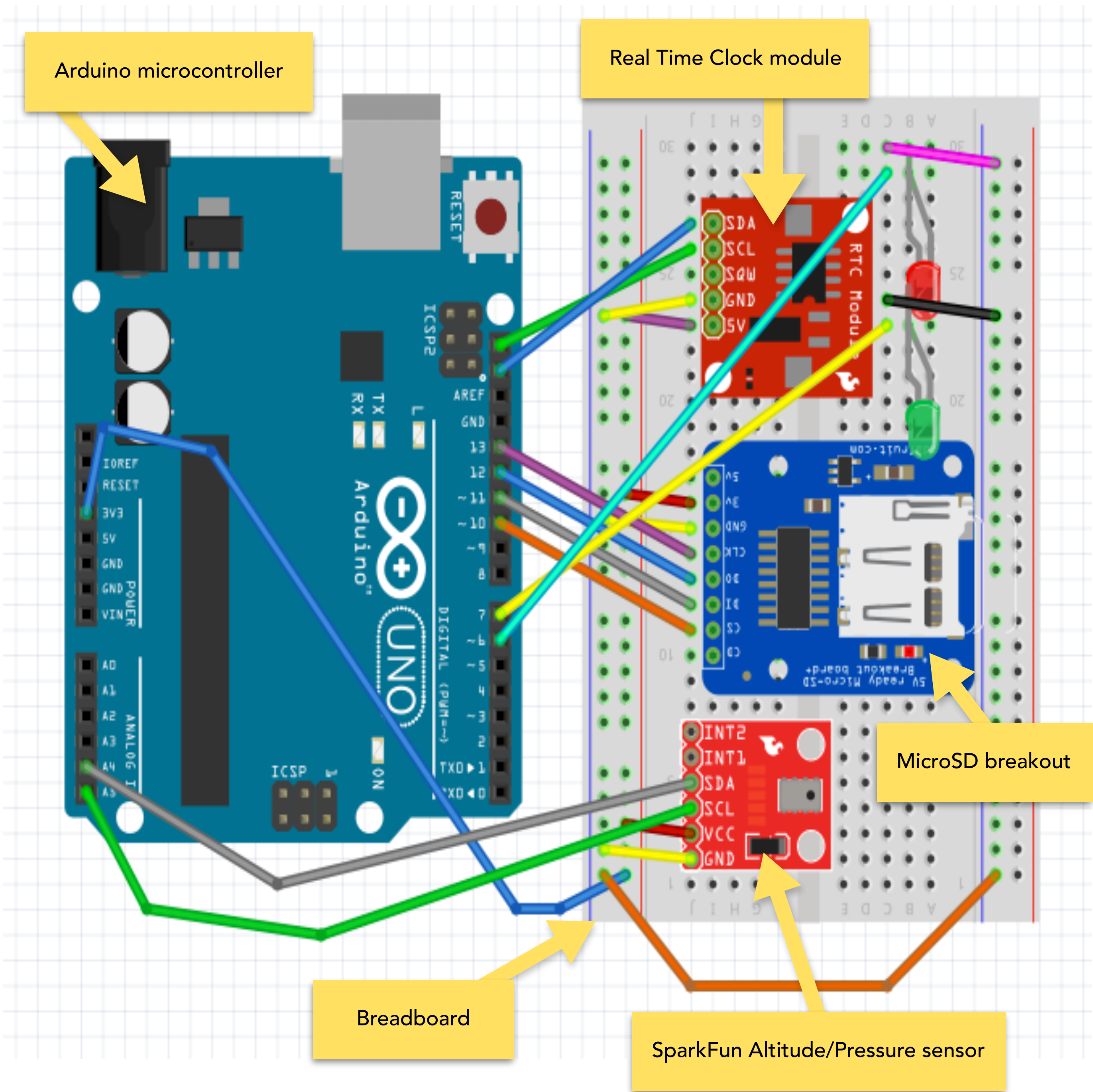



## PROCEDURE PART 2 | Wiring the Sensor Platform

1. Wire your board and sensor platform as follows:

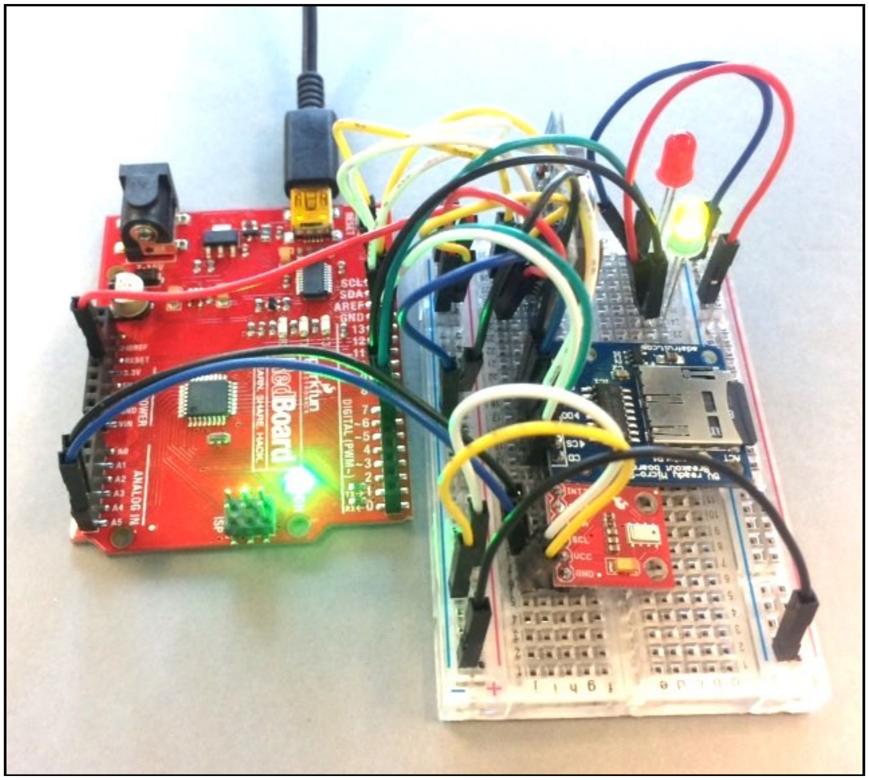
| From SparkFun Altitude/ Pressure Sensor: | From MicroSD Breakout: | From Real Time Clock Module: | LEDs: |
|---|---|---|---|
| SDA > A4 | 3.3v > 3.3v | 3.3v > 3.3v | **Green**: (+) > Pin 7 |
| SCL > A5 | GND > GND | GND > GND | (-) > GND |
| VCC > 3.3v | DO > 12 | SCL > SCL | |
| GND > GND | DI > 11 | SDA > SDA | **Red**: (+) > Pin 6 |
| | CS > 10 | | (-) > GND |
| | CLK > 13 | | |

** This sensor platform can be used with or without LEDs. To ensure optimal functioning of LEDs add resistors (one for each LED) to the circuit. One end of the resistor connects to the same row as the longer wire lead (+)/ wire connecting to Arduino pin, and the other end plugs into the same row as the shorter LED wire lead (-) connected via wire to the blue ground rail.




*Schematic made with fritzing.org*

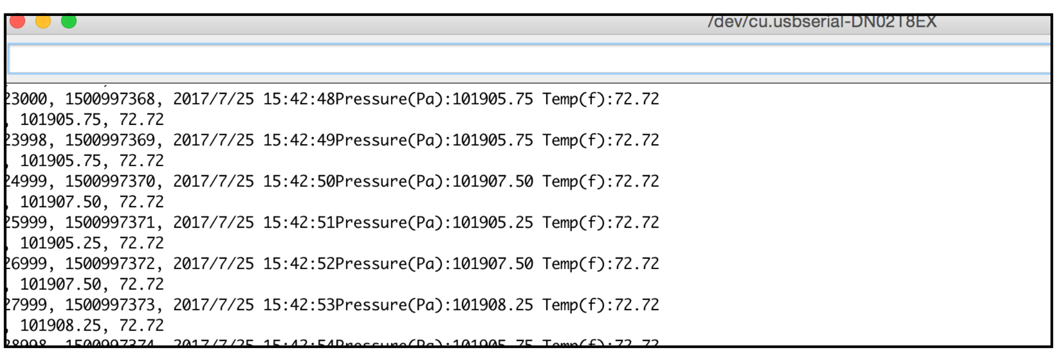
2. When wired and connected via USB to a computer, the board should look like the example below including the green LED lit up.



3. Insert a microSD card into the SD breakout board and upload the Temperature Sensor Code to the Arduino microcontroller: (http://nautl.us/2gQmCor)

To examine each component of this code, see this deciphered walkthrough: Annotated Code (http://nautl.us/2vsNCNT )

4. Open the serial monitor to check that the code is running properly. The display should resemble the following, with accurate time-stamped data:





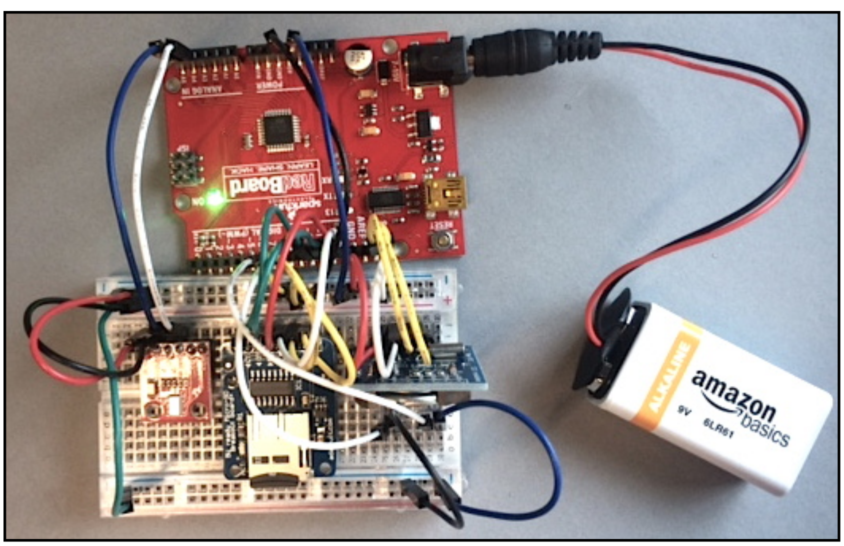
## PROCEDURE PART 3 | Using the Sensor Platform & Visualizing Data

**Congratulations! Your sensor platform is up and running!**

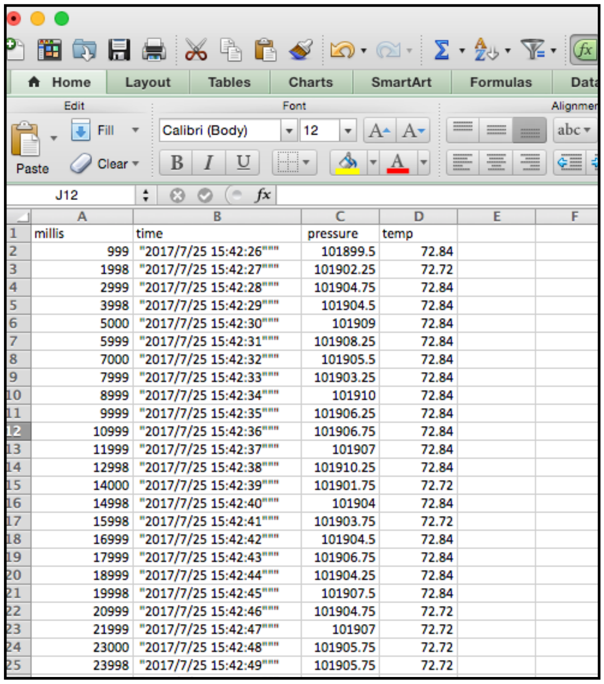
1. For greater versatility in collecting data and to make your sensor independent of the laptop/computer, it is possible to power your sensor off a battery. The student Resource Bank has detailed instructions on assembling external power sources. The most simple setup uses a 9-volt battery and DC power adapter clip.


2. In this example, a platform modification was needed for the sensor to run properly on a 9-volt external power source. Removing two LEDs reduced the current draw ensuring the sensor was supplied enough power by the battery. Students may need to experiment with their own sensors to troubleshoot issues as they arise.

3. Insert the DC plug into the DC adapter on the Arduino board. The built-in light should turn on. Test the sensor by letting it collect data for a few minutes. *Note: the Arduino will automatically run whatever code was last uploaded.*

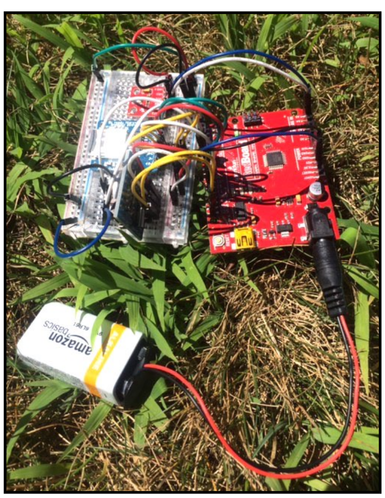


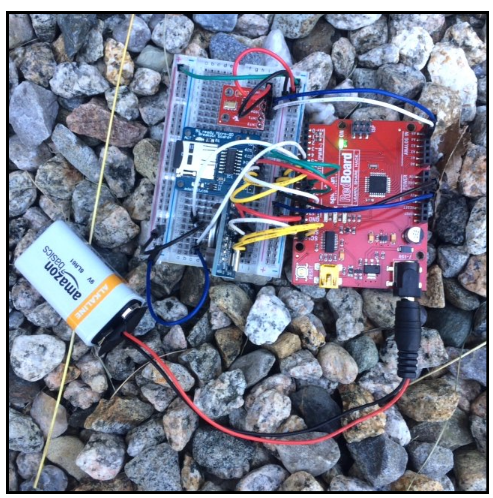
4. Remove the MicroSD card from the data logger and insert it into a reader on your computer. Open the file in a spreadsheet program like Excel, Numbers or Google Sheets to view and graph the data. Add or adjust data labels and units if needed.



| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | millis | time | pressure | temp | | |
| 2 | 999 | "2017/7/25 15:42:26""" | 101899.5 | 72.84 | | |
| 3 | 1998 | "2017/7/25 15:42:27""" | 101902.25 | 72.72 | | |
| 4 | 2999 | "2017/7/25 15:42:28""" | 101904.75 | 72.84 | | |
| 5 | 3998 | "2017/7/25 15:42:29""" | 101904.5 | 72.84 | | |
| 6 | 5000 | "2017/7/25 15:42:30""" | 101909 | 72.84 | | |
| 7 | 5999 | "2017/7/25 15:42:31""" | 101908.25 | 72.84 | | |
| 8 | 7000 | "2017/7/25 15:42:32""" | 101905.5 | 72.84 | | |
| 9 | 7999 | "2017/7/25 15:42:33""" | 101903.25 | 72.84 | | |
| 10 | 8999 | "2017/7/25 15:42:34""" | 101910 | 72.84 | | |
| 11 | 9999 | "2017/7/25 15:42:35""" | 101906.25 | 72.84 | | |
| 12 | 10999 | "2017/7/25 15:42:36""" | 101906.75 | 72.84 | | |
| 13 | 11999 | "2017/7/25 15:42:37""" | 101907 | 72.84 | | |
| 14 | 12998 | "2017/7/25 15:42:38""" | 101910.25 | 72.84 | | |
| 15 | 14000 | "2017/7/25 15:42:39""" | 101901.75 | 72.72 | | |
| 16 | 14998 | "2017/7/25 15:42:40""" | 101904 | 72.84 | | |
| 17 | 15998 | "2017/7/25 15:42:41""" | 101903.75 | 72.72 | | |
| 18 | 16999 | "2017/7/25 15:42:42""" | 101904.5 | 72.84 | | |
| 19 | 17999 | "2017/7/25 15:42:43""" | 101906.75 | 72.84 | | |
| 20 | 18999 | "2017/7/25 15:42:44""" | 101904.25 | 72.84 | | |
| 21 | 19998 | "2017/7/25 15:42:45""" | 101907.5 | 72.84 | | |
| 22 | 20999 | "2017/7/25 15:42:46""" | 101904.75 | 72.72 | | |
| 23 | 21999 | "2017/7/25 15:42:47""" | 101907 | 72.72 | | |
| 24 | 23000 | "2017/7/25 15:42:48""" | 101905.75 | 72.72 | | |
| 25 | 23998 | "2017/7/25 15:42:49""" | 101905.75 | 72.72 | | |

5. If data is recording properly, the sensor is ready for use! You can place the platform and power source anywhere to collect data without the computer. Choose the scale of the project whether groups will examine a single variable together and share data or if they will work independently on their own sensors. Encourage students to be creative designing their experiments. Refer to the student-version of this module for tips on graphing data and considerations for using sensors in an outdoor environment - like building water-proof or salt-proof housings.





**A few notes about Pressure and Altimeter data:**

If you compare your collected pressure data with local weather stations' data, you may see surprising differences. The MPL3115A2 Pressure/Altimeter sensor outputs pressure in a unit called Pascal. Weather stations report pressure in lots of different units:

- millimeters Mercury (mmHg)
- inches Mercury (inHg)
- millibars (mbar)
- hectopascals (hPa)
- pounds per square inch
- atmospheres (Atm)
- kilogram per centimeter
- inches of water (http://nautl.us/2uC2qeF)

Always consider units and any needed conversions when you begin data analysis.

| Unit | Average Air Pressure at Sea Level |
|---|---|
| pascal (Pa) | 101,325 |
| kilopascal (kPa) | 101.325 |
| atmosphere (atm) | 1 |
| millimeters of Mercury (mmHg) | 760 |
| inches of Mercury (inHg) | 29.92 |
| torr (torr) | 760 |
| pounds per square inch (psi or $lbs/in^2$) | 14.7 |

| Unit | Units Symbol | Conversion | Country/ Region of Use |
|---|---|---|---|
| Pascal | Pa | 1 bar = 100,000 Pa | — |
| Bar | bar | 1 bar = 1 bar | Western Europe |
| Kilopascal | kPa | 1 bar = 100 kPa | Australia |
| Megapascal | MPa | 1 bar = 0.1 MPa | China |
| Pound per square inch | psi | 1 bar = 14.5 psi | North America |
| Kilogram per square centimeter | $kg/cm^2$ or $kg(f)/cm^2$ | 1 bar = 29.53 inHg | North America |

Additionally consider the MPL3115A2 sensor outputs absolute pressure data. Understanding different pressure data formats is also important when interpreting your data. Look closely at local weather station data to understand if data is shown in absolute pressure or one of the following formats.

- Station pressure: pressure observed at a specific site without any adjustment for elevation of that location and is the true atmospheric absolute pressure of a location.
- Barometric pressure: station pressure adjusted to a representative pressure of those conditions at mean sea level so multiple locations can be compared. This pressure reading is most commonly used by meteorologists to track weather systems. When measuring pressure at sea level, station pressure and barometric pressure are equal.

***Remember, this can be a learning experience for both you and your students! Experiment with different codes, sensors and troubleshooting. Some methods that may work with one sensor may not be best with another. The options for personalized and differentiated learning are endless with this module series!***

Ocean Exploration Trust is very interested in your feedback as you use this module series! Please complete this module questionnaire to help us improve our STEM resources. We are eager to share educators' tips and tricks with our national educator cohort and to showcase samples and photos of successful student projects. You can reach our team with questions, comments or feedback at education@oet.org.

# SENSE YOUR SURROUNDINGS | STUDENT

Module 3: Sensor Technology Series

## *Learning Goals*

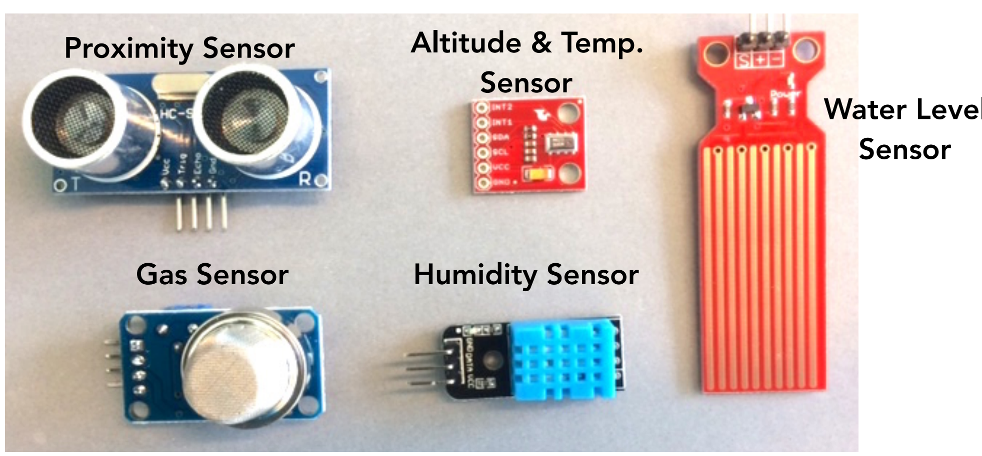
- Design and build a sensor platform to monitor one environmental condition.
- Understand the components involved with creating a unique data collection system utilizing sensors and micro controllers.
- Practice technical skills such as coding, wiring circuits and soldering.
- Use a computer program to graph data and analyze results.
- Present project and findings in a clear and appropriate way.

**Introduction |** Get ready to put your technology skills to the test in this culminating project of the Sensor Technology Series! On Exploration Vessel *Nautilus*, data engineers design, wire and code programs for a variety of sensors that are used to monitor environmental conditions on the ship. Specially engineered sensors are also used to collect measurements such as temperature and gas levels far beneath the sea's surface. Collecting and monitoring data via sensors is a crucial component that allows the *Nautilus* team to explore the world's oceans and share these discoveries with a global audience. Think back to the **partner brainstorm** question you answered in the last module:

> 4. **Partner Brainstorm:** What is one experiment you could perform in your school or community utilizing a sensor (ask your teacher for guidance if needed) to collect environmental data. What are some questions you would like to research?

**Your challenge for this lesson is to create your own Arduino-based sensor system to monitor and collect data on one environmental variable. This data needs to help you answer a valid research question.**

Work as a team to research what kind of sensor you need to assemble to answer your testable question. Use the guides provided in this module to help your team plan your experiment and sensor set-up. Your team will be responsible for presenting your project, its findings and a working prototype to the class as specified by your instructor. Complete the Skills Check on the next page to see what areas your team needs to reinforce before getting started!



### *Think, Pair, Share*

Examine the sensors shown on the previous page with a partner. Are you familiar with the functions of each one? If not, research some applications of each one and share your learning with your partner.

**Skills Self Check!** Rate your confidence in the following areas. Any categories rated with a 1 be sure to practice before proceeding!

| | Not Confident<br>1 | Somewhat Confident<br>2 | Confident<br>3 |
|---|---|---|---|
| Following a diagram or schematic to wire a breadboard. | ______ | ______ | ______ |
| Knowing the difference between positive and negative power rails and the middle rows. | ______ | ______ | ______ |
| Familiar with basic components/ commands of a sketch. | ______ | ______ | ______ |
| Uploading a sketch to a board. | ______ | ______ | ______ |
| Accessing a serial monitor and viewing incoming data from a sensor. | ______ | ______ | ______ |
| Can distinguish the difference between the following components: sensor, LED, wires, resistor, breadboard, microcontroller. | ______ | ______ | ______ |

**Resource Bank |** Use the following guides to help you organize and plan your project. You may not end up using all categories. It may be helpful to assign specific guides to individual group members to review and share what was learned with the team. Come up with an action plan that will help your team utilize time effectively.

| | |
|---|---|
| **Sensor Overview (http://nautl.us/2eLSCtv)** | **Examples of Sensor Projects (http://nautl.us/2j1Hz0w)** |
| **Incorporating a Real Time Clock for Time-Stamping Data (http://nautl.us/2gHxOAl)** | **Soldering Basics (http://nautl.us/2j3DIjH)** |
| **Weatherproofing a Sensor Setup (http://nautl.us/2j4XxY1)** | **Supplying External Power (http://nautl.us/2w7GDJe)** |
| **Installing Libraries for Various Sensors (http://nautl.us/2xP8WhL)** | **Digital vs. Analog Inputs (http://nautl.us/2j9W5n0)** |
| **Formatting a Data Logger (http://nautl.us/2vMwOVQ)** | **Visualizing Data (http://nautl.us/2vKNZU0)** |

**Project Planning |** Use the space below to help document your ideas and workflow.

| |
|---|
| Project idea/what will we be testing? |
| What materials/sensor will we need? |
| Project timeline: |
| Presentation format/notes: |
| Additional notes/resources: |



Presentation Rubric

| **OBJECTIVE** | **CRITERIA** | | | |
|---|---|---|---|---|
| | 4<br>Exemplary | 3<br>Commended | 2<br>Emerging | 1<br>Developing |
| **Organization \|** | Student presents information in a logical, interesting sequence which audience can follow. Student capitalizes on audience interest and background knowledge to enhance understanding. | Student presents information in a logical sequence which audience can follow. Student utilizes some audience interest and background knowledge to enhance understanding. | Student inconsistently presents information in a logical sequence which audience can follow. Student attempts to utilize audience interest and background knowledge to enhance understanding. | Student has difficulty presenting information in a logical sequence which audience can follow. Does not utilize audience interest and background knowledge to enhance understanding. |
| **Content Knowledge \|** | Student does not rely on notes or memory aids; demonstrates full knowledge by answering questions with extended explanations and details. | Use of notes or memory aids is minimal; demonstrates knowledge by answering all questions; may fail to elaborate. | Student frequently relies on notes or memory aids; able to answer rudimentary questions. | Student does not have grasp of information; notes or memory aids may be heavily relied upon; student is unable to answer questions. |
| **Delivery and Audience Engagement \|** | Student uses a clear voice and correct, precise pronunciation of terms so that all audience members can hear. Maintains eye contact with audience. Relaxed and polished delivery style enhances presentation. | Student uses a clear voice and correct, precise pronunciation of most terms. Maintains eye contact with audience most of the time. Confident delivery style. | Student inconsistently uses a clear voice and correct, precise pronunciation of terms. Occasionally maintains eye contact with audience. Student has difficulty presenting confidently. | Student does not use a clear voice. Correct, precise pronunciation of terms is weak. Minimally maintains eye contact with audience. Student has difficulty presenting confidently. |
| **Graphics, Visual Aids, and/or Products \|** | Resources carefully prepared to enhance presentation; easy for audience to read and/or view; demonstrates creativity; contains no grammar or spelling errors. | Uses resources to relate to presentation; easy for audience to read and/or view; some creativity exhibited; may contain minor grammar or spelling errors. | Occasional use of resources which enhance presentation; may be distracting to audience or may be difficult to read or view; little creativity exhibited; contains grammar or spelling errors. | Minimal use of resources to enhance presentation; may be distracting to audience or may be difficult to read or view; Little to no creativity exhibited; Contains grammar or spelling errors. |
| **Total Score:**<br><br>____________ | **Comments:** | | | |

# How Large is Nautilus Nation?

*Tracking the reach of Ocean Exploration Trust's education programs is essential in ensuring we are funded to continue making discoveries and inspiring the next generation of explorers.*

**Name:**

**My Community (City, State):**

**Email Address:**

**School's Name:**

**Instruction date:**

**Grade level instructed:**

**Subject area:**

**My education space is a...**

- ❏ Classroom
- ❏ After school program / Club meeting
- ❏ Fair / Festival / Event
- ❏ Museum / Science Center
- ❏ Other. Tell us more:

**Who did you engage in your teaching?**

# Students

# Community Members

**Select all the OET materials you used in your instruction:**

- ❏ STEM Learning Modules. Which ones? ______________________________
- ❏ Digital Resource Library materials. Which ones? ______________________________
- ❏ Nautilus Live website: photo albums ☐ highlight videos ☐ live stream
- ❏ Meet the Team STEM mentor profiles
- ❏ Facebook (NautilusLive) ☐ Twitter (@EVNautilus) ☐ Instagram (@nautiluslive)
- ❏ Other. Tell us more: ______________________________
______________________________

**What made working with OET resources valuable to your instruction (select all that apply)?**

- ❏ Hands-on activities ☐ STEM career connections
- ❏ Easy to use lessons ☐ Standards-based lessons
- ❏ Website resource access ☐ Real world application of curricula topics
- ❏ Excitement of cutting-edge discoveries / Unfamiliarity of deep ocean
- ❏ Another reason. Tell us more: ______________________________
______________________________

| | | |
|---|---|---|
| Using OET resources increased my confidence in teaching my science, technology, engineering, or math subjects. | ☐ Yes | ☐ No |
| OET provided me with helpful and relevant teaching resources. | ☐ Yes | ☐ No |
| Using OET resources increased my awareness of STEM careers. | ☐ Yes | ☐ No |
| If yes, how so? How can we improve? | | |

Please scan this document or snap a picture of it with your phone. Email the feedback or questions to education@oet.org. You can also submit feedback online: http://nautl.us/2cp3PNu

**Thank You For All You Do!**