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Article

Cocreating a Field Practical through a Participatory and Inclusive Approach, Involving Lectures, Measurements and Data Analysis, to Understand Key Air Quality Concepts

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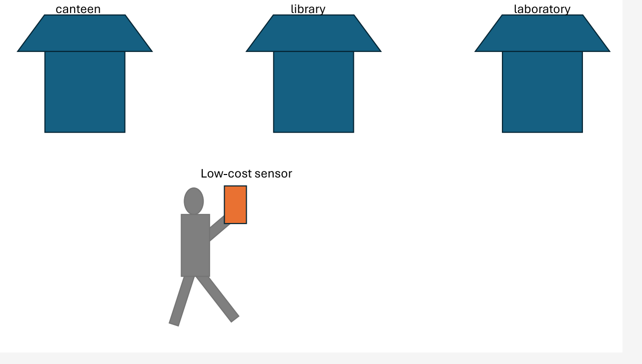
ABSTRACT: Most curriculums in the field of environmental science and engineering have limited hands-on training opportunities for students to understand the key concepts of air quality or atmospheric science. In this project, I used key pedagogical literature to design and develop a field practical for undergraduate (UG) Environmental Science students using low-cost air quality sensors. Through a co-creation based approach, students understood key concepts of indoor, outdoor, and personal air quality exposure monitoring using a hand-held direct reading instrument. Lecture sessions covered the theoretical aspect of the air quality measurement, which was then further illustrated in the practical sessions. I then used the student assessment to evaluate the learning outcome and to critically assess the findings. The findings clearly indicate the need for a hands-on-based practical that can influence several positive learning experiences among the students. Some of the key pedagogical concepts, cocreation, research led teaching, project based learning, and hands-on training, were identified as an effective way of teaching air quality concepts to undergraduate environmental science students.



KEYWORDS: *Co-creation, Citizen Science, Air Pollution*

1. INTRODUCTION

Capturing the enthusiasm of contemporary students for environmental issues is challenging, primarily due to the institutionalization of environmental education.[1] To ensure an effective pedagogical approach for an air quality field-based experiment, it is essential to consider various pedagogical methods and their impacts on student learning. Mahmoud and Nagy (2009)[2] argue that poor learning in the laboratory may be due to insufficient activation of the prehension dimension of Kolb's cycle, providing a pedagogical explanation for the importance of incorporating experiential learning cycles to enhance student engagement and learning outcomes. Salimbene et al. (2022)[3] highlight the potential utility of Living Laboratories to promote innovative approaches for designing an urban-scale air-quality management plan, indicating the effectiveness of real-world experiential learning in addressing environmental challenges. Bhute et al. (2021)[4] emphasize the importance of transforming traditional teaching laboratories for effective remote delivery, indicating the need to adapt pedagogical approaches to different learning environments. An effective pedagogical approach for an air quality lab and field-based experiment should incorporate experiential learning cycles, active learning pedagogy, virtual lab simulations, and real-world experiential learning to enhance student engagement, learning outcomes, and understanding of environmental issues.

Clean air is an integral part of sustainable development goals,[5] and community science-based approaches using low-cost sensors for air pollution monitoring have been revolutionary in the recent past.[6] Indoor Air Quality (IAQ) is composed of several biological and chemical pollutants, and poor IAQ could be a possible reason for lower academic performance, absenteeism, dropout, and "freshers flu"—prevalent commonly among university students.[7] Inhaling air pollutants can lead to significant negative impacts on human well-being, underscoring the significance of maintaining good air quality as a crucial aspect of occupant health and safety. Research indicates that people spend approximately 90% of their time indoors,[8] which is expected to be even higher for students living in campus residences. University students may spend most of their day on campus, attending classes, studying in the library, participating in extracurricular activities, or working part-time jobs. Students are particularly vulnerable to air pollution as they have little

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2. Planning the experiment

2.1 Key Air Pollutant

Describe the air pollutant(s) you want to learn about and why, including any useful background information. To help you describe the educational goal, try to answer the following questions: - What specific kind of air pollution are you interested in (e.g., PM2.5, PM10, CO2 and HCHO)? - What health concerns related to air pollutants are you interested in? - Once you decide on a pollutant you want to measure, at what location do you want to measure it and why? You will want to end this section with at least 1 testable question that can be answered with the results of the project. The following below are examples of questions:

___(Location)___ is located in ______(specific area of UoY)________. We are concerned about the presence of (pollutant) in the area because (reason). [or] We are curious if the amount of (pollutant) here is different than the amount in/at (other location). The purpose of monitoring for (pollutant) is to educate ourselves of its presence in the area and how it may affect us and others in the area. We plan to collect air quality data using (name of sensor) to see if (pollutant) is present.

2.2 Project Location

Describe the area where the air quality data collection will occur and why. Explain if there's any significance to this area and/or time of day. Also mention here how many times a measurement will be made and the duration of the measurement. Some of the locations you want to consider are mentioned in 1.1-1.6.

Measurements for __(pollutant)__ will be taken __(describe location)__ [add map if applicable to show the measurement locations]. We chose this location because __(reason for choice of location)__ and repeated the measurement because __(explain why, likely for comparison at different times/days)__.

Figure 1. Template that was provided to the students to plan their experiments.

control over their living spaces and are unaware of the potential risks associated.

Finding a reliable and low-cost method for measuring air quality to monitor pollutants and their impacts on students' health is crucial. Importance of using sensors was identified during COVID-19 where access to expensive analytical instruments was not feasible and remote asynchronous learning was necessary (De Vera et al., 2022).[9] A student led project on air quality monitoring using sensors can raise awareness about air quality and its health impacts, the principles of chemical reactions in the atmosphere, and climate change (Khalaf et al., 2023).[10] D'Eon et al. (2021)[11] in their study used a project-based learning experience, where students designed their own research question and then independently pursued a relevant air sampling. Zagatti, Russo, and Pietrogrande (2020),[12] in their study with high school students, provided lessons, equipment, and support for IAQ monitoring. De Vera et al. (2022) identified air quality teaching as an effective teaching tool for enhancing student experiential learning, participation, and engagement.[9] In the present study, a student-led initiative sought to engage UoY students in understanding and addressing air quality issues in the university campus.

2. DESIGNING THE CONTENT

In the following section, I discuss the teaching activities and how different pedagogical understanding (e.g., cocreation, project-based learning) were embedded in the study design to achieve the desired outcomes. This section and the actual study are divided into three parts: (a) student involvement and role (30 min session), (b) air quality monitoring using sensors (90 min session), and (c) data analysis and reporting (120 min session).

2.1. Student Involvement and Role

In the present study, students were trained through the initial session, where they understood the scientific method and how to operate and use air monitoring equipment. An instruction manual and a video demonstrating the use of the instrument were also uploaded in the Virtual Learning Environment (VLE). The students were divided into groups of 4−5 and, through an initial workshop, a sampling strategy was codesigned (location, time, frequency) to understand where students are exposed to the highest level of air pollution. Based on the findings of Varaden et al., (2021),[13] a template questionnaire was designed. A template questionnaire was provided to steer the discussion (Figure 1). Activities during the workshop would involve focus group discussion with students on identification of IAQ issues on campus initiating dialogue between student communities and an expert, brainstorming sessions on mitigation measures, and behavioral change activities. Frequently, the discussion centered on the indoor environment due to the inadequately characterized concentrations that tend to fluctuate with human activity. This inclination facilitated the formulation of research questions that can be tested effectively.[11]

A similar project based learning experience was designed by D'Eon et al. (2021),[11] where students design their own research question and then independently pursue the relevant air sampling. The amount of time university students spend on campus can vary significantly depending on their individual schedules, course load, and personal preferences. Personal exposure to air quality contaminants in different microenvironments of a UK university campus can vary significantly depending on various factors. The following are considerations for different microenvironments commonly found on university campuses:

I. Indoor Classroom and Lecture Halls:
   1. Exposure to indoor air contaminants, such as volatile organic compounds (VOCs) from furniture, cleaning products, and chemicals used in laboratories.
   2. Potential exposure to allergens like dust mites, mold spores, and pollen.
   3. Ventilation systems and the presence of windows can impact indoor air quality.

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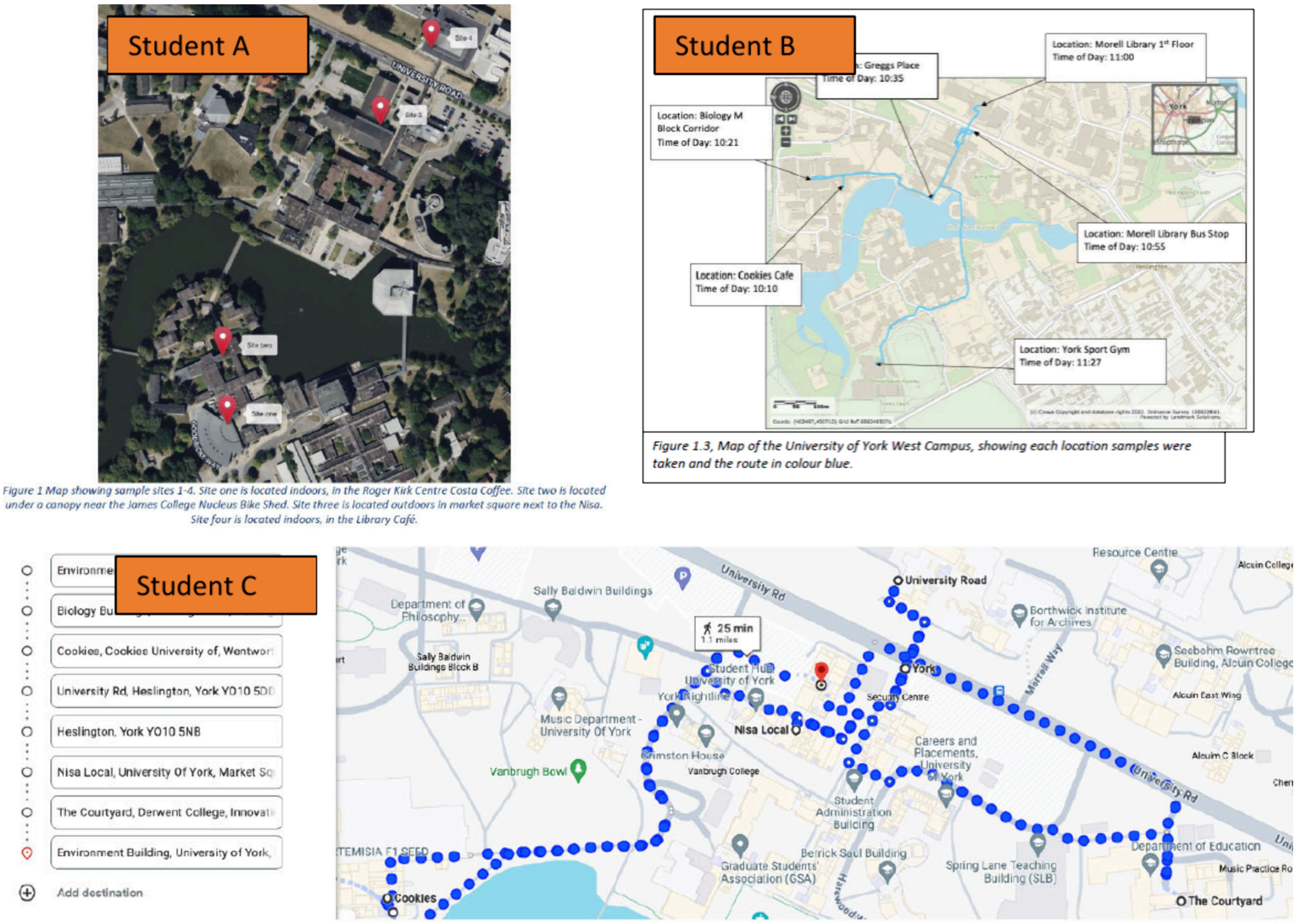

Figure 2. Example of monitoring locations carried out by students in different parts of the UoY campus.

II. Library and Study Areas
   1. Concentrations of indoor pollutants from materials, books, and people.
   2. Ventilation systems and air filtration can affect air quality.

III. Residence Halls
   1. Indoor air quality can vary depending on the age and maintenance of the building.
   2. Potential exposure to pollutants from cooking, cleaning, and personal products.
   3. Ventilation systems and the presence of smoking areas can impact air quality.

IV. Cafeterias and Dining Halls
   1. Exposure to cooking fumes and emissions from food preparation.
   2. Ventilation systems and kitchen exhaust can affect air quality.

V. Outdoor Areas
   1. Exposure to outdoor air pollutants, such as traffic-related emissions, industrial emissions, and pollen.

VI. Weather conditions (e.g., wind direction) can influence outdoor air quality.

VII. Laboratories and Research Facilities:
   1. Potential exposure to laboratory chemicals, fumes, and hazardous substances.
   2. Laboratory ventilation and safety measures are critical for controlling exposure.

Co-creation was made as an integral aspect of the project, and the students were involved in all stages of the study, from design to execution. Through a participatory and inclusive approach, involving lectures, measurements, and data analysis, we aimed to empower students to be air quality citizen scientists. Specifically, the following aims and objectives were formulated. Aim: To develop a spatial concentration of key air pollutants within the university campus. Objectives:

(1) Key sources and variability in exposure concentration
(2) Typical concentration in different locations of the campus

2.2. Air Quality Monitoring Using Sensors on Campus

In the present study, based on the outcome of the initial discussion during the seminar session, the students identified locations they wanted to sample, and monitoring using air sensors was carried out across different campus locations. Students used personal air quality monitoring equipment to measure the air quality that a student or a group is exposed to during their daily routine. Temtop M2000, a portable hand-held low-cost optical particle counter which measures PM2.5, PM10, CO_2, and HCHO, was used for the study. These devices can measure various pollutants and provide data on an individual's exposure levels. In this present study, to assess personal exposure to air quality contaminants in different microenvironments, students used personal air quality monitoring equipment and carried them with them throughout the session. The measurements from these monitors can show whether a pollutant is

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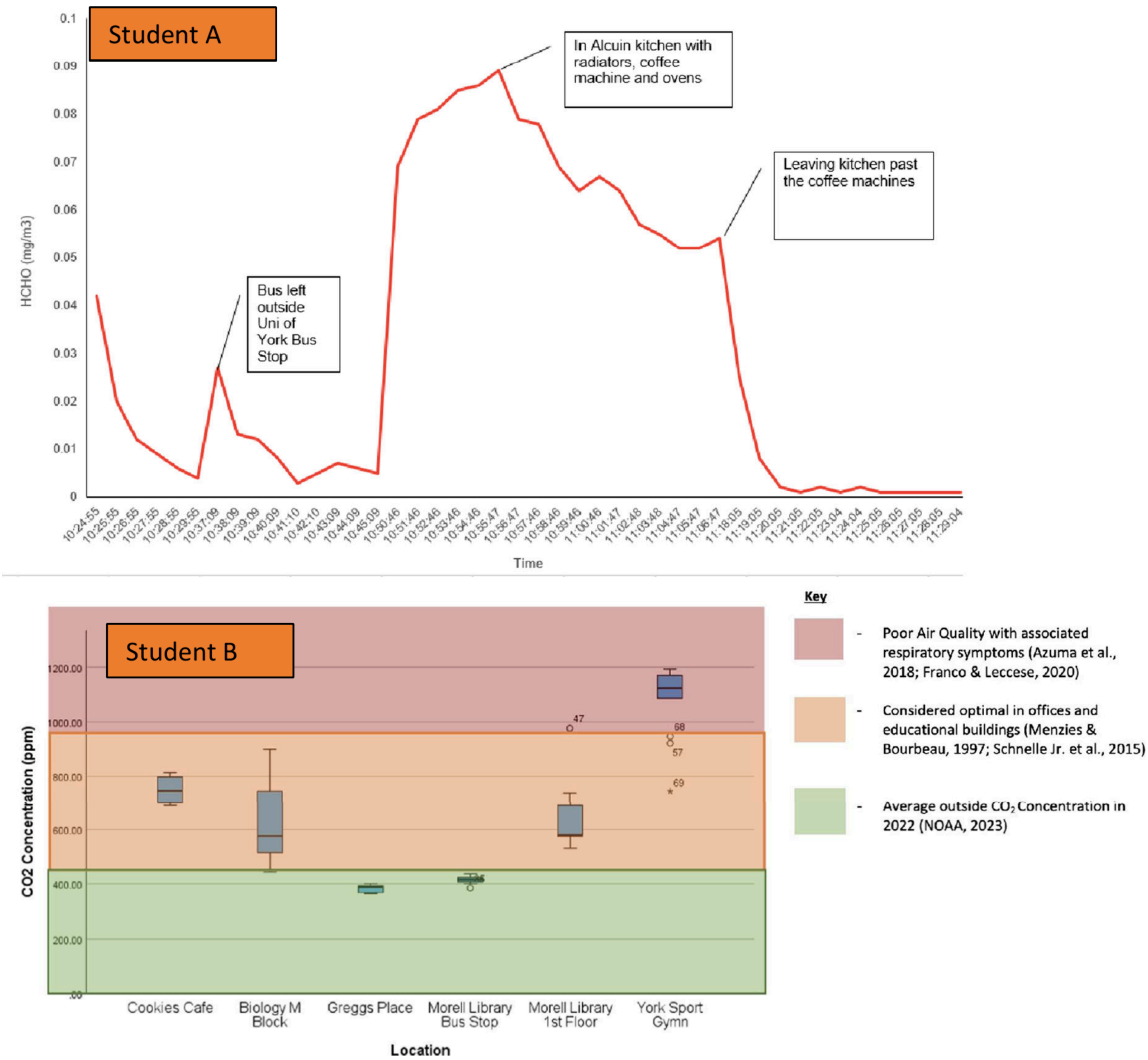

Figure 3. Example of results produced by the students as a part of the assignment.

present in different environments and at different times. They can be used to learn about air pollution on a university campus, the scientific method, and how to operate and use air monitoring equipment.

Each group collected their respective sensors. A hard copy of the data collection sheet was used to record all of the environmental conditions during the course of monitoring. A special emphasis was given on being rigorous and detailed in documenting the time−activity patterns in each location, as this would give more insight on the concentration variations, which were analyzed during the seminar session, as discussed in Section 2.3. The students worked in their allotted groups and measured their concentration across the university campus. Guidance on possible locations were provided in the lecture and workshop session material. The students were also advised to be at the chosen location for 10−15 min in order to capture representative concentration levels. Students were free to choose the route they took, but they were advised to document it in the data collection sheet. They were advised to mimic their normal daily routine on campus, which was compressed for a duration of the session. Which means if they are on campus for 6 h and at the library for 1 h on a usual day, in this 1 h session their time in library will be 1/6 = 10 min. The relative proportion was applied to all locations that they chose to sample. They were also instructed to explore the campus and to consider areas which they think are spatial hotspots within the university (see Figure 2 for examples of routes taken by students). Ideally at the end of the exercise, they were expected to have 60−90 min of data. I rotated around the campus to answer any queries. After the air quality monitoring exercise, the sensor and the data collection sheet was returned. Also, they needed to upload the data to the google drive. If there was rain predicted, they might want to avoid routes without an overhead shed. They should also use the sensor box to protect the instrument from any water damage and reread the guidance document, risk assessment, and instrument manual.

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2.3. Data Analysis and Reporting Tools

The significance of comprehending the interpretation and manipulation of large data sets has grown substantially in today's context. Nevertheless, the integration of this skill set into the typical undergraduate student's education has been progressing at a relatively sluggish pace (D'Eon et al., 2021).[11] Khalaf et al. (2023) evaluated student knowledge through poll questions and Kahoot games.[10] In the present study, the data analysis and reporting tools for the students were assessed through an essay type question, "Write a summary of the air pollution measurement campaign in university campus. Describe the key findings and observation in air quality concentration in different locations of the campus." The assignment had a 500-word limit excluding the reference list, figure and table captions, and table content. I used an anonymized student assessment using VLE and google drive as a source to collect the data required for the study. Ethics applications were also approved by the departmental ethics committee. The measurements from these sensors were used to compare exposures in different locations (e.g., campus accommodation, lecture hall) and identify sources (e.g., vaping, cooking).

The student analyzed the measurements, and some of the analysis is presented in Figure 3.

Preliminary results indicate high CO_2 concentrations in the gym, shopping complex, and lecture theaters; formaldehyde concentrations were found to be above permissible limits in food spaces. Zagatti, Russo, and Pietrogrande (2020) identified unacceptable high levels of fine particle matter ($PM_{2.5}$) mainly entered into indoor environments from highly polluted outdoor air and uncomfortably high CO_2 levels due to classroom crowding and inadequate ventilation.[12] This form of education will allow students to engage in multiple phases of experiential learning, such as conceptualization and experimentation, followed by reflection, analysis, and data interpretation (Bhute et al., 2021).[4]

Some of the module feedback received indicated that the students found this form of practical and data analysis sessions engaging and interesting. Similar findings were also reported by Khalaf et al., 2023 where the outcomes of the air quality outreach project, along with feedback from teachers, revealed that such initiatives can ignite an interest in scientific knowledge.[10] A similar previous experience encountered by the environmental science students of participating in a field-based sampling experiment was in their first year module "ecological principles".

A survey was carried out, and the following questions were formulated

Q1 I have engaged well with the live teaching sessions.
Q2 I have engaged well with the teaching materials provided on the VLE
Q3 Staff are good at explaining things.
Q4 Staff have made the module interesting.
Q5 The module was intellectually stimulating.
Q6 The module challenged me.
Q7 The module has provided opportunities to explore ideas and concepts in depth.
Q8 The marking criteria available on the VLE has been clear.
Q9 Marking and assessment has been fair.
Q10 Feedback on my work has been timely.
Q11 I have received helpful comments on my work.
Q12 I have been able to contact staff when I needed to.
Q13 I have received sufficient advice and guidance with studying.
Q14 The module was well organized and ran smoothly
Q15 The timetable worked efficiently for me.
Q16 Any changes in the module or teaching were communicated effectively.
Q17 The Department's module VLE pages worked effectively for me.
Q18 Overall, I am satisfied with the quality of the module.
Q19 What did you like about this module?
Q20 What do you think could be improved?

All questions were ranked on a scale of 1−5. 100% of the students found that they "mostly or definitely agree" that they engaged well with the live teaching session and found the teaching material helpful. 73% of the students also found the module to be stimulating, and 82 found it to be interesting. However, this is the first time the students designed something on their own. As this was the first time such a session was being carried out by the student themselves, I tried to be proactive in responding to the queries as was evidenced in the module feedback by one of the students—"I was also really grateful that every lecturer (particularly Darpan) that I emailed responded swiftly and with sufficient advice/information." However, since the assessment was in the form of 500 words, some of the students found it to be not optimum as one student said "I would have preferred the word count for each question in the assessment to be slightly longer (perhaps 700−750 words) as I didn't always feel I could go into as much detail/analysis as I would have liked."

Employing a citizen science methodology for data collection, involving students actively in the research process, not only facilitated the accumulation of a substantial data set by promoting participation and fostering adherence to the study protocol but also heightened the students' awareness of air pollution. It is anticipated that this, in turn, will motivate them to embrace positive behavioral changes aimed at minimizing their exposure.[13] The level of mentoring and the students' proficiency in spreadsheet and graphing software varied among these groups. However, all groups were able to successfully carry out their projects.

3. CONCLUSIONS

In the following section, I will discuss the study outcomes and short- and long-term changes the project can influence. Universities have high population densities, and students are particularly at high risk of being exposed to indoor air pollutants as they have little control over their living spaces and are unaware of potential risks associated. Maintaining a clean IAQ is important for maintaining student physical (e.g., asthma) and mental (e.g., cognitive) well-being. This UG module practical designed for Environmental Science students measured the IAQ in different microenvironments using low-cost air sensors. Through a comprehensive and innovative citizen science approach, we monitored and improved awareness of IAQ around the University of York campus. Specifically, we

(1) Enabled students to collect comprehensive IAQ data across different areas of the campus location
(2) Empowered UoY students with the tools and knowledge to monitor IAQ effectively using participatory sensing.
(3) Raised awareness among the student community around IAQ issues and promoted initiatives for cleaner air.

The present project focuses on student community, belonging, and mattering, and through team working skills they learned about air quality in different university campus

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microenvironments. Being involved in a practical problem with outcomes not known in advance can help students understand scientific uncertainty, limits to knowledge, the importance of precision, and reliability. The student community used sensors to estimate exposure for individuals in different locations of the campus. Zagatti, Russo, and Pietrogrande (2020) identified this approach as being able to engage students in real world science research and learning.

4. IMPLICATIONS

In the future, to have wider impact and inclusivity, the project will aim to recruit cross sectional student demographics to ensure the diversity of student views are captured. We will recruit students from different college accommodations to capture a wide variability of sources and activities, influencing exposure concentration. The results were compared with the Building Energy Management System (BeMS), maintained by the estate office. I envision translating findings of the study into information that is readily available and usable and disseminating information to UoY staff and students through a knowledge sharing platform (e.g., infographic Web site). The data collected will complement existing efforts by the UoY estate office and help fill the missing gaps (e.g., IAQ in campus accommodations, currently not measured by the estate). It will provide a more accurate and holistic picture of the air quality on the UoY campus and help prioritize areas of improvement, e.g., where students spend a significant amount of time (such as campus accommodations and laboratories) and where the highest inhalation rates are recorded (such as gyms and sports venues). Students will use this newfound empowerment to work along with the UoY estate office to develop/strengthen strategies to report IAQ issues effectively. The study would also give insight on under-utilized spaces (e.g., using CO_2 as a proxy of occupancy) and could lead to potential energy savings on the UoY campus.

The students were equipped with all skills during the course of the study to analyze the data and will present their findings at the end of the project. The present project also touches upon several themes of employability and skills development. Through the assignment exercise, the students also gained the ability to document their research, a much needed skill required for their dissertation. I believe that the present project will have a significant positive impact on the student community, fostering environmental stewardship and better air quality. Future funding for this project will not only benefit our students but also contribute to the larger cause of improving the quality of life worldwide through innovation and environmental monitoring.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.5c00374.

Figure S1: sample data sheets that students collected during the study; Figure S2: Essay assessment rubric used for marking the assignment (PDF, DOCX)

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Notes

The author declares no competing financial interest.

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