STEAMCITY CURRICULUM

PLANTS & THE CITY
Urban greening thanks to AI

thematic: artificial intelligence and new technologies

sub-theme: environment, well-being and public health

Introduction

As cities seek to become more sustainable, urban greening plays a crucial role. According to the US Environmental Protection Agency (EPA), green spaces in cities provide multiple benefits: **they regulate temperature, improve air and water quality, enrich biodiversity and contribute to better stormwater management**.

This educational protocol invites students to **create their own green wall**, thus combining environmental and technological learning. Through this concrete experience, they will discover the challenges of urban greening while developing skills in experimental sciences.

They will learn how to use **microcontrollers to measure environmental conditions** and will be introduced to new **research tools based on artificial intelligence (such as Copilot, ChatGPT, Gemini)** to select the plants best adapted to their environment.

Interdisciplinarity

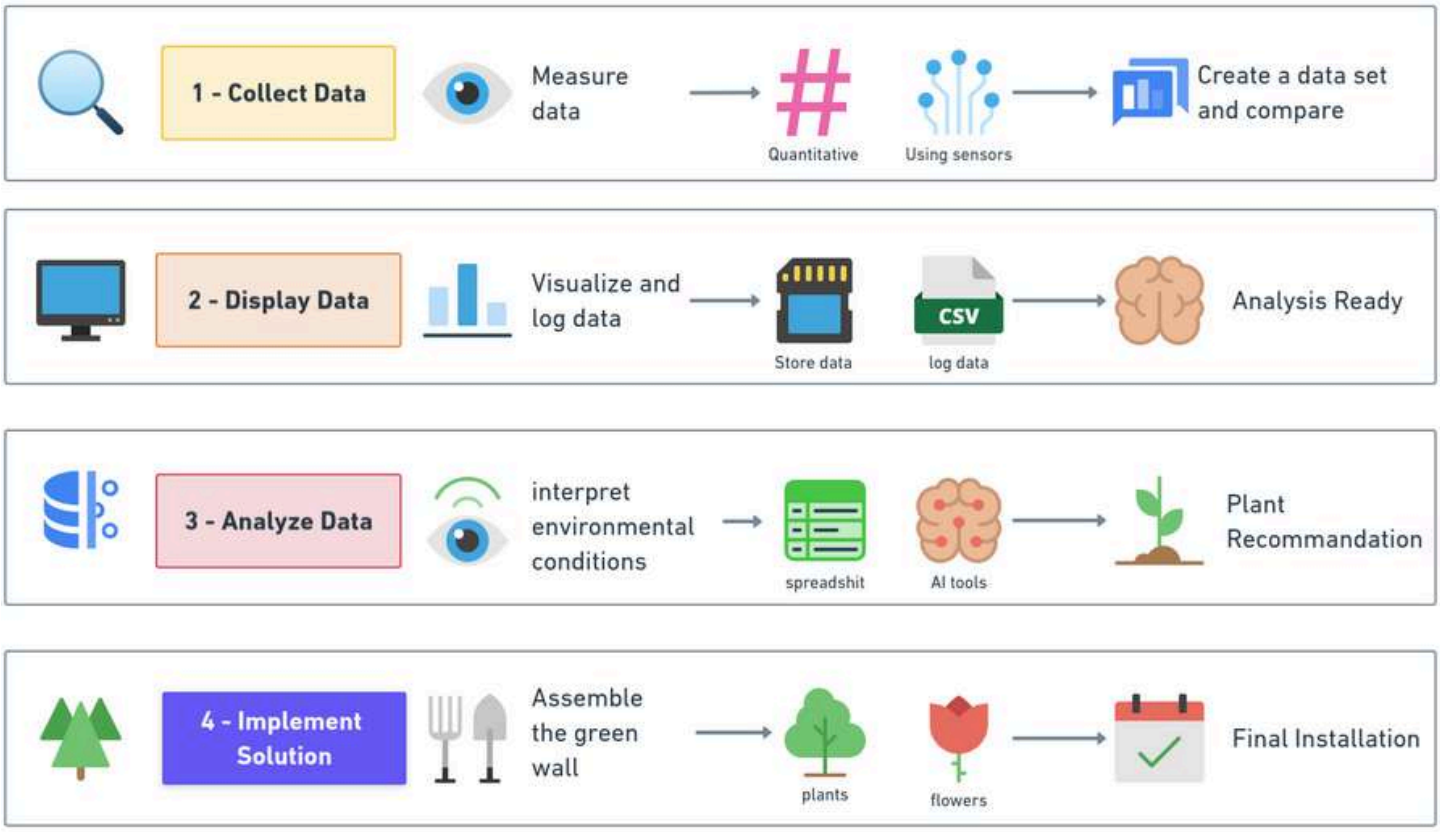
biology, life and earth sciences

technology, engineering

Sustainable Development Goals

Overview

Protocol Structure



Step 1 - Collect data. This first step of the protocol aims to set up an environmental measurement station to characterize the habitat of the future green wall. Students learn to identify the key parameters influencing plant growth (temperature, humidity, light), to assemble and program a measurement station with sensors and a Micro:bit card, and to understand the importance of calibration to obtain reliable measurements. This scientific and technical approach allows students to develop their environmental measurement skills while preparing the informed choice of plant species adapted to their environment.

Step 2 – Display the data to obtain the necessary information. The objective of Step 2 is to set up a system for storing the environmental data collected by the sensors. This step follows the implementation of the sensors in Step 1, adding the ability to record measurements over time rather than just having instantaneous values. Students must choose and implement a storage solution that is appropriate for their context, such as a micro-SD card system or a manual survey. The data collected over an extended period of time will serve as the basis for plant selection in the following steps, ensuring the viability of the green wall.

Step 3 – Analyze the data and learn from it. Step 3 of the protocol focuses on selecting the most suitable plants for our green wall, based on a rigorous documentary study. Using the precise environmental data collected during the previous phases (light, temperature, humidity), students can identify the plant species that will thrive in these specific conditions. To ensure informed choices, the class explores three different research approaches: traditional methods with botanical books and specialized databases, classic web research via horticultural sites, and the use of Artificial Intelligence tools. This diversity of approaches not only provides comprehensive information on potential plants, but also develops students' critical thinking when faced with different sources of information. Comparative analysis of the results makes possible to identify the most promising plant species for the wall, considering their adaptation to the measured conditions, their maintenance needs, and compatibility with each other. Students learn to cross-reference information obtained by different methods, ensuring the reliability of their choices for a sustainable installation.

Step 4 – Use the data to create a green wall. The final step of setting up the green wall is the concrete outcome of the protocol. It allows the physical construction of the wall according to the plans previously developed, accompanied by the installation of a connected monitoring system to monitor the health of the plants. This phase applies all the botanical and technological knowledge acquired to develop a sustainable and intelligent greening solution. This concluding phase allows all the theoretical and technical learning from the previous steps to be put into practice. It transforms environmental analyses, botanical studies and technological skills into a tangible achievement that concretely improves the urban environment. Success in this step demonstrates the students' ability to lead a complete environmental project, from its design to its completion, while integrating innovative technological solutions to ensure its sustainability.

Getting started

Duration: 4+h

Level of difficulty: *Intermediate (10-14 years old)*

Materials needed per group:

- 1 Micro:bit board
- 1 DHT-11 sensor
- 1 Micro:bit Grove Shield
- 3 Grove cables
- 1 x Micro USB Cable
- 1 Grove ↔ Dupont adapter cable
- 4 Dupont Cable Female-Female
- 1 OpenLog micro-SD card reader
- 1 micro-SD card
- 1 5V battery, e.g. power bank

Glossary

Keywords & Concepts	Definitions
Green Wall	A vertical structure covered with plants, used to improve air quality, regulate temperature, and enhance urban aesthetics.
Microcontroller	A compact integrated circuit designed to govern a specific operation in an embedded system. Example: Micro:bit used for environmental measurements.
DHT11 Sensor	A temperature and humidity sensor that provides accurate readings for monitoring environmental conditions.
OpenLog	A micro-SD card-based data logger used to store environmental data collected by sensors.
Light Intensity	The amount of visible light received at a location, measured in lux. A crucial factor for plant growth.
Environmental Variables	Factors such as temperature, humidity, light, and soil composition that influence plant health and growth.
AI Hallucination	A phenomenon where AI generates incorrect or nonsensical information due to limited context or misinformation.
CSV Format	A simple text file format used to store data in a tabular form, separated by commas, for easy import into spreadsheet software.
Plant Adaptation	The process through which plants adjust to their environment, such as climate or soil conditions, for optimal growth.
Urban Greening	The practice of introducing and maintaining vegetation in urban areas to improve biodiversity, aesthetics, and environmental quality.

Protocol

Step 1 - Collect data

Background and description of the problem to be solved in this step: To create a successful green wall, it is crucial to understand the environment in which it will be installed. Several parameters directly influence the growth and resistance of plants, including climate, exposure to light, soil composition, precipitation, air circulation and microclimatic characteristics. In an urban environment, these constraints can be reinforced by factors such as the presence of heat islands, pollution or limited root space. In order to choose plants adapted to these specific conditions, this first step allows students to carefully evaluate the environmental conditions to which they will be exposed.

Learning Objectives: Learn the key environmental variables that play a role in plant growth and health, including temperature, humidity, light, wind, and soil composition. Become familiar with using microcontrollers to make measurements.

Conceptualisation

How can we identify and measure the different environmental parameters that will influence the greening of our wall?

To explore this postulate scientifically, students will focus on two guiding questions:

- **What are the environmental variables crucial for plant life?**
  in order to identify the parameters to measure and understand their impact on plant growth.

- **How to set up an automated and reliable environmental conditions measurement system?**
  in order to develop a rigorous methodology to collect usable data.

Students will be led to approach the following concepts, which will be used in their scientific approach:

- Understanding the concept of **variables**
  Environmental variables play a crucial role in plant growth. Temperature directly influences photosynthesis and metabolism, while humidity is essential for transpiration and nutrient uptake. Light determines growth and flowering, and soil quality, including its pH and nutrient content, impacts the overall health of the plant.

- Identify relevant **and rigorous measurement techniques**
  When it comes to measurement techniques, it is important to understand how the different sensors used work. Each variable requires a specific measurement protocol, and the optimal frequency and duration of measurements to obtain meaningful data must be determined.

- Addressing **calibration** issues
  Finally, instrument calibration is a fundamental step in ensuring measurement reliability. This involves rigorous verification and calibration methods, the ability to identify and correct measurement errors, and validation of results by comparison with professional instruments.

This methodical approach will allow students to understand the complex interactions between the environment and plant development, while developing their critical thinking and technical skills.

This knowledge will be directly applied to select the plant species best suited to their green wall project.

Students Investigation

Define the parameters to ensure optimal plant growth

First, students will determine as a whole class what the important parameters of plant life are, drawing on their current knowledge and the literature. The teacher will be able to lead, guide and complete their conclusions to create a solid knowledge base around the variables related to plant growth.

Create a measuring station adapted to the identified parameters

Students will be divided into groups (according to the number of programmable cards available). The teacher will distribute to each group a set of sensors and a programmable card.

Students will have to identify, with the help of the documentation and the teacher, among the growth parameters defined during the class discussion, the variables that can be measured with these tools.

Once the measurable variables and associated sensors have been identified, the students will assemble the measuring station and create the program to carry out the measurements.

To carry out this activity, we recommend using the Micro:bit board and the DHT11 sensor because they are inexpensive, easy to program and accurate enough for this type of experiment. With these tools, students will be able to measure temperature, air humidity and light intensity.

Air temperature and humidity are measured using the DHT11 sensor, which provides accurate data on these two variables crucial for plant growth.

Light intensity can be measured directly by the LED array on the Micro:bit board. This feature relies on an interesting property of LEDs: while they emit light when current is applied to them, they can also generate a very small current when light is received. By measuring this current, we can estimate the amount of light received.

It will be important to explain this dual operation of the LED matrix to students so that they understand how the board can measure brightness without an additional sensor.

At the end of this protocol, you have access to a "Practical" section which presents you with a solution for programming the measuring station on the Micro:bit card.

Addressing the issue of calibration

The issue of calibration is important to address with students at this stage of the protocol. Indeed, the sensors used provide relative measurements that can vary from one station to another, which allow us to observe trends and variations over time (for example, the evolution of brightness over the course of a day), but which are not as precise as calibrated quantitative measurements. To understand this concept, here are some key points to discuss with the class:

- **What is calibration?** i.e. the process of ensuring that a measuring instrument gives reliable and comparable results
- **Why calibrate?** In order to be able to compare measurements between different stations and obtain absolute rather than relative values.
- **How to calibrate?** In particular, by accessing professional measuring devices (such as a luxmeter).

If you have access to this type of equipment, do not hesitate to carry out a calibration phase, which will allow students to convert their relative measurements into quantitative measurements (for example, associating a brightness level with a value in lux).

Conclusion & Further Reflexion

- **Knowledge Mobilised:** By the end of this phase, students will have a detailed understanding of key environmental factors such as temperature, humidity, and light, and their impacts on plant growth. They will also master the basics of sensor and microcontroller assembly and programming, while understanding the importance of a rigorous scientific approach.
- **Reflection on classroom implementation:** Students will have developed practical skills by working in groups to assemble their measurement station, manipulating technical instruments, and participating in collaborative discussions. This approach highlights the importance of teamwork and learning by doing.
- **General Learning Outcomes:** Students will have acquired technical skills in environmental measurement and the use of digital tools. They will have learned to identify key variables influencing plant growth and to set up an appropriate measurement protocol, while developing their critical thinking in the evaluation of different environmental variables.

This first step lays the foundations for exploring the protocol around the green wall by allowing the installation environment to be scientifically characterized. Thanks to precise measurements of environmental conditions (temperature, humidity, brightness), we will be able to select plant species perfectly adapted to their future habitat. This rigorous, data-driven approach maximizes the project's chances of success by ensuring optimal growth of the chosen plants.

To further explore this phase, you can also open discussions using the following questions:

- **How can the data collected influence plant selection?** Encourage students to think about the relationship between environmental measurements and the specific needs of plants. Temperature, humidity, and light data can be compared to the requirements of different plant species to determine their compatibility with the environment.
- **What other environmental variables might be relevant to measure?** Beyond the variables already measured (temperature, humidity, light), encourage students to think about other factors such as soil quality, pH, air circulation, or wind exposure. This can lead to a discussion about the current technical limitations of their station and opportunities for improvement.
- **How could the accuracy and reliability of measurements be improved?** Focus on issues of calibration, measurement frequency, and comparison with professional devices. This allows you to address the concepts of scientific rigor and data reliability.
- **What are the advantages and limitations of sensors used in an urban environment?** Encourage students to think about the current technical limitations of their station and the possibilities for improvement.

Step 2 - Display the data to get the needed information

Background and description of the problem to be solved in this step: In the first stage, the students built a measuring station equipped with several sensors that measure various environmental variables (temperature, brightness, etc.). However, these stations can only provide instantaneous measurements, without storage capacity for later analysis. It is therefore necessary to add a data recording system, such as a micro-SD card, to store the measurements made.

Learning Objectives: Consider how a system can be improved to address a technical problem.

Conceptualisation

How to set up a data storage system to efficiently store and analyze environmental measurements over an extended period?

To guide students in their investigative process, they can explore the following questions:

- **What devices can be used to record the collected data?** This question encourages reflection on the tools available in the classroom (e.g. micro-SD card, online storage, manual recording) and their respective advantages in order to ensure the sustainability and usability of the environmental measurements collected.
- **Which backup method is best suited to our context?** This reflection allows us to identify the most relevant technical solution based on material and practical constraints, while understanding the importance of observing trends over a long period for precise analysis.
- **Why is it important to capture data over a long period of time?** This question helps students understand the need to observe trends or temporal variations for accurate and reliable analysis of environmental conditions.

Students will be led to address the following concepts:

- **Understanding Data Storage Systems**: Different storage solutions (SD card, database, manual readings) each have their advantages and limitations. Choosing the right solution depends on factors such as the required battery life, frequency of readings, and data accessibility.
- **Mastering data formats and structure**: The organization of the data collected must allow for their future exploitation. This involves defining a format, establishing a nomenclature and ensuring the traceability.
- **Understanding reliability issues**: The reliability of the storage system is crucial to avoid data loss. Students will need to think about potential risks (battery failure, backup error) and how to prevent them.

This approach will enable them to set up a robust system for collecting and storing environmental data, essential for the scientific monitoring of their green wall. The technical skills acquired will also be useful to them in other contexts requiring data management.

Students Investigation

Collective reflection phase

First, students are invited to open a discussion on the different possible methods for saving data collected by sensors. This reflection allows to explore all the more or less technical possibilities, from the simplest to the most complex, in a free manner (sending data using Wifi, taking photos of a screen that displays the data, etc.).

Following this exchange, a collective analysis will identify the solutions that can be achieved with the resources available in class and the programming tool used in step 1 (Vittascience platform for micro:bit).

The teacher will be able to guide the discussion and provide students with the technical documentation that could allow them to identify the feasible solutions.

Technical implementationTechnical implementation can be carried out using two approaches.

- The first is to use an OpenLog reader with a micro-SD card, allowing automatic and continuous data recording.
- The second approach uses a display screen requiring regular manual readings throughout the day.

In the "**Practical Implementation**" section, we have chosen to document the use of the **OpenLog reader**, which is the solution we recommend, although other options such as the screen are also feasible with the standard programming interface.

For classes with the necessary technical skills, a more advanced solution using a WiFi connection can be considered, provided that there is an internet connection at the installation location.

Data collection

The last step is to deploy the measurement station created in step 1 and improved with the data backup solution, on the study site for an extended period. Data acquisition over several days provides a more faithful and representative overview of the real climatic conditions of the site. This extended duration is essential to ensure the relevance of the data collected.

Conclusion & Further Reflexion

- **Knowledge Mobilised:** At the end of this phase, students will have developed an initial and applied understanding of data storage systems and their importance. They will have addressed the concepts of data backup, measurement reliability, and will understand the importance of systematic collection for relevant analysis.
- **Reflection on classroom implementation:** Students will have developed their ability to analyze and solve technical problems by evaluating different data storage solutions. The collective work will have allowed them to develop their communication and decision-making skills.
- **General Learning Outcomes:** Students will have acquired technical skills in data management and storage, as well as in critical analysis of technical solutions. They will have learned to evaluate different technological options and choose the most suitable one for their needs, while taking into account practical and material constraints.

This second step is crucial because it allows us to move from a simple collection of instantaneous measurements to a real monitoring of parameters over time. The students were able to reason and choose logically which was the most suitable solution to the problem posed, then implement it.

The ability to store and analyze data over time is essential to understanding environmental variations and their potential impact on the green wall.

To explore this phase further, several questions can be explored with students:

- **What measurement frequency is most relevant?** Encourage students to think about the balance between data accuracy and storage space management. Too high a frequency can result in redundant data, while too low a frequency could miss important variations.
- **How to organize data effectively?** Get students thinking about data structure (format, organization) to facilitate their future analysis. Clarity and consistency in data organization are essential for data exploitation.
- **How to visualize and interpret the data collected?** Encourage students to think about different ways to represent data (graphs, tables) to facilitate analysis and understanding.

Step 3 - Analyse the data and learn from them

Background and description of the problem to be solved in this step: Now that students have qualitative and quantitative data on the environmental conditions in which the plants will live, they must carry out documentary research to discover which plants will flourish best in these conditions. During this stage, they will be led to use research tools assisted by artificial intelligence (Gemini, Copilot) and to discover the issues related to the reliability of the sources.

Learning Objectives: Become familiar with text generation tools (ChatGPT, Microsoft Copilot, Google Gemini) and master the basics of formulating prompts. Understand the specificities of each tool to identify the most relevant ones for documentary research. Recognize the limitations of text generation models, including hallucinations. Analyze and exploit the data collected using a spreadsheet to derive useful knowledge.

Conceptualisation

How can we use the environmental data collected to determine the most suitable plants for our green wall through documentary research?

To guide students in their investigative approach, they can explore the following questions:

- **How to interpret collected environmental data?** This question encourages students to analyze temperature, humidity, and light measurements to understand site conditions. They will need to use analytical tools (spreadsheets, graphs) to identify important trends and features.

- **How to identify plants adapted to these conditions?** This reflection leads students to make the connection between environmental data and the needs of plants. They will have to use different research tools, including AI, to find compatible plant species.

- **How to formulate effective prompts to obtain reliable information on plant needs using different AI tools (Copilot, Gemini, etc.), while knowing how to verify and cross-reference the sources of the information obtained?**

- **How to verify the reliability of the information found?** This question makes students aware of the importance of validating sources, especially when using AI tools, and encourages them to cross-reference information.

This will allow them to approach the following concepts:

- **Mastering Data Analysis**: Understand how to transform raw data into actionable information through calculating averages, creating graphs, and identifying trends.
- **Understanding Plant Needs**: Identify critical environmental factors for plant growth (light, temperature, humidity) and their relative importance.
- **Develop critical thinking**: Learn to evaluate the reliability of information sources, especially when using AI tools, and understand the importance of data verification.

Students Investigation

Analysis of collected data

Students will be required to conduct a thorough analysis of the collected data. This analysis will include calculating averages and creating graphs showing how environmental variables change over time. The level of analysis will be appropriate to the students' skills.

If you have taken manual measurements, a first step will be to transfer the data to a usable digital format such as a spreadsheet. On the other hand, the data from the micro-SD card reader will be directly usable.

From this data analysis, students will have to determine several key factors to characterize the environment of the future green wall, for example the level of sunlight (full sun, partial shade, shade), or the type of climate (continental, oceanic, Mediterranean). To facilitate data analysis, students will create a structured table to summarize the measurements. This table will include key factors such as light, temperature, and humidity, with their measured values, classification, and impact on plant selection, for example:

Environmental factor	Measured values	Classification	Impact on the choice of plants
Brightness	[min-max]	Full sun / Partial shade / Shade	Notes on suitable plant types
Temperature	[min-max] Average:	Warm / Temperate / Cool	Resistance to heat/cold required
Humidity	[min-max] Average:	Dry / Normal / Wet	Corresponding watering requirements

This structured approach will enable students to efficiently organize their data, establish a standardized classification of environmental conditions, identify correlations between measurements and plant needs, and prepare a solid foundation for literature research. This information will serve as the basis for the next phase of documentary research on suitable plants.

Documentary research: A comparative approach to understanding the contribution of new technologies and AI

The analysis of environmental data carried out previously provided students with precise information on the conditions in which the green wall will have to live: light levels, temperature variations, humidity levels. These data form the basis for identifying the plant species best suited to our specific environment. Based on this information, students will have to carry out documentary research allowing:

- **to identify plants capable of thriving in the measured conditions**
- **to understand the specific needs of each plant species**
- **to anticipate potential maintenance challenges for the green wall**
- **to ensure the sustainability of the project by selecting compatible species**

To carry out this research, students will explore and compare different methodological approaches, combining traditional methods and modern tools with the aim of discovering the added value of technologies assisted by artificial intelligence and the different text and image generation tools.

To develop students' critical thinking regarding documentary research methods and understand the place of new technologies in this process, the class will be divided into three groups.

Each group will explore a different approach to identify plants adapted to the measured environmental conditions:

- **Group 1 - Traditional methods**
  - Use of reference books in botany and gardening
  - Consultation of specialized databases (Flora Data, Tela Botanica)
  - Analysis of horticultural journals and scientific publications

- **Group 2 - Classic web search**
  - Search engine exploitation (Google, Bing)
  - Browsing specialized horticulture sites
  - Participation in online gardening forums and communities

- **Group 3 - Artificial Intelligence Tools for example:**

- ChatGPT (OpenAI) : chat.openai.com
- Microsoft Copilot : https://copilot.microsoft.com/
- Google Gemini : https://gemini.google.com/
- Llama2 (Meta): https://www.llama2.ai/
- Mixtral (MistralAI) : https://chat.mistral.ai/
- Vittascience Platform: https://vittascience.com/ia/text.php

Each group will document their experience according to the following criteria:

- **Time and efficiency:** Time taken to find relevant information, ease of access to resources, amount of information obtained
- **Quality and reliability:** Accuracy of the information found, possibility of verifying the sources, consistency between the different sources consulted
- **Advantages and limitations:** Specific strengths of each method, difficulties encountered, suggestions for improving the research process

Synthesis and critical evaluation of AI tools

Once the group work is completed, students will share their conclusions and focus on comparing each method with the use of AI models. The pooling of findings will allow for a collective analysis of the different research approaches. Students will compare their experiences, identify the strengths of each method, and consider an optimal approach combining traditional tools and new technologies. This collective reflection will lead them to develop a nuanced view of the integration of technologies into their research process, while cultivating their critical thinking in the face of different sources of information. The discussion will focus on how these tools cite their sources and on the consistency of the information provided. Students will share their observations on the relevance of the answers obtained in relation to the specific environmental conditions of their project.

A crucial point of this discussion will be the exploration of the phenomenon of **AI hallucinations**. Through concrete examples, such as the erroneous description of moorhens' supposedly webbed feet, students will understand the importance of verifying sources.

It is important to consider that AI models are constantly evolving and improving rapidly. Examples of hallucinations or errors identified at one point in time may no longer be valid a few months later, as models are regularly updated and trained with new data. This is why it is crucial to develop a methodology for verifying information rather than relying on a list of known errors. This evolving nature of AI further reinforces the importance of adopting a systematic critical approach, regardless of the “reputation” or version of the model used.

Conclusion & Further Reflexion

- **Knowledge Mobilised:** At the end of this investigation phase, students will have developed an in-depth understanding of documentary research methods, comparing traditional approaches and AI tools. They will have acquired essential skills in source validation and critical analysis of information.
- **Reflection on classroom implementation:** Students will have experimented with different research methods through collaborative work in groups. This comparative approach will have allowed them to develop their critical thinking and to concretely evaluate the advantages and limitations of each method.
- **General Learning Outcomes:** Students will have acquired skills in documentary research and in the rational use of AI tools. They will be able to formulate precise queries, evaluate the reliability of sources and cross-reference the information obtained to make informed choices.

This comparative investigation phase is essential because it allows students to develop a rigorous methodological approach while discovering the potential and limitations of the different tools at their disposal. This methodology will

be directly applicable to the design of the green wall, where each decision must be based on reliable and verified data.

The supervised use of AI tools allows students to discover these technologies in a critical and reflective way. While AI facilitates access to information and the analysis of complex data, students also learn the importance of systematically verifying sources and comparing the results obtained. This critical approach is particularly important for the green wall project, where the choice of plants must be based on precise and reliable information to ensure the long-term viability of the installation.

To further this investigative approach, several avenues of reflection are proposed to students:

- **How to optimize your searches?** Students learn to formulate precise and relevant queries, whether for traditional search engines or AI tools.
- **How to assess the reliability of sources?** Development of evaluation criteria and methods for validating information.
- **How to spot potential errors?** Awareness of the limitations of different tools and the importance of cross-checking.
- **How to synthesize information?** Learning techniques for synthesizing and organizing collected data for informed decision-making.

Step 4 – Use the data to create a green wall

Background and description of the problem to be solved in this step: Now that the students have determined the appropriate plants through their comparative documentary research, it is time to move on to the practical phase of setting up the green wall. This crucial stage will allow students to apply their theoretical knowledge while developing practical skills in gardening and project management. The success of this phase will depend directly on the quality of the research carried out previously and their ability to transform this information into concrete actions.

Learning Objectives: Put into practice the knowledge acquired during the documentary research phase for plant selection; Learn the basics of gardening and planting techniques adapted to green walls; Develop skills in project management and collaborative work (task distribution, communication, problem solving); Apply the environmental data collected to optimize plant installation

Conceptualisation

How to set up and maintain a green wall in an urban environment?

Urban greening involves integrating **plant elements** into the **built environment** to create more **sustainable cities**. This approach brings many essential **environmental benefits**: regulating **urban temperature**, improving **air and water quality**, enriching **biodiversity**, and better managing **rainwater**. For **green walls**, this involves creating **vertical ecosystems**.

The project requires understanding essential aspects that have been covered in the previous steps: the **environmental conditions** (light, temperature, humidity) measured in steps 1 and 2, and the needs of the **chosen plants** analyzed in step 3. It now remains to put this knowledge into practice to ensure **successful installation** of the green wall thanks to an adapted **installation system** (structure, substrate, irrigation).

It is essential to understand that any system, no matter how well designed, has **limits and constraints**. In the case of urban greening, these limits may be related to available **resources** (water, nutrients), **environmental conditions** (temperature, light), or the **adaptive capacities** of the plants. Recognizing these **limitations** is not a hindrance to the project, but rather an opportunity to anticipate potential **difficulties** and develop appropriate **solutions**.

This realistic approach makes it possible to design more **resilient** and **sustainable systems**, taking into account constraints while maximizing the expected **benefits**. The **implantation method** includes several steps. First, the **analysis of the installation site**: study of the **orientation**, **exposure to the elements**, and **structural constraints**. Then, the **selection of suitable plants**, based on the environmental data collected and the documentary research carried out.

Finally, the establishment of a **monitoring system**, allowing the parameters to be observed and resources, particularly **water**, to be managed.

Students Investigation

During this stage, students will be required to assemble the green wall, based on the analyses, measurements, skills and knowledge acquired in the previous stages. This phase is intended to be more “free”, in the sense that students will be able to determine, with the help of their teacher, what their green wall project will look like and the distribution of tasks. However, here are some tips for putting this stage into practice.

Understanding the challenges of urban greening

To begin this step, we recommend that teachers initiate a class discussion on the challenges of urban greening, in order to give meaning to the project and contextualize it. This discussion will address current urban environmental challenges (heat islands, pollution, water management) and the solutions provided by greening. After this introduction, divide the class into small thematic groups, each exploring a specific aspect: environmental impact, social benefits or technical innovations. Plan regular exchanges between groups to facilitate the sharing of discoveries. Encourage students to diversify their sources of information (scientific documents, videos, expert interviews) and to share their discoveries through mini-presentations. This approach allows each student to develop their expertise while participating in the construction of a collective understanding of the project.

Collective construction of the project

Once all the contextual elements have been well analyzed, and based on the environmental data collected and their research, it is necessary for students to develop an action plan for the implementation of their project, exploring different dimensions of the project: the scientific optimization of growing conditions, the reasoned selection of plant species, the technical design of the irrigation system and the socio-environmental issues of greening. This methodological approach will allow them to concretely apply their scientific knowledge while developing their autonomy.

The organization of the work should reflect the collaborative nature of the project. Students will naturally be able to share responsibilities according to their affinities and skills: some will be able to focus on overall coordination, others on the technical aspects of the installation, or on the documentation and monitoring of the project. This group dynamic will encourage the emergence of individual talents while strengthening collective cohesion around a common objective.

In addition to the creation of the green wall (creation of the planting system, selection and addition of plants), it is interesting to reuse the skills acquired in programming and electronics in this protocol in order to develop a connected monitoring system incorporating the practices and skills acquired during the previous phases.

The micro:bit board, already used for our first environmental measurements, can be adapted to create a monitoring system for our green wall. The DHT11 sensor will allow us to monitor air temperature and humidity, two essential parameters for plant health. The brightness sensor integrated into the board will give us valuable information on light exposure, allowing us to adjust the positioning of the plants or consider supplementary lighting if necessary.

By adding soil moisture sensors directly into the substrate, we will be able to precisely monitor the water needs of each section of the wall. This data, combined with ambient temperature and humidity data, will allow us to develop a smart watering system that adapts to real-world conditions and the specific needs of our plants.

All the data collected will be displayed on a simple interface that we will program, allowing real-time monitoring of our green wall. This technological approach allows us not only to ensure the good health of our plants, but also to deepen our programming skills through a concrete and useful project.

Reflection and perspectives

Once the project is implemented, students will be able to reflect on the impact of their project on their immediate environment and more broadly on their city. Encourage them to document their approach, create communication materials, or organize awareness-raising events. This civic dimension of the project allows them to position themselves as agents of change in their community.

They will evaluate their project according to their own criteria for success. They will be able to suggest improvements, imagine extensions of the project, or think about new initiatives. This reflection phase will enhance their capacity for critical analysis and their long-term vision.

Going further - Artificial Intelligence as a creative and educational tool in the design of green walls: Generative Artificial Intelligence tools, such as DALL·E, ChatGPT or Midjourney, can be integrated in an innovative way into the design and construction process of the green wall. This approach not only enriches the educational project but also introduces students to the thoughtful and critical use of emerging technologies.

1. AI-assisted design: Students can use DALL·E to generate detailed visualizations of their project by specifying the precise environmental characteristics of their site. For example, they can ask: “Generate a green wall for a north façade with limited sun exposure in a Mediterranean climate.” The AI will produce several design proposals that take into account these specific constraints.

2. Validation and critical analysis: Visualizations generated by AI must be systematically compared with botanical and technical data from reliable scientific sources. This comparative approach allows students to identify potential inconsistencies between AI proposals and real constraints. They thus refine their understanding of the specific needs of different plant species while developing their critical thinking in the face of automatically generated solutions.

3. Virtual alternative and awareness: In cases where the physical implementation of a green wall is not possible, AI can be used to create innovative awareness-raising materials. Students can work on creating series of posters showing the possible evolution of urban spaces with different greening scenarios. They can also develop video mapping projections simulating the plant transformation of facades, or create educational materials illustrating the environmental benefits of urban greening.

4. Iterative process and learning: The use of AI allows for an iterative design process where students can quickly test different plant compositions and evaluate their visual impact. They can adjust their proposals based on feedback and identified constraints, while exploring various design solutions without material constraints.

5. Digital skills development: This approach allows students to develop essential skills in the use of emerging technologies. They learn to master prompts and dialogue with generative AI, to evaluate and validate automatically generated proposals, and to understand the potential and limitations of AI tools.

Here are two generations produced using DALL·E on the creation of a green wall in two climatic and urban contexts:

Prompt 1 - Create the implementation plan for a green wall in the city of Marseille
Creating a species implantation plan for a green wall in Marseille requires a selection adapted to local conditions: a Mediterranean climate characterized by hot and dry summers, mild winters, intense light, and moderate humidity.

Characteristics of the green wall

- **Sun exposure:** Check the orientation to adjust the distribution of plants. Marseille receives a lot of sun, so a southern orientation will require heat-resistant plants.
- **Watering:** A drip irrigation system is recommended for controlled humidity.
- **Substrate:** Light, well-drained substrate, enriched with organic matter.

Selection of plants suitable for Marseille and General layout plan

- **Sun-tolerant perennials** (top of wall)
  - **Sedum spectabile** (stonecrop): Drought-resistant and colorful.
  - **Euphorbia characias** (Mediterranean spurge): easy to maintain.
  - **Lavandula angustifolia** (lavender): Fragrant and suitable for dry climates.
  - **Phormium tenax** (New Zealand flax): Structural and colorful.
- **Hanging plants** (middle and bottom of the wall)
  - **Helichrysum italicum** (immortelle): Aromatic silvery foliage.
  - **Lonicera nitida** (dwarf honeysuckle): Density and flexibility to cover the wall.
  - **Erigeron karvinskianus** (fleabane): Flowers abundantly.
  - **Rosmarinus officinalis 'Prostratus'** (creeping rosemary): Persistent, aromatic and robust.
- **Trellis plants** (framing the wall)
  - **Trachelospermum jasminoides** (star jasmine): White, fragrant flowers.
  - **Bougainvillea glabra**: Bright color, ideal for Marseille.
  - **Passiflora caerulea** (passion flower): Exotic and resilient.
- **Partial shade plants** (shaded side)
  - **Asplenium scolopendrium** (deer's tongue fern): Adds texture.
  - **Heuchera spp.** (heuchera): Colorful decorative foliage.
  - **Carex oshimensis 'Evergold'** (sedge): Elegant and easy to maintain.

illustration representing the green wall adapted to the Mediterranean climate of Marseille. You can observe the different planting zones and the arrangement of the adapted species

detailed sketch representing the organization of the different zones of the green wall, with annotations indicating the types of plants and their location

Prompt 2 - Create the implementation plan for a green wall in the city of Brest
The city of Brest, located in Brittany, has an oceanic climate. This means moderate temperatures all year round, high humidity, frequent rainfall, and sometimes reduced light. These conditions influence the selection of plants.

Characteristics of the green wall

- **Climate and exposure:** Cooler and more humid than Marseille, less drought. Variable exposure.
- **Watering:** High ambient humidity reduces the frequency of necessary watering.
- **Substrate:** Draining substrate, enriched with organic matter, suitable for constant humidity.

Selection of plants suitable for Brest and General layout plan

- **Perennial and moisture-resistant plants** (top of the wall)
  - **Fatsia japonica** (aralia): Large exotic leaves.
  - **Dryopteris spp.** (ferns): Tolerates shade and humidity well.
  - **Alchemilla mollis** (lady's mantle): Soft, bright foliage.
  - **Heuchera spp.** (heuchera): Colorful foliage, tolerates humidity.
- **Hanging plants** (middle of the wall)
  - **Lonicera nitida** (dwarf honeysuckle) : Retombant.
  - **Vinca minor** (periwinkle): Evergreen foliage and small flowers.
  - **Campanula portenschlagiana** (bellflower): Cascading flowers.
  - **Hedera helix 'Miniature'** (dwarf ivy): Trailing, hardy and graphic.
- **Plants for the base of the wall** (lower area)
  - **Ajuga reptans** (creeping bugle): Perfect for covering bases.
  - **Primula vulgaris** (primrose): Brilliant flowering in cool climates.
  - **Hosta spp.** (hosta): Lush foliage, ideal for humid areas.
- **Climbing plants** (framing the wall)
  - **Hydrangea petiolaris** (climbing hydrangea): Flowers adapted to shade.
  - **Clematis montana** (clematis): Spectacular flowering.
  - **Parthenocissus tricuspidata (Virginia creeper): Dense, colorful foliage.**

illustration representing a green wall designed for the city of Brest, integrating plants adapted to the oceanic climate and a typical urban environment

detailed sketch representing the organization of the different zones of the green wall, with annotations indicating the types of plants and their location

Conclusion & Further Reflexion

- **Knowledge Mobilised:** To set up the green wall, students used their skills in environmental analysis, their botanical knowledge and their mastery of technological tools. They also developed practical skills in gardening and irrigation system management.
- **Reflection on classroom implementation:** This final phase made it possible to translate theoretical learning into tangible achievement. Students had to demonstrate adaptability and creativity to overcome practical challenges, while rigorously applying their scientific knowledge.
- **General Learning Outcomes:** Students developed their ability to apply their knowledge of botany in a real-world context. They acquired expertise in setting up and using environmental monitoring systems. The project allowed them to develop skills in collaborative management and technical problem solving. Finally, they improved their communication skills and learned how to effectively document a scientific process.

Overall assessment of the protocol: This educational project allowed students to develop expertise combining science, technology and environmental awareness. Progression through the measurement, analysis, design and implementation phases built their understanding of the challenges of urban greening. Students worked on collecting and analyzing environmental data, designing a monitoring system, applying botanical and ecological principles, project management and documenting the scientific process.

This experience reinforced their role in environmental change within their school community. By using technological tools to develop concrete ecological solutions, they demonstrated how innovation can serve sustainable development. This pedagogical approach constitutes a model for teaching science and technology to address current environmental issues.

From this work, it is possible to open new avenues of study and collective questioning:

- **How to adapt this system for other urban contexts?** Exploration of the possibilities of adapting the system for different urban environments, taking into account the constraints specific to each situation.
- **What technological improvements could optimize the system?** Identification of possible technical innovations to improve the efficiency and performance of the greening system.
- **How to measure the real environmental impact of the green wall?** Development of methodologies to quantify the concrete environmental benefits of the project, particularly in terms of air quality and biodiversity.
- **How to share this experience with other institutions?** Development of strategies for disseminating and sharing the knowledge acquired to enable the reproduction of the project in other educational contexts.

Practical Implementation

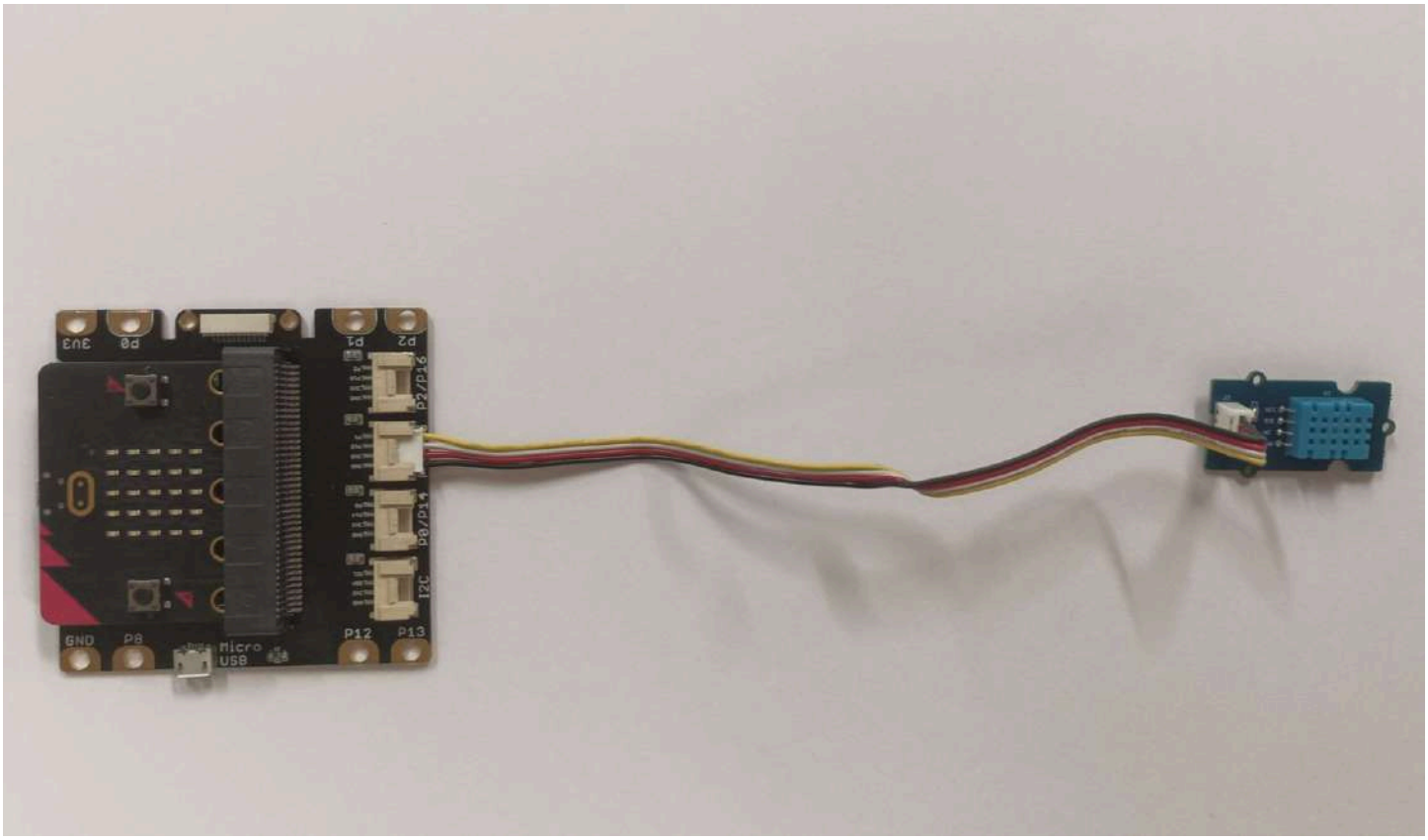
Create and program our measuring station

In our example, the measuring station was programmed on the Vittascience platform: Vittascience — Micro:bit

Collect Data - Setting up and programming the measuring

Station assembly

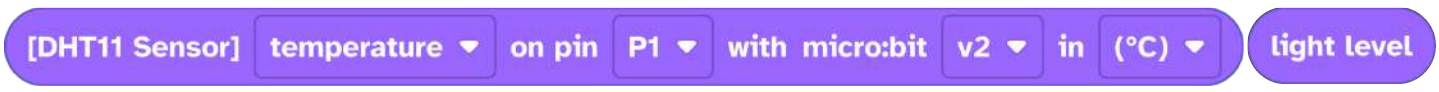
The micro:bit card must be connected to the grove shield. The temperature/humidity sensor can be placed on pins **P1/P15** or **P2/P16** of the grove shield.



Station programming

The code of this part can be found by following this link: Vittascience — Micro:bit

The purpose of this station is to measure temperature, relative humidity and ambient brightness, and display them at regular intervals on the computer. To carry out the measurements, we will need the following blocks, available in the **sensors** category:

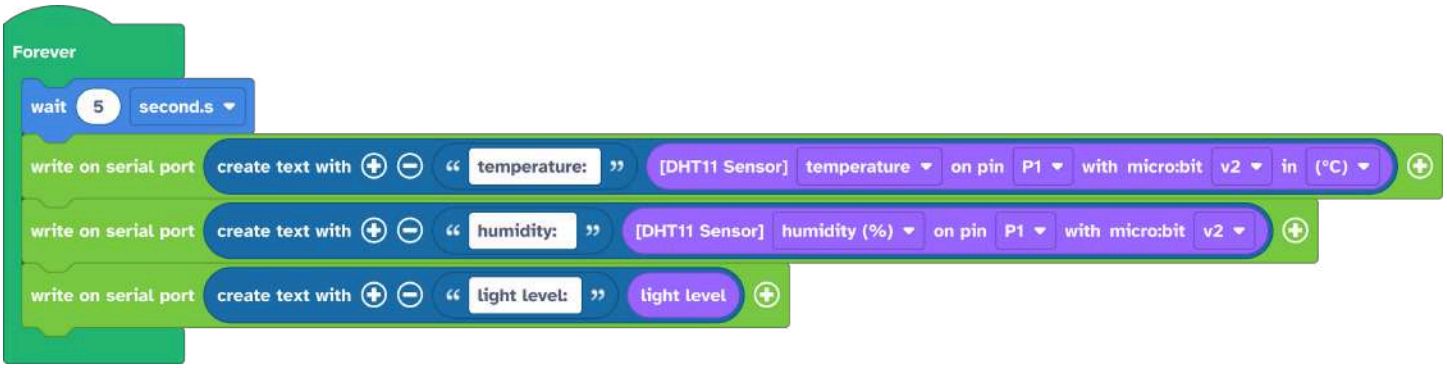


To display blocks in the computer console, the block to use is this one, present in the **communication** category:

To facilitate display in the console, you can use the following block in the **text** category:

Finally, to avoid flooding the console with measurements, you need to slow down the program. To do this, the following block in the **Inputs/Outputs** category must be used:

The final program is as follows:



The program only works if you have connected the DHT11 to the nearby P1/P15 of the shield grove. If you have connected the DHT11 to another pin, you will need to modify the program accordingly. Also, if you have micro:bit V1 and not V2 (to verify, check the writing on the back of the board at the bottom right), you will need to modify the program accordingly.

Program test

To download the program to the micro:bit card, first connect it to the computer via USB.

⚠ You need to connect the USB cable to the card's micro USB port, not to the grove shield, which is only capable of powering the micro:bit.

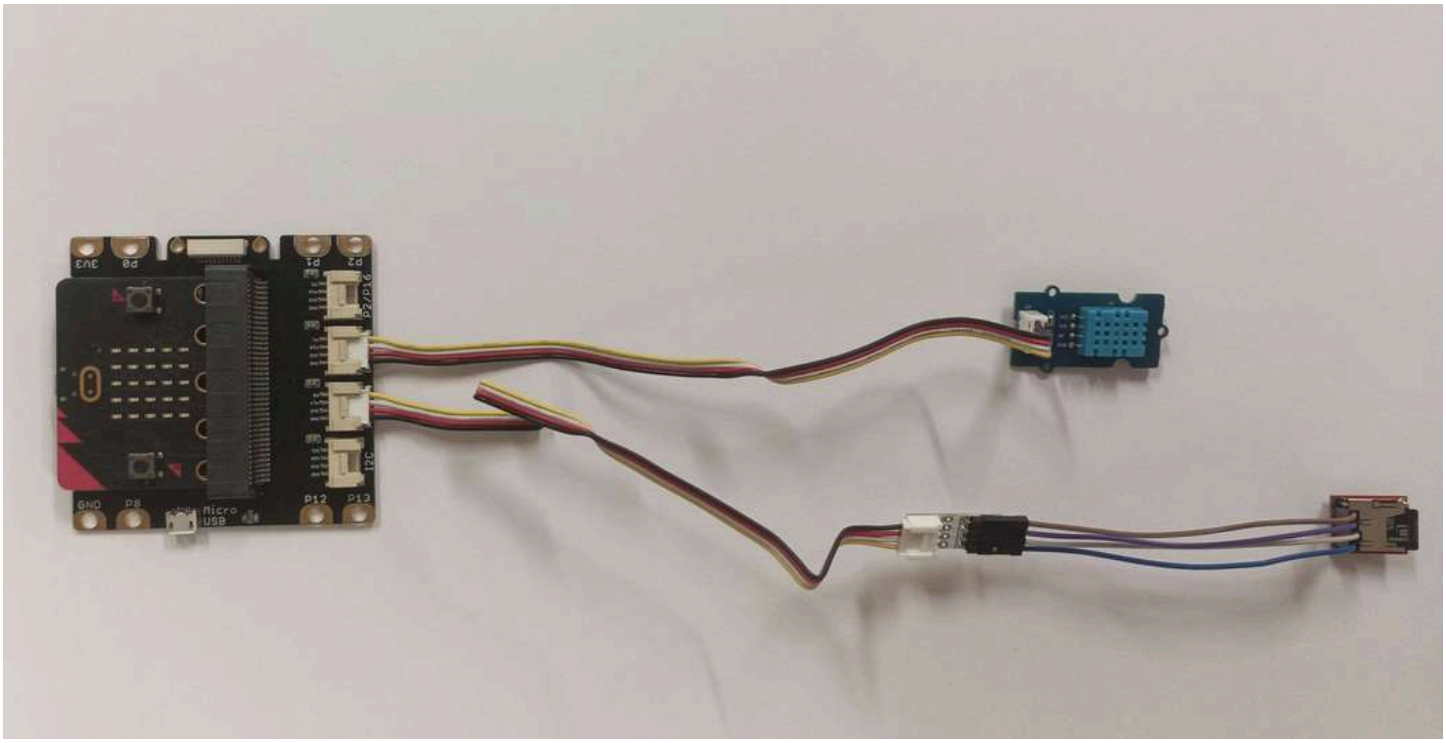
Next, click on the upload button at the top center of the programming interface, select the card and confirm. A second window will appear, asking you to pair a serial port. Select the first (and normally only) port in the list, then click on confirm. The card should now send data to the computer every 5 seconds, which should be displayed on the interface console at the bottom of the screen.

💡 It is normal for the DHT11 sensor to return 0 for temperature and humidity at the start of the program, as it is initializing. After a few tens of seconds, the temperature and humidity measurements should appear correctly.

Display Data - Setting up and programming the measuring station

Station assembly

The OpenLog reader must be connected to the P0/P14 port of the grove shield, using the Dupont ↔ Grove adapter, so that the **GND**, **VCC**, **TXO** and **RXI** pins of the OpenLog are respectively connected to the **black**, **red**, **white** and **yellow** wires of the grove cable.



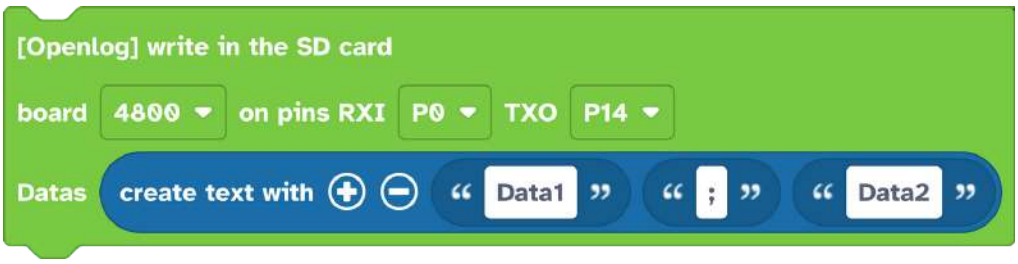
Station programming

The code of this part can be found by following this link: 🌐 Vittascience — Micro:bit

The challenge here will be to save the data collected on a micro SD card, in a format that can be used by a spreadsheet program, so as to be able to analyze the results obtained. To achieve this, the data will be saved in CSV format. This simple text format allows you to simulate a spreadsheet by separating columns with a comma, semi-colon or space, and rows with a line break. Here's an example of a CSV file:

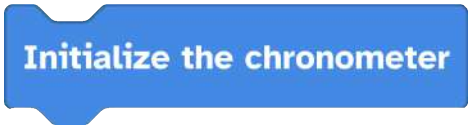
```
name;first name;birth date

Bocuse;Arnaud;30/03/1997

Leloup;Davy;14/02/1968

Neri;Régis;07/09/1990
```

In the program, column headers are written to the sd card, followed by the data. The data is written using the following block in the **communication** category:

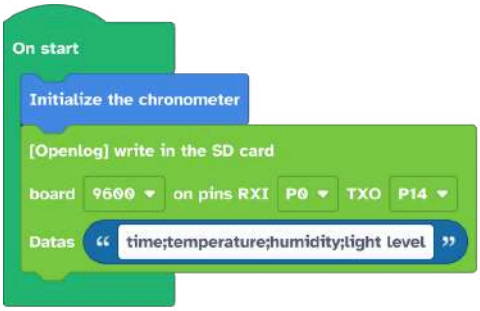


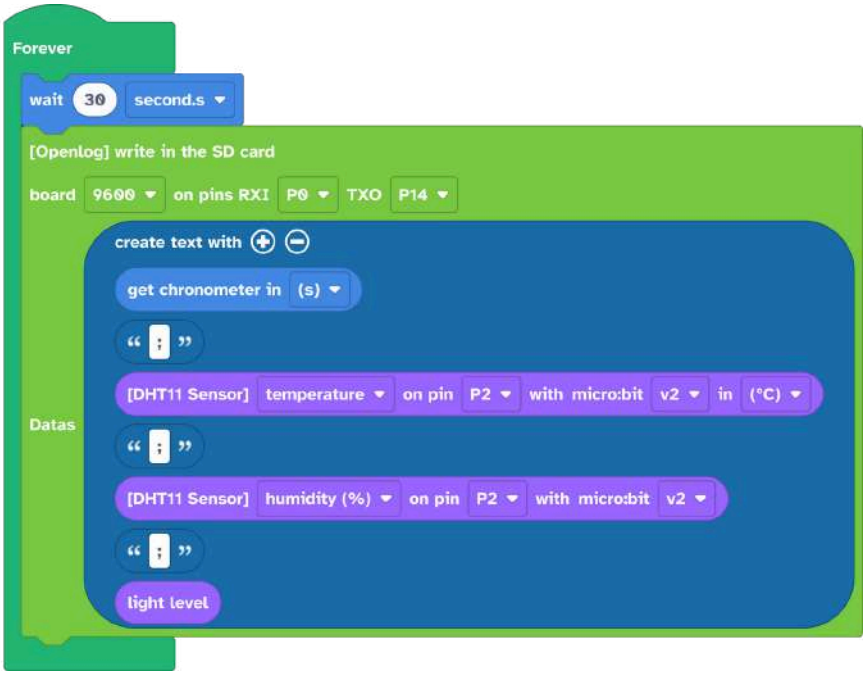
In addition to temperature, humidity and luminosity, it may be useful to record the time corresponding to each measurement.

To do this, use the following blocks to start a stopwatch and retrieve its value:



The final program is as follows:





As in the previous section, this program only works if the DHT11 is connected to pin **P1/P15** and OpenLog to pin **P0/P14**.

Test the program

As in the previous section, you need to connect the card to the computer via USB, and upload the program. Don't forget to insert a micro-sd card in the OpenLog reader. If everything is working correctly, the blue LED should flash every time data is sent to the sd card (in this case, every 30 seconds). If something goes wrong with your setup (or if you forget to insert the card into OpenLog), it may flash blue 3 times at regular intervals to indicate that something is wrong.

Once the measurements are complete, you can retrieve the micro-sd card and insert it into a computer. A file named logXXXXX.TXT (with the X's being numbers) should then appear, and the data should be stored in it. You can then import this data into the spreadsheet program of your choice.

Doing the measures

Once the station has been set up and programmed, it is advisable to create a case to contain the board and power bank, so that the measurement station can be placed at the measurement site without the risk of deterioration due to the weather.

Exploring the issue through other initiatives

Plant monitoring

A simple improvement to this protocol would be to add a capacitive soil moisture sensor (like the Grove Moisture Sensor v1.4) to measure the moisture level of the substrate. This sensor, which is easy to integrate with the micro:bit via the Grove shield, can detect when plants need to be watered. Simply connect it to an analog port and use the "read analog value" block to get a measurement between 0 (very dry) and 1023 (very wet). To go further, students could take inspiration from systems used in urban agriculture like Farmbot that integrate more sophisticated sensors: electrical conductivity (EC) to measure nutrient concentration and a pH meter to monitor the acidity of the substrate. This additional data allows for more precise monitoring of plant health.

Plant growth timelapse

Setting up a timelapse system, similar to Raspberry Pi's GrowLapse project, would allow the wall's evolution to be visually documented. Students could use a Raspberry Pi camera programmed to take photos at regular intervals (e.g. every 12 hours) and create a time-lapse video showing the plants' growth over several weeks or months.

This video could be shared on the school's social networks, presented during exhibitions in the school hall, or even screened during neighborhood events to raise awareness in the community about the challenges of urban greening.

AI-assisted design

It may be interesting to introduce students to other types of generative AI such as image generation, by having them generate images of green walls by taking as a base an image of the place to be greened, and modifying it with the AI model. The use of tools such as Midjourney or DALL-E (https://openai.com/dall-e-3) could help visualize the final result before installation. These visualizations could be exhibited in public spaces in the neighborhood (libraries, neighborhood town halls, community centers) to raise awareness among residents about the possibilities of urban greening. For example, students could use specific prompts such as "vertical green wall in a schoolyard with Mediterranean plants" to generate different development proposals, present them during a public exhibition, and allow residents to vote for their favorite concepts.