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Board 145: Development of Air Quality Assessment Activities Using a Coding-Based Microcontroller for an After-School STEM Program (Work in Progress)

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Development of Air Quality Assessment Activities Using a Coding-Based Microcontroller for an After-school STEM Program (Work in Progress)

SUPERCHARGE (STEM-based University Pathway Encouraging Relationships with Chicago High schools in Automation, Robotics, and Green Energy) is an NSF-funded after-school STEM program through which an interdisciplinary team of faculty, staff, and students at Illinois State University is collaborating with teachers from four high schools in Chicago, Illinois in the U.S. and four non-profit Community-Based Organizations (CBOs) in the surrounding communities to develop innovative hands-on activities for underrepresented students. These informal educational activities are centered on topics such as robotics, automation, and renewable energy. In the program's inaugural year, one of the four units will focus on assessing air quality, employing the micro:bit microcontroller for programming and the Kitronik Air Quality Board for sensing and data collection. All the air quality unit activities were developed by undergraduate students under the guidance of faculty advisors. High school teachers mentoring the student learners in the after-school STEM program iteratively reviewed all activities when these activities were developed. These air quality assessment activities are outlined as follows. Activity 1: Students are introduced to the significance of indoor and outdoor air quality. They subsequently learn about air quality components, including temperature, pressure, humidity, air quality index, and CO_2 equivalent. Activities 2 & 3: Students collect air quality data from different locations and visualize the collected data to comprehend variations among these locations. An extension activity is available for students interested in collecting air quality data over an extended period, allowing them to evaluate the correlation between indoor conditions and air quality changes. Activity 4: Students learn to program the micro:bit to display air quality status using LED lights on the air quality board. Activity 5: The learning unit concludes by presenting air quality conditions in their neighborhood in collaboration with their CBOs. Students can assess the air quality using the hand-held device they programmed and compare their findings to data collected by existing air quality monitoring sensors in their communities. Preliminary data collected during the testing phase indicate that the developed programs effectively display air quality. These activities were designed to help student learners comprehend coding, microcontroller technology, and data collection and visualization. In the summer of 2023, the SUPERCHARGE team organized two one-day professional development workshops. Teachers who participated in these summer workshops completed a selection of air quality assessment activities. They provided feedback, confirming that the programs on the air quality board work seamlessly. Minor suggestions were received, and the instructions were modified accordingly. This Work in Progress paper aims to document one of the first year's learning activities of the highly collaborative after-school STEM program, demonstrate the activity development processes, and foster an exchange of ideas and feedback among educators in related fields.

Introduction

SUPERCHARGE (STEM-based University Pathway Encouraging Relationships with Chicago High schools in Automation, Robotics, and Green Energy) is an NSF-funded after-school STEM program through which an interdisciplinary team of faculty, staff, and students at Illinois State University is collaborating with teachers from four high schools in a large school district in the U.S. and four non-profit Community-Based Organizations (CBOs) in the surrounding communities to develop innovative hands-on activities for underrepresented students. These informal educational activities are centered on topics such as robotics, automation, and renewable energy. In the program's inaugural year, one of the four units will focus on assessing air quality, employing the micro:bit microcontroller for programming and the Kitronik Air Quality Board for sensing and data collection.

Students spend significant time at school, making the environment a potentially important contributor to air quality exposure [1]. Chatzidiakou et al. (2023) developed and tested a citizen science framework for collecting classroom climate and indoor air quality data and simultaneously used the method to raise community awareness. Subsequently, the data they collected represented the air quality of more than 120 schools. They helped these schools manage their indoor environment better and empowered students and teachers to reduce environmental health risks [1]. Miao et al. (2023) also emphasized the importance of modeling indoor air quality and thermal conditions in educational buildings as they are relevant to students' health, well-being, and productivity [2]. Their developed model with initial data collection can be utilized in other local schools without requiring monitoring sensor networks. It becomes a cost-effective solution for assessing indoor air quality and thermal comfort to help relevant stakeholders improve school building management practices [2]. Intervention strategies were adopted and evaluated to enhance indoor air quality in and around schools. Rawat and Kumar (2023) assessed technological, behavioral, and physical barriers and policy and regulatory interventions. Intervention methods were introduced, including the HVAC system combined with high-efficiency filters, citizen science campaigns, and green infrastructure as a physical barrier [3]. Most schools worldwide have basic natural ventilation systems, which are typically inadequate for meeting the needs of students [4]. Exposure to various air pollutants in school buildings risks severely damaging students' health [4]. Sadrizadeh et al. (2022) noted a great need for more comprehensive studies with larger sample sizes to study environmental health exposure, student performance, and indoor satisfaction [4]. Outdoor air quality can impact indoor air quality in the region. In June of 2023, Chicago had some of the worst air quality in the world as wildfire smoke from Canada seeped into the Midwest [5]. The raging fires have impacted parts of the US since earlier that month, and Chicago hit the purple zone of the air quality index (AQI) [5].

As highlighted in the reviewed literature, understanding indoor and outdoor air quality is relevant to the quality of life. Therefore, the air quality assessment activities will be pivotal in enhancing students' and teachers' awareness. In addition, the data collected from the project can be used as important information for subsequent research projects about the regional school's indoor air quality. All the air quality unit activities were developed by undergraduate students under the guidance of faculty advisors. High school teachers mentoring the student learners in the after-school STEM program iteratively reviewed all activities while these activities were developed.

Activity Organization

The air quality assessment activities are outlined as follows. Activity 1: Students are introduced to the significance of indoor and outdoor air quality. They subsequently learn about air quality components, including temperature, pressure, humidity, air quality index, and CO2 equivalent. Activities 2 & 3: Students collect air quality data from different locations and visualize the collected data to comprehend variations among these locations. An extension activity is available for students interested in collecting air quality data over an extended period, allowing them to evaluate the correlation between indoor conditions and air quality changes. Activity 4: Students learn to program the micro:bit microcontroller to display air quality status using LED lights on the air quality board. Activity 5: The learning unit concludes by presenting air quality conditions in their neighborhood in collaboration with their CBOs. Students can assess the air quality using the hand-held device they programmed and compare their findings to data collected by existing air quality monitoring sensors in their communities. These activity descriptions can be accessed via the following link. https://about.illinoisstate.edu/supercharge/ More details about each activity are given in the next section.

Activity 1 provides background information about indoor and outdoor air quality, followed by the equipment setup for the activity. Students learn that the air quality in homes and schools is usually worse than outside air quality. Most of the time in Chicago, the outdoor air quality is moderate to good, although traffic congestion and industrial activities can negatively impact it. Indoor air quality (IAQ) is essential to environmental health because people spend significant time indoors, particularly in buildings with air conditioning and heating systems that recirculate air. Poor IAQ can cause various health problems, such as respiratory issues, allergies, headaches, and fatigue. The air quality index (AQI) measures air pollution in a given area. It considers a range of pollutants, including particulate matter, ozone, carbon monoxide, sulfur dioxide, and nitrogen dioxide. These are air pollutants that can have negative impacts on our daily lives. Reducing exposure to these pollutants is essential to protect our health and well-being. Higher AQI values indicate poorer air quality and increased health risks. CO2e measures the amount of carbon dioxide equivalent in the air. High levels of CO2e can indicate poor ventilation and the presence of indoor air pollutants such as VOCs, which building materials, furnishings, and cleaning products can emit. Subsequently, students are given the equipment used for this unit's activities and learn how to program to collect essential elements for air quality assessment, including the micro:bit and Kitronik Air Quality Board.

In Activity 2, students will learn how to program the micro:bit and Kitronik Air Quality Board to collect air quality data from different school locations. Each group will choose 4-5 measurement locations with good or bad air quality. Here are the step-by-step programming instructions that were prepared for the data collection.

Step 1: Open MakeCode and start a new project. A suggested file name would be “3.2 Kitronik AQ_Part 2”.
Step 2: Click on the extensions tab. This is the tab with the plus sign. It is at the bottom of the list, beneath the math tab.
Step 3: After you enter the tab, type in “Kitronik air quality.” You should choose the one that says “kitronik-air-quality-v2-only”. Please note that the micro:bit's LED screen should be facing in when plugged into the AQ board.
Step 4: Start with “on start” and add “establish gas baseline” and “setup gas sensor.”
Step 5: Start with “on start” and add “establish gas baseline” and “setup gas sensor.”
Step 6: Repeat the previous step to add Pressure, Humidity, IAQ, and eCO2.

Step 7: Add a "pause (ms)" block with a 5-second interval.

Step 8: This shows how appropriate units are labeled with the data measured. In addition, you can see that a "T:" was added, so when it pops up on the Kitronik AQ display screen, it tells you what you are measuring with a proper unit that goes with the measurement.

Now, students can start recording the data. Students are provided with the table below for data logging.

Table 1	Location A	Location B	Location C	Location D	Location E		what you measured	
Temperature (oC)							Temperature (oC)	-40oC to 85oC
Pressure (hPa)							Pressure (hPa)	300 hPa to 1100 hPa
Humidity (RH)							Humidity (RH)	0% RH to 100% RH
Air quality index (IAQ)							Air quality index (IAQ)	0 ppm -500 ppm (0=excellent, 500 =polluted)
eCO2 (ppm)							CO2 (ppm)	250 tp 40000+ ppm

One extension activity is provided for students who want more programming experience. The initial program they made allowed them to collect the data manually. The extension activity provided a way to automate this process by pressing the control board's button. As this advanced programming required a few additional steps, a couple of suggestions helpful for this extension activity were provided to the students.

1. You need to set the date and time in the program before you download, as the time stamps will be posted with the data measurements.
2. After downloading the program, wait 5 minutes to set up the gas sensor and establish the gas baseline and ambient temperature. Once it's ready, you will see "✓" on the micro:bit display.
3. To collect data at each location, press the "A" button.
4. Once you finish the data measurements, **turn off the AQ board**. Then you turn it on and connect the micro:bit to the computer.
5. Now download the coding again to "transfer" the collected data to your computer. Wait for 5 minutes as you did in Step 2. Once it's ready, press the "B" Button to transfer the data.
6. By pressing the "B" button, you will see "Show data" on the screen. Press it to see the collected data. This button is at the lower left corner, as shown in Figure 1.
7. Finally, you can export the collected data as a text file by pressing the icon at the top right corner of the screen.
8. downloading the collected data as an Excel file ("Export Data") doesn't work well. That's the blue icon right next to the one we used.
9. Once the text file is downloaded, you can generate the graph using Google Sheets or Microsoft Excel, as demonstrated in the next activity.

Activity 3 allows students to visualize the data they collected from the previous activity. Collecting data at different locations is a common way to study air quality in a particular environment. The Kitronik Air Quality Board is an excellent tool as it can continuously monitor multiple parameters, including pressure, IAQ, humidity, and eCO2, in different environmental conditions. Students can use data visualization techniques such as line graphs, scatter plots, and histograms to understand the trends and patterns in the data. By examining the chart, students can observe any significant changes in these parameters and investigate the possible causes of these changes. Overall, analyzing the data collected by the Kitronik Air Quality Board can help us better understand the air quality in a particular environment and identify any potential health risks associated with poor air quality. Figure 1 shows the example data and graph of the air quality index.

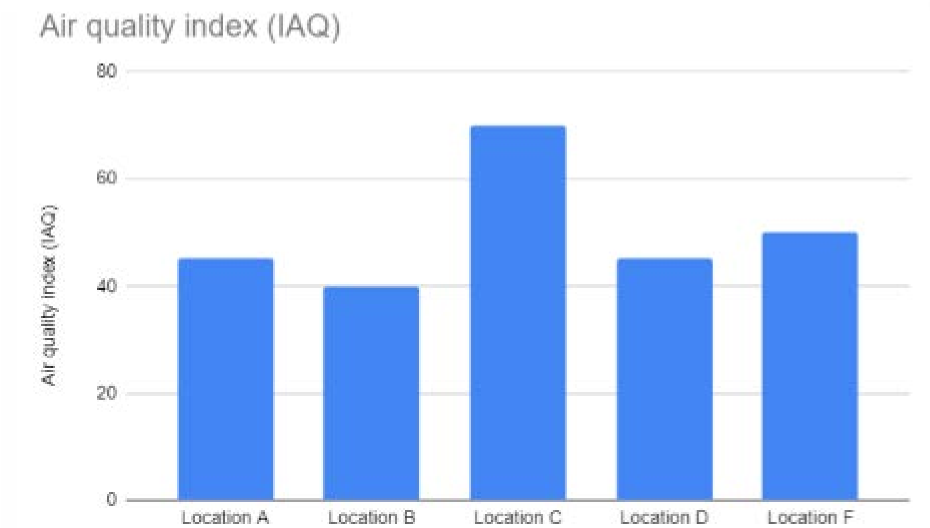

Figure 1. Collected air quality data and graph example

Another extension activity was provided for students to collect long-term data. Collecting air quality data over a more extended period can give students a better idea of how it changes over a certain period.

In Activity 4, students will review the neighborhood's air quality and try to relate it to the indoor air quality data they collected. Students will also modify the previous coding to incorporate LED lights. The AirNow webpage (www.airnow.gov) provides information on air quality in our neighborhood. Students will evaluate and compare the current AQI to the collected air quality data. Then, students will revise the previous coding to add LED light signals. This is one way of visualizing the real-time data collected, and students can relate this to the existing air quality index with different color schemes, as shown in Figure 2. This program is designed to display red, yellow, and green colors depending on the IAQ score when the AQ board reads the air quality data.

IAQ Index	Air Quality	Impact (long-term exposure)	Suggested action
0 – 50	Excellent	Pure air; best for well-being	No measures needed
51 – 100	Good	No irritation or impact on well-being	No measures needed
101 – 150	Lightly polluted	Reduction of well-being possible	Ventilation suggested
151 – 200	Moderately polluted	More significant irritation possible	Increase ventilation with clean air
201 – 250	Heavily polluted	Exposition might lead to effects like headache depending on type of VOCs	optimize ventilation
251 – 350	Severely polluted	More severe health issue possible if harmful VOC present	Contamination should be identified if level is reached even w/o presence of people; maximize ventilation & reduce attendance
> 351	Extremely polluted	Headaches, additional neurotoxic effects possible	Contamination needs to be identified; avoid presence in room and maximize ventilation

Figure 2. Air Quality Index Impact and Suggested Action (www.airnow.gov)

Finally, in Activity 5, students will explore the buildings in the community that have purposes that are valuable to the people in their neighborhoods and the air quality around those assets. Chicago has sensors in different neighborhoods in partnership with government organizations. As students have been gathering air quality data with their micro:bit and AQ board, they will provide valuable information for the surrounding community. Students will review common air pollutants, including ozone, carbon monoxide, sulfur oxides, nitrogen oxides, particulate matter, and lead. Students will go out and identify some built assets in their community and gather air quality data at each site to share with the community-based organization partnered with their school.

Further Development

Preliminary data collected during the testing phase indicate that the developed programs effectively display air quality. These activities were designed to help student learners comprehend coding, microcontroller technology, and data collection and visualization. In the summer of 2023, the SUPERCHARGE team organized two one-day professional development workshops. Teachers who participated in these summer workshops completed a selection of air quality assessment activities. They provided feedback, confirming that the programs on the air quality board work seamlessly. Minor suggestions were received, and the instructions were modified accordingly. As the developed air quality activities are implemented by the participating students in Spring 2023, more collected data and feedback from students and teachers will be available at the end of the semester. This work-in-progress paper can be developed further into a full research paper in 2024.

Conclusions

This Work in Progress paper aims to document one of the first year's learning activities of the highly collaborative after-school STEM program, demonstrate the activity development processes, and foster an exchange of ideas and feedback among educators in related fields. Students are introduced to the significance of indoor and outdoor air quality through the five different activities. They subsequently learn about air quality components, including temperature, pressure, humidity, air quality index, and CO2 equivalent. Students can collect air quality data from different locations and visualize the collected data to comprehend variations among these locations. Students also learn to program the micro:bit to display air quality status using LED lights on the air quality board. Finally, the learning unit concludes by presenting air quality conditions in their neighborhood in collaboration with their CBOs.

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