STEAMCITY CURRICULUM

MONITORING INDOOR AIR QUALITY

thematic: environment, well-being and public health

Introduction

Regular airing of rooms is recommended to reduce the level of airborne particles and thus limit the spread of the viruses. While it is not possible to measure viruses, several studies have demonstrated the relationship between CO2 concentration in a room and virus concentration. When CO2 concentration becomes too high, it's a sign that ventilation is needed.

This experiment makes it possible to build a carbon dioxide detector.

Once assembled and programmed, the detector can be used to measure the carbon dioxide rate in a room. It can be used to show students how to set up a chain of measurements, monitor changes in the level over time and critically assess the correlation between changes in CO2 rate and ventilation.

Warning: This experiment gives an indicative value of the evolution of the carbon dioxide (CO2) rate in the environment in which the sensor is located. It cannot be used for anything other than educational purposes, and is no substitute for a calibrated and certified device.

Interdisciplinarity

biology

physics

Sustainable Development Goals

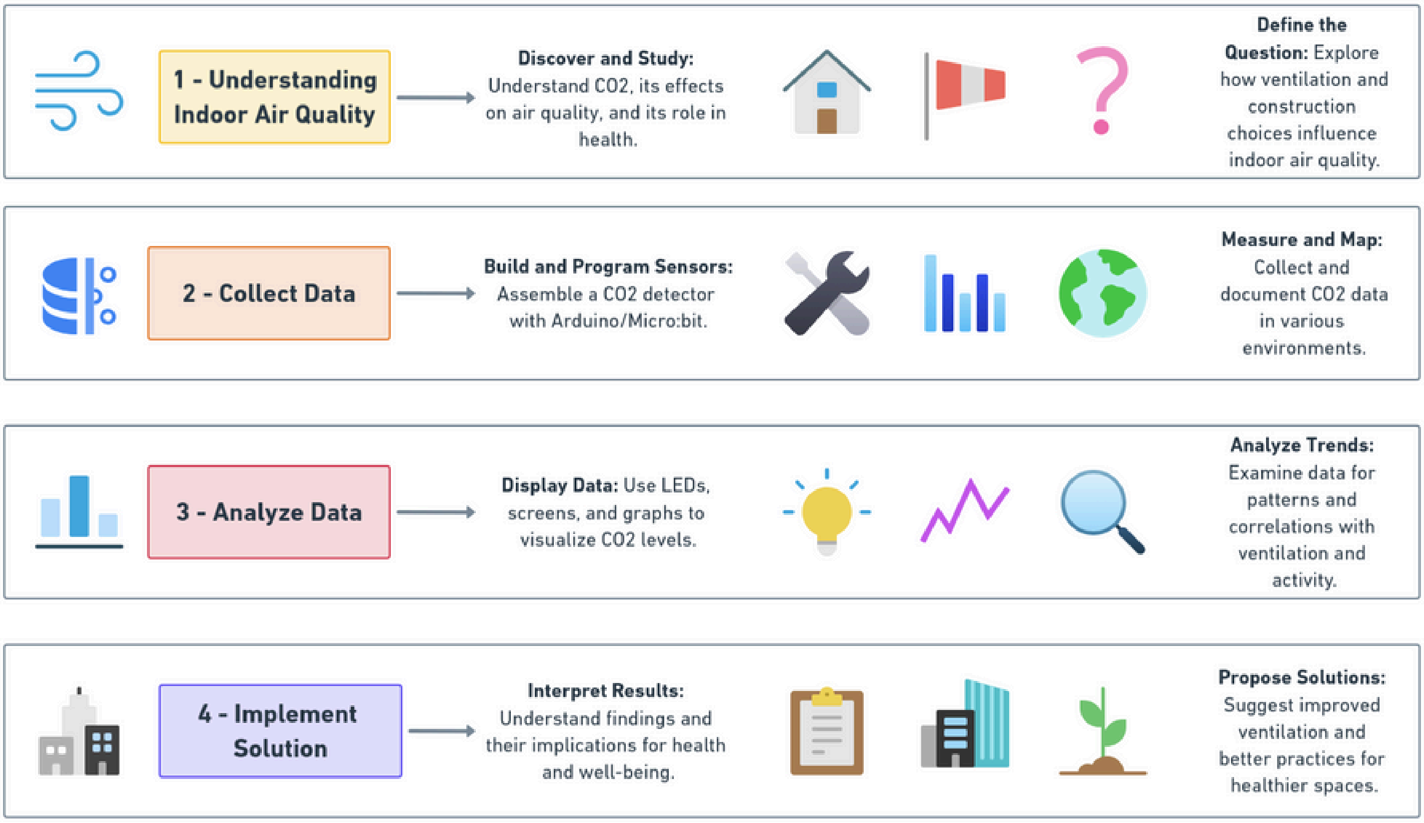
3 GOOD HEALTH AND WELL-BEING

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

4 QUALITY EDUCATION

Overview

Protocol Structure



Step 1 - Collect Data. Step 1 introduced students to the fundamentals of CO2 detection through hands-on programming activities. By building a basic CO2 detector using an SCD30 sensor and LED display system, students gained essential skills in environmental monitoring and basic programming concepts. This initial step laid the groundwork for understanding how to collect environmental data and interpret it through visual indicators, setting up the foundation for more advanced data display and analysis methods in subsequent steps.

Step 2 - Display the data to get the needed information. Step 2 focuses on enhancing data visualization capabilities by teaching students how to modify their CO2 detector program to display measurements graphically. This activity builds upon the basic sensor programming from Step 1, introducing students to more advanced data representation techniques. By using the Vittascience interface to create graphical displays and export data to spreadsheet formats, students learn valuable skills in data visualization and analysis. This step serves as a crucial bridge between raw data collection and meaningful data interpretation, preparing students for the deeper analysis work that follows in subsequent steps.

Step 3 - Analyse the data and learn from them. Step 3 is a crucial phase in the CO2 monitoring protocol where students move from data collection to meaningful analysis. Over approximately 60 minutes, students learn to identify patterns in CO2 levels and correlate them with specific events or behaviors in their environment. By recording factors like window openings, room occupancy, and ventilation patterns, students develop analytical skills while understanding the practical implications of air quality management. This step bridges the gap between raw data collection and actionable insights, preparing students to make informed decisions about ventilation practices. It is particularly valuable for teaching scientific methodology, data interpretation, and the real-world application of environmental monitoring.

Step 4 - Use the data for changing your behaviour/improving the starting situation. Step 4 is the culmination of the CO2 monitoring protocol, where students transform their data analysis into actionable solutions. This 40-minute phase focuses on practical applications of the collected data, encouraging students to develop real-world solutions for improving air quality. Students learn to apply statistical analysis techniques, share their findings through global platforms like Vittamap, and develop concrete recommendations for behavioral changes. This step is crucial as it bridges the gap between scientific observation and practical implementation, teaching students how to use data to make informed decisions about ventilation practices and environmental management. It emphasizes the importance of global scientific collaboration while maintaining a local focus on immediate environmental improvements.

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

Glossary

Keywords & Concepts	Definitions
Carbon dioxide	Carbon dioxide is an odorless, colorless and tasteless gas. So it is hard to be aware of its presence anywhere. A carbon dioxide molecule is made up of one carbon atom (C) and two oxygen atoms (O). But where does it come from? When we breathe in, we inhale dioxygen (O_2) from the air and exhale carbon dioxide (CO_2). Human activity also produces carbon dioxide, notably during the combustion of hydrocarbons (wood heating, fuel combustion, coal-fired power stations, etc.). In a closed room, carbon dioxide can be considered to come solely from the breathing of the people inside.
PPM unit	PPM stands for Parts Per Million. This unit of measurement is often used by scientists, particularly when measuring pollution levels. As its name suggests, this unit indicates how many pollutant molecules there are in a million molecules of air. By way of comparison, 1% corresponds to 1 million / 100 = 10,000 ppm. For example, 800 ppm CO_2 means that out of 1 million molecules in the air, 800 are carbon dioxide molecules. In other words, the percentage is 800/10000 = 0.08%.
Carbon dioxide rate in ppm	It is useful to know the rate of carbon dioxide in a room, for example, to determine whether a threshold has been crossed and a room needs to be ventilated. This rate is measured in ppm: parts per million (see definition above). The average rate of CO_2 outdoors is around 400 ppm, excluding pollution peaks and in areas with little pollution. This average rate can be higher, for example outdoors near a freeway junction. The reference value for the average outdoor rate is set by measurements taken at the Mauna Loa observatory in Hawaii. This site is considered ideal, as it is located high above a volcano. These measurements have been taken since 1958. This average rate has been increasing for decades. You can check the average rate "live" on the Global Monitoring Laboratory website.
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.). Sensors using LoRa technology (radio wave modulation) connect to the Internet via gateways. These can be antennas (as in France with Orange) or boxes to connect to your personal fibre/ADSL network. This technology is compatible with NUCLEO-L476RG ; Arduino and micro:bit programmable board.

Protocol

Step 1 - Collect Data

Background and description of the problem to be solved in this step: This first step familiarizes students with key concepts and tools (interfaces and hardware). It can be done in the classroom. The idea is to display the value of the carbon dioxide level on an LCD or computer screen, and to alert the user to the value of the level reached, based on the color of a light-emitting diode (LED).

Learning Objectives: The aim of this step is to learn how to collect data using programming and sensors (CO2), it's crucial to proceed step by step, asking students what the fundamentals are (the impact of too high a level of carbon dioxide on humans), and then determining the thresholds of data to be collected.

Conceptualisation

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

What happens if there's too much carbon dioxide in a room? When one or more people are present in a room, oxygen levels fall, while carbon dioxide levels rise. In high concentrations, carbon dioxide can become asphyxiating. The lack of oxygen due to high carbon dioxide levels can have more or less serious consequences for the body: accelerated heart rate, tiredness (and therefore reduced intellectual capacity, such as concentration or decision-making), nausea, vomiting, collapse and even, in extreme situations, coma or death. It is therefore important to ventilate a room to avoid carbon dioxide saturation. It should be noted that carbon dioxide concentration depends on a number of parameters: the number of people in a room, the type of activity they are engaged in (singing, sport, study, etc.), the volume of the room, the number of open windows, the presence of a ventilation system, and so on.

Indirectly, what can CO2 rate measure? Some viruses (such as the coronavirus responsible for COVID-19) are transmitted via aerosols (a suspension of particles in a gas). When people speak or breathe, they emit aerosols (contaminated or not) into the surrounding air. These aerosols are very fine droplets, less than one micrometer (1 µm =10-6 m) in diameter. In the case of COVID-19, there are three modes of contamination: by droplet projection, falling rapidly to the ground (at a distance of up to 2 meters from the emitter), by direct or indirect contact, and by aerosols, which remain in suspension for several hours (at a distance of more than 2 meters from the emitter).

In other words, a person emits aerosols and carbon dioxide! Knowing the rate of carbon dioxide is a way of obtaining indirect information on the concentration of aerosols (contaminated or not) in a room. Carbon dioxide can be described as an aerosol “marker”. Of course, aerosol sensors are available, but they are very expensive. Measuring carbon dioxide does not indicate the quantity of aerosols, but it does give an approximation of their presence in a room. So, depending on the carbon dioxide thresholds that need to be defined, it may be possible to decide when a room needs to be ventilated.

How to calibrate a carbon dioxide sensor? There are many types of carbon dioxide sensor, the reliability of which depends on the measurement technique used. The sensor used in this experiment is the SCD30 NDIR sensor, a non-dispersive infrared sensor from Sensirion. This technology is more reliable than MOX-type sensors (e.g. the MQ135 sensor uses tin dioxide SnO2, whose electrical conductivity varies according to the presence of pollutants) or MOS-type sensors like the SGP30 (giving a value in CO2 Equivalent). To make usable measurements, the sensor must be calibrated in the same way as a balance must be tared (a balance must display 0 gram when its pan is empty): typically, if the sensor is placed outdoors where the rate is (approximately) 400 ppm, the measured value must therefore be 400 ppm. There are several ways to calibrate a sensor:

1. **Factory calibration**: the process has been carried out at the factory and is valid for a period indicated in the manufacturer's manual;
2. **Forced calibration**: this requires knowing the value of the carbon dioxide rate at the calibration point; this value is considered a reference value. A program is inserted into the sensor, specifying that the measurement to be taken will correspond to the known reference value;
3. **Automatic calibration**: the sensor is placed outdoors for a long period (around 5 days) in a place where the carbon dioxide rate is constant and known. A program is imported into the sensor to perform this calibration over a long period of time. The sensor regularly measures carbon dioxide rate, recording the lowest values and averaging them to form a reference value. For the sensor used in this experiment, calibration can be carried out using the second or third method.

For ease of use, we describe here the second, as it is the faster method:

1. Connect the board to the computer via the usb cable, with the SCD30 sensor plugged into the I2C socket.
2. Make sure the board is outdoors.
3. Open the Vittascience interface and select the NUCLEO-L476RG ; micro:bit or Arduino interface, depending on the board used.
4. In the "sensors" menu choose the block : [SCD30 sensor] force calibration to (420) (ppm)
5. Then drag this block into the "At startup" block.

Documentation. According to the scientists who have contributed to the nousaerons.fr website, the following thresholds should be taken into consideration:

CO2 rate ~ 410 ppm: this is the average rate measured outdoors, excluding pollution episodes; the closer you get to this rate in a room, the better, as this is a sign that the air is being renewed. Conversely, in a confined space, without sufficient air renewal, the risk of contamination by aerosols increases rapidly, and this is reflected in the rise in CO2 rate in the room.
CO2 rate < 600 ppm: this rate is recommended by many scientists to combat COVID-19 and other airborne viruses in catering areas where masks cannot be worn. You can download the ventilation instructions implemented in Nantes Métropole canteens in **PDF format** or in **ODT editable format** to adapt them to your situation.
CO2 rate < 800 ppm: this rate is recommended by scientists to combat COVID-19 and airborne viruses in enclosed spaces; it is a recommendation of the Haut Conseil de la Santé Publique and corresponds to satisfactory air renewal in the December 27, 2022 decree of the Environment Code for schools.
CO2 rate > 1500 ppm: corresponds to a threshold for immediate action, recommended by the Haut Conseil de la Santé Publique and in the decree of December 27, 2022 of the French Environment Code.
CO2 rate = 5000 ppm: corresponds to the Occupational Exposure Limit (OEL).

A carbon dioxide rate of 800 ppm is a threshold also mentioned in the References for aeration and ventilation of school spaces - April 2021:

Measuring carbon dioxide CO2

Carbon dioxide, also known as carbon dioxide or CO2, is a gas exhaled during human respiration that accumulates in poorly ventilated enclosed spaces. Measuring the concentration of CO2 in the air is therefore an easy way of assessing whether or not air renewal is sufficient. Outdoors, the concentration of CO2 in the air is around 0.04%, or 400 ppm (parts per million). Ideally, indoor concentrations should not exceed 600 ppm, especially in areas where masks cannot be worn, such as school canteens. Concentrations in excess of 0.08% or 800 ppm are indicative of inadequate ventilation in a COVID-19 context (current recommendation of the Haut Conseil de la Santé Publique www.hcsp.fr). *Extract p.2 of the document Repères pour l'aération et la ventilation des espaces scolaires (April 2021)*

What are the different ways of ventilating a room? There are several ways of ventilating a room, depending on needs, architectural constraints and the level of air quality required. Here are the main ways of ventilating a room:

1. **Manual ventilation**: Open windows and doors.
2. **Natural ventilation**: Ventilation grilles: installed in walls or windows, they provide continuous ventilation without human intervention. Chimneys or vertical ducts: Use the natural draught effect to extract warm air and renew the air in the room.
3. **Mechanical ventilation**: Ventilation Mécanique Contrôlée (VMC): Suction of stale air from wet rooms (kitchen, bathroom) and renewal of air in other rooms via air vents.
4. **Forced ventilation**: Air-conditioning systems with air-exchange function: Some air-conditioners are equipped with ventilation functions that bring in fresh air from outside. Air purifiers with ventilation function: In addition to filtering air, some models can also renew indoor air. These different methods can be combined to optimize indoor air quality and meet the specific needs of each space, whether to reduce humidity, prevent condensation, or simply ensure good air circulation.

Students Investigation

Activity 1: CO2 Threshold Setup (10 minutes). The activity is launched by the teacher with the support of the whiteboard, papers or A4 sheets. It can be carried out in groups or with the whole class.

Instruction for the students: Set 4 levels of actions to light up the LED in different colors depending on the CO2 rate. They can be adjusted according to the environment (city, countryside, pollution peaks, create a ventilation) and calibration quality. Hereunder is the correct answer. You can distribute an empty version of this table to your students.

Carbon dioxide levels (in ppm)	LED color	Action
less than 600 ppm	green	no specific action
between 600 and 800 ppm	yellow	wearing a mask is strongly recommended
between 800 and 1000 ppm	orange	we recommend ventilating the room
beyond 1000 ppm	red	It is advisable to leave the room and air it out

Activity 2: CO2 Display Programming (10 minutes). The activity is launched by the teacher with the support of the Vittascience interfaces and the SCD30 sensor.

Instruction for the students: Create a program to display the **CO2 rate in the room on the LCD screen with the SCD30 sensor**. Use the Vittascience interfaces to make it happen, assemble the components (NUCLEO-L476RG ; micro:bit or Arduino programmable board, sensor SCD30, LCD screen, 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. To verify that the programme works, you can blow on it to check that the measured value is increasing. Outdoors, if the sensor is properly calibrated, the indicated value is around 400 ppm.

You will find an example of working programme to complete this activity available in the section "Practical Implementation 1 - Display the CO2 rate on an LCD screen using the SCD30 sensor".

Activity 3: LED Color Configuration (10 minutes). The activity is launched by the teacher with the support of the Vittascience interfaces and the SCD30 sensor. It can be carried out in groups or with the whole class.

Instruction for the students: Switch on an LED (Neopixel type) with a orange color. This step enables you to get to grips with the next step, which offers a more complete program. Use the Vittascience interfaces to make it happen.

Good to know: R, G and B stand for Red, Green and Blue respectively. The superimposition of these three colored lights, in different proportions, creates all colors according to the principle of additive synthesis. These proportions vary between 0 and 255, corresponding respectively to 0% and 100% luminosity. So, for example, if you wish to obtain :

- WHITE light, choose: R: 255; G: 255; B: 255.
- BLACK light, choose: R: 0; G: 0; B: 0.
- RED light: R: 255; G: 0; B: 0.
- ORANGE light: R: 255; G: 96; B: 0.

By combining these values, we can theoretically obtain 16 777 216 colors (there are 256 possible shades for each color, from 0 to 255, making a total of 2563 =16 777 216 colors). There's another block for selecting the color of the light emitted by the LED. This block is presented later in the booklet. It allows a simpler, but more limited, choice of colors using a pre-selected palette.

You will find an example of working programme to complete this activity available in the section "Practical Implementation 2 - LED Color Configuration".

Activity 4: CO2 LED Indicator (10 minutes). The activity is launched by the teacher with the support of the Vittascience interfaces and the SCD30 sensor. It can be carried out in groups or with the whole class.

Instruction for the students: Measure CO2 rate using the SCD30 sensor, display values (expressed in ppm) on the LCD screen and light up a different colored LED depending on the rate measured. Refer to Activity 1 to create a program to change the color of a LED according to the CO2 rate detected by an SCD30 sensor. Use the Vittascience interfaces to make it happen, remember to pause briefly between sending data, to avoid display bugs, 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.

You will find an example of working programme to complete this activity available in the section "Practical Implementation 3 - CO2 LED Indicator".

Conclusion & Further Reflexion

The teacher can end the activity by asking students to re-explain the key concepts they have learned: which air pollutants are harmful to health, how can they be measured and what environmental construction data must be taken into account? These three concepts will enable students to study the results of their measurements.

- **Knowledge Mobilized**: Students learn about CO2, its impact on health, and how sensors can measure indoor air quality.
- **Classroom Implementation Reflection**: Students program and assemble a CO2 detector, setting thresholds for action based on CO2 levels.
- **General Learning Outcomes**: Students gain hands-on experience in using technology to collect and interpret environmental data.

Step 2 - Display the data to get the needed information

Background and description of the problem to be solved in this step: This second step allows students to take their programming skills a step further with tools (interfaces and hardware). It can be done in the classroom. Switch on a different-colored LED according to the CO2 level measured, and display the value on the computer screen.

Learning Objectives: The aim of this step is to measure the CO2 level using the SCD30 sensor and display the values (expressed in ppm) on the computer screen, lighting up a different colored LED according to the level measured.

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, which will help them find answers for future activities.

How can you display the CO2 value on the computer?
The previous program can be modified to display the measured CO2 value on the computer screen via the Vittascience interface. This can be useful, for example, if you wish to video-project the measured values. The set-up is the same as for Activity 4 in Step 1. However, it is possible to dispense with the LCD module in the setup if you don't want a display on this screen.

Which part of the program needs to be modified?
The two blocks referring to the LCD30 screen, they must be deleted to be displayed on the computer.

Looking at the programming interface, what can you add to your program to display it on the console?
In the "communication" section, you'll find a block of instructions for writing to the console. This instruction enables the board to send the measurements taken (via the SCD30 CO2 sensor) to the computer via its serial port. This requires the board to remain continuously connected to the computer. This display is possible via an area of the Vittascience interface ("the display console").

Students Investigation

Activity 1: CO2 Display (10 minutes)
The activity is launched by the teacher with the support of the Vittascience interfaces and the SCD30 sensor. Students can build on the previous program to create the new one. It can be carried out in groups or with the whole class.

Instruction for the students: Measure CO2 rate using the SCD30 sensor, display values (expressed in ppm) on the support chosen (computer screen) and light up a different colored LED depending on the rate measured. Refer to Activity 4 of the step 1 to create a program to change the color of a LED according to the CO2 rate detected by an SCD30 sensor. Use the Vittascience interfaces to make it happen, 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.

You will find an example of working programme to complete this activity available in the section "Practical Implementation 4 - CO2 Display".

Activity 2: Data Visualization (10 minutes)
The activity is launched by the teacher with the support of the Vittascience interfaces and the SCD30 sensor. Students can build on the previous program to create the new one. It can be carried out in groups or with the whole class.

Instruction for the students: Modify the previous program slightly, replacing the display of the simple CO2 value in the console with a graphical display of the value. Remember to personalize the name of your collected data. Use the Vittascience interfaces to make it happen, 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.

You will find an example of working programme to complete this activity available in the section "Practical Implementation 5 - Data Visualization".

Conclusion & Further Reflexion

The teacher can end the activity by asking the students what they learned in step 1 and what more they can do now that they've completed step 2. They have learn to use different methods to understand the importance of data representation. Each of these is then used to analyze the data in order to understand the influence of the data on the result.

- **Knowledge Mobilized**: Students explore methods for visualizing data, such as using LEDs and computer screens.
- **Classroom Implementation Reflection**: Students modify programs to display CO2 values and observe how visual feedback (LEDs) helps interpret air quality.
- **General Learning Outcomes**: Students understand how to represent environmental data effectively for decision-making.

Step 3 - Analyse the data and learn from them

Background and description of the problem to be solved in this step: This step allows students to collect and analyze data to determine the key elements that change CO2 levels in a room. It can be done in a classroom, in a building, in a restaurant, in a lunchroom…

Learning Objectives: Learn to perform in-depth analysis of raw data to look for patterns, trends and measures in an existing dataset.

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.

What factors should be taken into account when analyzing the data?
For example, it may be possible to record the times at which windows are opened and closed, breaks and recesses are taken, classes start, numbers of people in the room, size of the room, the presence of ventilation, and so on. And compare these key moments with the consequences on the evolution of the carbon dioxide levels measured. In this way, the usefulness and effectiveness of room ventilation can be demonstrated quantitatively.

Students Investigation

Activity 1: Configurate and Install the device (20 minutes)
The activity is launched by the teacher with the support of the Vittascience interfaces and the SCD30 sensor. It can be carried out in groups or with the whole class.

Instruction for the students: Determine how long the device should be left in the chosen location to obtain sufficient data for future analysis. Then install the device, during the selected time, in the chosen location and collect the data.

Activity 2: Analyse the data (30 minutes)
The activity is launched by the teacher with the support of the Vittascience interfaces and the SCD30 sensor. It can be carried out in groups or with the whole class.

Instruction for the students: Analyze the data. Demonstrated quantitatively the usefulness and effectiveness of room ventilation.

Conclusion & Further Reflexion

Data analysis is an essential step in transforming raw data into information, enabling students to learn how to draw conclusions. Ask students to draw conclusions between the analysis environment and quality of life. **How can the ventilation of a building influence the well-being of its occupants?**

- **Knowledge Mobilized**: Students analyze collected data to identify patterns and understand the factors affecting CO2 levels.
- **Classroom Implementation Reflection**: Students compare CO2 trends with activities like ventilation, occupancy, and room size to draw conclusions.
- **General Learning Outcomes**: Students develop critical thinking skills and learn to use data analysis to assess environmental health.

Step 4 - Use the data for changing your behaviour/improving the starting situation

Background and description of the problem to be solved in this step: The last step, allow students to draw conclusions from data analysis, identify weaknesses in the current system and identify areas for improvement in everyday life.

Learning Objectives: Advanced data analysis, statistical reasoning, improvement ideation

Conceptualisation

Before getting started, the teacher encourage students to consider factors other than the simple value of CO2 in the air. Help them explore the correlation between specific human activities, temporal variables and variations in CO2 levels. Formulate hypotheses about potential factors influencing observed trends.

Students Investigation

Activity 1: Statistical Data Analysis (20 minutes)

The activity is launched by the teacher with the support of the data collected by the students with the SCD30 sensor. It can be carried out in groups or with the whole class.

Instruction for the students: Guide students in the use of statistical techniques such as correlation analysis and regression to identify relationships between variables. Encourage critical thinking about potential confounding factors and ways to control for them in their analysis.

Activity 2: Data Sharing and Comparison Activity (10 minutes)

The activity is launched by the teacher with the support of the data collected by the students with the SCD30 sensor. 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 have collected (using LoRa technology, see more information **here**) 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!

Using the Vittamap Sharing Tool

You will find a map called Vittamap on the Vittascience website, which lists all the experiments carried out around the world. Log on to the Vittascience website and access the Vittamap map: vittascience.com/vittamap. Click on the **"+"** → **"Add an experience"** button.
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*. Once you have filled in all the fields, all you have to do is click on the **"Add experience"** button. Your data is now available to the Vittascience user community on the Vittamap map. Students can then compare it with other similar experiments. 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 and find for exemple, the most positive and the most negative data.

Conclusion & Further Reflexion

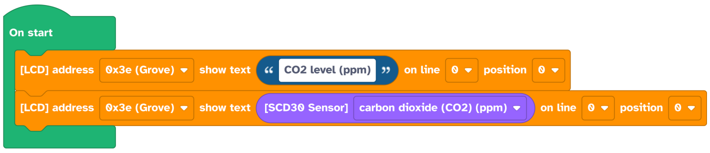
The teacher encourage students to share ideas for improving the CO2 level in the chosen location throughout the week. Summarize the ideas in the form of a summary of best practices to be implemented.

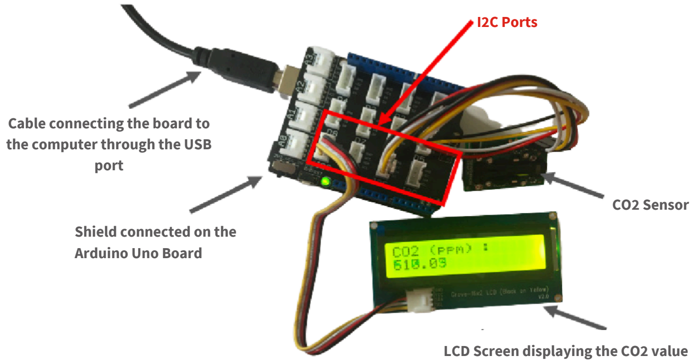
- **Knowledge Mobilized**: Students apply statistical reasoning to propose solutions for improving air quality based on their data.
- **Classroom Implementation Reflection**: Students create recommendations for better ventilation practices and share findings globally via Vittamap.
- **General Learning Outcomes**: Students link data-driven insights to real-world actions, fostering a sense of responsibility for sustainable living.

Practical Implementation 1.

Display the CO2 rate on an LCD screen using the SCD30 sensor

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





Code

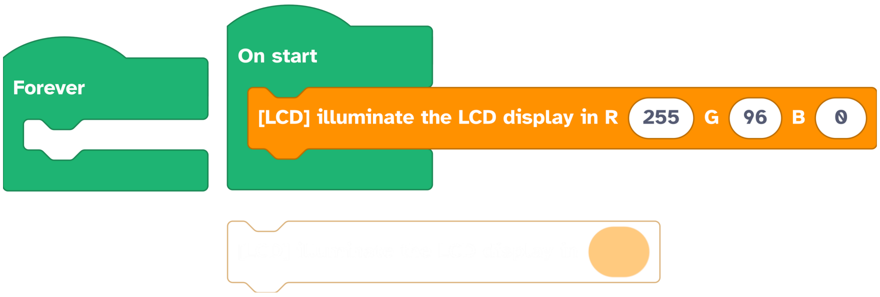
```
#include <Wire.h>
#include <rgb_lcd.h>
#include <SCD30.h>

rgb_lcd lcdRgb;

float t_scd;
float scd30_co2 = 0;
float scd30_t = 0;
float scd30_h = 0;

void serial_setupConnection(int baudrate) {
     Serial.begin(baudrate);
     while (!Serial) {
     Serial.println("En attente de l'ouverture du port série...");
         delay(1000);
     }
     Serial.println("Port série activé. Baudrate: " + String(baudrate));
     delay(50);
}

float scd30_read(uint8_t dataSelect) {
     t_scd = millis() - t_scd; if (t_scd > 1000 && scd30.isAvailable()) {
         float result[3] = {0};
         scd30.getCarbonDioxideConcentration(result);
```

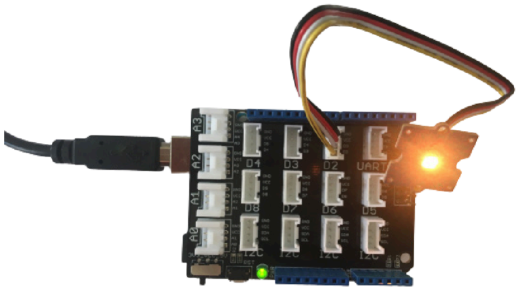
```
        scd30_co2 = result[0];
        scd30_t = result[1];
        scd30_h = result[2];
    }
    switch (dataSelect) {
        case 0: return scd30_co2;
        case 1: return scd30_t;
        case 2: return scd30_h;
    }
}

void setup() {
    lcdRgb.begin(16, 2);
    serial_setupConnection(9600);
    Wire.begin();
    scd30.initialize();
    t_scd = millis();
    lcdRgb.setCursor(0, 0);
    lcdRgb.print(String("CO2 level (ppm)"));
    lcdRgb.setCursor(0, 0);
    lcdRgb.print(String(scd30_read(0)));
}

void loop() {}
```

Practical Implementation 2.

LED Color Configuration

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





Code

```
#include <Wire.h>
#include <rgb_lcd.h>

rgb_lcd lcdRgb;

void setup() {
    lcdRgb.begin(16, 2);
    lcdRgb.setRGB(255, 96, 0);
}

void loop() { }
```

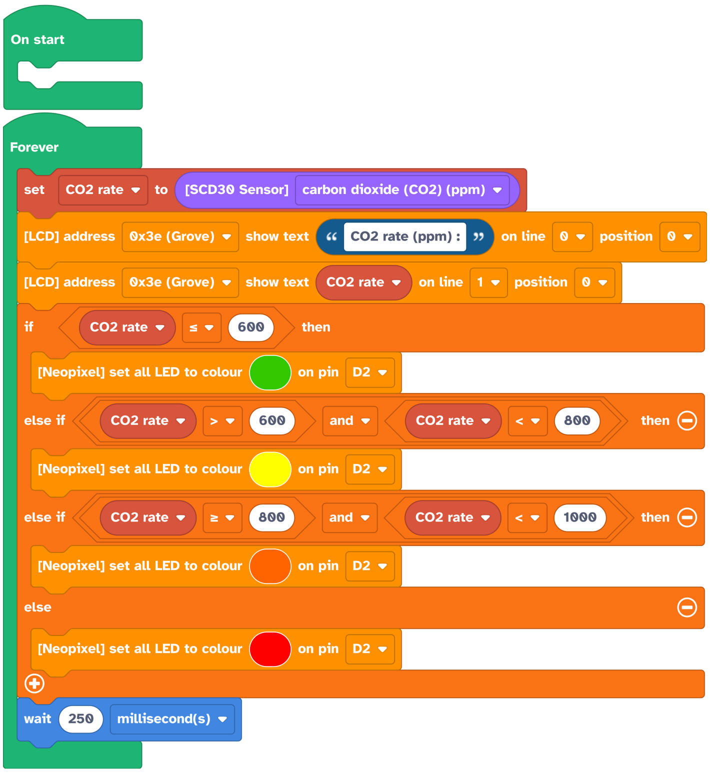
Practical Implementation 3.
CO2 LED Indicator

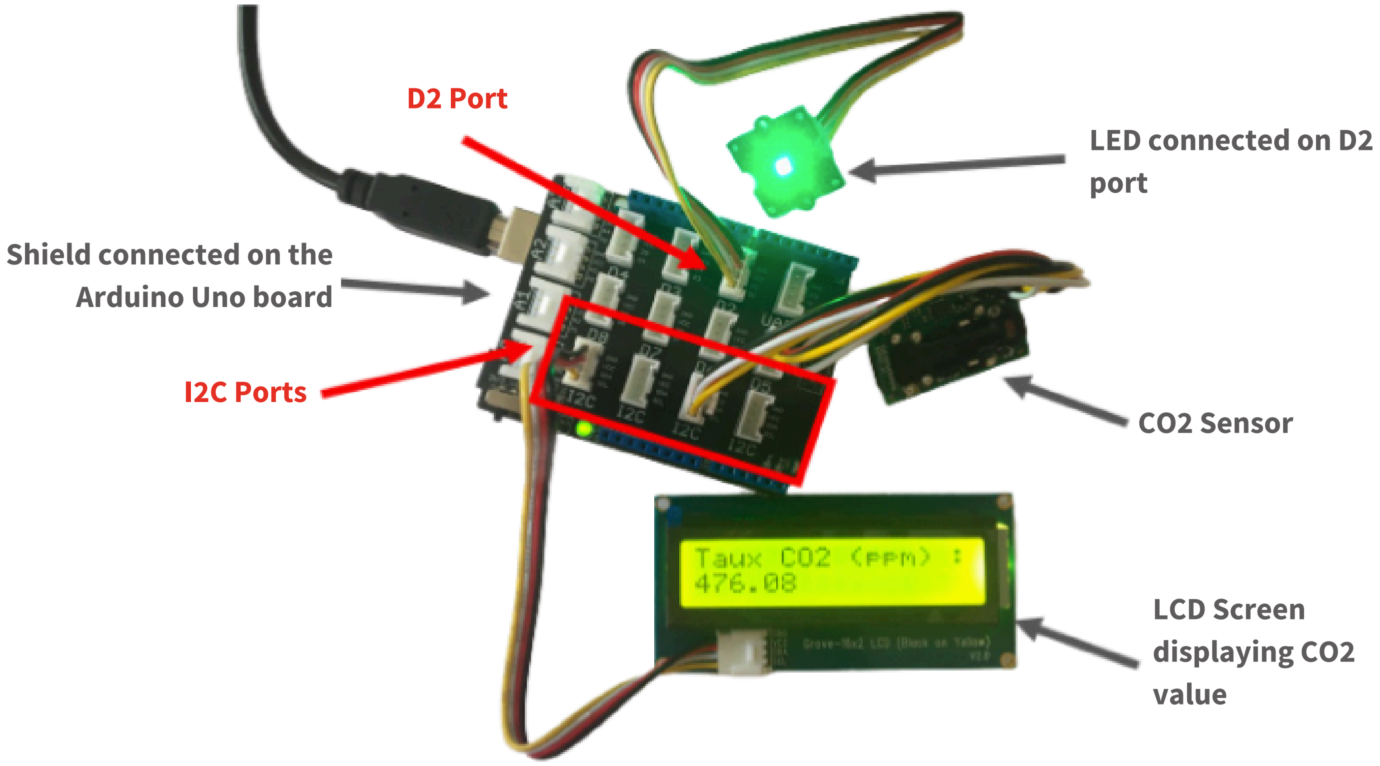
Editor used: vittascience.com/l476 ; vittascience.com/arduino or vittascience.com/microbit

In the program, you then need to add "conditional structure" blocks. These blocks have a nomenclature such as : if this condition is met, then execute an instruction otherwise execute another instruction. In this case, there are four conditions to anticipate, because there are four CO2 rate intervals. This program combines the programs created in steps 1 and 2, with the addition of a conditional structure block.

In this program, the carbon dioxide value is compared with various thresholds. In order to avoid having to take several measurements of the rate, which will then be compared with the different thresholds, it is possible to store the measured value in a variable. We suggest naming this variable "CO2 rate". To create this variable, click on the Variables heading.

A side panel opens: click on "Create a variable". Name the variable "CO2 rate" for example, then click on OK. Blocks specific to this new variable are created and accessible from the Variables heading. To use this variable, click on the Variables heading.





Code

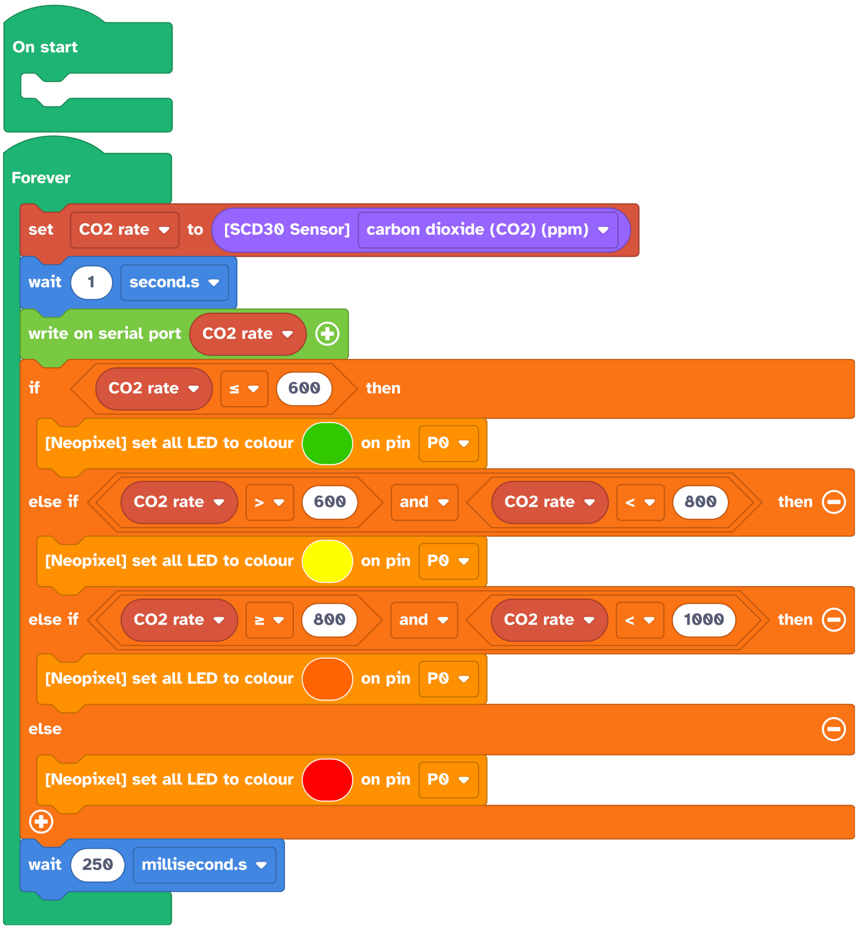
```
#include <Wire.h>
#include <SCD30.h>
#include <rgb_lcd.h>
#include <Adafruit_NeoPixel.h>

#define NP_LED_COUNT_2 30

rgb_lcd lcdRgb;
Adafruit_NeoPixel Neopixel_2(NP_LED_COUNT_2, 2, NEO_GRB + NEO_KHZ800);

float t_scd;
float scd30_co2 = 0;
float scd30_t = 0;
float scd30_h = 0;
float CO2_rate;

void serial_setupConnection(int baudrate) {
    Serial.begin(baudrate);
    while (!Serial) {
        Serial.println("En attente de l'ouverture du port série...");
        delay(1000);
    }
    Serial.println("Port série activé. Baudrate: " + String(baudrate));
    delay(50);
}

float scd30_read(uint8_t dataSelect) {
    t_scd = millis() - t_scd; if (t_scd > 1000 && scd30.isAvailable()) {
        float result[3] = {0};
        scd30.getCarbonDioxideConcentration(result);
        scd30_co2 = result[0];
        scd30_t = result[1];
        scd30_h = result[2];
    }
    switch (dataSelect) {
        case 0: return scd30_co2;
        case 1: return scd30_t;
        case 2: return scd30_h;
    }
}
```

```
void neopixel_showAllLed(Adafruit_NeoPixel *neoPx, uint8_t ledCount, uint8_t
r, uint8_t g, uint8_t b) {
     for (int i=0; i<ledCount; i++) {
        neoPx->setPixelColor(i, neoPx->Color(r, g, b));
     }
     neoPx->show();
}

void setup() {
     serial_setupConnection(9600);
     Wire.begin();
     scd30.initialize();
     t_scd = millis();
     lcdRgb.begin(16, 2);
     Neopixel_2.begin();
}

void loop() {
     CO2_rate = scd30_read(0);
     lcdRgb.setCursor(0, 0);
     lcdRgb.print(String("CO2 rate (ppm) :"));
     lcdRgb.setCursor(0, 1);
     lcdRgb.print(String(CO2_rate));
     if (CO2_rate <= 600) {
        neopixel_showAllLed(&Neopixel_2, NP_LED_COUNT_2, 51, 204, 0);
     }
     else if (CO2_rate > 600 && CO2_rate < 800) {
         neopixel_showAllLed(&Neopixel_2, NP_LED_COUNT_2, 255, 255, 0);
     }
     else if (CO2_rate >= 800 && CO2_rate < 1000) {
         neopixel_showAllLed(&Neopixel_2, NP_LED_COUNT_2, 255, 102, 0);
     }
     else {
        neopixel_showAllLed(&Neopixel_2, NP_LED_COUNT_2, 255, 0, 0);
     }
     delay(250);
}
```

Practical Implementation 4.

CO2 Display

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



Remember to add a 1 second pause to limit the frequency with which values are displayed on the computer screen. This makes it easier to read the measured values.

Code

```
#include <Wire.h>
#include <SCD30.h>
#include <rgb_lcd.h>
#include <Adafruit_NeoPixel.h>

#define NP_LED_COUNT_2 30

rgb_lcd lcdRgb;
Adafruit_NeoPixel Neopixel_2(NP_LED_COUNT_2, 2, NEO_GRB + NEO_KHZ800);

float t_scd;
float scd30_co2 = 0;
float scd30_t = 0;
float scd30_h = 0;
float CO2_rate;
```

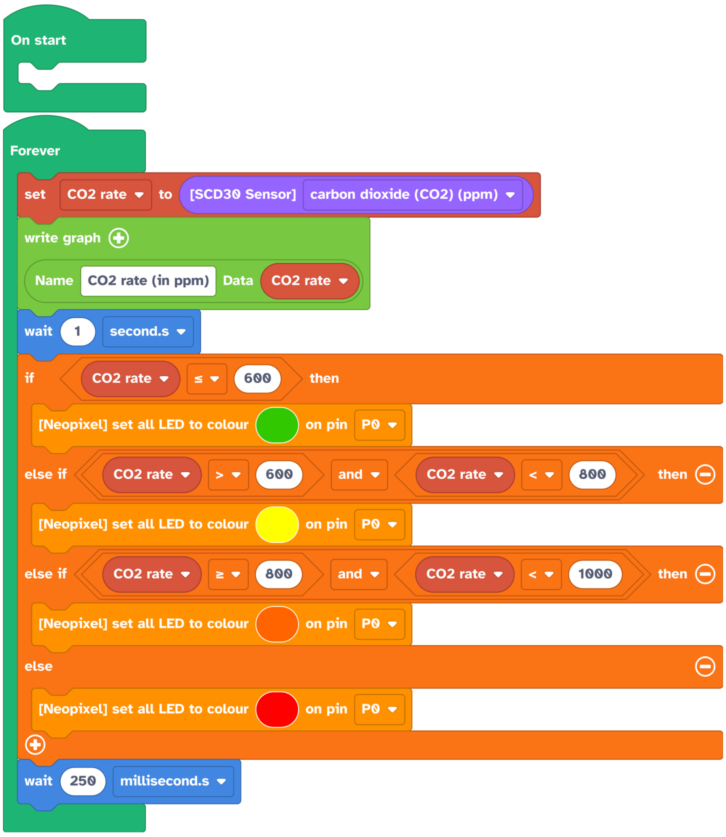
```
void serial_setupConnection(int baudrate) {
     Serial.begin(baudrate);
     while (!Serial) {
        Serial.println("En attente de l'ouverture du port série...");
        delay(1000);
     }
     Serial.println("Port série activé. Baudrate: " + String(baudrate));
     delay(50);
}

float scd30_read(uint8_t dataSelect) {
     t_scd = millis() - t_scd; if (t_scd > 1000 && scd30.isAvailable()) {
        float result[3] = {0};
        scd30.getCarbonDioxideConcentration(result);
        scd30_co2 = result[0];
        scd30_t = result[1];
        scd30_h = result[2];
     }
     switch (dataSelect) {
        case 0: return scd30_co2;
        case 1: return scd30_t;
        case 2: return scd30_h;
     }
}

void neopixel_showAllLed(Adafruit_NeoPixel *neoPx, uint8_t ledCount,
uint8_t r, uint8_t g, uint8_t b) { for (int i=0; i<ledCount; i++)
     {
        neoPx->setPixelColor(i, neoPx->Color(r, g, b));
     } neoPx->show();
}

void setup() {
     serial_setupConnection(9600);
     Wire.begin();
     scd30.initialize();
     t_scd = millis();
     lcdRgb.begin(16, 2);
     Neopixel_2.begin();
     CO2_rate = scd30_read(0);
     delay(1000*1);
     Serial.println(String(CO2_rate));
     lcdRgb.setCursor(0, 0);
```

```
    lcdRgb.print(String("CO2 rate (ppm)"));
    lcdRgb.setCursor(0, 1);
    lcdRgb.print(String(CO2_rate));
    if (CO2_rate <= 600) {
       neopixel_showAllLed(&Neopixel_2, NP_LED_COUNT_2, 51, 204, 0);
    } else if (CO2_rate > 600 && CO2_rate < 800) {
        neopixel_showAllLed(&Neopixel_2, NP_LED_COUNT_2, 255, 255, 0);
    } else if (CO2_rate >= 800 && CO2_rate < 1000) {
        neopixel_showAllLed(&Neopixel_2, NP_LED_COUNT_2, 255, 102, 0);
    } else {
       neopixel_showAllLed(&Neopixel_2, NP_LED_COUNT_2, 255, 0, 0); }
    delay(250); }

void loop() { }
```

Practical Implementation 5.

Data Visualization

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



1. To view the graph, in the display console, select "Graph mode" on the right.

2. From this graphical representation, it is possible to export all data as a .csv file (readable by spreadsheet programs such as Excel, Libre Office Calc, GoogleSheet, Numbers, etc.). To do this, simply click on the Export button at the bottom of the window. Data will be accessible from the spreadsheet program used by default on the computer. The spreadsheet's "graphing" function can be used to draw a graph showing the evolution of carbon dioxide levels over time, which can then be printed out.

Code

```
#include <Wire.h>
#include <SCD30.h>
#include <rgb_lcd.h>
#include <Adafruit_NeoPixel.h>

#define NP_LED_COUNT_2 30

rgb_lcd lcdRgb;
Adafruit_NeoPixel Neopixel_2(NP_LED_COUNT_2, 2, NEO_GRB + NEO_KHZ800);

float t_scd;
float scd30_co2 = 0;
float scd30_t = 0;
float scd30_h = 0;
float CO2_rate;

void serial_setupConnection(int baudrate) {
```

```
    Serial.begin(baudrate);
    while (!Serial) {
        Serial.println("En attente de l'ouverture du port série...");
        delay(1000);
    }
    Serial.println("Port série activé. Baudrate: " + String(baudrate));
    delay(50);
}

float scd30_read(uint8_t dataSelect) {
    t_scd = millis() - t_scd;
    if (t_scd > 1000 && scd30.isAvailable()) {
        float result[3] = {0};
        scd30.getCarbonDioxideConcentration(result);
        scd30_co2 = result[0];
        scd30_t = result[1];
        scd30_h = result[2];
    }
    switch (dataSelect) {
        case 0: return scd30_co2;
        case 1: return scd30_t;
        case 2: return scd30_h;
    }
}

void neopixel_showAllLed(Adafruit_NeoPixel *neoPx, uint8_t ledCount, uint8_t
 r, uint8_t g, uint8_t b) {
    for (int i=0; i<ledCount; i++) {
        neoPx->setPixelColor(i, neoPx->Color(r, g, b));
    } neoPx->show();
}

void setup() {
    serial_setupConnection(9600);
    Wire.begin();
    scd30.initialize();
    t_scd = millis();
    lcdRgb.begin(16, 2);
    Neopixel_2.begin();
    CO2_rate = scd30_read(0);
    delay(1000*1);
    Serial.print("@Graph:");
    Serial.print("CO2 rate (in ppm):");
```

```
    Serial.print(CO2_rate); Serial.print("|");
    Serial.print("\n");
    delay(50);
    lcdRgb.setCursor(0, 0);
    lcdRgb.print(String("CO2 rate (ppm)"));
    lcdRgb.setCursor(0, 1);
    lcdRgb.print(String(CO2_rate));
    if (CO2_rate <= 600) {
      neopixel_showAllLed(&Neopixel_2, NP_LED_COUNT_2, 51, 204, 0);
    }
    else if (CO2_rate > 600 && CO2_rate < 800) {
      neopixel_showAllLed(&Neopixel_2, NP_LED_COUNT_2, 255, 255, 0);
    } else if (CO2_rate >= 800 && CO2_rate < 1000) {
      neopixel_showAllLed(&Neopixel_2, NP_LED_COUNT_2, 255, 102, 0);
    } else {
      neopixel_showAllLed(&Neopixel_2, NP_LED_COUNT_2, 255, 0, 0);
    }
    delay(250);
}

void loop() { }
```

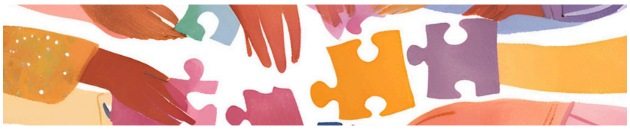
Exploring the issue through other initiatives

Building on the knowledge and skills developed in the classroom, students can deepen their understanding of indoor air quality by applying what they have learned in their own living spaces. This activity bridges the gap between theoretical knowledge and practical application, empowering students to become proactive environmental stewards in their daily lives.

Exploring Indoor Air Quality at Home

In this extension, students will monitor the air quality of their rooms using CO2 sensors, reinforcing their understanding of how ventilation impacts health and well-being. By observing and recording CO2 levels at different times of the day, they can identify patterns influenced by activities like sleeping, studying, or the number of occupants in the room.

Making Connections



As students gather data, they will connect the scientific principles discussed in class to their lived experiences. This activity encourages them to reflect on how air circulation, room size, and ventilation methods contribute to air quality. By understanding these dynamics, students can make informed choices to improve their immediate environment, such as adjusting windows or using simple ventilation techniques.

Applying Knowledge for Daily Impact

Students can also explore the effectiveness of specific changes in their room environment. For instance, they might compare CO2 levels with windows closed versus partially opened or experiment with airflow using fans. These observations help translate abstract concepts into tangible actions.

Engaging the Household

Encouraging family participation can amplify the activity's impact. By sharing their findings with others in the household, students can advocate for practices that promote better air quality, fostering a culture of environmental awareness within their community.

From Monitoring to Advocacy

This hands-on experience transforms students into advocates for healthier living spaces. Equipped with their data and observations, they can discuss broader implications of air quality, such as its role in reducing airborne diseases, improving focus, and enhancing sleep quality. The activity thus instills not only scientific literacy but also a sense of responsibility toward sustainable living.

Bibliography

1. **Average CO2 Rates (Live Data)**
   Source: *Global Monitoring Laboratory*
   URL: https://gml.noaa.gov/ccgg/trends/
   Interest: Provides real-time data on atmospheric CO2 levels, essential for understanding global carbon trends and informing climate action.

2. **CO2 Thresholds and Impact on Air Quality**
   Source: *NousAérons.fr*
   URL: http://nousaerons.fr/
   Interest: Discusses CO2 thresholds and the importance of air quality in indoor environments, particularly relevant to health and ventilation.

3. **Aeration and Ventilation in School Spaces**
   Reference: *Ministry of Education, France* (April 2021)
   URL: https://www.education.gouv.fr/media/88756/download
   Interest: A guide on best practices for ventilation in educational settings, highlighting its role in reducing airborne disease transmission.

4. **Arduino-Based Alert for Aeration**
   Guide: Vittascience, *Alerte Aération Arduino*
   URL: https://fr.vittascience.com/learn/tutorial.php?id=340/guide-d-utilisation-alerte-aeration-arduino
   Interest: Offers a step-by-step tutorial for implementing an Arduino-based alert system to optimize air quality in enclosed spaces.

5. **Micro:bit-Based Alert for Aeration**
   Guide: Vittascience, *Alerte Aération Micro:bit*
   URL: https://fr.vittascience.com/learn/tutorial.php?id=339/guide-d-utilisation-alerte-aeration-micro-bit
   Interest: Provides instructions to build a simple, interactive alert system using Micro:bit to improve indoor air quality.