AirU Sensor

Summary:

Poor air quality is a problem that affects the health of many communities, and measuring air quality can be extraordinarily important to people with health problems. An important part of measuring air quality is how accurate the data is. Currently, there are spatial and temporal disparities in air quality data throughout the Salt Lake Valley that depend on a variety of factors (e.g. elevation, airflow, weather). In this module you will learn how to set up and take care of our low-cost AirU Air Quality PM Sensors and how to analyze data taken from them. Taking care and setting up the AirU Air Quality PM Sensors will be important in creating a live air quality map that will take care of the spatial and time disparities in air quality data collection.

General Information:

Main Curriculum Tie:	Environmental Science
Additional Curriculum Ties:	Physics, Electronics
Career Connections:	Many engineers spend their careers working to keep our environment clean. Doing so requires understanding of where pollution is and where it comes from.
Typical Time Frame:	50 minutes - 1.5 hours
Typical Group Size	Whole classroom (20-30 students)
Student Prior Knowledge:	Some basic knowledge of electronics

Essential Questions:

- What is air pollution made of?
    - What is $PM_{2.5}$?
- How can we measure air quality?
- What is scattered light?
- How can we take care of the sensors?
    - Where should they be placed?
    - How do we setup the sensors?
- How can we tell apart good data from bad data?
- How can a live air quality map positively impact the community?

Materials:

- The AirU Sensor
- The AirU Circuit Board
- AirU Housing
- A micro USB cord
- An adequate power supply

Instructional Procedures:

1. Give the background information on air quality and how the AirU Sensors work through light scattering (If the class went through our Lego Air Quality Sensor teaching module, review the information and include that the AirU sensors work the same way).
2. Introduce the students to the actual AirU sensor that will be deployed in the classroom and pass the completed sensor around
3. Go over how to put together sensor (https://docs.google.com/presentation/d/1BIzyq2EhCyUjSdWnCx8S7HnOBfrYaFPs6o7DSXzxVeM/edit#slide=id.g1fa16f8861_0_13)

    a. Go over in steps:
        i. Make sure all parts are present
        ii. Insert circuit board to back
        iii. Slide circuit board all the way in
        iv. Insert the wires attached to the actual PM sensor into the side of the circuit board
        v. Insert sensor in the cover (make sure the entry of the sensor matches up with the hole in the cover).
        vi. Fold wire around the side of the sensor inside of the cover
        vii. Attach the two parts of the case together
        viii. Rotate cover until cover is firmly attached
        ix. Attach cable into the board through the hole on the bottom of the sensor case
        x. Make sure the power cord and sensor opening are facing down when sensor in operating outdoors to prevent water damage from rain

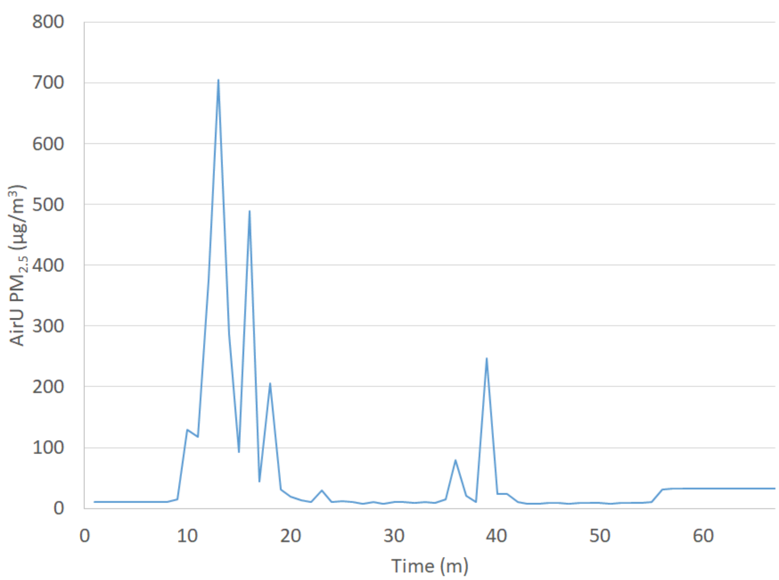
4. Go over where and how the AirU should be placed?
    a. Ask the students what they think.
    b. Go over four options
        i. Stringing the sensor
            1. Hook the eyelet supplied with the assembly onto a hanging device, for example, a planter hook or a string or rope attached to a ceiling
        ii. Wall mounting with screws
            1. Use the PDF template to align and drill the 2 accompanying screws into a secure wall.
            2. Insert the back of the assembly onto the screws using the screw slots.
        iii. Nailing the back of the sensor into a wall
            1. Open the assembly
            2. Remove the circuit board
            3. Gently nail the back of the assembly securely into a wall
            4. Reassemble the device
        iv. Mounting the sensor with zipties around a pole
            1. Insert 2 zip ties through the zip tie squares, located on the back of the flat round part of the housing
            2. Wrap zip ties around a pole and tighten
    c. Introduce the students to the data collection site
        i. Go over how to make sure the sensor is connected to WiFi
    d. Go over how to analyze the collected data
        i. Compare what normal data and irregular data should look like
        ii. Go over how to troubleshoot irregular data

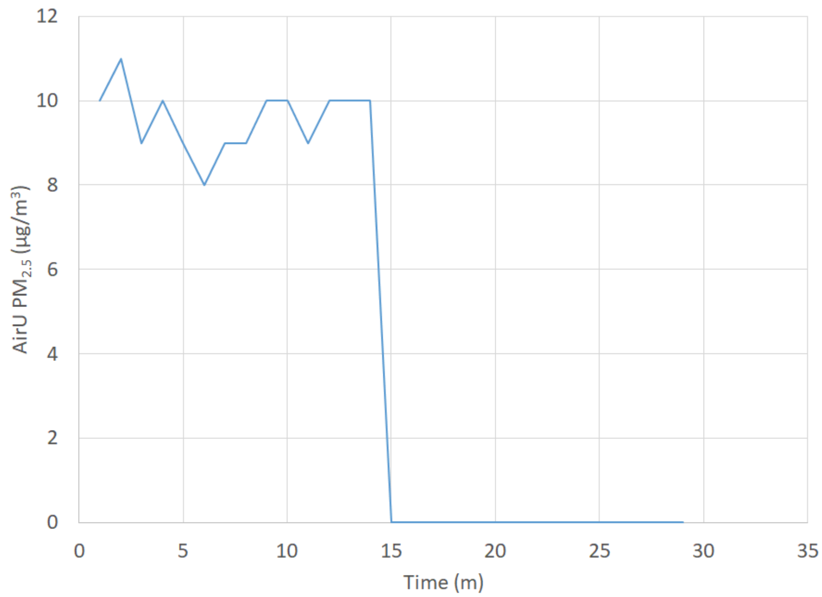
e. Reiterate with the students the importance of the sensors
   i. What are the potential positive outcomes for the community?
   ii. How can it address certain air pollution-related health issues?

Background for Teachers:

To present the background you may use the accompanying slide show:
https://docs.google.com/presentation/d/1Blzyq2EhCyUjSdWnCx8S7HnOBfrYaFPs6o7DSXzxVeM/edit#slide=id.g23dc12a7d5_0_19

Examples of different sensor readings:

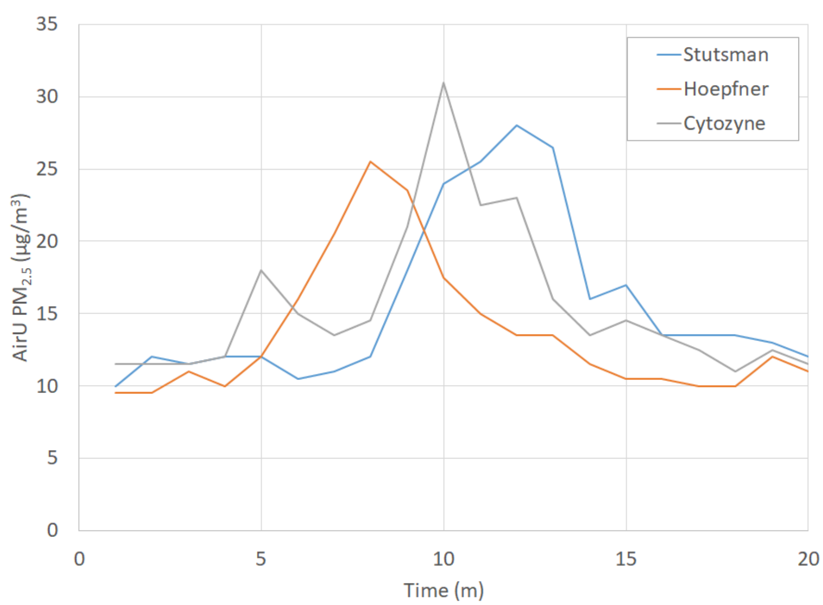
Irregular Data	
	Spike in Data • We typically don't see $PM_{2.5}$ measurements > 500 µg/m^3 • If this ever appears in the data, it is probably due to something getting stuck in the sensor or a smoker or so walking past • It would be best to disregard this piece of data • If something is stuck, carefully disassemble the sensor from the housing and carefully remove what was stuck



<u>Flatlining Data</u>

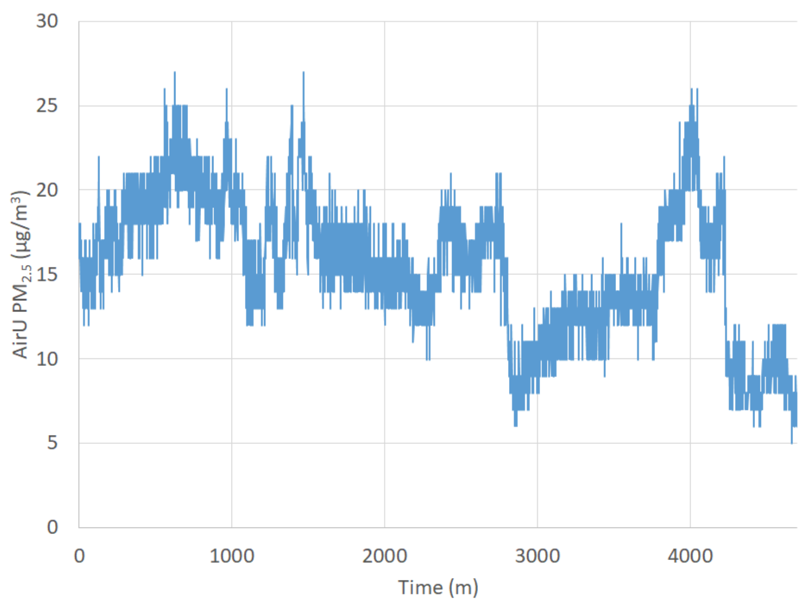
- This is when the sensor is reading one consistent measurement for an extended period of time
- This is most likely due to a coding error
- The sensor should be restarted by unplugging it and plugging it back in

Normal Data



<u>Windstorm Data</u>

- The data looks irregular because the sensors peak at different times
- However, this data was collected during a windstorm blowing from west to east and is actually normal data
- The Hoepfner sensor peaked first because it was the westmost sensor of the 3

<table>
<tr>
<td>
</td>
<td><u>Typical Data</u>
● There are no strange irregularities
● The readings vary at a reasonable amount
● There are no extreme peaks or any flatlining</td>
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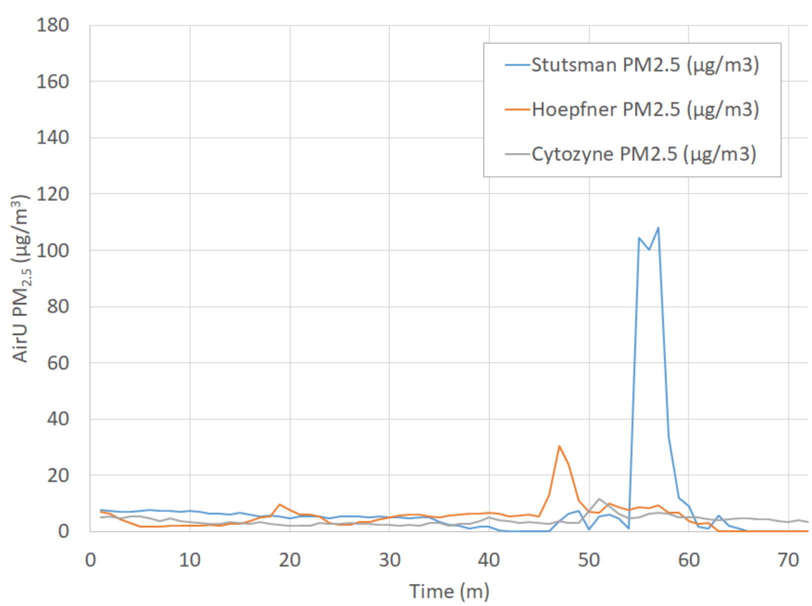
<td>
</td>
<td><u>Fireworks Data</u>
● This data also looks irregular due to the higher peaks
● However, it was reading air pollution from fireworks on Pioneer Day
● The peaks seen should be present in the data when fireworks roll around</td>
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<tr>
<td colspan="2">Sensor Comparisons</td>
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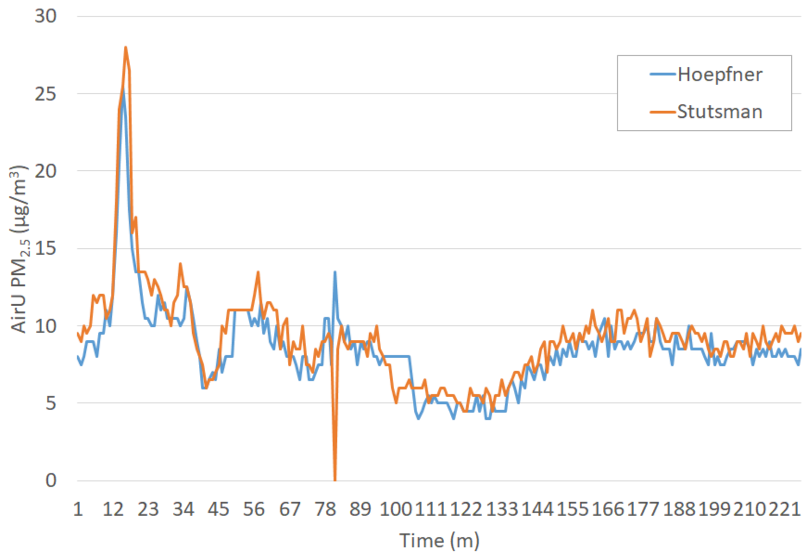
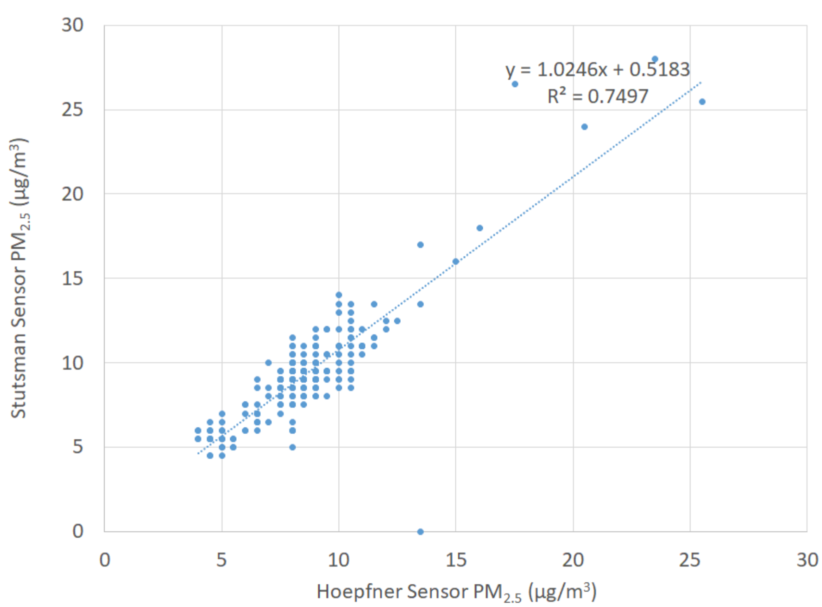


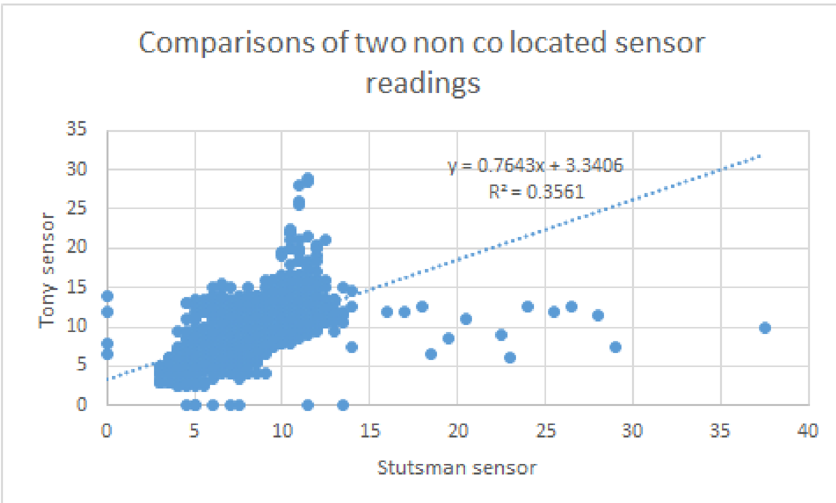
<u>Time Series of Two Co-located Sensors</u>

- The readings are quite similar, but not exactly the same
- This makes sense due to the sensors being in the same location



<u>Comparison of Two Different Sensors #1</u>

- The sensors were close in proximity to each other
- There is a strong linear correlation between the two sensors



Comparison of Two Different Sensors #2

- The sensors were further away from each other
- There is a weak linear correlation between the two sensors
- This shows that air pollution is not evenly distributed across the whole entire valley
- This shows the importance of a live air quality pollution map

Air Quality Background:

The World Health Organization estimates that in 2012 approximately 3.7 million people died as a result of ambient air pollution. Among commonly monitored air pollutants, fine particulate matter ($PM_{2.5}$), particles with diameters smaller than 2.5 microns, has the greatest adverse health effects. Elevated $PM_{2.5}$ levels are a particularly important issue in northern Utah where $PM_{2.5}$ levels can exceed national ambient air quality standards for periods ranging from a few days to weeks, particularly in the winter. These episodes of poor air quality create significant health and quality-of-life consequences for the region's citizens, including increased incidence of asthma, juvenile arthritis, and mortality.

Government agencies, such as the Utah Division of Air Quality (DAQ), and citizens rely on air-quality data from sparsely distributed monitoring stations for planning purposes and for communicating air quality. These stations are equipped with high-quality, costly instruments that meet federal monitoring requirements. However, sparsely distributed stations may not accurately represent the pollutant gradients within a city. In Salt Lake City differences in elevation, land use and other factors result in daily average $PM_{2.5}$ concentrations at the neighborhood-level that may not be well represented by the nearest state monitoring station. In addition to sparse spatial distribution, the government monitoring stations have limited temporal resolution. For example, only two stations in Salt Lake County provide hourly $PM_{2.5}$ levels. This gap in temporal resolution is particularly important in light of studies suggesting that even short-term increases in pollutant levels increase the incidence and severity of asthma and cardiac events.

Networks of low-cost, air-quality sensors can help bridge these spatial and temporal gaps and provide key information to air-quality managers, health-care providers, and the community at large to better understand air quality and minimize exposure risks. However, many of these low-cost sensors lack independently gathered calibration data, quality assurance procedures, or descriptions of when the sensors may provide inaccurate readings. Presenting unreliable or uncertain information from sensor networks can cause either unnecessary public concern or complacency about pollution levels and the associated health risks.

Two of the project goals are to leave each classroom with a low-cost, air-quality sensor and to have your class help determine:

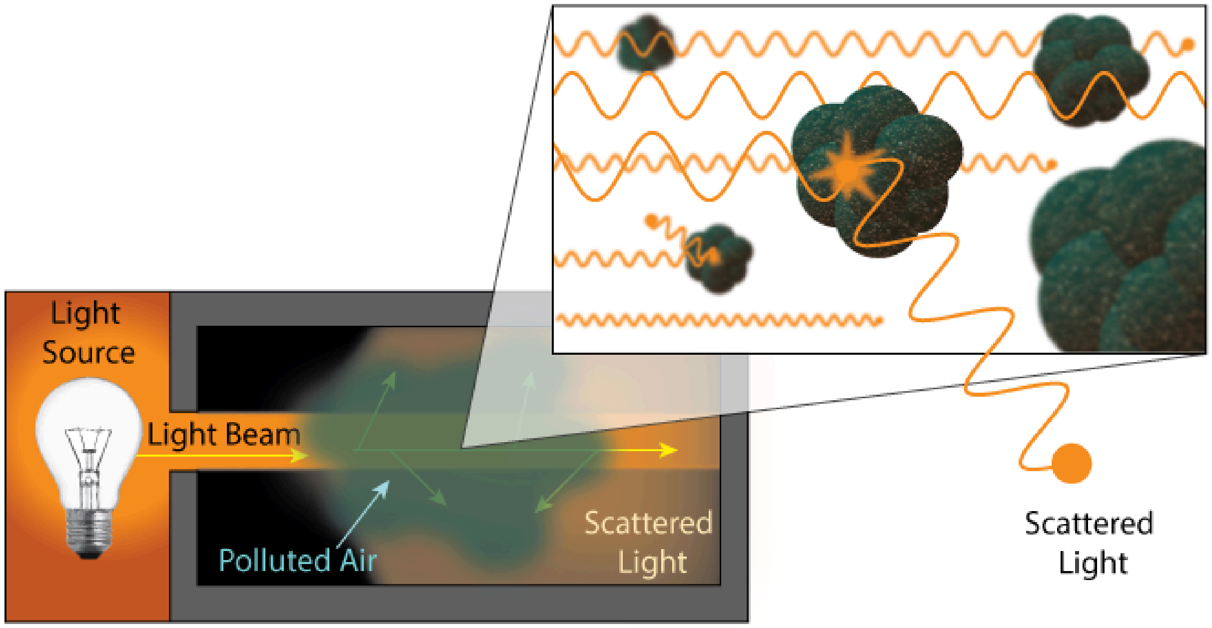
- *How well outdoor air-quality measurements represent local air quality in and outside your school.*
- *How well the sensors perform over time.*

Electronics Background:

Only very basic understanding of electronics is useful but not absolutely necessary.

Light Scattering Background:

The AirU Sensors work by measuring scattered light. As light travels through clean air, which is free of particulate pollution, it travels roughly in a straight path. Almost none of the light could make, say, a 90° turn. However, if particulate matter filled the air, light may be reflected off the particles in a random direction. You can readily see such scattered light if, for example, you shine a laser through a cloud of smoke; the result will appear as a line of scattered light traveling through the cloud, whereas with clean air you may not ever detect a laser was passing through the space (Such a demonstration with a laser pointer and fog machine can be a good introductory addition to this module; you could also use a blue laser and tonic water compared to regular water as the tonic water's quinine will scatter the laser light).



While this light is scattered randomly, some of the light will be scattered towards our sensor and be detected. The more particulate matter in the air, the more likely it is that a photon of light will find its way to the sensor (a photoresistor in the instance of this module), and therefore we can quantify the amount of particulate pollution in the air. Scattered light is a prefered indicator of particulate matter because 1. such sensors are typically more sensitive to the range of light intensity between zero and minimal light than between two large intensities of light; and 2. scattered light can be more indicative of particle size.

Video Demonstrations of This Module

https://drive.google.com/drive/u/0/folders/0B38VA6_R7hSdLVB2eTdBbDI3OEE

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