



## Energy Flow In Ecosystem



Co-funded by  
the European Union

# STEAM4Climate Teacher's Guide to Project-Based Climate Education

**Project: From measurements to meaning – studying ecosystems in  
the STEAM way**

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# Introduction

## UN Sustainable Development Goals



## 1. Learning Overview

This project invites students to explore biodiversity and ecosystems through a hands-on, interdisciplinary STEAM approach. By designing and monitoring self-contained “ecosystems-in-a-jar,” participants combine scientific inquiry with engineering creativity, digital technology, and data analysis to better understand how life interacts with its environment.

Using a set of sensors with a data acquisition module, students measure key environmental parameters like temperature, humidity, CO<sub>2</sub> levels, light intensity, or soil moisture. They build a foundation in scientific methods by calibrating sensors, forming hypotheses, and analyzing real-time data. The project explores the invisible dynamics of life, including response to man-made intrusions.

From sealed terrariums and aquatic ecosystems to fungal microhabitats and hydroponic systems, each student-designed jar becomes a living laboratory. By bridging disciplines, this project nurtures curiosity, systems thinking, and environmental awareness.

**Key Concept:** Getting acquainted with the datalogging of a set of environmental parameters and developing confidence in interpreting

**Duration:** 2h for the introduction, the rest depends on the particular project

**Number of Sessions:** at least two, for setting up equipment and running longer measurements (analysis of data collected during the week)

**Target Age Group:** high school, 15+

## 2. Learning Objectives & Methodology

Students participating in this project will:

- learn how environmental parameters (e.g. CO<sub>2</sub> concentration, temperature, humidity, light) are measured and recorded in practice;
- gain experience working with sensors and data acquisition systems (DAQ);
- understand the difference between instantaneous readings and time-series data;
- recognize practical limitations of measurements, such as sensor warm-up time, response inertia, and uncertainty;
- interpret data using simple plots and relate numerical results to observed physical, chemical, and biological processes;
- explain how small-scale processes observed in experiments relate to large-scale climate and ecosystem dynamics.

### Methodology

The project follows an **inquiry-based, project-based learning (PBL)** approach.

Teaching is structured around three recurring elements:

1. **Hands-on measurement:** Students collect real data using sensors, focusing on correct setup, calibration, and observation.
2. **Data interpretation:** Recorded data are visualized and discussed in relation to experimental events, helping students connect measurements with cause–effect relationships.
3. **Open-ended investigation:** In extended and capstone activities, students design their own experiments (e.g. sealed ecosystems, smart farming scenarios), formulate hypotheses, and evaluate outcomes.

The emphasis is placed on **interpreting measurements**, not just collecting them, reflecting how environmental and climate research is conducted in real-world contexts.

### 3. A “Low Floor, High Ceiling, Wide Walls” Approach

In STEAM4Climate, we adapted an approach that empowers students to explore ecosystems and biodiversity with various sensors, regardless of their technical abilities.

- **Low Floor:** Beginners can easily get started with basic tools like a pre-built Arduino sensor kit, simple jars, and everyday materials (soil, moss, water). No prior coding or electronics experience is required in this scenario if *STEAM4Climate Environmental Kit* is used. Quantitative observations will give students insights into the ecosystem dynamics. Also, for every scenario, code is available for copying.
- **High Ceiling:** Advanced learners can incorporate more sophisticated sensors (for example NO<sub>2</sub>, CH<sub>4</sub>, and ethanol sensors, apart from just CO<sub>2</sub>) for appropriate scenarios and self-program their projects. For top-tier students qualitative analysis is possible. They can be encouraged to run additional experiments, like observing the effect of overfertilization of soil leading to nitrogen compound emission or studying the long-term sustainability of sealed biospheres.
- **Wide Walls:** The possibilities are broad – students can choose to model different ecosystems (soil-based ecosystems, hydroponic systems, aquatic environments), sealed or open, aerobic or anaerobic. Each jar becomes a unique scientific and creative composition, encouraging experimentation with multiple iterations. Ultimately, why stick to the jar, if measurements can be done outdoors, in your garden compost or nearby wetlands?

Whether indoors or in the field, every learner’s path is different – and every ecosystem jar tells its own story. We hope that immersive experience promotes curiosity and a lasting appreciation for the complexity of life and the environment.

# Materials

## 4. Materials Included in Toolbox for basic version

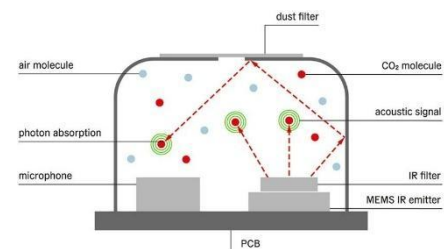
- CO2 sensor (Gravity: SEN0536)
- DAQ module (Gravity: SCI DAQ Module)
- Battery booster
- Two batteries
- Wires: Double-headed PH2.0-4P, battery in (self-made)

### Basic sensors – temperature, humidity, CO<sub>2</sub> concentration

Temperature and humidity sensors are usually integrated units (like DHT11 or DHT22). Even though they can be bought and connected separately, using a board with embedded detectors is more convenient, reducing the need for wire management. The basic sensor for CO<sub>2</sub> concentration we recommend as cost-effective is **SCD41**:

*“The SCD4x is Sensirion’s second generation series of optical CO2 sensors. The sensor series builds on the photoacoustic NDIR<sup>1</sup> sensing principle and Sensirion’s patented PASens<sup>®</sup> and CMOSens<sup>®</sup> technology to offer accuracy at an attractive price and small form factor. SMD assembly allows cost- and space-effective integration of the sensor combined with maximal freedom of design. On-chip signal compensation is realized with the built-in SHT4x humidity and temperature sensor.”<sup>2</sup>*

*“SCD41 sensor detects the amount of energy that is absorbed by CO2 molecules. When pulsing the infra-red emitter, CO2 molecules absorb infrared light periodically. This causes additional molecular vibration resulting in a pressure wave inside the measurement*



<sup>1</sup> NDIR – Non-Dispersive Infra-Red

<sup>2</sup> <https://sensirion.com/products/catalog/SCD41>

chamber. The higher the CO2 concentration, the more light is absorbed, and thus the greater the amplitude of this acoustic wave becomes. A microphone inside the gas chamber measures this, from which the CO2 concentration can then be calculated.”<sup>3</sup>

Various manufacturers sell this sensor using slightly different designs of PCB boards. To avoid the need for soldering and to use a consistent set of sensors, we decided to use **the Gravity platform designed by DFRobot company**. Therefore, we decided to implement the project using the **DFRobot SEN0536** module.



### Gravity: Science Data Acquisition (SCI DAQ) Module

Specification<sup>4</sup>:

- Operating Voltage: 3.3-5.5V DC
- Operating Current: 40mA
- Output Signal: I2C (0x21-0x23)
- Input Interface: 1 x Digital/Analog, 2 x I2C/UART
- Onboard Storage: 16M
- RTC Battery: CR1220
- Screen Info: 1.3 inches OLED
- Product Dimension: 62×52×13mm



<sup>3</sup> [https://wiki.dfrobot.com/SKU\\_SEN0536\\_Gravity\\_SCD41\\_Infrared\\_CO2\\_Sensor](https://wiki.dfrobot.com/SKU_SEN0536_Gravity_SCD41_Infrared_CO2_Sensor)

<sup>4</sup> <https://www.dfrobot.com/product-2655.html>

## 5. Other components for basic version

- Sealed container (1l jar or plastic bottle)
- Pack of dry yeast (5g)
- Pack of baking soda
- Pack of citric acid or vinegar
- Sugar
- Tap water
- Piece of soil

## 6. Components for the extended version

According to the “wide walls” approach, there are many options to expand the project with the use of the provided SCI DAQ module, as it supports various sensors relevant to study environments:

- analogue soil moisture, ambient light sensor
- non-contact IR Temperature Sensor,
- water quality: pH, electrical conductivity, TDS, waterproof thermometer
- gas detectors (electrochemical)

In case of simultaneous use of many sensors, an additional “I2C hub” is required, but there are some technical difficulties – we recommend using a separate DAQ instead. The full list of supported equipment is available on the manufacturer's website:

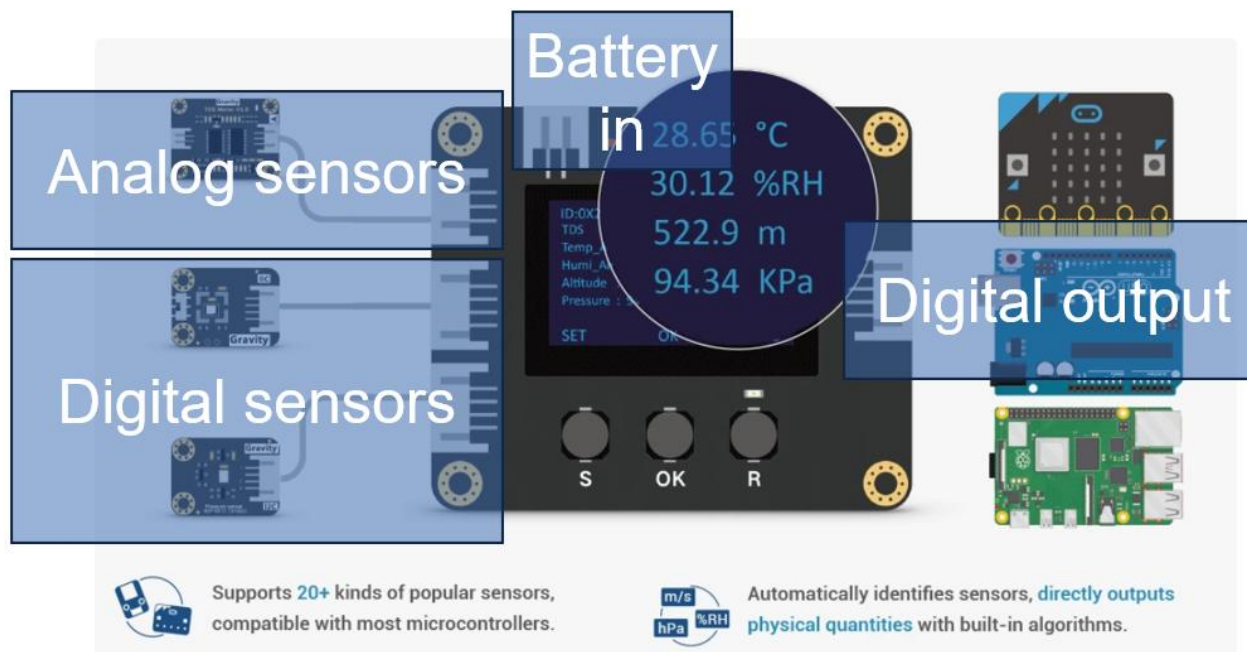
<https://www.dfrobot.com/product-2655.html>

# Activity Instructions

## 7. Pre-Activity Preparation

### 7.1 Connection equipment

SCI DAQ module needs to be powered – in our setup, we are using a battery with a step-up booster; therefore, two AA batteries are enough to power the DAQ. The 2-pin battery socket is located above the display, while our sensor should be connected via a 4-pin socket to the left of the display. Alternatively, it can be powered via USB-C cable (connected to a power bank – not included):<sup>5</sup>



Activity for students:

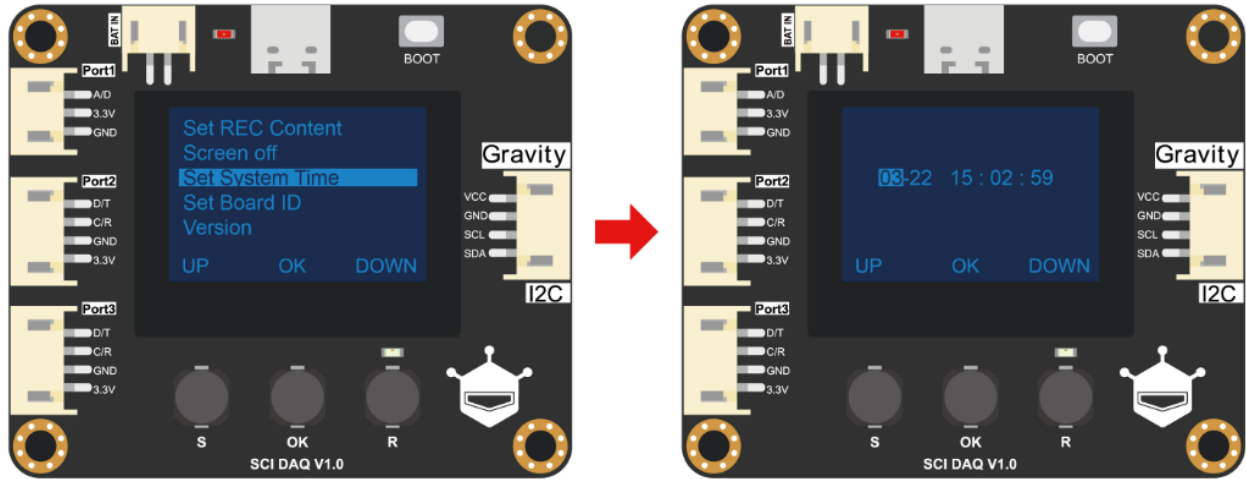
- Connect and read the CO2 concentration (in ppm, parts per million)
- Compare values displayed indoors and outdoors
- Check how the sensor reacts to your breath

<sup>5</sup> Picture in the back – manufacturer website: <https://www.dfrobot.com/product-2724.html>

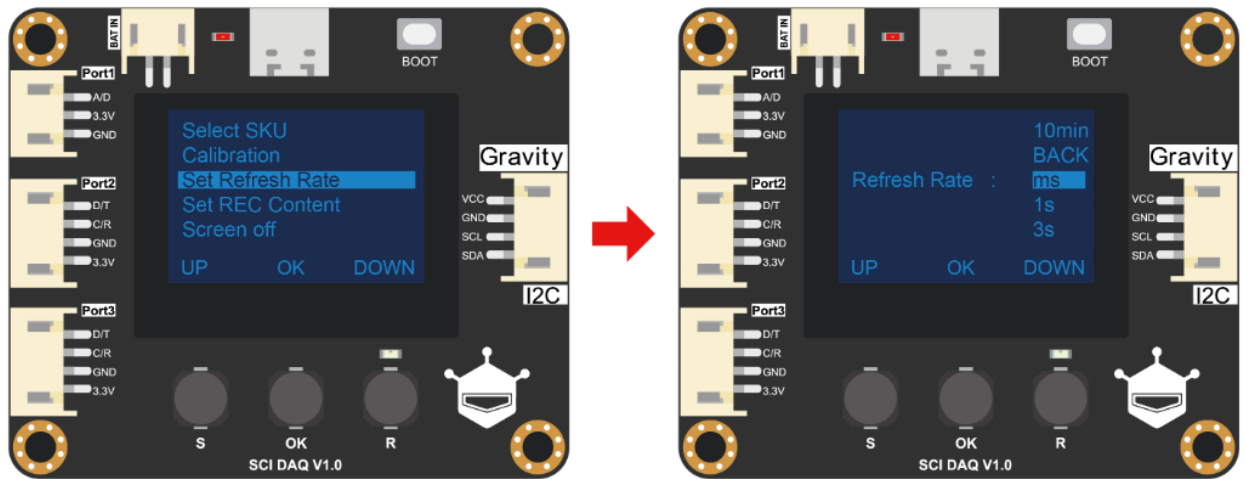
## 7.2 Datalogging

To record the measurements, two setups are expected:

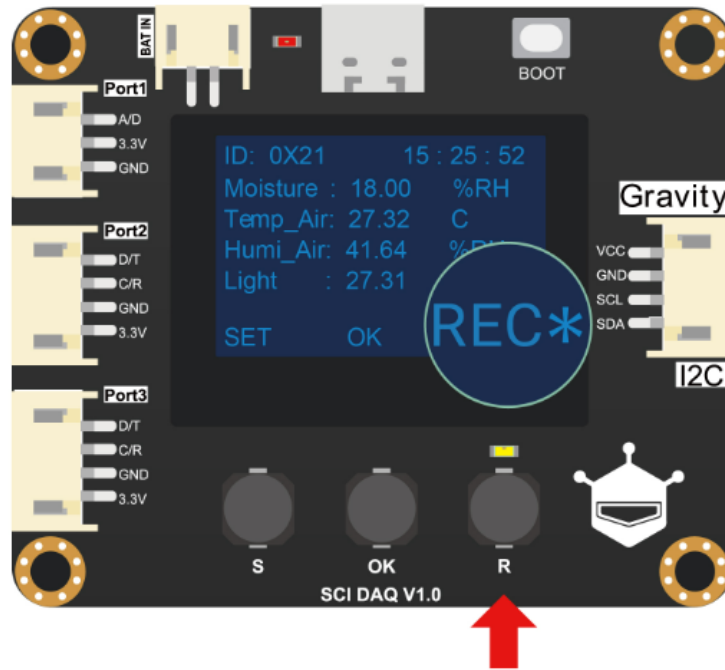
Setting System Time:



Setting the refresh rate:

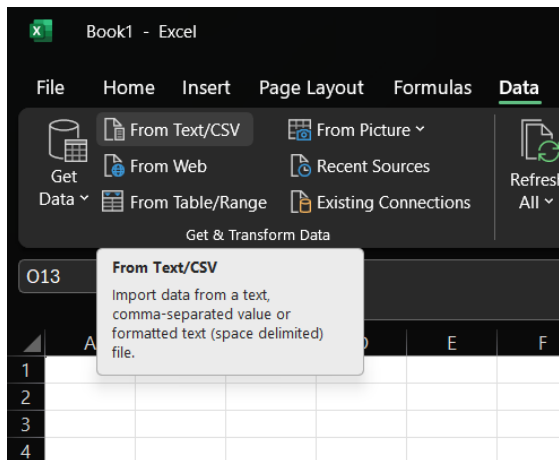


With the right button, datalogging can start.



The blinking of the yellow diode is to indicate that the recording is in progress.

After recording the data, the CSV file is created with “,” as a separator. To read the file we recommend use of Excel (or similar software), following the steps: Data -> Read from CSV -> Load.



## 8. Activity Execution

Below is a list of exercises on a different level of complexity. It is up to a teacher to choose which exercises to run with a particular group of students.

### 8.1 Making sense of ppm

#### Objective:

To understand what “ppm” means, measure CO<sub>2</sub> levels in different environments, and analyze how concentration changes over time.

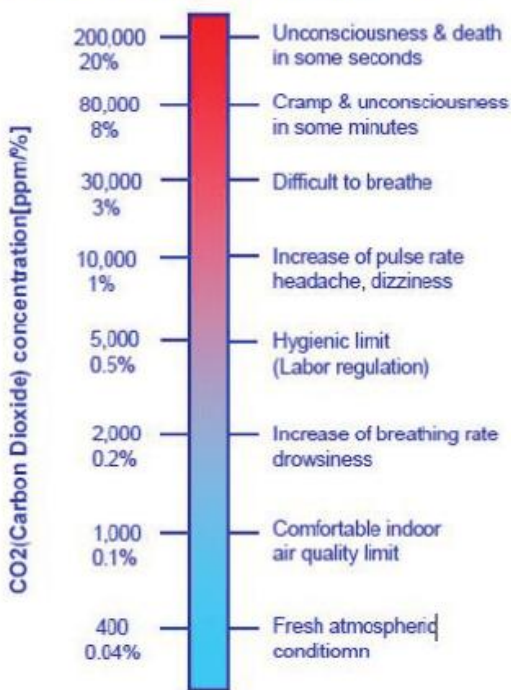
#### Procedure:

1. Turn on the CO<sub>2</sub> sensor and wait a few minutes until the readings stabilize (warm-up).
2. Start recording data with the detector. While it runs, observe the values live on the display.
3. Take the sensor around:
  - Measure in the classroom.
  - Step outside and compare outdoor values.
  - Breathe on the sensor briefly in open air (note the quick spike).
  - Place it in a closed jar/box, exhale inside, and cover (note how long the values stay high).
4. After finishing the walk/experiments, stop the recording.
5. Connect the sensor to a computer via USB-C. Locate the most recent CSV file (separator = “,”), copy it to your device, and free up logger memory.
6. Make a scatter plot: CO<sub>2</sub> concentration (ppm) vs. time (s).
7. Compare the graph with your observation notes:
  - When you moved indoors/outdoors,
  - When you breathed on the sensor,
  - How quickly the values rose and fell (detector inertia).

## What does this have to do with climate?:

- Outdoor air normally contains ~400–450 ppm CO<sub>2</sub>, while indoor spaces can reach 1000–2000 ppm without ventilation.
- Globally, CO<sub>2</sub> levels before the Industrial Revolution were about **280 ppm**. Today they exceed **420 ppm**, a ~50% increase in just 200 years – the fastest rise in Earth’s recent history. This extra CO<sub>2</sub> traps more heat in the atmosphere, amplifying the greenhouse effect and driving climate change.
- Human breath contains ~40 000 ppm CO<sub>2</sub>, showing how even small emissions in a confined space quickly accumulate.
- By recording, plotting, and linking measurements with observations, students experience how invisible gases can be tracked — exactly how climate scientists monitor the planet’s changing atmosphere.

### How does CO<sub>2</sub> affect the human body?



### ASHRAE Standard

ASHRAE : American Society of Heating, Refrigeration and Air-conditioning Engineers

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<sup>6</sup> <https://gasalarm.com.au/importance-of-co2-measurement-inside-meeting-rooms-classrooms-offices-etc/>

## 8.2 Chemical production of CO<sub>2</sub>

### Objective:

To demonstrate how chemical reactions can produce large amounts of CO<sub>2</sub>, and to measure this gas using both mass changes and direct sensors.

### Procedure:

1. Prepare 5 g baking soda (NaHCO<sub>3</sub>) and 3,8 g citric acid (C<sub>6</sub>H<sub>8</sub>O<sub>7</sub>) dissolved in 30–50 ml of water (vinegar can be used as an alternative).
2. Place the container with the acid solution on an electronic balance and tare it (set to zero).
3. Add the baking soda and observe: bubbling in the liquid and decreasing mass on the display. Record the changes over time.
4. Repeat the experiment in a jar with a lid:
  - Attach the CO<sub>2</sub> sensor under the lid (above the liquid).
  - Start data recording, add the baking soda, and close the jar (leave a small gap for safety).
  - Record the rapid increase of CO<sub>2</sub> concentration for at least several dozen seconds.
5. Export the data file (CSV) and make a scatter plot of CO<sub>2</sub> concentration (ppm) vs. time (s). Compare with your notes from direct observations (bubbles, mass change).

### What does this have to do with climate?:

- The reaction clearly shows the release of CO<sub>2</sub> gas. The “disappearing” mass on the balance and the rising sensor readings are two perspectives on the same process: invisible gas leaving the liquid into the air.
- On a global scale, industrial chemical processes are major CO<sub>2</sub> sources. Burning fossil fuels (coal, oil, gas) adds ~35–37 billion tons of CO<sub>2</sub> annually. Cement production adds another ~2.5–3 billion tons (≈7–8% of global emissions).

- Just like in the jar, the Earth's atmosphere is a closed space: the CO<sub>2</sub> we emit accumulates.

### Optional – calculations:

#### Step 1: Molar Masses

Compound	Formula	Molar Mass (g/mol)
Baking Soda	NaHCO <sub>3</sub>	84.01
Citric Acid	C <sub>6</sub> H <sub>8</sub> O <sub>7</sub>	192.12
Carbon Dioxide	CO <sub>2</sub>	44.01

#### Step 2: Moles of Baking Soda (given)

$$n_{\text{NaHCO}_3} = \frac{5 \text{ g}}{84.01 \text{ g/mol}} \approx 0.0595 \text{ mol}$$

#### Step 3: Stoichiometry

From the balanced reaction:

- 1 mol citric acid reacts with **3 mol NaHCO<sub>3</sub>**, so:

$$n_{\text{citric acid}} = \frac{1}{3} \times 0.0595 \text{ mol} \approx 0.01983 \text{ mol}$$

#### Step 4: Mass of Citric Acid Needed

$$m_{\text{citric acid}} = n_{\text{citric acid}} \times M_{\text{citric acid}} = 0.01983 \text{ mol} \times 192.12 \frac{\text{g}}{\text{mol}} \approx 3.81 \text{ g}$$

#### Step 5: CO<sub>2</sub> Produced

From the balanced reaction:

- The reaction produces **3 mol CO<sub>2</sub> per 3 mol NaHCO<sub>3</sub>**, so:

$$n_{\text{CO}_2} = 0.0595 \text{ mol}$$

$$m_{\text{CO}_2} = 0.0595 \text{ mol} \times 44.01 \frac{\text{g}}{\text{mol}} \approx 2.62 \text{ g}$$

#### Summary:

- One needs **3.81 g of citric acid** to react with **5 g of baking soda**.
- One will produce approximately **2.62 g of CO<sub>2</sub> gas**.

### 8.3 Biological production of CO<sub>2</sub> – yeast and the role of temperature

#### Objective:

To observe CO<sub>2</sub> production during fermentation by yeast and connect biological processes to greenhouse gas emissions.

#### Procedure:

1. Prepare:

- 1 packet of dry yeast (~7 g),
- 1 teaspoon sugar,
- warm water (30–40 °C), around 100 ml
- a plastic bottle or jar,
- a balloon for bottle or lid for a jar,
- a CO<sub>2</sub> sensor with DAQ,
- thermometer to measure water temperature.

2. Add yeast and sugar to the container, pour in warm water (measure the initial temperature), and stir.

3. Close the container:

- If using a balloon, place it over the neck so it can inflate with gas (this is a qualitative demonstration of gas production for younger students)
- If using a lid, attach the CO<sub>2</sub> sensor under the lid (above the liquid) and start recording data.

4. Observe for 15–30 minutes:

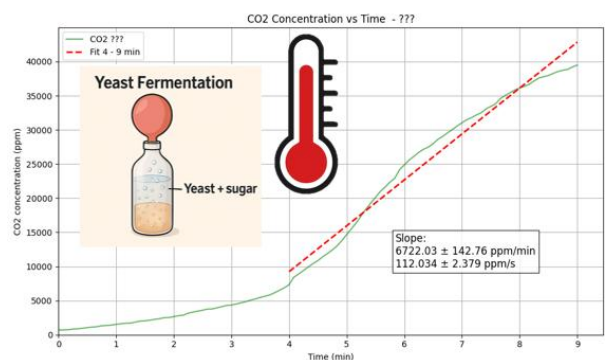
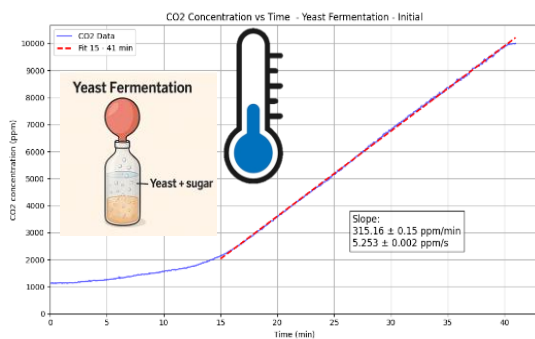
- foam appears on the surface,
- the balloon inflates,
- the CO<sub>2</sub> sensor shows a gradual rise (often several thousand ppm).

5. Export the data (CSV) and make a scatter plot: CO<sub>2</sub> concentration (ppm) vs. time (s). Compare the graph with notes of what you saw happening (foam, balloon inflating).

## Extended version:

Ask students to prepare several containers with water at different temperatures (e.g. cold  $\sim 10\text{ }^{\circ}\text{C}$ , room temperature  $\sim 20\text{ }^{\circ}\text{C}$ , warm  $\sim 30\text{--}40\text{ }^{\circ}\text{C}$ , hot  $\sim 50\text{ }^{\circ}\text{C}$ ). Add the same amount of yeast and sugar to each. Record  $\text{CO}_2$  concentration over time with the sensor (or compare balloon inflation). This extension lets students test how temperature affects the rate of biological  $\text{CO}_2$  production and identify the “optimum range” for yeast activity. It links directly to climate science, since temperature strongly regulates biological processes such as respiration, decomposition, and microbial activity in soils.

In the example below, the rate of  $\text{CO}_2$  release changes over 20 times because of changing the water temperature:



## What does this have to do with climate?:

- Fermentation is a biological process where yeast breaks down sugar into alcohol and  $\text{CO}_2$ . The experiment shows that living organisms can be important  $\text{CO}_2$  sources.
- On a global scale, similar biological processes contribute to greenhouse gas emissions in agriculture and food production. Farming, livestock, and land use changes emit about **6 billion tons of  $\text{CO}_2$  equivalent annually** ( $\sim 15\text{--}20\%$  of human-caused greenhouse gases). Agriculture is one of the major sectors responsible for global warming.

- Dramatic ecological events remind us of the sensitivity of ecosystems: for example, the **mass die-off of saiga antelopes in Kazakhstan**<sup>7</sup> in 2015, where climate conditions enabled bacterial infection that killed over 200,000 animals. Such cases illustrate how subtle shifts in temperature and humidity can trigger large biological feedbacks, just as small microbial processes in this experiment scale up to affect global climate.

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<sup>7</sup><https://www.theguardian.com/science/animal-magic/2016/apr/14/mass-death-saiga-antelope-kazakhstan-bacterial-infection>

## 8.4 Biological production of CO<sub>2</sub> – soil

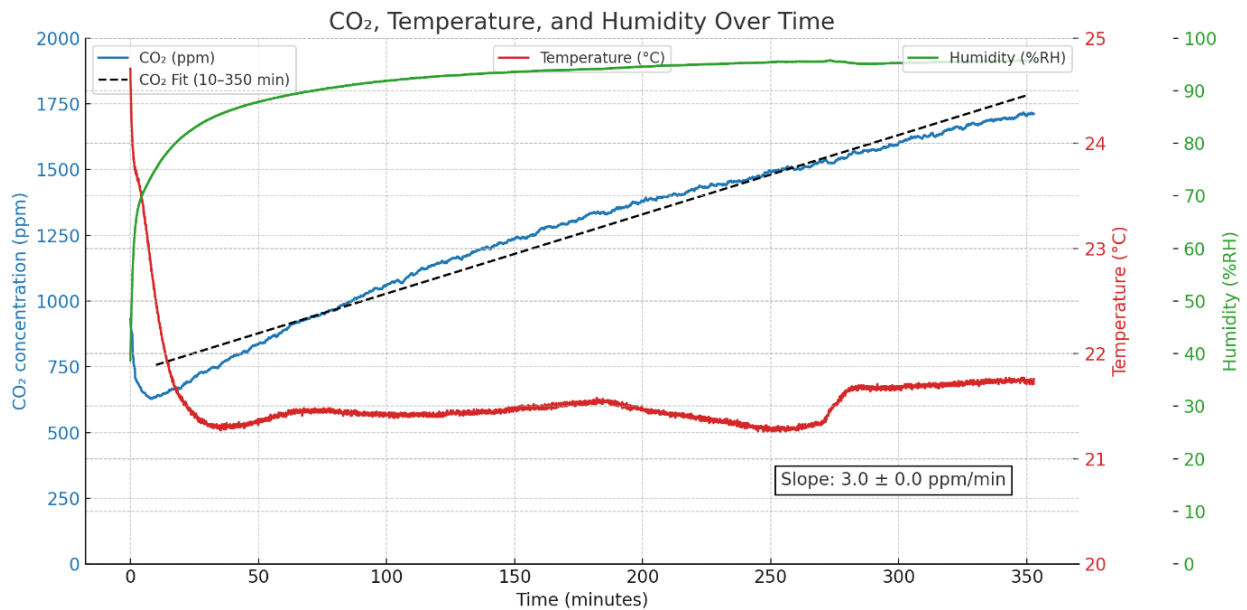
### Objective:

To demonstrate that soil is an active biological system and can be a source of CO<sub>2</sub> due to microbial respiration and decomposition of organic matter.

### Procedure:

1. Prepare a clean jar and place a portion of moist soil inside (do not compact it).
2. Attach the CO<sub>2</sub> sensor under the lid so that it does not touch the soil surface.
3. Close the jar and start recording data.
4. Leave the setup undisturbed for 10–20 minutes.
5. Observe how the CO<sub>2</sub> concentration changes over time.
6. Repeat the measurement with an empty jar (control experiment) and compare the results.
7. Plot CO<sub>2</sub> concentration (ppm) vs. time (s) and relate the curve to what is happening inside the soil.

The graph below presents the changes in environmental parameters over course of a few hours



### **What does this have to do with climate?:**

- Soil contains large numbers of microorganisms that respire and decompose organic matter, releasing CO<sub>2</sub> as a natural part of the carbon cycle.
- Globally, soils store more carbon than the atmosphere and vegetation combined. Small changes in soil conditions (moisture, temperature, organic matter) can therefore strongly affect CO<sub>2</sub> emissions.
- Agricultural practices such as tillage, irrigation, and fertilization influence soil microbial activity and can increase emissions not only of CO<sub>2</sub>, but also other greenhouse gases like nitrous oxide (N<sub>2</sub>O) and ammonia (NH<sub>3</sub>).
- This experiment shows that soils are not passive surfaces but dynamic ecosystems whose management plays a key role in climate change mitigation and adaptation.

## 8.5 Introduction to Smart Farming

### Objective:

To introduce the concept of smart farming by using sensor data to support decisions about plant watering, instead of relying on fixed schedules or intuition.

### Procedure:

1. Prepare a potted plant or a container with soil and a growing plant.
2. Insert a soil moisture sensor into the soil near the plant roots.
3. Connect the sensor to the DAQ module and start data recording.
4. Observe soil moisture values over time under normal conditions (no watering).
5. Water the plant and observe how the soil moisture reading changes.
6. Continue monitoring for several hours or days to see how quickly the soil dries.
7. Discuss or define a **threshold value** below which watering is necessary.

### Extended version:

The smart farming activity can be extended by introducing **automated irrigation**, where soil moisture data are used to trigger watering automatically (e.g. via a relay-controlled pump or valve). Students can define threshold values and test how different strategies affect plant growth and water use.

A further extension is to conduct the experiment inside a **growbox** or mini-greenhouse, where additional parameters such as light intensity, temperature, and humidity are controlled or monitored. This allows students to compare open and controlled environments, explore feedback loops between climate conditions and plant needs, and discuss how controlled agriculture (e.g. greenhouses, vertical farming) can help adapt food production to climate change while reducing resource use.

### What does this have to do with climate?:

- Agriculture is highly sensitive to climate change, especially to increasing drought frequency, heat waves, and irregular rainfall.
- Traditional irrigation often wastes water by watering too early or too late, while smart farming uses real-time data to optimize resource use.
- Sensor-based irrigation reduces water consumption, energy use, and fertilizer runoff, lowering greenhouse gas emissions associated with agriculture.
- This activity introduces students to **climate adaptation strategies**, showing how technology can help ecosystems and food production systems cope with changing environmental conditions.
- The same data-driven logic is used in large-scale agriculture, where sensors, satellites, and models guide decisions that affect global food security and climate resilience.

## 8.6 Building a self-sustaining sealed ecosystem – PBL challenge

### Objective:

To design, build, and monitor a small sealed ecosystem that can function over time without external inputs, and to understand feedback loops, limits, and balances in closed environmental systems.

### Procedure:

1. Divide students into small groups and present the challenge:  
*Build a sealed ecosystem that can sustain itself for as long as possible.*
2. Ask students to bring spare materials such as a transparent jar or container, soil, small plants or moss, water, and optional natural elements (stones, leaf litter).
3. Ask students to plan their ecosystem before building it, considering:
  - amount of water,
  - type and number of plants,
  - presence of soil and organic matter,
  - available light.
4. Place the CO<sub>2</sub>, temperature and humidity sensors connected to DAQ inside the jar, attached to the lid.
5. Start data logging and seal the container.
6. Monitor changes over time (hours, days, or weeks) – compare data readings to visible changes in plant condition (growth, wilting, condensation).

### What does this have to do with climate?:

- A sealed ecosystem is a powerful model of the Earth system: energy enters mainly as sunlight, while matter circulates internally.
- Small imbalances in carbon, water, or energy can lead to large changes over time, just as in the real climate system.

- Rising CO<sub>2</sub> levels, overheating, or water imbalance inside the jar mirror global challenges such as climate change, drought, or ecosystem collapse.
- This activity highlights feedback loops (e.g. plant photosynthesis vs. respiration), delays, and tipping points — key concepts in climate science.
- By designing and testing their own ecosystems, students experience how human decisions influence environmental stability, reinforcing the idea that Earth's climate is not infinitely resilient.

**Optional reflection questions:**

- What made some ecosystems more stable than others?
- Did the system reach a balance, or did it drift toward failure?
- Which processes were fast, and which were slow?
- In what ways is Earth *similar to* and *different from* a jar ecosystem?

# Post lesson follow-up & summary

## 9. Discussion Topics

The following discussion topics help students reflect on their measurements and connect experimental results with broader ecosystem and climate processes:

- **Different sources of CO<sub>2</sub>:** How did CO<sub>2</sub> production differ between chemical reactions, biological processes (yeast, soil), and respiration inside sealed ecosystems? Which sources were fast, and which were gradual?
- **Closed vs. open systems:** How did CO<sub>2</sub> behave in open air, ventilated spaces, jars, and sealed ecosystems? How does this help us understand the Earth's atmosphere as a system? Is Earth an open or closed system?
- **From ppm to climate change:** How does a short-term spike in CO<sub>2</sub> concentration compare to the long-term increase observed since the pre-industrial era? Why is a seemingly small change in ppm important at the global scale?
- **Feedback loops and tipping points:** Which experiments showed stabilizing feedbacks (e.g. plant growth)? Which showed runaway effects or system failure? How do these relate to real climate tipping points?
- **Measurement and uncertainty:** What limitations did you observe in sensors and data logging (warm-up time, inertia, noise)? How do scientists account for similar issues in climate research?
- **Decision-making based on data:** How did measurements guide actions in smart farming and ecosystem design? Why is data-driven decision-making essential for climate mitigation and adaptation?
- **Human responsibility:** Which experimental interventions resemble human actions in real ecosystems? What lessons do these experiments offer for managing land, agriculture, and emissions sustainably?

## 10. Assessment

Assessment focuses on **process, understanding, and reflection**, rather than on correct numerical results. The goal is to evaluate how students use measurements to reason about ecosystems and climate.

### **Formative assessment (during activities)**

Teachers may observe and assess students' ability to:

- correctly set up sensors and data logging;
- record observations alongside numerical data;
- recognize measurement limitations (sensor warm-up, inertia, noise);
- relate changes in graphs to experimental actions and environmental processes;
- collaborate effectively during group-based tasks.

### **Reflection-based assessment**

To emphasize understanding over memorization, students may respond to open questions such as:

- What did the measurements reveal that was not visible at first glance?
- Which experiment changed your understanding of CO<sub>2</sub> and ecosystems the most, and why?
- How does measuring a small system help us understand global climate processes?

## 11. Extensions

Teachers and students are encouraged to design their own extensions using the equipment provided in the toolbox or by expanding its capabilities. The DAQ module supports multiple types of sensors, while platforms such as micro:bit allow for additional programming and customization.

### 1. **Compost and organic waste monitoring**

Measure CO<sub>2</sub> (and optionally other gases) released during composting or decomposition of organic waste, as well as the change in the pile's temperature. This activity connects waste management, biological activity, and greenhouse gas emissions.

### 2. **Real ecosystem measurements**

Perform measurements outside the classroom, such as in a school garden, park, forest edge, or wetland – take DAQ to trips and holidays, build “inquiry culture”.

### 3. **Long-term monitoring projects**

Repeat measurements over weeks or months to observe slow changes in ecosystems. This helps students understand long-term trends, seasonal effects, and the difference between short-term fluctuations and sustained change.

### 4. **Comparing different ecosystem types**

Design and monitor multiple ecosystems (e.g. soil-based, aquatic, moss-based, hydroponic) and compare their gas exchange, stability, and resilience.

### 5. **Linking ground measurements with external data**

Combine sensor data with local weather records, air-quality data, or satellite observations. This introduces students to multi-source environmental analysis used in real climate research.

### 6. **Building IoT systems for environmental monitoring**

Extend the project by connecting sensors and DAQ modules to the internet, enabling remote data access, dashboards, or alerts.