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Applied Classroom Use of a Mobile Multifunctional Weather Station

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I am a senior at Central Michigan University studying Integrated Science for Secondary Education. For the last two years, I have participated in the National Science Foundation's Research Experience for Teachers program at Central Michigan University. I have a great passion for science education, and I hope to be able to influence my future students to find what they are passionate about and pursue it, just as I have.

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Kumar Yelamarthi received his Ph.D. and M.S degree from Wright State University in 2008 and 2004, and B.E. from University of Madras, India in 2000. He is currently the Assistant Director for the School of Engineering and Technology, and Professor of Electrical & Computer Engineering and at Central Michigan University (CMU). He serves as the chair for Electrical Engineering and Computer Engineering programs at CMU. His research interest is in the areas of wireless sensor networks, Internet of Things, assistive devices, mobile robots, embedded systems, and engineering education. He has published over 140 articles in archival journals and conference proceedings and delivered over 75 talks in these areas. He has served as a chair, technical program committee chair, treasurer for several IEEE/ASME/ASEE international conferences, and as a reviewer and panelist for numerous externally funded proposals. He served as the general chair for 2016 ASEE NCS Conference, 2011 ASEE NCS conference, Technical Committee Member for IEEE ISVLSI, IEEE MWSCAS, IEEE WF-IoT, and currently serves on the editorial board for International Journal of Forensic Software Engineering. He has served as the Chair of IEEE Northeast Michigan Section, and vice-chair for ASEE North Central Section. He served as PI, co-PI, and senior personnel in several externally funded grants from organizations such as NSF, NASA, and the regional industry. He is a founding advisor for the IEEE Student Chapter at CMU, an elected member of Tau Beta Pi engineering honor society, Omicron Delta Kappa national leadership honor society, a senior member of IEEE, and a senior member of IETI.

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Abstract

In April of 2013, the Next Generation Science Standards (NGSS) were released, this came many years after the previous science standards had last been updated, allowing the standards to match the many recent scientific advancements, including the development of science education. The NGSS were created through a collaborative effort involving the National Research Council (NRC), the National Science Teaching Association (NSTA), the American Association for the Advancement of Science (AAAS), and adept science educators and leaders from 26 states [1]. The NGSS include engineering and engineering practices as integrated parts of K-12 science education, which allows students to practice not only science content, but also problem solving and critical thinking skills that are desperately sought after by colleges and employers.

In 2009, state leaders, educators, and standards experts in 48 states came together to collaborate on the Common Core State Standards Initiative with the goal of laying out a clear set of standards for K-12 students in English language arts and mathematics in order for them to be college- and career-ready. The Common Core State Standards (CCSS) for secondary mathematics aim to have students practice applying what they learn to real-world scenarios and problems, while also emphasizing communication, collaboration, problem solving, and critical thinking skills, similar to the NGSS [2].

Currently, many K-12 science classrooms are faced with challenges when giving students real opportunities to do science involving true inquiry and hands-on learning, especially in high-minority enrollment schools, as they face underfunding and under resourcing, and have increasingly less access to certified science teachers [3]. This project, a mobile multifunctional weather station, utilizes a fairly simple design with several mostly inexpensive sensor components which can easily be exchanged for other components if so desired. The design, development, and use of a wireless weather station device can be used in science, technology, engineering, and math (STEM) experiences to introduce secondary students to the science and engineering practices laid out in the NGSS. Incorporating this device into high school science classrooms will not only allow students to use the weather station, they will also integrate engineering practices into their science education by building the weather station in small teams. By doing so, students will need to collaborate with other students, communicate with their groups, and practice their problem solving and critical thinking skills, which are emphasized in the NGSS and CCSS.

I. Introduction

Over the last several years, there has been an extreme push for more STEM in K-12 and post-secondary education due to an increase in jobs and a projected job growth of 8.8% from 2018-2028 in STEM-related fields [4]. Many schools have tried to implement STEM education programs, but they are often missing an important part of STEM - engineering. This is concerning, as there is an overall projected job growth of 4.0% for engineers from 2014-2024

[5]. Mechanical engineering jobs are projected to grow by 5.3%, electrical engineering jobs are projected to grow by 1.0%, and computer engineering jobs are projected to grow by 3.1% in this same time span [5]. While these are some of the main engineering occupations, collaboration of interdisciplinary engineering practices occur regularly, and engineers often end up in careers that vary from the degree they earned, requiring engineers to be flexible and able to widely apply engineering practices.

Engineering is really everywhere in our daily lives and everywhere in other fields of study. Science, technology, engineering, and mathematics are all integrated subjects - yet they have often been taught separately from one another. This is something that the NRC, the NSTA, and the AAAS have all recognized and in response, have developed the NGSS and implemented these standards in twenty states and the District of Colombia, which is representative of 36% of US students [1]. The NGSS include engineering and engineering practices as required parts of science education. Some of the states that have led the movement to add engineering standards to our nation's science standards were able to integrate engineering into their science curriculum, showing that the goal is to incorporate engineering into other subjects, not to teach engineering as a separate subject [6]. This reinforces that by adding engineering standards, the NGSS do not require the development of engineering classes, but rather the incorporation and implementation of engineering and its practices into current science and math courses. The need for more authentic science education following the improved standards is how this project was born.

II. Motivation

This research is rooted in the need for a mobile device to use inside and outside of high school science classrooms to measure, collect, and compile weather and water data. This project will not only allow students to use this weather station, but to also incorporate engineering practices into their science education by contributing to building it. After the completion of this project in science classes, students will have experience using engineering practices, problem solving, and critical thinking skills to assemble a simple Internet of Things (IoT) device. While completing this project, obstacles arose that students will likely face, such as limitations in the required power of all sensors, and I am now better equipped to assist them when these problems arise.

As an educator, I hope to spark the interests of my students by giving them new and exciting ways of learning and doing science through inquiry based learning and hands-on activities. Understanding and having experience with the fundamental practices of researching, designing, building, testing, evaluating, and improving upon a design will allow me to show students how an engineer thinks and what an engineer does, things that many students are not currently fully exposed to. This project will also prepare me to work with my future colleagues to ensure that our students are graduating with a well-rounded understanding of science, the world around us, and are prepared for their next stages of life.

III. Related Literature

Weather Stations

Intelligent weather stations are not a new concept, they have been around for several years, often functioning on a large scale to collect weather, wind, and solar data to be used for forecasts, energy management and savings in large buildings, in agriculture, and in the planning of clean energy projects [7]. These tools have also been named automatic weather stations (AWSs), they have been developed to function wirelessly and to remotely send their collected data to be stored or displayed for research and development purposes [8]. Wireless weather stations typically consist of an array of sensors to measure temperature, humidity, wind speed and direction, solar radiation, and atmospheric pressure. They also include a battery to power the station and a base that processes collected data and has the capabilities to send and/or store the data.

Science Education

The application of the wireless weather station stretches farther than the need for forecasts and clean energy development in the real world. Many smart classrooms utilize a similar device to notify the need for adjustment of the interior temperature and lights to best suit the learning environment of students. In fact, this is one of the defining features of a smart classroom [9]. The design, development, and use of a wireless weather station device, or any device like this, can also be used in STEM experiences to introduce students to the science and engineering practices laid out in the NGSS that are supported by many national science organizations, including the National Science Foundation (NSF). The NSF has found that when educators engage in true scientific research, they have a better knowledge and skill base to then go and teach integrated STEM subjects to their students, with a clearer vision of what engineering consists of [10]. The NGSS encourage the active inquiry and participation of students in constructing their own scientific questions, therefore shaping their own curriculum. These are examples of democratic practices that can lead to students reaching their full potential, particularly in STEM classrooms [11]. This device and others like it can lead to the opening of a new world and meaning of science to students through real life inquiry and understanding.

IV. Proposed System

For this project, the proposed system is built upon a Raspberry Pi 3 Model B+ running code in Python. This microcomputer is a great model to introduce secondary students to programming and IoT. Raspberry Pis offer several options for coding languages, such as Scratch and Python, which are ideal for students who have little or no experience with coding. The skills developed from programming in Scratch and Python can be easily applied to other programming languages when students have a more in-depth understanding of programming and move on to projects that require different languages.

The components of this weather station include a gas sensor (SGP30) to measure the air quality index; a temperature, humidity, and atmospheric pressure sensor (BME280) to collect weather data; an IR and visible light sensor (SI1145) to convert readings into UV index values;

and a lab grade pH probe to measure outdoor water quality. This data will be sent to the cloud, using Adafruit IO, allowing students access in order to further analyze and identify weather trends.

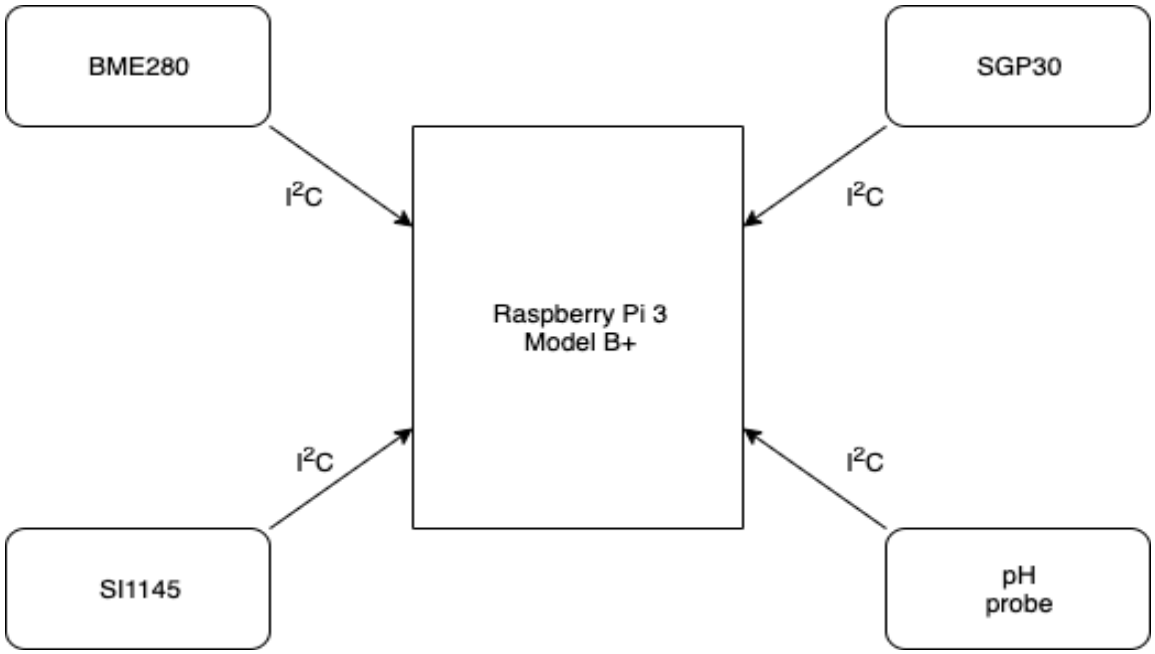


Figure 1. The sensor components of this project are all connected to Raspberry Pi via I^2C .

The sensors are all connected to the Raspberry Pi using the Inter-Integrated Circuit (I^2C) bus. This interface allows for each sensor to be connected to the Pi on the same bus, only requiring each sensor to be connected by two pins, the SCL (serial clock) and SDA (serial data), allowing for many devices to be connected to the bus with minimal pins needed for each sensor. The protocol works by sending a start condition (S) from the Pi to one of the sensors, followed by the device address. The address for each sensor is a unique, seven-bit address that is written using bits one through seven. This is used to identify each device that the Pi is powering [12]. The Pi then sends instructions in the bit zero to the sensor so that it knows to collect data from its environment, allowing the Pi to read from the sensor, and the sensor sends a message back to the Pi acknowledging its instructions before data is read from it. As shown in Figure 1, when the Pi has received all of the bits and it is time for it to read data from a different sensor, it must send a stop condition (P) to the first sensor it was reading from, allowing another sensor to use the bus. Then, the process restarts with the next sensor, cycling through each sensor connected via I^2C.

The components of the device will be enclosed in a custom 3-D printed case, which will require students to place and measure the hardware components in a way such that they will fit into a compact space while utilizing an innovative design for the outer shell. If 3-D printing is not an available option, students can still use the free, open-source software to design a 3-D case and use the dimensions of their design to create the case out of cardboard, poster board, or any other appropriate materials.

V. Results

The multiple components of the weather station require test runs to ensure their capability to correctly collect data. This is done by running the project's codes for the sensors. The weather station is equipped with a pH probe to use in field work to analyze acidity of water samples. The probe was tested by inserting it into a cup of liquid with a known pH of 4.0. The BME280 and SGP30 sensors were tested together to collect data on the temperature, humidity, and atmospheric pressure, and total volatile organic compounds (tvoc) in the air and the equivalent carbon dioxide (eCO2) reading. This component is used to measure air quality. Finally, the SI1145 sensor was tested indoors and yielded appropriate results for UV index measurements and visible light measurements.

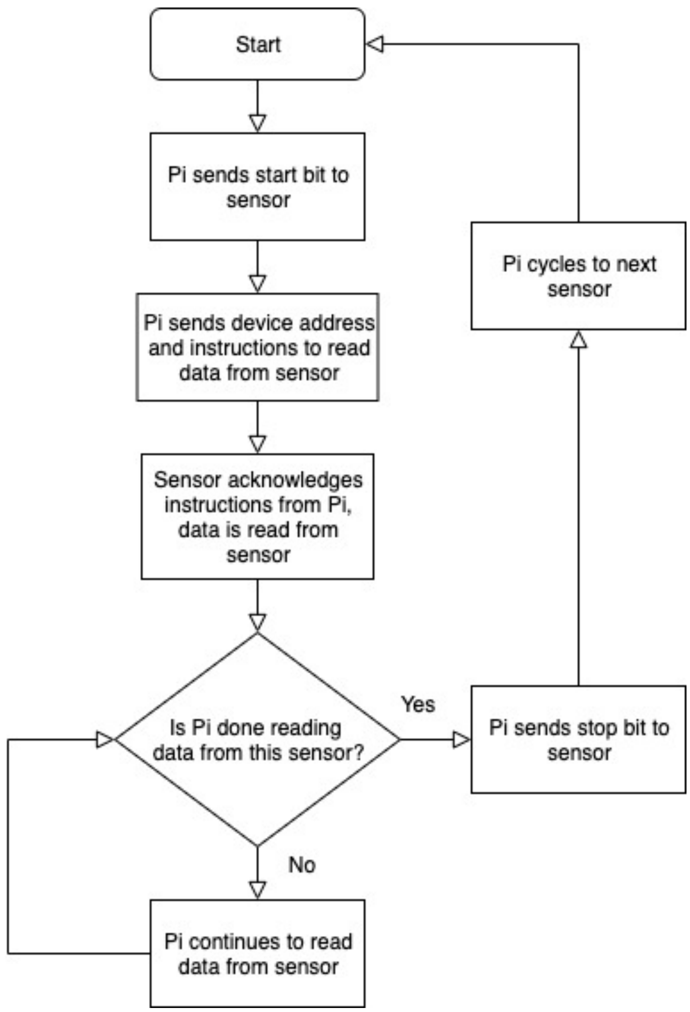
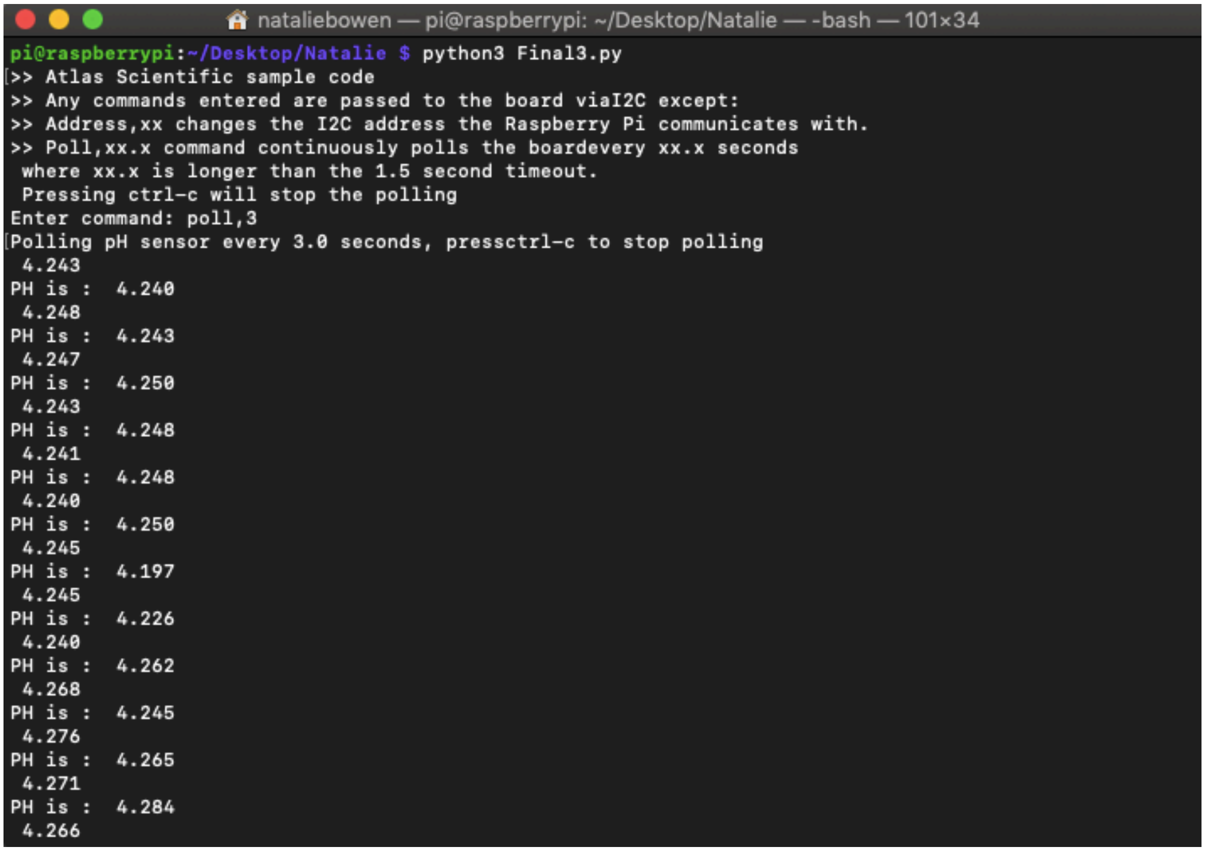


Figure 2. The Raspberry Pi cycles through the steps of sending a start condition to a sensor, followed by instructions to read data from the sensor before receiving acknowledgement from it and then reading data. When the Pi is done reading data from the sensor it sends a stop condition to end the data transmission and cycles through the steps again with the next sensor.



```
nataliebowen — pi@raspberrypi: ~/Desktop/Natalie — -bash — 101×34
pi@raspberrypi:~/Desktop/Natalie $ python3 Final3.py
>> Atlas Scientific sample code
>> Any commands entered are passed to the board viaI2C except:
>> Address,xx changes the I2C address the Raspberry Pi communicates with.
>> Poll,xx.x command continuously polls the boardevery xx.x seconds
 where xx.x is longer than the 1.5 second timeout.
 Pressing ctrl-c will stop the polling
Enter command: poll,3
Polling pH sensor every 3.0 seconds, pressctrl-c to stop polling
 4.243
PH is :  4.240
 4.248
PH is :  4.243
 4.247
PH is :  4.250
 4.243
PH is :  4.248
 4.241
PH is :  4.248
 4.240
PH is :  4.250
 4.245
PH is :  4.197
 4.245
PH is :  4.226
 4.240
PH is :  4.262
 4.268
PH is :  4.245
 4.276
PH is :  4.265
 4.271
PH is :  4.284
 4.266
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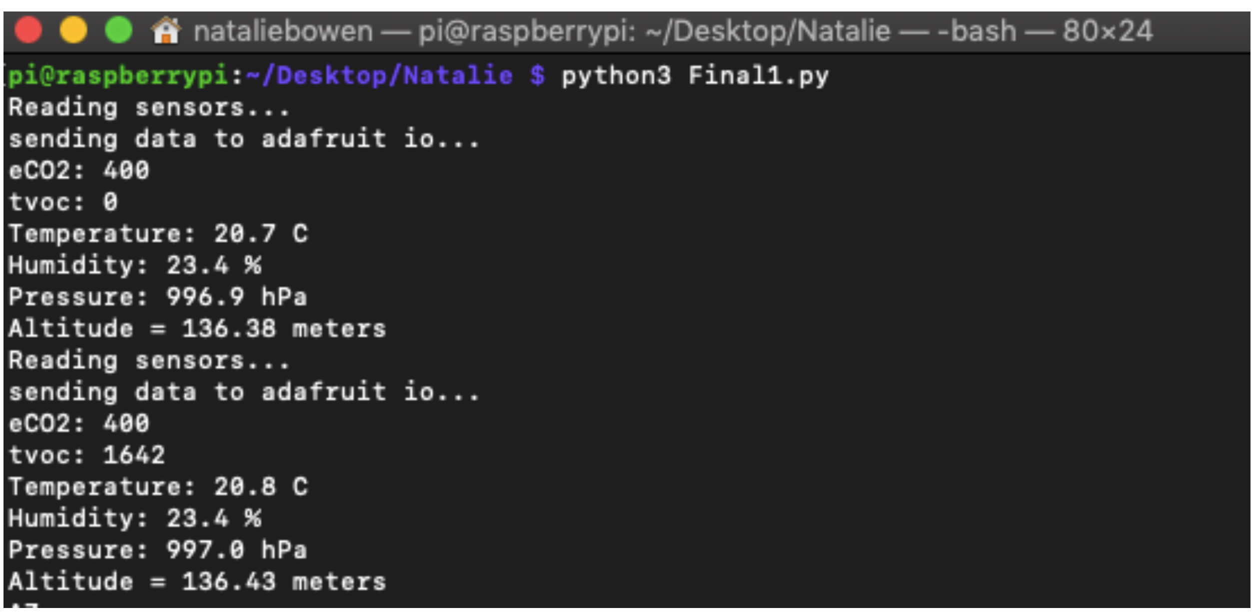
Figure 3. The results displayed in the terminal of a test of the pH sensor integrated into the weather station. The probe was placed in a cup filled with liquid of an acidic pH.



```
nataliebowen — pi@raspberrypi: ~/Desktop/Natalie — -bash — 80×24
pi@raspberrypi:~/Desktop/Natalie $ python3 Final1.py
Reading sensors...
sending data to adafruit io...
eCO2: 400
tvoc: 0
Temperature: 20.7 C
Humidity: 23.4 %
Pressure: 996.9 hPa
Altitude = 136.38 meters
Reading sensors...
sending data to adafruit io...
eCO2: 400
tvoc: 1642
Temperature: 20.8 C
Humidity: 23.4 %
Pressure: 997.0 hPa
Altitude = 136.43 meters
```

Figure 4. The results of the test of the SGP30 gas sensor and the BME280 temperature, humidity, and atmospheric pressure sensor. This test was performed inside at a temperature of approximately 21°C.

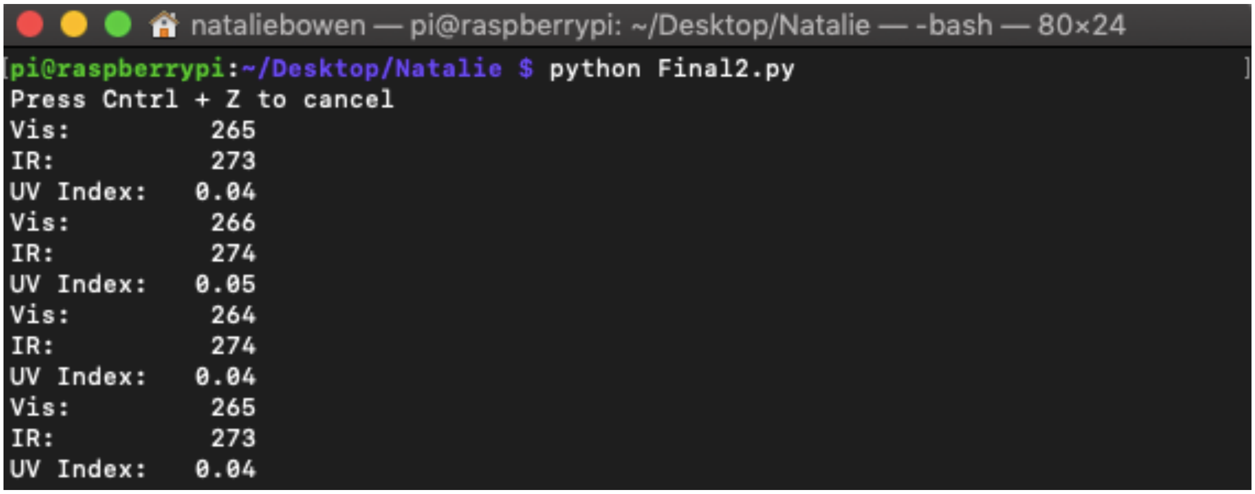


Figure 5. The results of the test of the SI1145 IR and visible light sensor with values converted into UV index readings. This test was performed inside.

The components of this project connect to Raspberry Pi via I^2C, therefore a T-Cobbler is necessary to extend the necessary pins to multiple sensors. The placement of the sensors is easy to manipulate and change because of this element, allowing for different prototypes and ways for students to use their critical thinking skills.

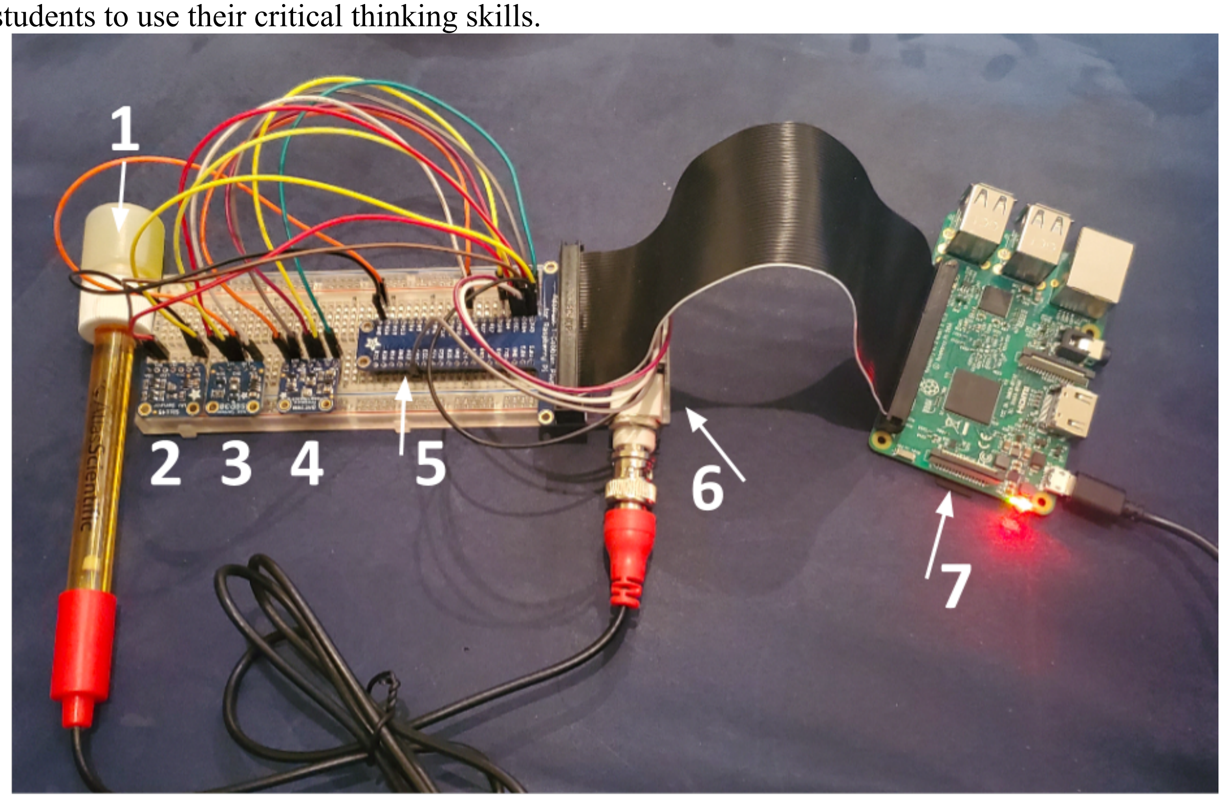


Figure 6. A prototype of the weather station with all of its components, labelled as follows: 1. pH probe; 2. SI1145; 3. SGP30; 4. BME280; 5. Adafruit T-Cobbler Plus for Raspberry Pi; 6. pH OEM Circuit; 7. Raspberry Pi 3 Model B+.

VI. Discussions and Future Research

While this project is a fully functioning weather station, more sensor components could easily be added in order to collect and analyze more data. This would be an extension of the project that students could complete in another class, or even on their own in order to gain more experience working with a Raspberry Pi. Students could also build upon this project by modifying the weather station to create an indoor version that could be incorporated into a smart classroom, or they could use their knowledge and skillset from creating this weather station to create a new project using a Raspberry Pi. This project can also be simplified in order to be implemented in an elementary or a middle school classroom. The components of the weather station may be modified to best suit the age group working on the project. This may require a modified plan for teaching students how to code and might work better with a simpler coding language, such as Scratch. Nevertheless, this would still be an authentic, unique experience for students to learn and apply engineering practices.

Projects which involve coding and creating machines that read and analyze data relate directly to the emphasized Science and Engineering Practices of the NGSS, which include developing and using models and analyzing and interpreting data [13]. Developing and using models is something that every scientist does in one way or another, as there are many options for models including diagrams, replicas, mathematical representations, and computer simulations. Many secondary students do not have the opportunities to develop computer simulations before they enter higher education, but projects like this mobile weather station will allow them to practice developing and become more familiar with these kinds of models. All scientists work with analyzing and interpreting data, and students generally have practice doing this with data provided for them, but many do not have the complete experience of collecting the data for themselves to analyze, which creates a much more authentic scientific process and inquiry.

VII. Conclusion

The end goal of this project is to implement the weather station in science curriculum in order to give students exciting opportunities to learn and do science using hands-on activities. This will aid students in acquiring an understanding of the fundamental engineering practices of researching, designing, building, testing, evaluating, and improving upon a design. This project integrates science fields such as earth and atmospheric science, engineering, and computer science, giving students a rounded understanding of science in its many forms. Incorporating this device into high school science classrooms will allow students to use the weather station and to integrate engineering practices into their science education by building the weather station in small teams. Group work on this project will require students to collaborate with others, communicate with their groups, and practice the problem solving and critical thinking skills emphasized in the NGSS and CCSS. This weather station is not rigid in its requirements, it can be manipulated to fit the needs of the class it is being used in. The project can easily be scaled down for younger students or scaled up for more advanced students. Depending on where the weather station is being used, components can be added or removed to collect relevant weather data for the region. Through rich, hands-on learning opportunities that teach and allow students to practice problem solving and critical thinking skills, we as educators are able to inspire the next generation of STEM workers.

References

[1] National Science Teaching Associaion, "About the Next Generation Science Standards," National Science Teaching Association, 2014. [Online]. Available: ngss.nsta.org/About.aspx . [Accessed 23 February 2020].

[2] Common Core Standards Initiative, "About the Standards," Common Core Standards Initiative, [Online]. Available: corestandards.org/about-the-standards/frequently-asked-questions/ . [Accessed 23 February 2020].

[3] National Academices of Sciences, "Science and Engineering for Grades 6-12: Investigation and Design at the Center," The National Academies Press, Washington DC, 2019.

[4] Occupational Employment Statistics Program, "Employment in STEM Occupations," United States Department of Labor, Bureau of Labor Statistics, Washington DC, 2019.

[5] US Bureau of Labor Statistics, "TED: The Economics Daily," US Department of Labor, Bureau of Labor Statistics, Washington DC, 2016.

[6] M. E. Cardella, J. Strobel and S. Purzer, Engineering in Pre-College Settings: Synthesizing Research, Policy, and Practices, West Lafayette: Purdue University Press, 2014.

[7] G. Mestre, A. Ruano, H. Duarte, S. Silva, H. Khosravani, S. Pesteh, P. M. Ferreira and R. Horta, "An Intelligent Weather Station," *Sensors,* vol. 15, pp. 31005-31022, 2015.

[8] K. M. Dadesh and S. M. Ben Rhouma, "Low Cost High Altitude Automatic Weather Station Design," *Solar Energy and Sustainable Development,* vol. 7, no. 2, pp. 1-12, 2018.

[9] B. Li, S. C. Kong and G. Chen, "Development and Validation of the Smart Classroom Inventory," *Smart Learning Environments,* vol. 2, no. 3, pp. 1-18, 2015.

[10] Committee on Science and Technology House of Representatives, "STEM Education Before High School: Shaping our Future Science, Technology, Engineering, and Math Leaders of Tomorrow by Inspiring our Children Today," US Government Printing Office, Washington DC, 2008.

[11] W. Daher and A.-G. Saifi, "Democratic Practices in a Constructivist Science Classroom," *International Journal of Science and Mathematics Education,* vol. 16, pp. 221-236, 2018.

[12] "I2C-bus specification and user manual," 4 April 2014. [Online]. Available: https://www.nxp.com/docs/en/user-guide/UM10204.pdf. [Accessed 23 February 2020].

[13] National Science Teaching Association, "Science and Engineering Practices," National Science Teaching Association, [Online]. Available: https://ngss.nsta.org/PracticesFull.aspx. [Accessed 23 February 2020].