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# Experiential Virtual Learning on the impacts of Covid-19 on Air Quality through Integration of Research in STEM Education

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Dr. Madhumi Mitra is a tenured full professor of Biological and Environmental sciences in the Department of Natural Sciences at the University of Maryland Eastern Shore (UMES). She is the coordinator of biology and chemistry education programs at UMES. She has received her doctoral degree in Plant Biology from North Carolina State University, Raleigh, NC, USA. Her B.S. and M.S degrees are in Botany from the Presidency College (now Presidency University) and University of Calcutta, India respectively. She is also the recipient of a master's degree in the nation's first-degree program in Medical Cannabis Science and Therapeutics from the School of Pharmacy from the University of Maryland Baltimore (UMB) in 2021. Two of her students in Biology Education have been the recipients of the Presidential Awards for Excellence in Mathematics and Science Teaching (PAEMST), which is the highest honors bestowed by the United States government specifically for STEM teachers. One of her students was awarded the Maryland Teacher of the Year award in 2019. Her research interests and expertise include micro and macroalgal ecology; seaweeds in human health and nutrition; biomonitoring and biosorption potential of seaweeds and seagrasses; bioenergy from algae; water quality; and sustainable robotic farming with applications of seaweeds as biostimulants. She is the recipient of various research and teaching awards, and has published in many peer-reviewed journals and proceedings, and presented her research at national and international conferences. She also co-edited and coauthored a book on Bioenergy with Springer Academic Publishers in 2020. She is currently working on her second book on Artificial Intelligence in the 21st Century for CRC Press (a Taylor and Francis group). Dr. Mitra has given keynote addresses at international conferences on Bioenergy and related disciplines in the STEM areas. She holds a strong record of competitive funding from federal and state agencies. She has been a recipient of more than 15 million dollars grants as a principal and a co-principal investigator. She has served in various leadership roles for many professional organizations. She was the Division Chair of the Energy Conversion and Conservation Division (ECCD) of the American Society of Engineering Education (ASEE). She has also served on the Board of Directors for Assateague Coastal Trust (ACT) for more than five years; serves as a member of the commission on Diversity, Equity, and Inclusion of ASEE; and have been an advocate for renewable energy and climate change. Dr. Mitra also led several meditation and yoga workshops for the local and regional communities organized by the hospitals and Salisbury University (SU), and at national conferences for STEM teachers.

**Dr. Abhijit Nagchaudhuri, University of Maryland Eastern Shore**

Dr. Abhijit Nagchaudhuri is currently a tenured professor in the Department of Engineering and Aviation Sciences at the University of Maryland Eastern Shore(UMES). Dr. Nagchaudhuri received his baccalaureate degree from Jadavpur University (India) with honors in mechanical engineering in 1983. Thereafter, he worked in a multinational industry for a little over three years before joining Tulane University as a graduate student in the fall of 1987. He received a master's degree from Tulane University in 1989 and a doctoral degree from Duke University in 1992. He is a member of the American Society for Mechanical Engineers (ASME), the American Society for Engineering Education (ASEE), and, has also been involved with the American Society for Agricultural and Biological Engineers (ASABE). He is actively involved in teaching and research in the fields of (i) robotics and mechatronics, (ii) remote sensing and precision agriculture, and,(iii) biofuels and renewable energy. He has been involved with several extramurally funded projects as PI or Co-PI to support outreach, education, and research activities from various state, federal, and private agencies; served in leadership roles in professional societies; and has received several awards and certificates from his home institution as well as professional societies.

**Will Klein, University of Maryland, College Park**

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## Abstract

Poor air quality can be detrimental to human health, by causing or exacerbating health conditions. Sensitive groups such as children and the elderly with underlying conditions are at an increased risk for adverse health effects due to poor air quality. Due to the Covid-19 Pandemic, there is an observed change in air quality due to government restrictions and lockdown from 2020-2022 in many of the populated cities of the world. The University of Maryland Eastern Shore students (UMES) students in 3 undergrad courses (Introduction to Environmental Sciences; Biology for Honors students; and Ecology) and 1 graduate course (Teaching STEM at K-12 schools), and summer-exchange undergraduate engineering and high school interns had the opportunity to research the effects of Covid-19 pandemic on air quality for selected overpopulated cities in the world. The data collected were from March 2020 through summer of 2022. The objectives of integrating this research in STEM education are: a) to find a correlation among air quality parameters because of Covid-19; b) to analyze the effects of the pandemic on CO, $NO_2$, $O_3$, $PM_{2.5}$, $PM_{10}$, and $SO_2$ in some of the selected populated cities (Kolkata, Milan, Los Angeles, São Paulo, Shanghai, and Sydney); c) to hone content knowledge in environmental science, chemistry, physics, and statistics; and d) to enhance data analytical skills, problem solving skills, as well as presenting research. By analyzing the effects of the Covid-19 pandemic on air quality, the scope for environmental restoration is addressed as more information is disseminated on what contributes to air quality, and how humans can manipulate it. In each of the courses mentioned above, two modules were dedicated to this topic. The first module introduced the topic and background information and the second one required relevant data analysis and presentations. Since the Environmental Science class had over 40 students, the students were broken down into groups for this activity. Various relevant governmental websites were used to gain background knowledge about the satellites and sensors. The data were collected from the Air Quality Open Data Platform https://aqicn.org/data-platform/Covid19 Worldwide Covid-19 dataset. The engineering and the high school interns continued with this work during the summer. Because of this approach, there was a continuous collection and analyses of data for this project. Efforts are underway to include this topic in the Engineering Statistics course in Spring 2023/Fall 2023. By analyzing the effects of the Covid-19 pandemic on air quality, the scope for environmental restoration is addressed as more information is disseminated on what contributes to air quality, and how humans can manipulate it. The findings from this study, and other contemporary ones, can aid in efforts towards combating climate change and sustaining human life in a holistic manner. This multidisciplinary project synthesized research and education from biology, chemistry, environmental sciences, engineering, and statistics. It also opened avenues to discuss potential solutions for two of the NAE Grand Engineering Challenges: developing carbon sequestration methods, and engineering the tools of scientific discovery. The students had very positive feedback on their learning experiences such as honing their multidisciplinary content knowledge; applying their knowledge to real-world situations; improving their critical thinking, data analytical, and presentation skills.

**Keywords**

Covid-19; air pollution; grand challenges of engineering; STEM; multidisciplinary; sustainability;

## 1.0 Introduction

Air pollution is a major public health concern, and long-term exposure to air pollutants can increase the risk of respiratory and cardiovascular diseases, including asthma, strokes and heart attacks. In addition, air pollution can cause various types of cancers, and can lead to neurological disorders and reproductive problems.[1,2]. The most common sources of air pollution are emissions from the burning of fossil fuels, industrial and agricultural activities, and the release of pollutants from automobiles and other forms of transportation.[3,4]

The pollutants, such as carbon monoxide, oxides of nitrogen, sulfur dioxide, ozone, and particulate matter, can be inhaled and absorbed into the bloodstream, causing serious health problems.[5,6,7] Particulate Matter <2.5μm, which is referred to as $PM_{2.5}$, is one of the most harmful pollutants that can cause respiratory problems, heart attacks, and early deaths. The wildfires, trash, and coal burning, as well as dust from cars, construction, and power generation plants could contribute to generation of this noxious pollutant. Particulate matter pollution contributes to acid rain and can change weather patterns, causing drought, and ocean acidification. Nitrogen Dioxide ($NO_2$) is formed by the combustion of motor engines, and decomposes in presence of sunlight to $O_3$. $NO_2$, when present in high concentrations in the air, could lead to asthma and respiratory infections. Ozone ($O_3$) is formed by the decomposition of volatile organic compounds, including $NO_2$. The highest levels of $O_3$ are in the summer as direct sunlight catalyzes the rapid decomposition of $NO_2$. $O_3$ in low concentrations could impact breathing, inflame the airways, and make the lungs more susceptible to infections.[7,8,9] Sulfur dioxide ($SO_2$), is produced by the combustion of fossil fuels from power plants, engines, volcanoes, and ore extraction processes of aluminum, copper, zinc, lead, and iron. It can irritate the skin and membranes of the eyes, nose, throat, and lungs, which can lead to and exacerbate respiratory illnesses[10]. $SO_2$ emissions when mixed with other chemicals in the atmosphere form sulfuric acid causing damage to trees, foliage, and farmland, and forming air particulates. Table 1 documents the health implications of the six pollutants of interest for this study. AQI or Air Quality Index is a measure of air pollution, which ranges from 0 to 500. When the value is less than 50 or below, it is a representation of good air quality; and when it exceeds 100, the air quality is designated as unhealthy. The values close to 300 are hazardous[11].

The six harmful pollutants were selected for the study on the impacts of covid-19 on air pollution. The research that was conducted by the student interns during their summer internships, as well as students in the designated courses, covered air pollution data from 2020-2022. The purpose was to assess whether the pandemic lockdown played a role in reducing the concentrations of pollutants in some of the densely populated cities in the world or not. In addition, through literature review, the student interns and the students in STEM courses wanted to see the extent of consistency among the findings between this research and other established studies on covid-19 and air quality.

| AQI | CO (ppm) | $NO_2$ (ppb) | $O_3$ (ppb) | $PM_{2.5}$ (μg/m$^3$) | $PM_{10}$ (μg/m$^3$) | $SO_2$ (ppb) | Health implications |
|---|---|---|---|---|---|---|---|
| Unhealthy | 12.5-15.4 | 361-649 | 165-204 | 55.5-150.4 | 255-354 | 186-304 | Respiratory discomfort to sensitive groups |
| Very Unhealthy | 15.5-30.4 | 650-1244 | 205-404 | 150.5-250.4 | 355-424 | 305-604 | Breathing discomfort with prolonged exposure |
| Hazardous | 30.5 + | 1245+ | 405+ | 250.5+ | 425+ | 605+ | Health alert: respiratory effects experienced by everyone |

Table 1. AQI and the pollutants of interest and their health implications[11]

## 2.0 Student Exchange Programs

The COVID-19 pandemic has resulted in lockdowns and travel restrictions in many cities around the world, leading to a reduction in human activity and transportation. This reduction in human activity has resulted in changes to air quality, and there is growing interest in understanding the impacts of lockdowns on air quality in cities.[12,13] During the Covid-19 pandemic, it was challenging to train STEM undergraduate students without giving them any hands-on lab exposures. The summer exchange programs for undergraduate STEM students were funded through Maryland Space Grant Consortium (MDSGC) in the year of 2020 and 2021. The opportunity for this virtual research experience was one of the avenues to hone a variety of data analytical skills along with gaining content in the environmental sciences and engineering with a special emphasis in statistics and chemistry. The activities were adapted for remote research experience, which facilitated student engagement and allowed the interns to interact with their peers and professionals for feedback and guidance. The faculty mentor supervised the interns, and provided structured mentoring throughout the duration of the internship.

The MDSGC Summer Exchange Internship Program is a paid internship that spans across a 10-week period during every summer. It recruits mainly engineering undergraduate students from participating member institutions of the MDSGC to participate in hands-on research experiences outside their home institutions. The students are first required to contact the faculty coordinator at their respective institutions, who play pivotal roles in identifying suitable projects for the students interested in the internship program. The mentors, who are typically faculty, from participating member institutions have to submit project proposals in the STEM areas that are relevant to the National Aeronautics and Space Administration's (NASA's) mission and are aligned with the needs of the future workforce. The student recruitment plan targeting women and members of underrepresented minorities was included. Each project included the learning outcomes, timeline, mentoring plan, and expected deliverables. For each project, financial support for one to two students was requested. The students need to be US citizens and either rising sophomores or juniors or seniors majoring in STEM disciplines pertaining to the project. The interns were required to be enrolled in the member institutions that are participating in this internship. They also made the commitment to work at least for 10 weeks during the summer. Following their applications, the faculty research mentors who supervised the projects interviewed the prospective interns to assess whether they were a good fit for their projects or not. Following selection, the students were assigned to their research mentors during the entire 10-week period of the summer exchange program. A senior from a local high school was also involved with the project. The student intern remotely participated in the project and worked closely with the undergraduate intern in 2022 to assist with literature review; collecting data from the websites; analyzing data. At the end of the experience, the high school student as well as the interns also submitted a short report reflecting on the experience and results of the findings.

## 3.0 Objectives of the Project

The project on the impacts of Covid-19 pandemic on the air quality for selected populated cities across the globe" aimed at analyzing historical and real-time data from a number of governmental websites as well as Air Quality Open Data platform for worldwide covid-19 dataset. The data were analyzed to understand the pandemic's impacts on selected air pollutants of interest (listed in the Introduction section) and how these have changed since the beginning of the 2020 through 2022. The objectives of the study are: a) to find a correlation among air quality parameters as a consequence of COVID-19; and b) to analyze the effects of the pandemic on CO, $NO_2$, $O_3$, $PM_{2.5}$, $PM_{10}$, and $SO_2$ in the selected populated cities; c) to hone content knowledge in environmental science, chemistry, physics, and statistics; and to enhance data analytical skills, problem solving skills, as well as presenting research, and d) to enhance data analytical skills, problem solving skills, as well as presenting research. Research pertaining to this subject could have a major importance in the future, as it could disseminate insightful information on the activities causing pollution; how these pollutants could affect public health; and the mitigation efforts to regulate the pollutants' levels/

## 4.0 Experiential Learning for Students

The research mentor provided clear expectations and objectives of the program. Through google meet, meetings were set up during the beginning (Monday) and end (Friday) of each week. The student interns outlined what they would do for the entire week, and during the end of the week meeting, they discussed how their weekly objectives were met/not met. The mentor guided the interns throughout their virtual experiential learning. Time management was of critical importance, and progress towards the project goals were documented by both the mentor and the mentees.

The websites of NASA, NOAA, EPA, and ESA were used to gain background, such as the NASA $NO_2$ watch website. The knowledge about the satellites and sensors that make the measurements and calculations were gained from these websites that contained information on the Ozone Monitoring Instrument on the Aura Satellite. This helped the students to understand what a vertical column is, to a pixel filter. The diverse heavily populated cities with records of pollution were selected to study the effects observed due to lockdowns. The cities selected were Kolkata (India), Los Angeles (USA), Milan (Italy), São Paulo (Brazil), Shanghai (China), and Sydney (Australia).

The data were collected from the Air Quality Open Data Platform https://aqicn.org/data-platform/Covid19 Worldwide Covid-19 dataset[14]. The data sets are a consortium of other countries' EPA like agencies. More than 30,000 stations have contributed/contributing data to this set. The data were also based on the U.S. EPA Instant-Cast Standard. Microsoft Excel was used for calculations, graphing, and analyses.

## 5.0 Results, Data Analysis, and Discussion

The students following the data analyses presented the results graphically of AQI (Air Quality Index) levels for CO, $NO_2$, $O_3$, $SO_2$, and the AQI for $PM_{10}$ and $PM_{2.5}$ in each of the selected cities beginning Jan. 7th, 2020, to July 4th, 2022. Some common trends are CO, $NO_2$, PM, and $SO_2$ peaks in the winter; while $O_3$ peaks in the summer. Figure 1 (a-l) represents the following as described.

a= AQI values for CO, $NO_2$, $O_3$, $SO_2$ for Kolkata; b= AQI values $PM_{10}$ and PM2.5 for Kolkata

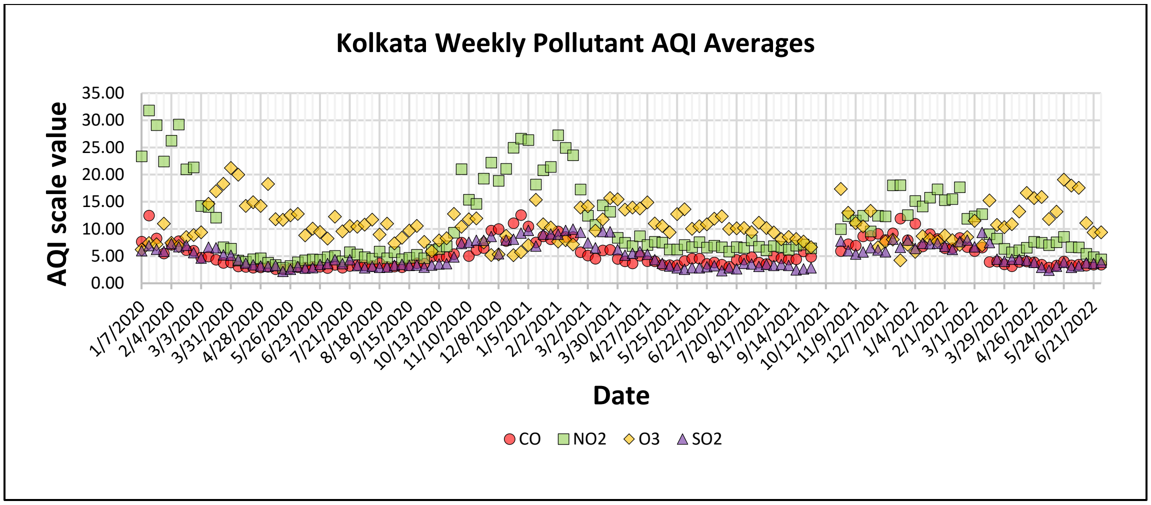
c= AQI values for CO, $NO_2$, O3, $SO_2$ for Los Angeles; d= AQI values $PM_{10}$ and $PM_{2.5}$ for Los Angeles

e= AQI values for CO, $NO_2$, $O_3$, $SO_2$ for Milan; f= AQI values $PM_{10}$ and $PM_{2.5}$ for Milan

g= AQI values for CO, $NO_2$, $O_3$, $SO_2$ for São Paulo; h= AQI values $PM_{10}$ and $PM_{2.5}$ for São Paulo

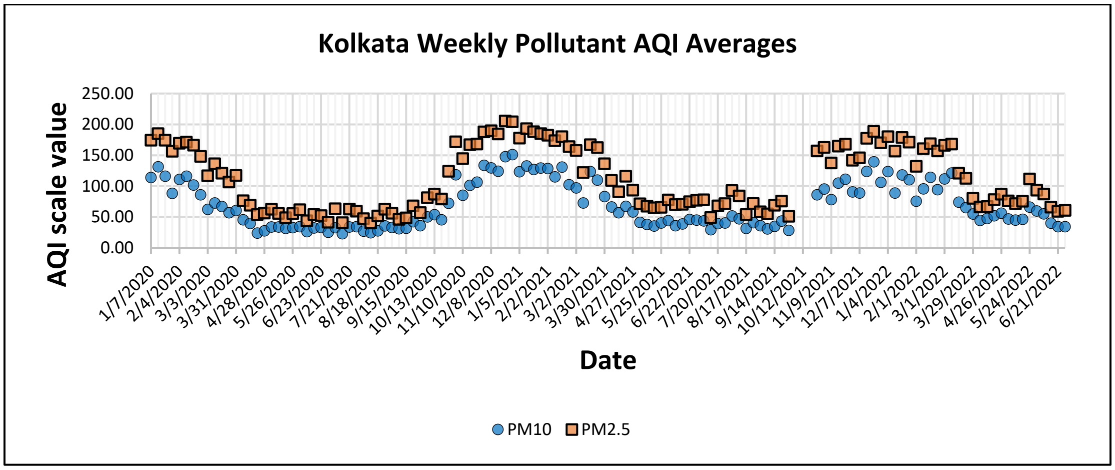
i= AQI values for CO, $NO_2$, $O_3$, $SO_2$ for Shanghai; j= AQI values $PM_{10}$ and $PM_{2.5}$ for Shanghai

k= AQI values for CO, $NO_2$, $O_3$, $SO_2$ for Sydney; l= AQI values $PM_{10}$ and $PM_{2.5}$ for Sydney



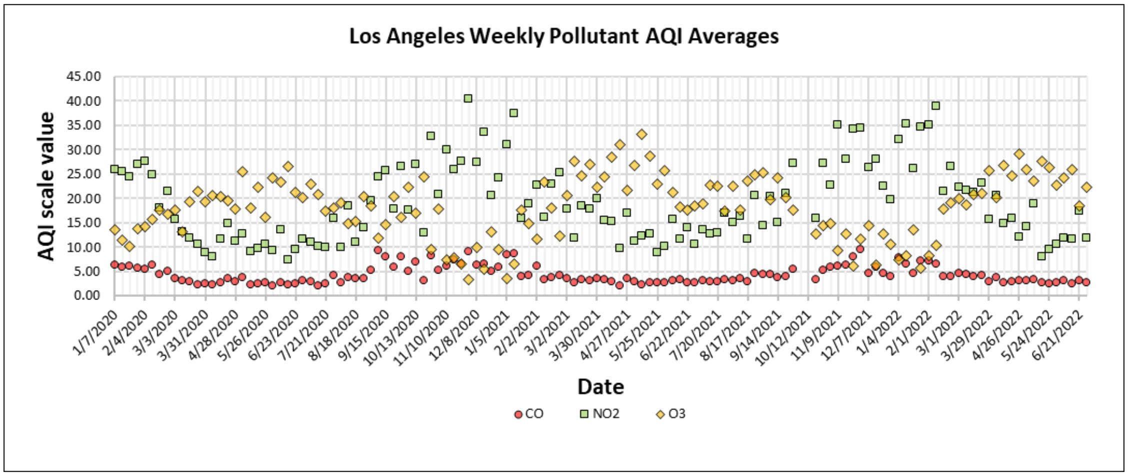
Kolkata Weekly Pollutant AQI Averages
AQI scale value
Date
CO
NO2
O3
SO2


a



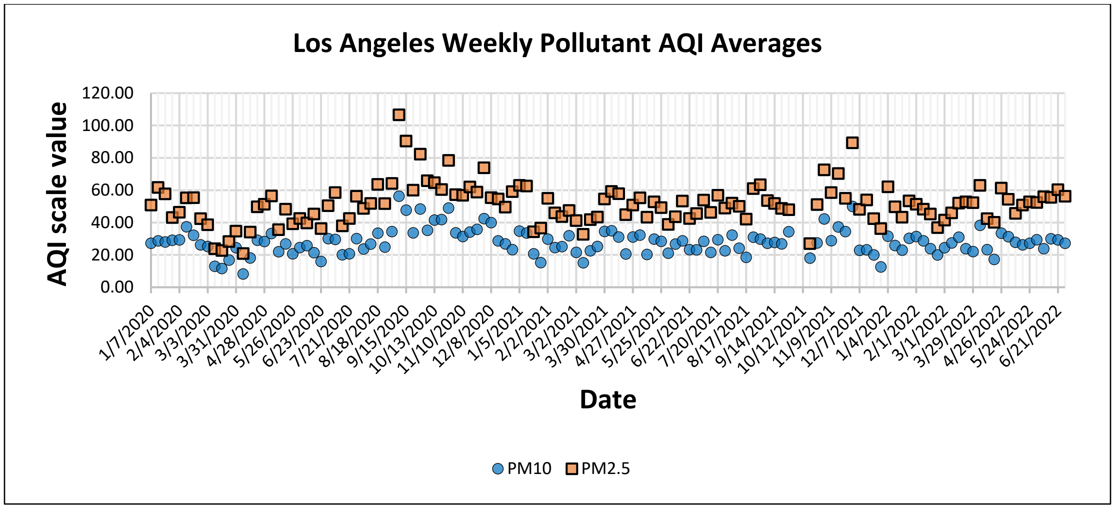
Kolkata Weekly Pollutant AQI Averages
AQI scale value
Date
PM10
PM2.5


b

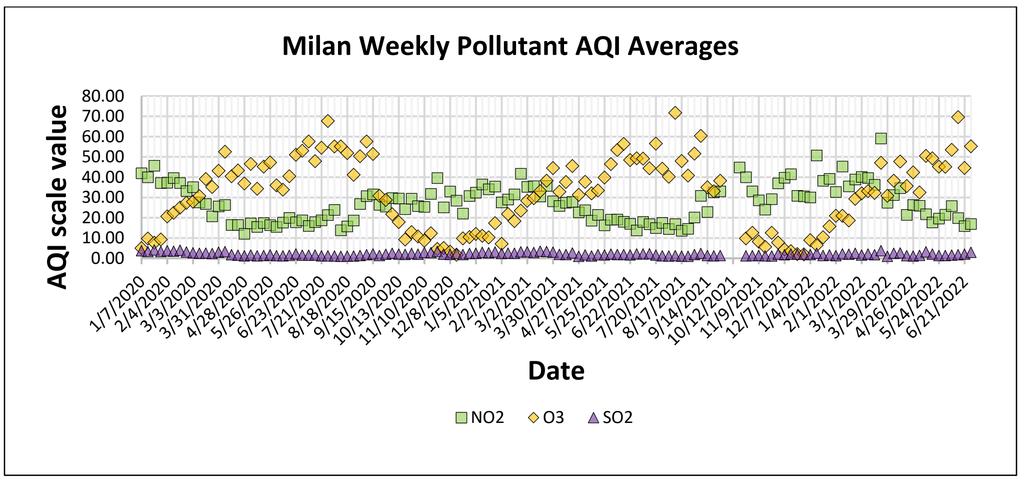


Los Angeles Weekly Pollutant AQI Averages
AQI scale value
Date
CO
NO2
O3

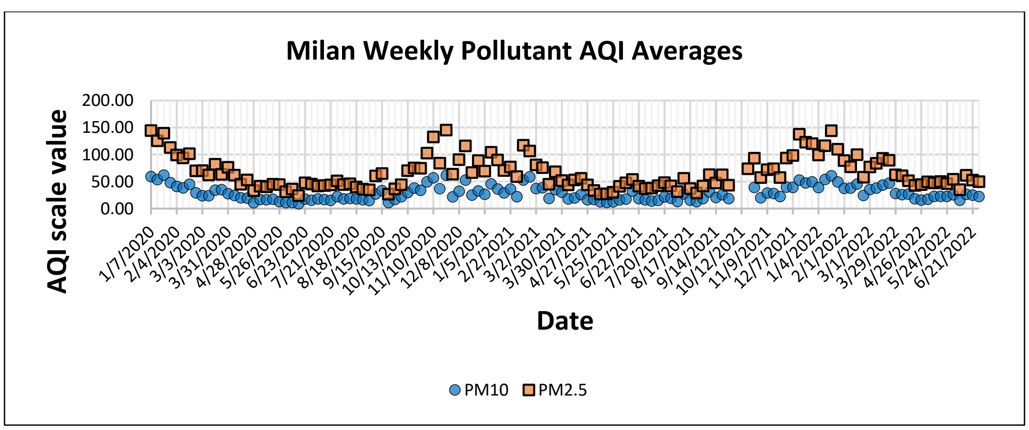

c


Los Angeles Weekly Pollutant AQI Averages
AQI scale value
120.00
100.00
80.00
60.00
40.00
20.00
0.00
1/7/2020 2/4/2020 3/3/2020 3/31/2020 4/28/2020 5/26/2020 6/23/2020 7/21/2020 8/18/2020 9/15/2020 10/13/2020 11/10/2020 12/8/2020 1/5/2021 2/2/2021 3/2/2021 3/30/2021 4/27/2021 5/25/2021 6/22/2021 7/20/2021 8/17/2021 9/14/2021 10/12/2021 11/9/2021 12/7/2021 1/4/2022 2/1/2022 3/1/2022 3/29/2022 4/26/2022 5/24/2022 6/21/2022
Date
PM10 PM2.5

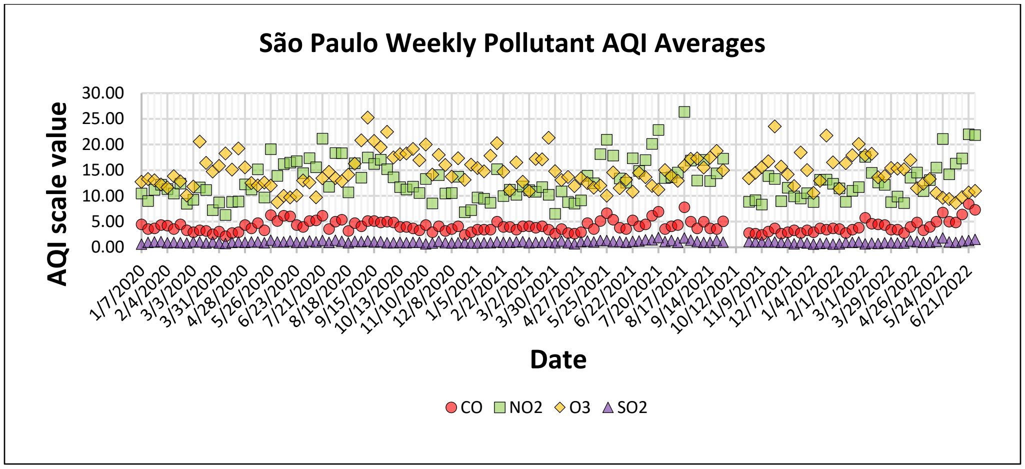
d


Milan Weekly Pollutant AQI Averages
AQI scale value
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1/7/2020 2/4/2020 3/3/2020 3/31/2020 4/28/2020 5/26/2020 6/23/2020 7/21/2020 8/18/2020 9/15/2020 10/13/2020 11/10/2020 12/8/2020 1/5/2021 2/2/2021 3/2/2021 3/30/2021 4/27/2021 5/25/2021 6/22/2021 7/20/2021 8/17/2021 9/14/2021 10/12/2021 11/9/2021 12/7/2021 1/4/2022 2/1/2022 3/1/2022 3/29/2022 4/26/2022 5/24/2022 6/21/2022
Date
NO2 O3 SO2

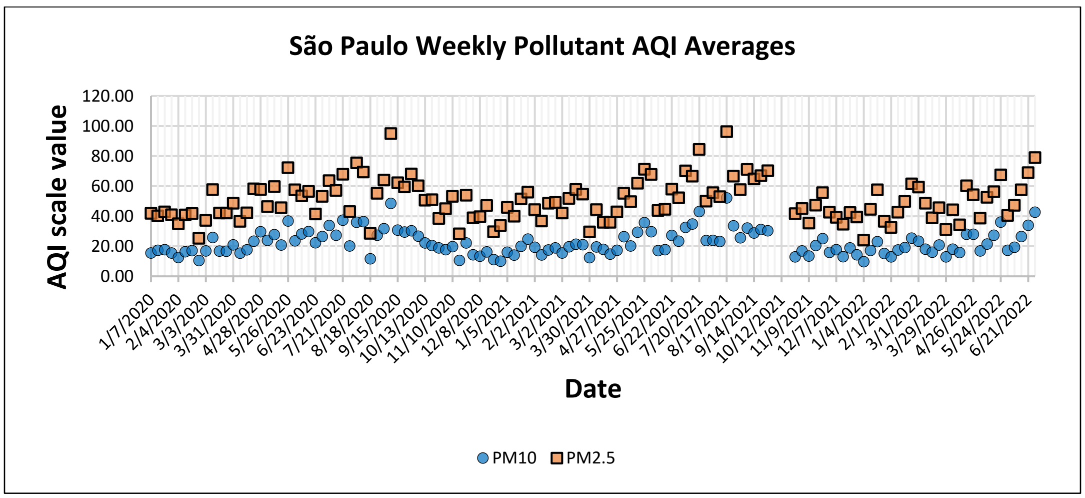
e


Milan Weekly Pollutant AQI Averages
AQI scale value
200.00
150.00
100.00
50.00
0.00
1/7/2020 2/4/2020 3/3/2020 3/31/2020 4/28/2020 5/26/2020 6/23/2020 7/21/2020 8/18/2020 9/15/2020 10/13/2020 11/10/2020 12/8/2020 1/5/2021 2/2/2021 3/2/2021 3/30/2021 4/27/2021 5/25/2021 6/22/2021 7/20/2021 8/17/2021 9/14/2021 10/12/2021 11/9/2021 12/7/2021 1/4/2022 2/1/2022 3/1/2022 3/29/2022 4/26/2022 5/24/2022 6/21/2022
Date
PM10 PM2.5

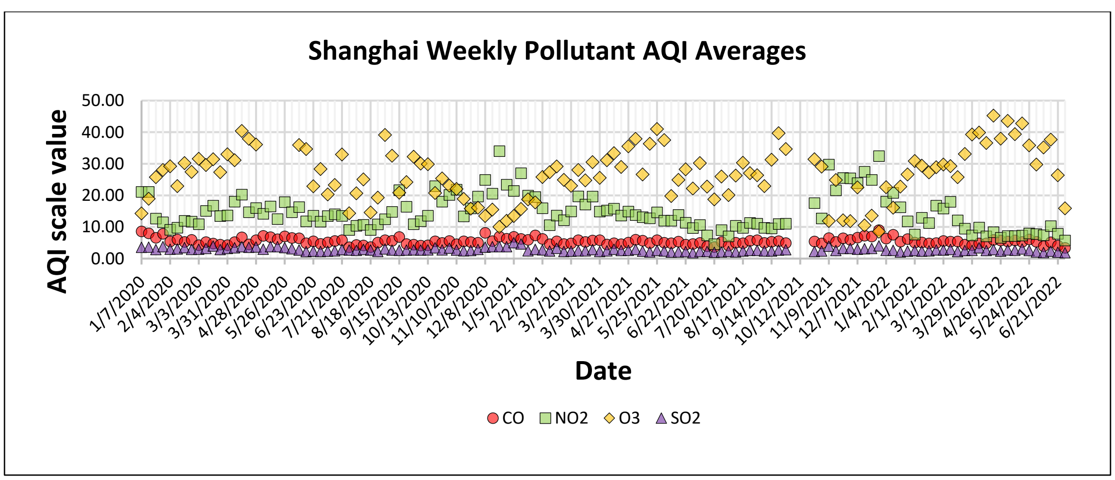
f


São Paulo Weekly Pollutant AQI Averages
AQI scale value
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1/7/2020 2/4/2020 3/3/2020 3/31/2020 4/28/2020 5/26/2020 6/23/2020 7/21/2020 8/18/2020 9/15/2020 10/13/2020 11/10/2020 12/8/2020 1/5/2021 2/2/2021 3/2/2021 3/30/2021 4/27/2021 5/25/2021 6/22/2021 7/20/2021 8/17/2021 9/14/2021 10/12/2021 11/9/2021 12/7/2021 1/4/2022 2/1/2022 3/1/2022 3/29/2022 4/26/2022 5/24/2022 6/21/2022
Date
CO NO2 O3 SO2

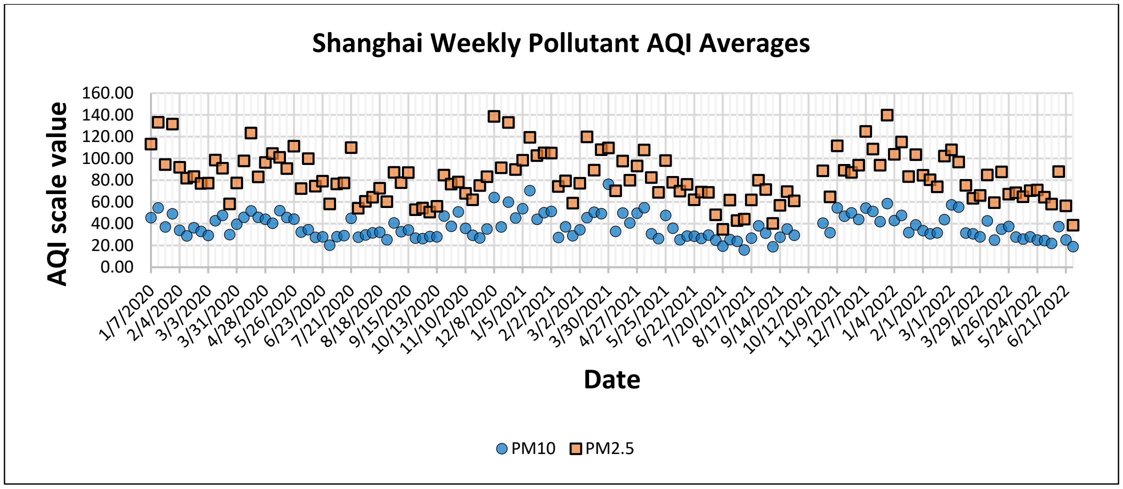
g


São Paulo Weekly Pollutant AQI Averages
AQI scale value
120.00
100.00
80.00
60.00
40.00
20.00
0.00
1/7/2020 2/4/2020 3/3/2020 3/31/2020 4/28/2020 5/26/2020 6/23/2020 7/21/2020 8/18/2020 9/15/2020 10/13/2020 11/10/2020 12/8/2020 1/5/2021 2/2/2021 3/2/2021 3/30/2021 4/27/2021 5/25/2021 6/22/2021 7/20/2021 8/17/2021 9/14/2021 10/12/2021 11/9/2021 12/7/2021 1/4/2022 2/1/2022 3/1/2022 3/29/2022 4/26/2022 5/24/2022 6/21/2022
Date
PM10 PM2.5

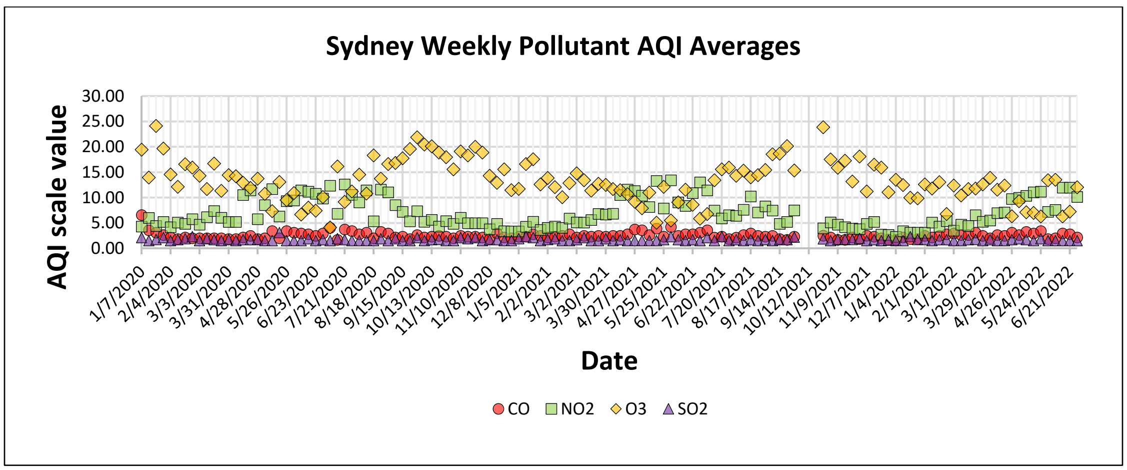
h


Shanghai Weekly Pollutant AQI Averages
AQI scale value
50.00
40.00
30.00
20.00
10.00
0.00
1/7/2020 2/4/2020 3/3/2020 3/31/2020 4/28/2020 5/26/2020 6/23/2020 7/21/2020 8/18/2020 9/15/2020 10/13/2020 11/10/2020 12/8/2020 1/5/2021 2/2/2021 3/2/2021 3/30/2021 4/27/2021 5/25/2021 6/22/2021 7/20/2021 8/17/2021 9/14/2021 10/12/2021 11/9/2021 12/7/2021 1/4/2022 2/1/2022 3/1/2022 3/29/2022 4/26/2022 5/24/2022 6/21/2022
Date
CO NO2 O3 SO2

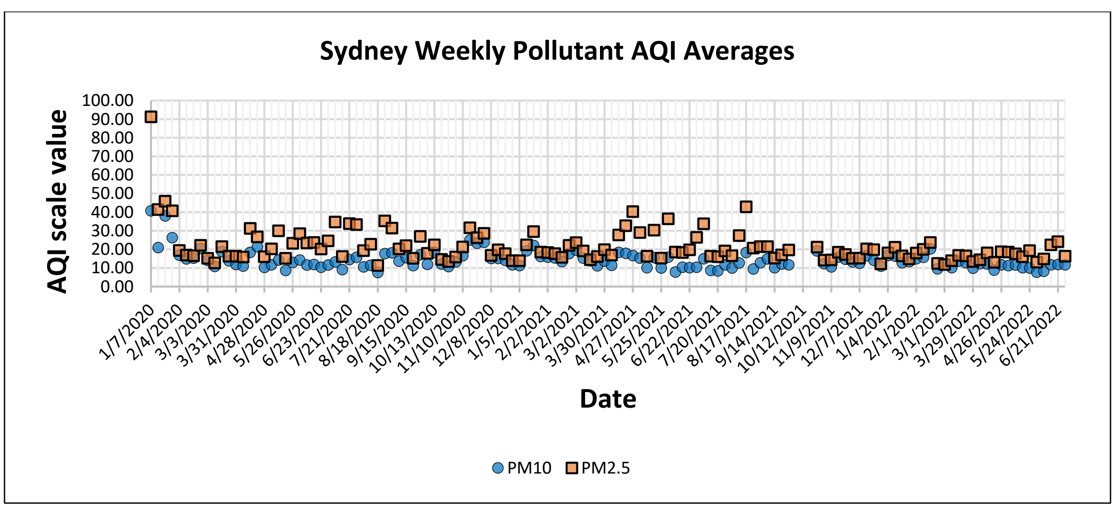
i


Shanghai Weekly Pollutant AQI Averages
AQI scale value
Date
PM10
PM2.5

j


Sydney Weekly Pollutant AQI Averages
AQI scale value
Date
CO
NO2
O3
SO2

k


Sydney Weekly Pollutant AQI Averages
AQI scale value
Date
PM10
PM2.5

l

Pearson Correlation Coefficient matrices for each city between each pollutant was calculated. The closer a value is to a negative 1 or a positive 1, the stronger the relationship is between the two data sets[15]. The data show that there were positive correlations of CO with $NO_2$, PM, and $SO_2$; $NO_2$ with PM and $SO_2$; and PM with $SO_2$. There were negative correlations of $O_3$ with CO and $NO_2$. A sample correlation coefficient matrix for Kolkata is depicted in Figure 2.

A comparative analysis of the pre-covid data based on AQI averages for all the six cities was conducted. The results showed that in Kolkata, there was a decrease in particulate matter (PM) in all winters since 2019. There was also a decrease in $NO_2$ for all winters since 2019. Industries, diesel engines, trash burning, road dust, and construction dust in Kolkata, India, have contributed to air pollution. When these activities were minimized at the beginning of the pandemic, there were reductions in the pollution levels. However, as vaccine trials and easing of restrictions started to roll in, pollution, particularly $PM_{2.5}$, levels went up. Due to a lack of governmental regulations and enforcement of environmental policies within the city, the mitigation measures to combat air pollution remain non-existent.[16]

Los Angeles showed an increase in PM since 2019. Los Angeles' biggest contributors to pollution are wildfires and construction. In 2020 Los Angeles' had its worst year for wildfires, as several fires burned out of control for weeks. The state of California witnessed a considerable reduction in the number of firefighters in 2020. The state prisoners participated in the firefighting force, and were restricted from leaving the prisons due to COVID protocols. This contributed to increased concentrations of particulate matter and nitrogen dioxide.[17,18].

Milan showed a decrease in $NO_2$ values since 2019, which increased in 2022 following the lifting of the restrictions of covid-19. Milan's topography contributes to winter pollution. The city is in a low-lying basin, surrounded by mountains like the Alps. Because of this unique location and being so close to the warm Mediterranean, thick fog always casts over the area during the winter months. The fog protects atmospheric pollutants such as $PM_{2.5}$ from being transported in the wind and blocks the sunlight's intensity so that $NO_2$ is unable to decompose or produce $O_3$. Commuters, traffic, and the agricultural industry are all sources of emissions, and because of this thick fog, those emissions linger over Milan for months[19].

São Paulo showed small decreases in $NO_2$, $O_3$, and PM from 2019. São Paulo is one of the most populated cities in Brazil. Motor vehicles and emissions are the main cause of pollution in Sao Paulo. However, these motor vehicles are outdated, inefficient, and run-on diesel fuel. Due to the urban sprawl, vehicle usage has risen sharply contributing to rise in air pollution. Buses, trucks, and construction equipment are also contributors to particulate matter, which is generated from the combustion of materials such as wood or plants from open burning sites. The deforestation of the Brazilian rainforests is also another factor that has accelerated the production of greenhouse gasses. Forests help reduce the effects of climate change and greenhouse gasses, as these serve as carbon sinks mitigating the adverse effects of climate change.[18,20].

In Shanghai, the PM, $O_3$, and $NO_2$ decreased in 2019; but $NO_2$ rebounded in 2022. The main reason for this decrease was the reduction in traffic and industrial activities because of the lockdown measures. There was a reduction in emissions of nitrogen oxides (NOx) and volatile organic compounds (VOCs), which are major contributors to air pollution in Shanghai. Similarly, the reduction in industrial activity led to a decrease in emissions of PM. Once the lockdown measures were lifted in 2022, the air quality began to deteriorate again as economic activity resumed[21].

Unlike the other cities selected in the study, Sydney has better regulations with respect to the air pollutants. The increased frequency of bushfires, relatively relaxed vehicle emission laws, and power plant dependency are some of the main contributors to air pollution in Sydney[22]. A definite decrease in PM and $NO_2$ was seen in Sydney since 2019 due to the lockdown.

**Kolkata Correlation Matrix**

| | CO | NO2 | O3 | PM10 | PM2.5 | SO2 |
|---|---|---|---|---|---|---|
| CO | | | | | | |
| NO2 | 0.851 | | | | | |
| O3 | -0.510 | -0.422 | | | | |
| PM10 | 0.906 | 0.889 | -0.305 | | | |
| PM2.5 | 0.881 | 0.880 | -0.251 | 0.986 | | |
| SO2 | 0.755 | 0.797 | -0.199 | 0.898 | 0.901 | |

Figure 2. Correlation Coefficient Matrix of the pollutants for Kolkata

## 6.0 Experiential Learning Outcomes, Assessing Data Analytical and Problem-Solving Skills, and Grand Challenges of Engineering

The interns and the high school senior through their reflective essays on their learning experiences during the beginning and the end of the course demonstrated their perspective of acknowledging the big picture; ability to apply knowledge gained to real-world situations; and displaying empathy by perceiving the challenges of the pandemic, and the extent the underrepresented populations are disproportionately affected.

### *Experiential Learning Outcomes*

Some of the experiential learning outcomes included the following:

a. ***Applied Knowledge***: Summer interns were able to apply knowledge from multiple disciplines, including environmental science, public health, and data analysis, to understand the impacts of COVID-19 on air quality. Through discussions through focus groups and surveys at the end of the internships, this was a relevant outcome.

b. ***Critical Thinking***: Students critically analyzed data and information to identify patterns and trends related to air quality and COVID-19.

c. ***Problem-Solving***: Students worked collaboratively with high school interns to identify potential solutions to address the negative impacts of COVID-19 on air quality. They also presented to the mentor at the end of the internship. The qualitative survey taken by the interns validated that the students found that their problem solving skills improved following this internship.

d. ***Communication***: Students effectively communicated their findings and recommendations through written reports, posters, and presentations made at the symposium.

e. ***Civic Engagement***: Through qualitative surveys and focus group discussions, the Students felt that they would participate in community awareness activities through raising awareness about the impacts of COVID-19 on air quality, and advocating for policies and practices that promote environmental and public health.

***Assessing Data-Analytical, Problem Solving, and Presentation Skills***

To know if students have enhanced their data analytical skills, problem-solving skills, and presentation skills, assessments were designed to measure the specific learning outcomes related to these skills. The following were incorporated in the Environmental Science course, which had students from all STEM majors including Engineering and Aviation Sciences.

1. ***Data Analytical Skills***: a) Exams and quizzes with data analysis questions b) Project that required data analysis and interpretation on the impacts of Covid-19 on the air quality

2. ***Problem Solving Skills***: Case study analysis required students to identify problems related to air quality prior, during, and post Covid-19 pandemic. The students were required to generate possible solutions, and choose the best course of action. In addition, there was a group project, and each group was assigned a different city to study the impacts of covid-19 on its air quality, and present on their project, and discuss potential solutions to combat air pollution following covid-19 pandemic.

3. ***Presentation Skills***: a) Oral presentation with a visual aid was incorporated as part of the assessment b) Poster presentation, and a c) Video presentation on the class project.

   In addition to these assessments, it was important to provide students with feedback and opportunities for reflection during the semester so that they can see how they are progressing and where they need to improve. Rubrics used were helpful to provide clear expectations and criteria for success.

***Grand Challenges of Engineering in Addressing Air Quality***:

Air quality is a critical issue facing the world today, with numerous sources of pollution contributing to poor air quality in many regions. This problem affects human health, the environment, and the economy, and it requires a comprehensive and interdisciplinary approach to be addressed effectively.[1,2,3,4] Engineering has a key role to play in addressing air quality, as engineers are involved in the design, development, and implementation of technologies and systems to improve air quality[23]. The grand challenges of engineering[24] in addressing air quality, including the need for new technologies to measure and monitor air quality, the development of effective strategies for reducing emissions from various sources, and the need for interdisciplinary collaboration to address the complex issues involved in improving air quality, were discussed as part of the brain-storming sessions with interns. These are outlined in the next three paragraphs.

***Developing new technologies to measure and monitor air quality***: One of the grand challenges of engineering in addressing air quality is to develop new technologies to measure and monitor air quality in real-time. This includes the development of new sensors, algorithms, and data analysis techniques to accurately measure and track air quality in different regions and under different conditions.

***Reducing emissions from various sources***: Another grand challenge of engineering in addressing air quality is to develop effective strategies for reducing emissions from various sources, including transportation, industry, and energy production. This requires the development of new technologies, such as electric vehicles, clean energy sources, and efficient industrial processes, as well as the implementation of policies and regulations to encourage the adoption of these technologies.

***Interdisciplinary collaboration***: The complex issues involved in improving air quality require interdisciplinary collaboration between engineers, scientists, policy makers, and communities. Engineers must work closely with other professionals to understand the social, economic, and environmental factors that influence air quality and to develop integrated solutions that address these factors.

## 7.0 Integration of Experiential Learning on Covid-19 and Air Quality in STEM courses

The findings from the research of summer exchange programs were infused in some of the STEM courses such as Environmental Sciences for majors in Engineering, Aviation Sciences, Biology, Statistics for Engineers at the parent institution. Incorporating the impacts of air quality due to COVID-19 lockdown in courses were accomplished in various ways depending on the specific course and its objectives. One approach was to add a module on air quality. The module covered the basics of air pollution, the impacts of air pollution on human health, and the changes in air quality observed during the COVID-19 lockdown. Case studies can be a powerful tool to illustrate the impacts of air quality on human health and the environment. Case studies of cities or regions where air quality improved during the lockdown, and the associated benefits observed during this period were incorporated in some of the courses. In addition, students in the Engineering Statistics and methods courses were involved with data analysis of air quality during the COVID-19 lockdown. Students used the publicly available data from air quality monitoring stations to analyze changes in air quality, and the associated impacts on human health and the environment. The instructors provided the students with resources such as scientific papers, reports, and online resources that discuss the impact of air quality during the COVID-19 lockdown. The resources were from reputable sources such as the World Health Organization (WHO), the US Environmental Protection Agency (EPA), and the European Environment Agency (EEA). By incorporating the impacts of air quality due to COVID-19 lockdown in courses, the students gained a better understanding of the link between human activity, air pollution, and its impact on human health and the environment.

## 8.0 Interdisciplinary Approach

A project on the impacts of COVID-19 on air quality can provide an excellent opportunity for students to enhance their interdisciplinary collaboration skills. Here are some ways in which students in the Environmental Science course developed these skills through the project:

1. ***Working with students from different disciplines***: The students got the opportunity to collaborate with peers from different academic backgrounds, since this course was opened to STEM majors across disciplines. This helped them to develop a deeper understanding of other disciplines and how they can work together to address complex problems.

2. ***Developing a shared understanding of the problem***: To effectively collaborate on a group project, students must develop a shared understanding of the problem they are trying to solve. This required effective communication, active listening, and a willingness to consider different perspectives and ideas.

3. ***Identifying and leveraging individual strengths***: In interdisciplinary collaboration on the project, each team member brought unique strengths and expertise to the table. By recognizing and leveraging these strengths, students worked together more effectively and produced better outcomes.

4. ***Developing a shared vision and goals***: To collaborate effectively, students in the course developed a shared vision and goals for their group project. This required ongoing communication and feedback, as well as a willingness to adjust and adapt the approach as needed.

Overall, the interdisciplinary collaboration skills that students enhanced through their group project on the impacts of COVID-19 on air quality included effective communication, active listening, collaboration, leveraging individual strengths, and developing a shared vision and goals.

## 9.0 Conclusions

The challenges of engineering in addressing air quality are numerous and complex, requiring new technologies, effective strategies, and interdisciplinary collaboration to be addressed efficiently. By working together, engineers and other professionals can help to improve air quality, protect human health, and promote sustainable development. As air quality continues to be a critical issue facing the world, the role of engineering in addressing this challenge will become increasingly important. The experiential learning for the interns was engaging, and motivated them more than traditional classroom-based learning, as interns were actively involved in the learning process and were able to see the practical applications of what they were learning, although through a virtual format. This approach of learning can help learners develop a range of soft skills, such as communication, teamwork, leadership, and adaptability, which are highly valued by employers. Overall, incorporating research findings into courses is important for enhancing the learning experience, and preparing students for future success. By staying informed about the latest research in their field, the instructors can help ensure that their courses are relevant, engaging, and impactful for their students.

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