STEAMCITY CURRICULUM

MONITORING OUTDOOR AIR QUALITY

thematic: environment, well-being and public health

Introduction

The "**Monitoring Outdoor Air Quality**" protocol aims to guide the creation of a functional air quality monitoring station within the classroom. Air pollution is an environmental challenge that affects ecosystems, infrastructure, and public health. Pollutants from industrial processes, transportation, and other human activities add particulate matter, nitrogen oxides, volatile organic compounds, and other substances to the atmosphere. These pollutants can contribute to respiratory conditions, reduced air visibility, weathering of buildings, and alterations in environmental cycles.

Environmental monitoring helps build **environmental awareness**. By understanding the sources, patterns, and effects of air pollution, individuals can contribute to evidence-based solutions.

From a technical perspective, this project introduces the **Internet of Things (IoT), sensor technology, and data visualization**—components of modern environmental monitoring systems. Through hands-on experience with programmable boards, sensors, and data logging equipment, the students will gain practical skills useful in STEM fields.

The scientific dimension of the project connects learners with concepts in **chemistry, physics, and environmental science**. They explore the chemical composition of air pollutants, principles of particle detection, and environmental factors influencing air quality. By conducting measurements and comparing results with established standards, participants apply the scientific process and understand its practical applications

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Interdisciplinarity

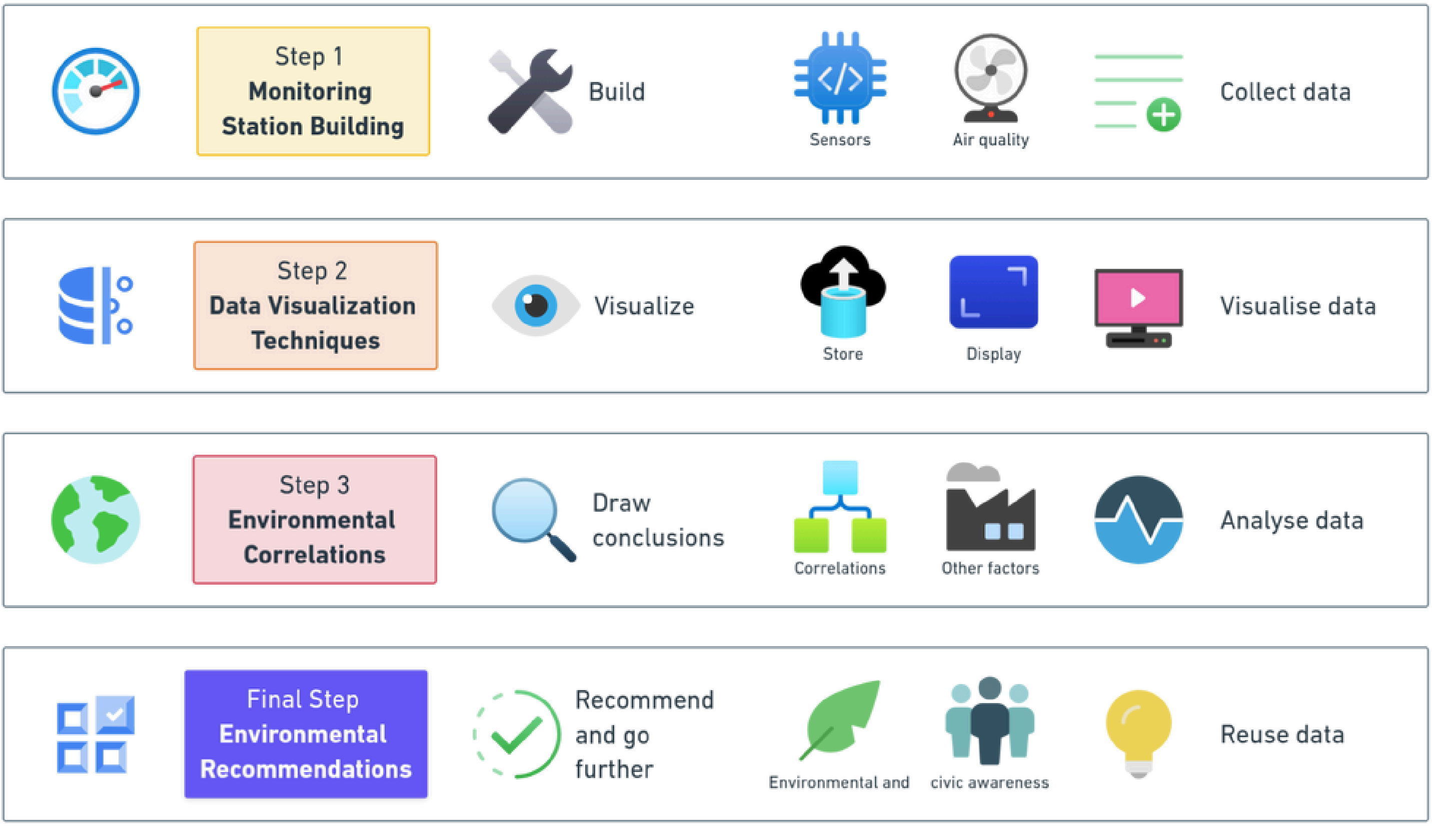
biology
chemistry / physics
technology

Sustainable Development Goals

Overview

Protocol Structure

The protocol functions as a learning journey through four connected steps:



- **Step 1: Collect Data - Building and Deploying Sensor Equipment** - Students build their air quality monitoring station and learn to collect measurements using sensors. This initial step introduces the technical components and concepts while generating the raw data needed for subsequent analysis.
- **Step 2: Display the Data - Visualization and Data Representation Techniques** - Building on the data collection, students learn to visualize their measurements through graphs and data displays. This step develops data literacy skills and helps students identify patterns that are not evident in raw numerical form.
- **Step 3: Analyze the Data - Identifying Patterns and Environmental Correlations** - With visualized data, students perform analysis to identify correlations, understand influencing factors, and draw evidence-based conclusions. This analytical step transforms raw measurements into insights.
- **Step 4: Use the Data for Action - Developing Environmental Recommendations** - The final step encourages students to apply their findings to real-world situations, comparing their results with other data and developing recommendations for improving air quality. This connects scientific inquiry to civic action and environmental awareness.

Each step builds upon the previous one, creating a learning progression that begins with concrete measurements and advances toward analysis and practical applications. Together, they represent the scientific process from observation to communication of findings.

Getting started

Duration: 180 minutes or 3 lessons (1 for step 1, 1 for step 2 & beginning of step 3, and 1 for end of step 3 & step 4)

Level of difficulty: *Easy (from middle school to high school)* ★☆☆☆☆

Material needed: 1 programmable board (NUCLEO-L476RG ; Arduino ; micro:bit) ; 1 Grove shield ; 1 Neopixel RGB led ; 1 LCD display ; 1 SCD30 Sensirion sensor ; 1 HM10 BLE Bluetooth module ; 1 battery ; 1 battery connector ; 1 USB cable

Resources:
Vittascience User's Guide : https://fr.vittascience.com/learn/tutorial.php?id=330/guide-d-utilisation-qualite-d-air
CNES : https://cnes.fr/fr
Calisph'air : https://enseignants-mediateurs.cnes.fr/fr/projets/calisphair

Glossary

Keywords & Concepts	Definitions
Particulate Matter - PM10 & PM2.5	Particulate Matter (PM) are formed by a complex mixture of solid and liquid particles, organic and mineral substances suspended in the air. They can be of natural origin (volcanism, erosion...) or generated by human activities (heating, road transport, industry...). They are classified according to their size: PM 2.5 (particles with a diameter less than or equal to 2.5µm), PM 10 (particles with a diameter less than or equal to 10µm). By way of comparison, a human hair has a diameter of 50 to 70 µm.
Nitrogen dioxide - NO2	Nitrogen dioxide (NO2) emissions come mainly from fossil fuel combustion (heating, electricity generation, car and boat engines).
Carbon monoxide - CO	Carbon monoxide (CO) results from incomplete combustion (wood, butane, coal...) due to poorly regulated installations (heating) or vehicle exhaust fumes. Many domestic accidents occur every year in winter due to carbon monoxide poisoning inside homes. (Ministry of Solidarity and Health, 2017).
Volatile Organic Compounds - VOC	Volatile Organic Compounds (VOC) are mainly secondary pollutants created by chemical reactions from other pollutants, but can be of many kinds. There are over 400 of them in the air, including hydrocarbons, benzene, and aldehydes. They are mainly emitted by vehicles, solvents, and industry.
Ozone - O3	A first layer of ozone in the upper atmosphere is known as "good ozone" because it acts as a protective layer against the sun's ultraviolet rays. Another, present at ground level, is known as "bad ozone". According to the World Health Organisation, "In this latter case, ozone is a secondary pollutant, formed through photochemical reactions between various pollutants such as nitrogen oxides (NOx) emitted by vehicles and industry, and volatile organic compounds (VOCs), emitted by vehicles, solvents, and industry.".
Carbon dioxide - CO2	Carbon dioxide (CO2) is a colorless and odorless gas, accounting for 77% of greenhouse gas (GHG) emissions of human origin. Naturally present in small quantities in the atmosphere, it is formed in certain natural processes (the carbon cycle) and above all during the combustion of carbon-containing substances. It can become harmful to the environment and human health. It can come from the transport sector, industry (use of fossil fuels) and housing (heating, lighting, etc.).
Air quality index	The air quality index is a value used to summarize the various air quality measurements. In France, Atmo France, the federation of air quality monitoring associations, publishes an index for the public. It summarizes the monitoring of five pollutants: sulfur dioxide SO2, nitrogen dioxide NO2, ozone O3, and fine particles (PM10 and PM 2.5). This index is published for an agglomeration (with more than 100,000 inhabitants) or a region, each day. It comprises 6 colored levels, ranging from good to extremely poor.

Technical Material

Material	Description
Multi-channel gas sensor MICS6814	This multi-channel gas sensor (capable of measuring several gases simultaneously) must be connected to the shield's I2C port. It has 4 measuring elements. It can detect the following gases: carbon monoxide CO: 1 - 1000ppm, nitrogen dioxide NO_2: 0.05 - 10ppm, ethanol C_2H_5OH: 10 - 500ppm and volatile organic compounds: 1 - 500ppm.
HM3301 sensor	The HM3301 is a laser sensor for detecting fine particles. It can continuously detect dust in the air in real time. It must be connected to the shield's I2C port. Fan blades draw air through a detection chamber. The laser light scatters on the dust particles and is picked up by a photodiode. After amplification in the electronic circuit, this sensor gives the mass concentration of the particles as well as a particle count.
DHT11	The DHT11 is a digital temperature and humidity sensor. It must be connected to a digital port on the shield (D0 to D13 on Arduino and P0 to P20 on micro:bit). This module is based on capacitive humidity components.
LoRa	LoRaWan technology is a radio communication protocol (868 mHz frequency in France) that allows data exchange between connected objects. The signal is emitted over a wide spectral range, limiting the risk of interference and allowing data to be sent from outside or inside over long distances (1km in urban areas - up to 20km in rural areas). Sending messages is unlimited. However, unlike 4G and 5G networks, LoRaWan data rates are very low, just a few kilobits per second. This type of network is therefore used for the Internet of Things (IoT), i.e. fixed sensors (e.g. temperature, humidity, etc.).

Protocol

Step 1: Collect Data - Building and Deploying Sensor Equipment

Background and description of the problem to be solved in this step: This first step familiarizes students with key concepts of air pollution and tools (interfaces and hardware) used to measure it. Working in the classroom environment, students will become familiar with various sensors and their interfaces while beginning to collect data on different pollutants.

Learning Objectives: Understand the primary types of air pollutants and their sources. Learn how to assemble and configure sensor equipment for environmental monitoring. Gain basic programming skills for data collection from multiple sensor types. Develop an understanding of measurement units and calibration principles. Apply scientific measurement methods to a real-world environmental challenge.

Conceptualisation

Before getting started, you need to assess the students' level of knowledge and get them to think about key concepts.

To help you do this, here are some questions to work on with them.

> The air we breathe is made up of various chemical elements, in gaseous, liquid or solid form, which, at varying levels, can have harmful repercussions on our health, the environment, and the economy.
>
> "Worldwide, 7 million premature deaths are linked to air pollution every year" (WHO, 2014).
>
> Pollutants such as aerosols, nitrogen oxides, heavy metals, carbon monoxide, volatile organic compounds, etc. are considered indicators of air pollution. They are therefore closely monitored by various control bodies (national, such as the ATMO agencies https://atmo-france.org/la-carte-des-aasqa/, or international, such as the WHO).

Research Question 1: What are environmental pollutants?

Hypothesis: Air pollutants from both natural and anthropogenic sources accumulate in different concentrations depending on location, time, and weather conditions.

Key concepts:

- **Primary Pollutants:** Chemical substances emitted directly from a source, such as carbon monoxide from vehicle exhaust or sulfur dioxide from industrial processes.
- **Secondary Pollutants:** Compounds formed through chemical reactions in the atmosphere when primary pollutants interact with each other or with natural atmospheric components, such as ozone formed from nitrogen oxides and volatile organic compounds in the presence of sunlight.
- **Environmental Health:** The field that studies how environmental factors, including air quality, impact human health and disease patterns in populations.

You can find in appendix a complete glossary of pollutants.

Research Question 2: How can we quantify different types of air pollutants?

Hypothesis: Electronic sensors can detect and measure specific pollutants through different physical and chemical detection principles.

Key concepts:

1. **Sensor Technology:** Devices that detect and respond to inputs from the physical environment, converting physical parameters into signals that can be measured and analyzed.
2. **Parts Per Million (PPM):** A measurement unit used to quantify low concentrations of pollutants in air, representing the number of pollutant particles found among one million air particles.
3. **Calibration:** The process of configuring a sensor or measurement tool by comparing its readings with a known standard to ensure accuracy in data collection.

Research Question 3: Where is air quality an important issue?

Hypothesis: Areas with higher population density, industrial activity, and traffic concentration experience greater air quality concerns compared to rural or less developed areas.

Key concepts:

1. **Urban Hotspots**: Specific locations within cities where air pollution tends to concentrate due to traffic patterns, building configurations, and human activities.
2. **Vulnerable Populations**: Groups particularly affected by air pollution, including children, elderly people, and those with pre-existing respiratory conditions.
3. **Geographical Factors**: Natural and built features that influence air quality in a specific location, such as topography, wind patterns, and building density.

Introductory Activity: Identify with the students the places where to measure the air quality, and where the air quality is an important subject (e.g. in front of the schools, habitations close to the industry zone, areas with more or less vegetation/trees). And ask students in groups to choose geographical areas where they will analyze the data in order to answer the question: What is the impact of urban pollutions on the citizens' life quality?
Duration: 25 minutes

Students Investigation

Now that we know more about these different pollutants, let's see how to measure them by assembling the sensors and programming the electronic board. Start by testing this activities in class, then ask students in groups to place them in the different locations/geographical areas chosen earlier.

Do not forget to collect data on the study site (e.g. road traffic, peak hours, presence of trees, etc.).

Activity 1: VOC Measurement (10 minutes)
The activity is launched by the teacher with the support of the Vittascience interfaces and MICS6814 sensor, display screen, Openlog module for recording data on an SD card. It can be carried out in groups or with the whole class.

Instruction for the students: Create a program to measure VOC, then record it on a microSD card or display it on an LCD screen. Use the Vittascience interfaces to make it happen, assemble the components (NUCLEO-L476RG ; micro:bit or Arduino programmable board, MICS6814 sensor, display screen, Openlog module for recording data on an SD card, wire usb, compteur), check that there are no syntax errors on the program and then click on "Send" to upload the program directly to the NUCLEO-L476RG ; micro:bit or Arduino programmable board. Connections are made with Grove cables (4 wires in 1 with coding).

Good to know: Electronic components are sensitive to water and humidity: please make sure to protect them with a semi-waterproof cover (opening from the bottom) when using them outdoors.

Programming in this step: You will find complete code and assembly instructions for this activity in the section "Practical Implementation 1: VOC Monitoring System with LCD Display".

Activity 2: Multi-Parameter Monitoring (15 minutes)

The activity is launched by the teacher with the support of the Vittascience interfaces and HM3301 sensor, MICS6814, DHT11 humidity sensor, display screen, Openlog module for recording data on an SD card. It can be carried out in groups or with the whole class.

Instruction for the students: Create a program to measure various environmental parameters, then record them on a microSD card or display them on an LCD screen. Use the Vittascience interfaces to make it happen, assemble the components (programmable board, HM3301 sensor, MICS6814 sensor, DHT11 humidity sensor, display screen, Openlog module for recording data on an SD card, wire usb, compteur), check that there are no syntax errors on the program and then click on "Send" to upload the program directly to the NUCLEO-L476RG ; micro:bit or Arduino programmable board. Connections are made with Grove cables (4 wires in 1 with coding).

Good to know: Electronic components are sensitive to water and humidity: please make sure to protect them with a semi-waterproof cover (opening from the bottom) when using them outdoors.

Programming in this step: You will find complete code and assembly instructions for this activity in the section "Practical Implementation 2: Multi-Sensor Environmental Data Collection".

Conclusion & Further Reflexion

The teacher can end the activity by asking students to re-explain the key concepts they have learned: what are environmental pollutants and how can they be measured? These two concepts will enable students to study the results of their measurements.

- **Knowledge Mobilized**: Students have learned about primary and secondary pollutants, their sources, and measurement methods using electronic sensors.
- **Classroom Implementation Reflection**: This step can be implemented in a standard classroom with access to computers for programming. Consider dividing students into small groups, each responsible for a different sensor setup.
- **Learning Outcomes**: Students should now be able to identify air pollutants, understand their measurement units, and use basic programming to collect environmental data. This foundation prepares them for data visualization and analysis.

Step 2 - Display the Data - Visualization and Data Representation Techniques

Background and description of the problem to be solved in this step: Having connected sensors and programmed the electronic board to generate air quality data in the previous step, students now learn to display and visualize this information. Sensor values can be viewed on the LCD screen or recorded for further analysis. This visualization step transforms raw numbers into recognizable patterns and enables students to identify trends that may not be apparent in numerical data.

Learning Objectives: Understand different methods for visualizing environmental data. Learn to use graphical interfaces to create real-time data displays. Develop skills in data export and storage for later analysis. Recognize how different visualization techniques highlight various aspects of the same dataset. Apply appropriate visualization methods based on the type of data and analysis needs.

Conceptualisation

Before getting started, you need to assess the students' level of knowledge and get them to think about key concepts. To help you do this, here is a question to work on with them, which will help them find answers for future activities.

Research Question: What methods can effectively visualize environmental data?

Hypothesis: Time-series graphs reveal temporal patterns in pollution levels that are not apparent in raw numerical data.

Key concepts:

1. **Data Visualization:** The representation of information and data using visual elements like charts, graphs, and maps to communicate relationships in data.
2. **Real-time Monitoring:** The continuous collection and display of data as it occurs, allowing for immediate observation of changes and trends.
3. **Asynchronous Recording:** The collection and storage of data for later retrieval and analysis, enabling examination of historical patterns and long-term trends.

Introductory Activity - Ask the students how they can display the sensor values? Two solutions are available for the students. Either synchronously, with live display on the computer, or asynchronously, with data recording on the microSD card supplied in the kit.
Duration: 10 minutes

Students Investigation

Activity 1: Real-Time Graphing (20 minutes)
The activity is launched by the teacher with the support of the Vittascience interfaces. It can be carried out in groups or with the whole class.

Instruction for the students: Create a graph in real time with the graphical mode of the Vittascience interfaces. Here is the procedure for retrieving data from the console :

1. First of all, the programmable boad must be connected to the computer via the USB cable. Then click on the "connect" button in the toolbar.
2. In the window that opens, select your programmable board, then click on the "Connection" button.
3. The console then displays the data.
4. To view data evolution in graphical form, click on the "graph mode" button in the right-hand console.
5. A graph with the data will appear.

6. All that's left to do is adjust the graphics console parameters by clicking on the setup icon on the left of the console.
7. Students can choose the data to be displayed and the number of values to be displayed across the width of the console.
8. To retrieve the encrypted data, click on the "export" button in the bottom right-hand corner of the console.

Good to know: At any time, we can clear the data to resume data acquisition using the "clear data" button in the console settings. Place your cursor over the curve to see the value. CSV format is required to process this information in a spreadsheet.

Activity 2: Data Recording (20 minutes)

The activity is launched by the teacher with the support of the Vittascience interfaces. It can be carried out in groups or with the whole class.

Instruction for the students: Create a program to record data on an SD card using an OpenLog recorder module with the support of the Vittascience interfaces.

Once recording is complete, remove the microSD card from the reader. Insert it into the microSD/USB adapter, then insert the adapter into the computer.

Programming in this step: You will find complete code and assembly instructions for this activity in the section "Practical Implementation 3: Automated SD Card Data Logging for Air Quality Measurements".

Conclusion & Further Reflexion

The teacher can end the activity by showing students that they have learned to use different methods to understand the importance of data representation. Each of these methods can then be used to analyze the data and understand the influence of the data on the result.

- **Knowledge Mobilized**: Students have learned methods to visualize environmental data through real-time graphing and data recording for asynchronous analysis.
- **Classroom Implementation Reflection**: This activity works well in a computer lab setting where students can connect their devices and experiment with different visualization techniques. Share examples of effective visualizations before students create their own.
- **Learning Outcomes**: Students should now understand how different visualization methods reveal distinct aspects of the same data and be able to choose appropriate visualization techniques for specific types of environmental data.

Step 3 - Analyze the Data - Identifying Patterns and Environmental Correlations

Background and description of the problem to be solved in this step: Building on the data collection and visualization in previous steps, students now perform analysis to extract useful insights. This step transforms raw measurements into practical knowledge by identifying patterns, correlations, and potential relationships. Students learn to examine both temporal and spatial aspects of air quality data and connect these to environmental factors.

Learning Objectives: Develop analytical skills to interpret environmental data. Learn to identify patterns and correlations in air quality measurements. Understand how environmental factors influence pollutant concentrations. Apply basic statistical concepts to environmental data analysis. Form evidence-based conclusions from collected measurements.

Conceptualisation

Before getting started, you need to assess the students' level of knowledge and get them to think about key concepts. To help you do this, here are a question to work on with them, which will help them find answers for future activities.

Research Question 1: What factors influence the variation in air pollutant levels?

Hypothesis: Pollutant levels correlate with specific human activities and time periods, such as rush hour traffic increasing NO_2 and CO.

Key concepts:

1. **Temporal Patterns:** Recurring cycles in data measurements over time, including daily fluctuations, weekly patterns, and seasonal variations.
2. **Spatial Distribution:** The arrangement of pollutant concentrations across different geographical locations, revealing hotspots and clean areas.
3. **Confounding Variables:** Factors that can influence both the dependent and independent variables in an analysis, potentially creating misleading correlations.

Introductory Activity - Ask the students what factors should be taken into account when analyzing the data? For example, it may be possible to record the times of the day, working hour and lunch break, road traffic, numbers of people in the city, city size, etc. And compare these key moments with the consequences on the evolution of the different levels measured by sensors.
Duration: 10 minutes

Students Investigation

Activity 1: Data Processing (10 minutes)
The activity is launched by the teacher with the support of the [Vittascience interfaces](). It can be carried out in groups or with the whole class.

Instruction for the students: Exploiting data. Remove the microSD card from the reader. Insert it into the microSD/USB adapter, then insert the adapter into the computer. To open the "LOG00002.txt" document on the microSD card, proceed as follows:

With Microsoft Excel

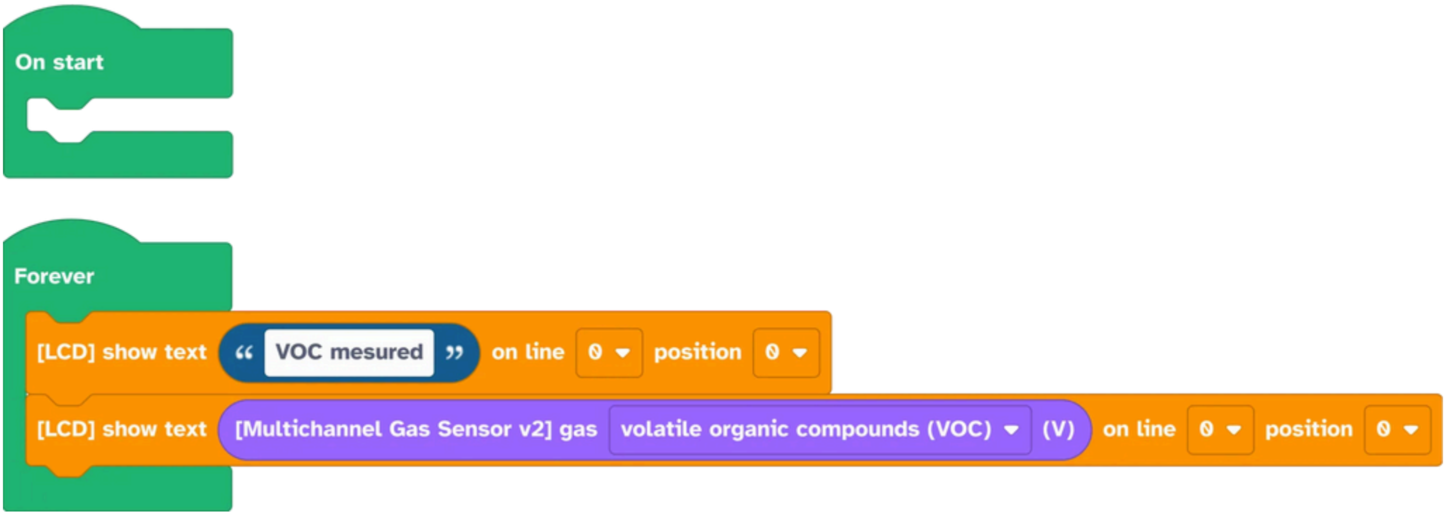
- Create a Microsoft Excel file on the microSD card, right click → "new" → "Microsoft Excel worksheet
- Name the Excel file, then open it. Go to "File" → "Open" → “Browse".

- Select the "Text files" file type.
- Open "LOG00002.txt" on the microSD card.
- An import helper opens, click on "Next" without modifying each step, and click on "Finish".
- Insert a row above the five columns and name them as follows:

Time (sec)	Temperature (°C)	Pressure (Pa)	Altitude (m)
0	17.48	99813.49	124.54
0	17.49	99814.79	124.23
1	17.49	99814.96	124.41

Particulate Matter - PM (µm)	Nitrogen dioxide - NO2 (ppm)	Carbon monoxide - CO (ppm)	Volatile Organic compounds - VOC (ppm)
2,5	42	27	100
2,7	46	26	110
2,8	48	26	115

- Drawing curves : Select data with title, then "Insert" → "Point cloud".
- Repeat the operation for each measured quantity.



With Libre Office

- Creating a LibreOffice Calc file.
- Open the Libre Office file.
- Go to the "File" tab → "Open" and select the file "LOG00002.text".
- A window opens:
  - Import: Do not change anything.
  - Separator options: choose Tab only.
  - Check that the preview at the bottom of the page is consistent.
- Data are displayed in the following order: Time (s), Temperature (°C), Pressure (Pa°) , Altitude (m), Particulate Matter - PM (µm), Nitrogen dioxide - NO2 (ppm), Carbon monoxide - CO (ppm), Volatile Organic compounds - VOC (ppm).
- Creating diagrams : Add a line to indicate what the data correspond to as follows:

Time (sec)	Temperature (°C)	Pressure (Pa)	Altitude (m)
0	17.48	99813.49	124.54
0	17.49	99814.79	124.23
1	17.49	99814.96	124.41

Particulate Matter - PM (µm)	Nitrogen dioxide - NO_2 (ppm)	Carbon monoxide - CO (ppm)	Volatile Organic compounds - VOC (ppm)
2,5	42	27	100
2,7	46	26	110
2,8	48	26	115

- Select the Time column and the second column corresponding to the data you want to display (by holding down the [ctrl] key).
- Click on “Insert” → “diagram”
- In step {1. choose a diagram type}: choose "line" and click Next.
- In step {2. choose a data range}: check the "First column as label" box, leave the rest untouched, click on Next.
- Step 3 appears, click on Next without changing anything.
- If you wish, add a title, a subtitle and the units of the displayed quantities.
- Click on Finish.

Activity 2: Pattern Analysis (10 minutes)

The activity is launched by the teacher with the support of the Vittascience interfaces. It can be carried out in groups or with the whole class.

Instruction for the students: Analyze the data. Find the elements of variation of Carbon monoxide in air.

Conclusion & Further Reflexion

Data analysis is an essential step in transforming raw data into information, enabling students to learn how to draw conclusions.

- **Knowledge Mobilized**: Students have developed analytical skills to identify temporal patterns, spatial distributions, and correlations between pollutant levels and environmental factors.
- **Classroom Implementation Reflection**: This analytical work can be conducted in pairs or small groups to encourage discussion. Provide structured worksheets to guide students through their first data analysis experience.
- **Learning Outcomes**: Students should now be able to interpret environmental data, recognize meaningful patterns, and understand how external factors influence air quality measurements.

Step 4 - Use the Data for Action - Developing Environmental Recommendations

Background and description of the problem to be solved in this step: The final step connects scientific investigation to real-world action. Students compare their findings with other data and develop evidence-based recommendations for improving air quality. This transforms the project from an academic exercise into an opportunity for environmental engagement, allowing students to see how scientific data can inform policy and personal decisions.

Learning Objectives: Develop skills in comparative data analysis across different locations. Learn to formulate evidence-based recommendations. Understand how scientific data can inform environmental policy and action. Communicate scientific findings to various audiences. Apply knowledge of air quality to propose practical improvement strategies.

Conceptualisation

Before getting started, the teacher encourage students to consider factors in the air. You can use the following research questions:

Research Question 1: How do our local measurements compare with data from other regions?

Hypothesis: Areas with similar characteristics show comparable pollution patterns despite geographical separation.

Key concepts:

1. **Comparative Analysis:** The examination of similarities and differences between datasets from different locations or time periods to gain context for local findings.
2. **Global Patterns:** Widespread trends in air pollution that transcend local conditions, often related to industrialization, urbanization, and economic development stages.
3. **Regional Variability:** Differences in air quality measurements between geographic areas due to local factors such as topography, climate, population density, and industrial activity.

Research Question 2: What actions could improve air quality based on our findings?

Hypothesis: Targeted interventions addressing identified pollution sources can improve local air quality.

Key concepts:

1. **Mitigation Strategies:** Approaches and techniques designed to reduce pollutant emissions or their concentration in ambient air.
2. **Source Control:** Methods targeting pollution reduction at its origin, such as emission standards for vehicles or industrial processes.
3. **Policy Framework:** The system of regulations, incentives, and guidelines established by authorities to manage air quality and reduce pollution.

Research Question 3: How can scientific data inform environmental decision-making?

Hypothesis: Data-driven recommendations lead to more effective environmental interventions than intuition-based approaches.

Key concepts:

1. **Evidence-based Decision Making:** The use of empirical data to guide actions and policies rather than relying solely on intuition or tradition.

2. **Stakeholder Engagement:** The involvement of various interested parties (community members, businesses, government) in the interpretation of data and development of response strategies.
3. **Environmental Justice:** The fair treatment and meaningful involvement of all people regardless of background with respect to environmental regulations and their implementation.

Introductory Activity - Help students exploring the correlation between human and city activities and temporal variables. Formulate hypotheses about potential factors influencing observed trends. **Where would the worst and best air qualities be found around a city and around the world?**
Duration: 10 minutes

Students Investigation

The final activity (10 minutes) is launched by the teacher, it can be carried out in groups or with the whole class.

Instruction for the students: Now that the data has been recorded, it can be interesting to compare it with other data around the world thanks to LoRa technology. Import the data you've collected (using LoRa technology, see more information on LoRa in the "Guidelines from Vittascience on LoRA with the current available material") and make them available for consultation on the school website or on the Vittascience website. You can publish the data collected in real time to the Internet via a server. For example, local air quality can be displayed on a website or social network. Please note, however, that setting up such a project is for experienced users only!

For Vittascience website: you'll find a map called Vittamap on the Vittascience website, which lists all the experiments carried out around the world thanks to LoRa technology.

1. Log on to the Vittascience website and access the Vittamap map: vittascience.com/vittamap. Click on the "+" → "Add an experience" button
2. On the form, fill in the following information, which will enable us to share your measurements: Project name, Type of kit: measuring station kit, How was the project carried out? (describe your measurement protocol here), Location, Measurement dates, Data: To add data, you can include several series of measurements. You can enter data directly into the "Data field" table, and/or add your own .csv file from your SD card, Photos/Videos, Language.
3. Once you've filled in all the fields, all you have to do is click on the "Add experience" button.
4. Your data is now available to the Vittascience user community on the Vittamap map. Students can then compare it with other similar experiments and find for exemple, the most positive and the most negative data. To do this, first filter the experiments by "Measuring station kit" type. Then click on an experiment and the "compare" button. Again, click on another experiment and click on the "compare with selected experiment" button. Repeat these operations ad infinitum, looking for similarities and differences. Ask your students what they notice.

Conclusion & Further Reflexion

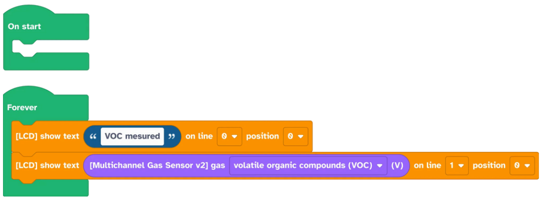
The teacher encourage students to share ideas for improving the air quality level in the world. Summarize the ideas in the form of a summary of best practices to be implemented.

- **Knowledge Mobilized**: Students have learned to compare local findings with external data and develop evidence-based recommendations for improving air quality.
- **Classroom Implementation Reflection**: This step benefits from a workshop format where student groups can present and discuss their findings and recommendations. Consider inviting local environmental experts if possible.
- **Learning Outcomes**: Students should now understand how scientific data can inform practical environmental actions and be able to communicate their findings in a way that supports evidence-based decision making.

Practical Implementation 1.
VOC Monitoring System with LCD Display

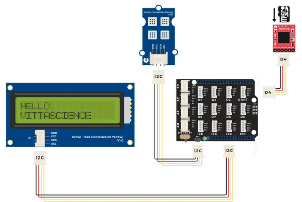
Programming interfaces for NUCLEO-L476RG ; micro:bit or Arduino boards are very similar. Here we present a program designed for micro:bit. It displays measured elements on the LCD screen.

Editor used: vittascience.com/l476 ;
vittascience.com/arduino or vittascience.com/microbit



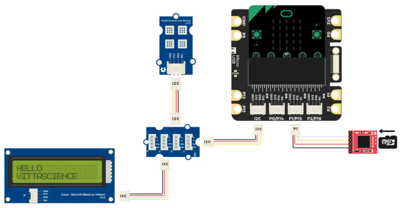
Assembly connection with an Arduino

- The MICS6814 multi-channel sensor is connected to an I2C port on the shield.
- The display is connected to an I2C port.
- The Openlog module for recording data on an SD card is connected to an analog port (D2 to D8).



Assembly connection with a micro:bit

- The MICS6814 multi-channel sensor are connected to an I2C port on the shield.
- The display is connected to an I2C port.
- The Openlog module for recording data on an SD card is connected to a P0 analog port.



Code

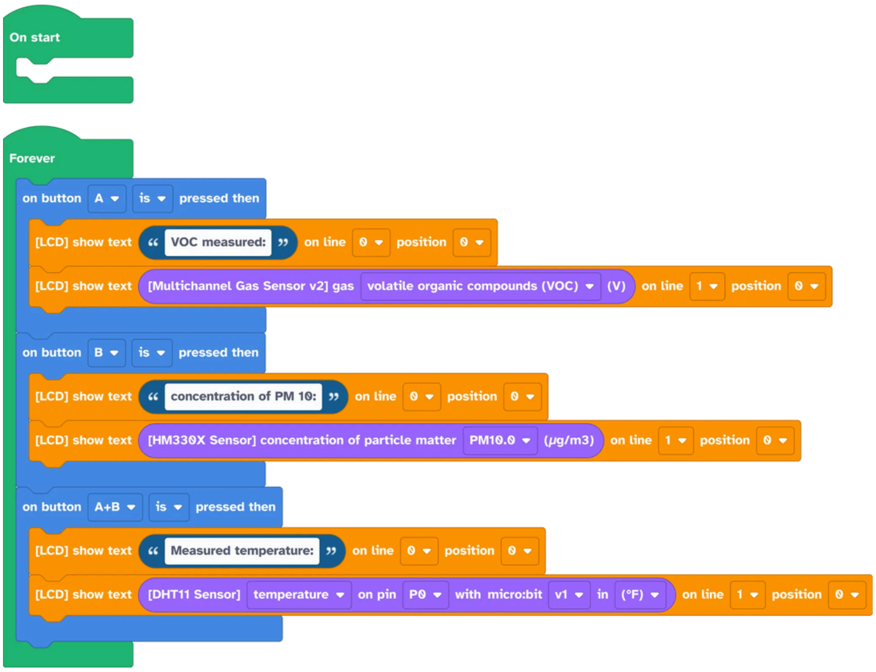
```
from microbit import *
from lcd_i2c import LCD1602
from gas_gmxxx import GAS_GMXXX

lcd = LCD1602()
multichannel_v2 = GAS_GMXXX(0x08)

while True:
    lcd.setCursor(0, 0)
    lcd.writeTxt('VOC mesured')
    lcd.setCursor(0, 1)
    lcd.writeTxt(str(multichannel_v2.calcVol(multichannel_v2.measure_VOC())))
```

Practical Implementation 2.

Multi-Sensor Environmental Data Collection

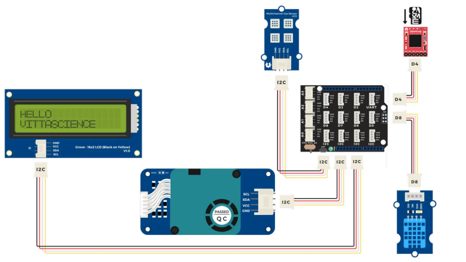
Programming interfaces for NUCLEO-L476RG ; micro:bit or Arduino boards are very similar. Here we present a program designed for the micro:bit board. It displays measured elements on the LCD screen.

Editor used: vittascience.com/l476 ; vittascience.com/arduino or vittascience.com/microbit



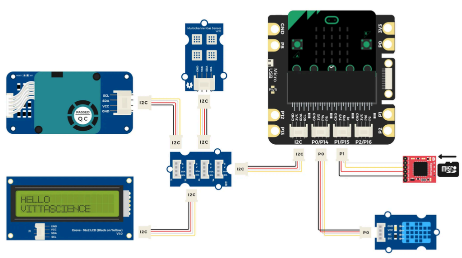
Assembly connection with an Arduino

- The HM3301 sensor is connected to an I2C port. The MICS6814 multi-channel sensor is connected to an I2C port on the shield.
- The DHT11 humidity sensor is connected to an analog port (D2 to D8).
- The display is connected to an I2C port.
- The Openlog module for recording data on an SD card is connected to an analog port (D2 to D8).



Assembly connection with a micro:bit

- The HM3301 sensor and the MICS6814 multi-channel sensor are connected to an I2C port on the shield.
- The DHT11 humidity sensor is connected to an analog port (P1 or P2 as required).
- The display is connected to an I2C port.
- The Openlog module for recording data on an SD card is connected to a P0 analog port.



Code

```
from microbit import *
from lcd_i2c import LCD1602
from gas_gmxxx import GAS_GMXXX
from hm330x import HM330X
from dht11 import DHT11

lcd = LCD1602()
multichannel_v2 = GAS_GMXXX(0x08)
hm3301 = HM330X()
# DHT11 Sensor on pin0
dht11_0 = DHT11(pin0)

while True:
    if button_a.is_pressed():
        lcd.setCursor(0, 0)
        lcd.writeTxt('VOC measured:')
        lcd.setCursor(0, 0)
        lcd.writeTxt(str(multichannel_v2.calcVol(multichannel_v2.measure_VOC())))
    if button_b.is_pressed():
        lcd.setCursor(0, 0)
        lcd.writeTxt('concentration of PM 10:')
        lcd.setCursor(0, 0)
        lcd.writeTxt(str(hm3301.getData(5)))
    if button_a.is_pressed() and button_b.is_pressed():
        lcd.setCursor(0, 0)
        lcd.writeTxt('Measured temperature:')
        lcd.setCursor(0, 0)
        lcd.writeTxt(str(dht11_0.getData(d=1)*9/5 + 32))
```

Practical Implementation 3.

Automated SD Card Data Logging for Air Quality Measurements

Editor used: vittascience.com/l476 ; vittascience.com/arduino or vittascience.com/microbit

Code

```
from microbit import *
from hm330x import HM330X
from gas_gmxxx import GAS_GMXXX

hm3301 = HM330X()
multichannel_v2 = GAS_GMXXX(0x08)
# Lecteur SD on pin0

while True:
    uart.init(baudrate=4800, bits=8, parity=None, tx=pin0, rx=pin14)
    uart.write(('{}' * 3).format(hm3301.getData(3), ';',
    multichannel_v2.calcVol(multichannel_v2.measure_NO2())) + '\n')
```

Going further

Exploring the issue through other initiatives

Building on the knowledge and skills developed in the classroom, students can deepen their understanding of outdoor air quality by applying what they have learned in diverse new projects such as:

Idea 1: Building a solar-powered shelter for your air quality station

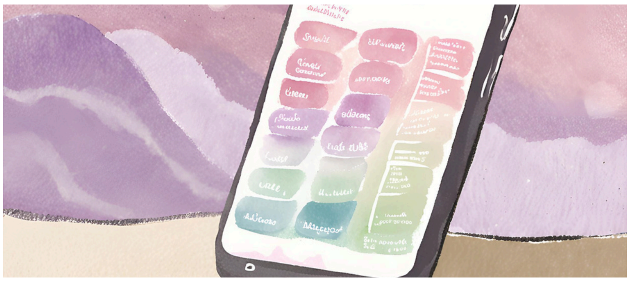
A shelter provides protection and support for your sensors. Equip it with a power supply module running on a battery and a solar panel. Simply connect it to your microcontroller.

Idea 2: Add an anemometer to your weather station

This will enable you to record wind speed.In addition to the anemometer or separately, you can add a rain gauge box. This measures the amount of rainwater that has fallen.

Idea 3: Transmit measured data from outside to inside

You need two cards. One with the sensors, the other inside with a display screen.



Idea 4: What if you could receive information from your station on your smartphone?

A Bluetooth module makes it possible! With a range of around 10m, it plugs into the card's shield, just like the other sensors.

Documentation: Glossary of pollutants

Pollutants	Effects on the environment (climate and local)	Health effects	Maximum values recommended by the WHO
Fine particulates PM10 / PM2.5	• Diffusing or absorbing effect, increasing the greenhouse effect • Damage to buildings and monuments: formation of a black layer, soiling	The finer the particle, the more harmful it is to the body: • PM10: retained in the nose and deep airways • PM2.5: penetrates deeply, crosses the pulmonary barrier and enters the bloodstream	• For PM2.5 : ○ 10 µg/m3 annual average ○ 25 µg/m3 24-hour average • For PM10 : ○ 20 µg/m3 annual average ○ 50 µg/m3 24-hour average
Nitrogen dioxide (NO2)	• Contributes to acid rain, affecting plants and soils • Responsible for the formation of nitrate aerosols and their accumulation in the soil	High concentrations can be toxic and cause severe inflammation of the respiratory tract.	• 40 µg/m3 annual average • 200 µg/m3 hourly average
Carbon monoxide (CO)	• Participates in the ozone formation mechanism • Transformation into CO2, contributing to the greenhouse effect	• Intoxication at high levels: if indoor pollution, risk of intoxication • Affects the central nervous system and sensory organs by binding to blood hemoglobin instead of oxygen	• 10 mg.m-3 averaged over 8 h • 30 mg.m-3 averaged over 1 h
Volatile organic compounds (VOC)	• Precursor to ozone formation	Various health effects depending on the specific compound	Varies by compound
Ozone (O3)	• Contributes to the greenhouse effect • Disrupts photosynthesis, leading to lower crop yields • Oxidation of materials	Gas irritating to the respiratory system. At excessively high concentrations, it can cause respiratory problems, asthma, reduced lung function and the onset of respiratory diseases.	100 µg/m3 8-hour average