STEM Project

Development of a Climate Controlled Smart Garden System (CCSGS)

Main school subjects involved

Biology & Informatics/Robotics

Complementary school subjects

Chemistry, Sciences, Economics

Participant Schools

School 1 Logo	School 2 Logo	School 3 Logo	School 4 Logo
School 1 Name	School 2 Name	School 3 Name	School 4 Name

Supporting Organizations

Organizational Endowment

International Schools Association (Switzerland)

Academic Advisor

Federal University of Rondonopolis (Brazil)

Agricultural Advisor

Fondo Cascina Don Guanella Coop. Sociale (Italy)

School term:

September 2024 - April 2025

Introduction

Greenhouses are designed to capture sunlight and create a controlled environment suitable for gardening. Normally, people manually control the soil quality and adjust the heat, light, and water that plants receive. However, the introduction of new and affordable technologies allows the automation of this process.

School greenhouses are an excellent way to introduce STEM education and teach students a wide range of concepts such as agriculture, ecology, food sustainability, energy sources, and the influence of climate. Modern technology enables climate control and process monitoring, providing challenges through which students can access extensive engineering and science knowledge applied to these systems.

Four secondary schools will form teams of students (ages 12 to 18) to work on this project throughout the school year under the supervision of a leading teacher. Each school team will be divided into sub-teams: the ICT sub-team, responsible for the construction and automation of the greenhouse, and the BIO sub-team, responsible for growing plants. Schools will receive the same type of tomato seeds from the same manufacturer and can purchase hardware for building the automatic control system.

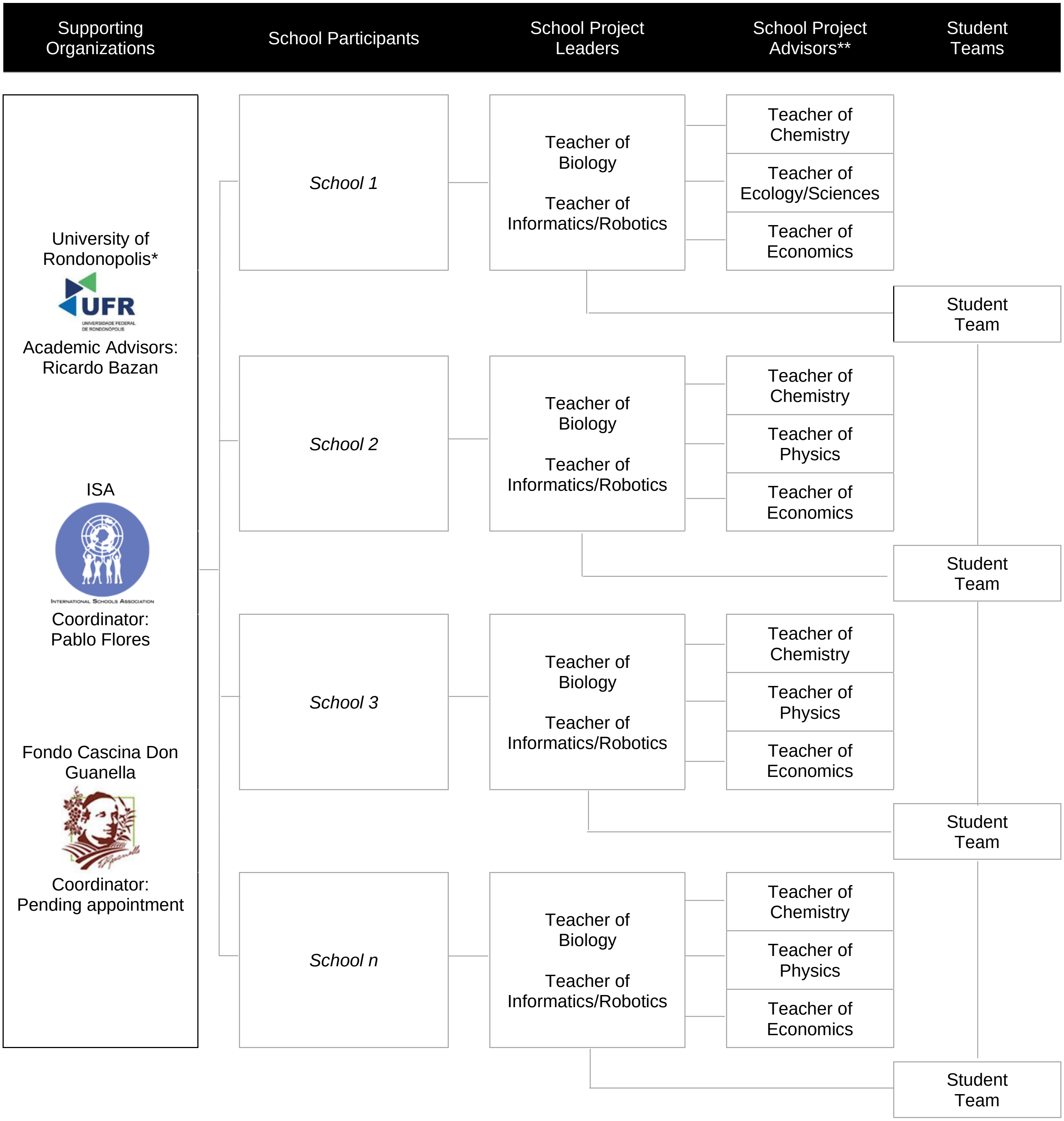
Each school team will build its own greenhouse and all schools will sow the seeds on the same day in November. Throughout the school year, students from all schools will collaborate through an online platform where they can share experiences and compare results. At the end of the project, the schools will present their work to a panel of experts from the supporting organizations, which can be presential at the farm of the Fondo Cascina Don Guanella Coop. Sociale, in Lecco, Italy, or online.

This project is student-driven, with teachers acting solely as supervisors of their teams. Students will engage in independent learning through various activities, project stages, and problem-solving tasks. The project will provide practical experience in agricultural and environmental issues and involve designing and building a system to monitor and optimize plant growth. Additionally, these activities will help young learners develop and strengthen both their cognitive skills, such as problem-solving, and non-cognitive skills, such as motivation to learn, environmental stewardship, multicultural communication, and teamwork.

Learning Objectives:

- *Develop an understanding of the principles of gardening and plant growth*. Students will learn about the principles of gardening and plant growth, including the importance of soil quality, watering, and sunlight in the growth of plants.
- *Develop an understanding of Internet of Things (IoT) technology*. Students will learn about the basics of IoT technology, including sensors, data collection, and wireless communication.
- *Develop technical skills in designing and building a smart gardening monitoring system.* Students will gain practical experience in designing and building a smart gardening monitoring system using hardware components such as sensors, microcontrollers, and wireless communication modules.
- *Develop teamwork and communication skills*. Through collaboration and communication with their peers from different parts of the world, students will learn how to work effectively as a team towards a common goal.
- *Foster an appreciation for sustainability and environmental responsibility*. Students will learn about the importance of sustainable gardening practices and how their project can contribute towards reducing their school's carbon footprint.

Organizational Workflow



** Department of International Relations.*

*** School Advisors can develop their own subprojects. For instance, the teacher of Economics may develop a subproject regarding the market analysis for the CCSGS, or the teacher of Physics may create a subproject to study the sources of heat and energy in and around the greenhouse.*

Two organizations are supporting the project with knowledge transfer and supplies: the University of Rondonopolis (Brazil) and the Fondo Cascina Don Guanella Coop. Sociale (Italy). They will provide dedicated lectures for a small fee during the project's development. These lectures are intended to support school teams with the necessary knowledge and help solve any challenges that arise.

Each school will have two teachers as project leaders related to the subjects of Biology (since the project focuses on agriculture) and Informatics/Robotics (due to the greenhouse automation process). Additionally, project leaders should collaborate with other teachers in related subjects such as Chemistry, Physics, Sciences, and Economics.

Project leaders must encourage their students to interact with students from other schools by exchanging experiences, ideas, and data, thereby strengthening their intercultural communication skills. Teachers of the same discipline are also encouraged to share experiences and information with each other.

To facilitate these interactions, a common platform will be needed for each subject involved in the project. Teachers can choose the most suitable platform for their subjects. Several platforms are available, such as Discord, Padlet, Google Workspace, MS Teams, or Slack.

Technical Characteristics

The Greenhouse

Every school must build its own greenhouse. There are no specific technical characteristics or limitations, which means that each school can build it according to its own criteria and possibilities. All schools will be supplied with exactly the same type of seeds from the same provider. During the preparation stage of the project, teachers of biology and ICT/Robotics will discuss details about the most convenient design.

The Automatic Control System

- All schools will be provided with the same hardware:

  1) The micro:bit Smart Agriculture Kit, which is a collection of micro:bit extensions that can be used in monitoring agriculture or similar applications with education purposes. The kit can be purchased from the Greek organization STEM Education (why.gr).

- Soil moisture sensor. It will detect the moisture of the soil and water it automatically if the value is less than the threshold. The water level sensor detects the water level in the container and display its status on micro:bit.

- Temperature sensor - to measure the temperature in the greenhouse.
- Humidity sensor - to measure the humidity levels in the greenhouse.
- Light intensity sensor - to detect the ambient light intensity with the micro:bit, if the light intensity is too weak, turn on the light automatically; or it turns off.
- Crops Sunshade Device - If the light intensity is too strong, the sunshade device will be lifted automatically to protect the crops. Photosynthesis is essential for plant growth, but excessive light can also harm plants physiologically, causing leaf burn or sunburn. To protect crops from these effects, a crop sunshade device can be used to filter out intense sunlight.

2) **Oxygen Sensor.** Oxygen sensor I2C can measure the O2 concentration of the environment with high accuracy. It can be applied in places such as industries, mines, warehouses and other places where air quality control is necessary.

3) **CO_2 Gas Sensor.** Octopus (MG811) CO2 Gas Sensor is a CO2 electronic brick. The higher the CO2 concentration is, the lower the output voltage would be.

4) **UV Sensor.** It can measure the total UV intensity of the sunlight; linear signal voltage output; and it can be used as UV dosimeters, flame detection, etc.

5) **Open-source Internet of Things (IoT) platform.** ThingSpeak is a free platform that allows to collect, store, and analyze data from sensors in real-time. It provides a user-friendly interface for users to manage and visualize their sensor data, making it easy to track changes in environmental conditions and make informed decisions. The data can be accessed from any device with a password.

Operational Characteristics & Estimated Schedule

Time Frame	Work	Operational Characteristics
August - October 2024	Project design	- Creation of Working groups per subject. Exchange contacts. First zoom meeting. Discussion of details. - Preparation and completion of the Greenhouse structure in each school. - Acquisition of the hardware by every school. - Start the design and construction of the automatic system.
November 2024	Start the operation of the Greenhouse	- Acquisition of the seeds by every school. - Sowing the seeds. - Second zoom meeting between project leaders (teachers of biology and informatics) from all schools involved. Discuss changes, ideas and troubles found to start operating the system.
December 2024 - March 2025	System monitoring	- Introduction of improvements and readjustments in the system. It is up to each school to introduce changes in the system according to their own needs. - Several zoom sessions must be carried out between the teams in order to share their experiences, discuss arising issues, and exchange useful information. The time and frequency must be agreed between project leaders. - One lecture per month would be provided by the Greek organization STEM Education in order to explain details of the system and solve raising questions regarding its functioning.
April 2025	End of the project	Presentation of the works in the Cascina Don Guanella (Italy), before a panel of experts. Closing ceremony.

Documentation of the Activities

Each team, in each school, should have a "Development report diary" to register details like stages, problems found, things to improve, etc. Project leaders may appoint a student that should be responsible for keeping that diary, take pictures and make short videos on the activities of his team.

Team "………" School Activity Diary		Teacher Supervisor________________________ Team coordinator________________________ Team members___________________________ ___________________________ ___________________________		School Logo
Lesson #	Activity	Working reflections	Difficulties found	Suggestions

Example of diary of activities

It is very important to keep properly the activity diary, since this diary will be the main source of information for the final writing of the research papers, and for the future continuation of similar projects with new students.

Blogging

- Blogging in the classroom, especially throughout project work, is a great way for students to document their work and experiments.
- The blog serves as a platform upon which to post written editorials, videos, photos, how-to instructions, and more.
- This would be a great way for students to take initiative, get involved, and share their stories with others.
- This type of documentation is recommended in the greenhouse classroom along with the Diary of Activities.

Safety

Safety is of utmost importance when developing a Smart Garden System in a greenhouse. As this project involves working with students, it is crucial to ensure the highest level of safety measures are implemented throughout the entire process.

First and foremost, electrical safety should be a primary concern. All electrical components, such as sensors, actuators, and control systems, must be properly installed and maintained. It is important to follow industry standards and guidelines for electrical wiring and connections to prevent any potential hazards like short circuits, overheating, or electric shocks.

Another critical aspect to consider is the handling and usage of chemical substances. Depending on the type of plants grown in the greenhouse, fertilizers, pesticides, and other chemicals may be required. It is essential to store and handle these substances properly, following the instructions provided by manufacturers and adhering to safety guidelines. Adequate ventilation should be provided to ensure a safe environment for both students and plants.

Fire safety precautions should also be taken into account. Greenhouses often contain flammable materials such as dry vegetation, wood, or cardboard. Implementing fire prevention measures, such as installing fire extinguishers, smoke detectors, and fire-resistant materials, can help mitigate potential fire risks. Regular inspections and maintenance of these safety measures are vital to ensure their effectiveness.

When considering the safety of students working in a smart garden system built in a greenhouse, special attention should be given to potential allergies. Allergies can vary among individuals, and exposure to certain plants, pollen, or other environmental factors within the greenhouse may trigger allergic reactions. It is crucial to identify and assess any potential allergens present in the garden system, such as specific plants or soil components. Implementing measures to minimize exposure, such as providing protective equipment like gloves and masks, ensuring proper ventilation, and educating students about potential allergens and their symptoms, can help create a safer environment for all participants involved in the project.

Estimated Budget per School

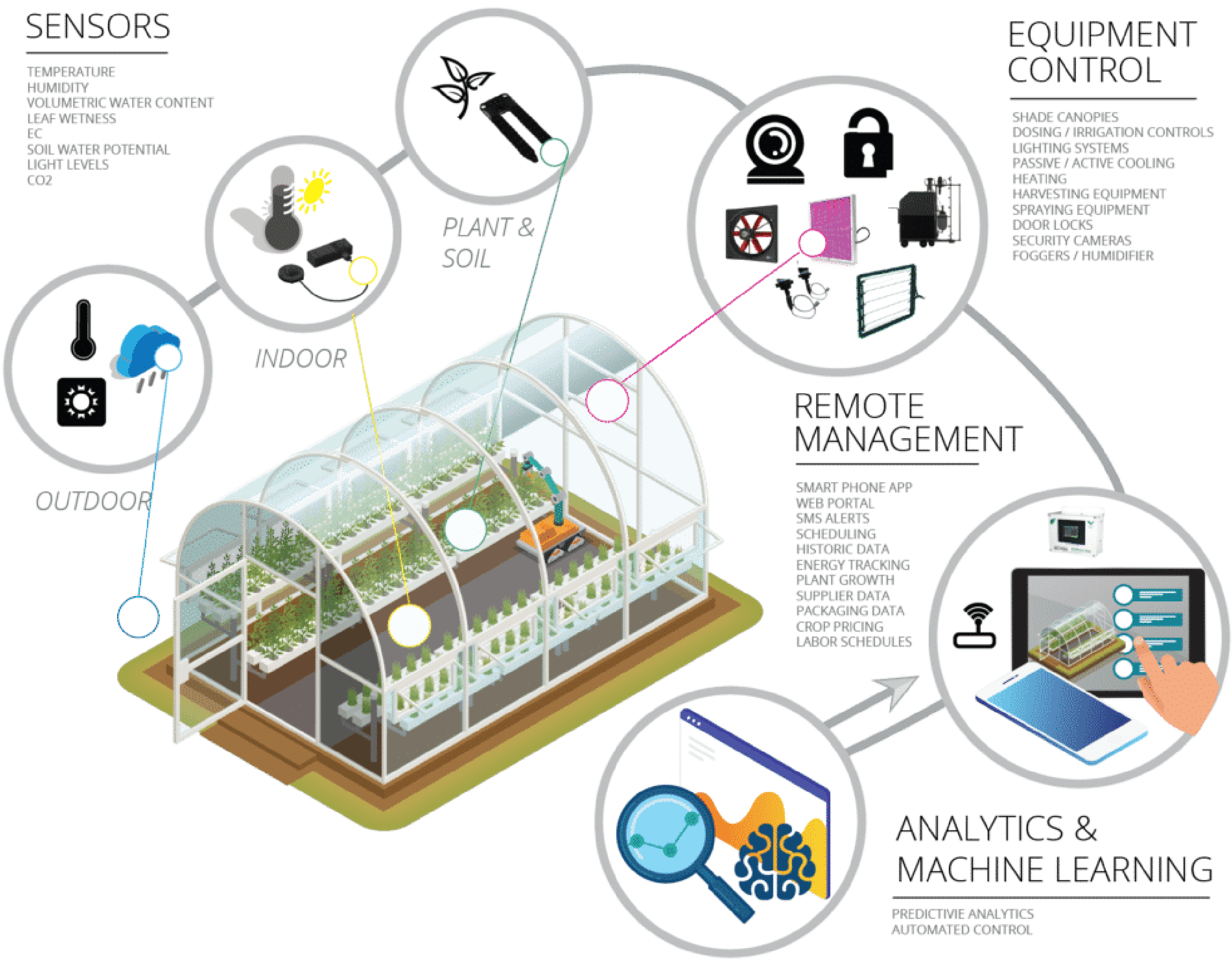
Greenhouse Construction*		
6 m^2 greenhouse structure		€ 200 - € 300,00 (average)
Tools, gloves, soil, fertilizers, etc.		€ 100 - € 200,00 (average)
		Total €300 - € 500,00 (average)
Automation System Hardware and Supporting Lectures (per school)		
Details	**Illustration**	**Estimated Cost (euros)**
Micro:bit Smart Agriculture Kit		The set can cover up to 0.7 square meters and has a cost of € 75,00
Octopus Analog UV Sensor		€ 8,20
Octopus CO2 Gas Sensor		€55,80
DFRobot Oxygen Sensor I2C		€ 70,00
4 Supporting lectures from STEM Education WRO	One lecture for teachers and 4 lectures for pupils of 40 minutes each, in cooperation with STEM Education-WRO - Greece, as part of the program development.	€ 125
		Total € **334**

* Each school may decide the structural type and size of the greenhouse. Accordingly, prices are only an approximation, as each school can arrange its own design. Please note that the greenhouse and all the automation elements can be reused for similar projects in subsequent years.

APPENDIX

Complementary Information and Supporting Material for the Activities

I. How a Greenhouse works *(Source Appvales, https://appvales.com/blog/automated-greenhouse-monitoring-systems)*



The key technologies used in the smart greenhouse market are HVAC, LED grow lights, communications technology, irrigation systems, materials handling, valves and pumps, and control systems. The LED grow light segment dominated the market in 2016, used as an artificial light source to stimulate plant growth.

Controllers

The controllers are the heart behind the greenhouse system, where actuators and sensors are connected to the automation software. They include soil, temperature, and humidity sensors as well as shade screens and LED lights actuators. What controllers do is integrate the climate systems with plant sensors, irrigation, and dosing systems.

Sensors

Sensors check and monitor overall internal and external greenhouse conditions like temperature, humidity, light levels, and carbon dioxide. In addition, there is another remote sensor for monitoring plant pH, moisture levels, and nutrient concentration.

The data collected is then processed by the climate control computer. Optimum climatic conditions already programmed into the greenhouse automation software will then regulate the growing conditions. If the recorded conditions are out of range, the remote monitoring systems will trigger any necessary action needed to balance out the greenhouse again.

HVAC system

Heating, Ventilating, and Cooling (HVAC) systems are designed to maintain optimal greenhouse growing conditions, which vary according to the crop grown, time of year, and local climate.

HVAC systems play a vital role in greenhouses by maintaining an ideal temperature for plant growth, nullifying the adverse impact of changes in the external temperature, and enabling cultivation throughout the year.

The use of HVAC systems for each greenhouse depends on the level of climate control desired by the greenhouse grower.

Low-tech greenhouses may use shading and ventilation as the primary sources of climate control. In contrast, the medium-and high-tech greenhouses tend to use evaporative cooling and supplemental heating in addition to shading and ventilation. High-tech greenhouses may also opt for refrigerant-based heating and cooling systems, especially for recirculating air systems.

Vertical farms, indoor gardens, and other closed plant production facilities typically use refrigerant-based HVAC systems.

Light-Emitting Diode (LED) Grow Lights

These growing lights are specially designed to substitute natural sunlight, stimulating photosynthesis and providing the right color spectrum for plants to grow and flourish. In addition, grow lights are used to provide the proper environment for photosynthesis.

Plants use light to synchronize their internal clocks, and growers can use LED light to artificially extend daylight hours, ensuring that their plants bloom earlier in the year.

Growers can also adjust the color of the light to stimulate growth. Plants only absorb blue, orange, and red light. As such, LED lights that use the optimal blue to red light ratio can fuel a plant's growth and increase yield.

Equipment status and control

It checks in on system performance and controls ventilation, fertigation, humidity, extraction fans/foggers, dosing & irrigation systems.

The process

The specific sensors to the level of carbon dioxide, oxygen, the volatile organic compound (VOC), air temperature and humidity, atmospheric pressure, soil moisture, nutrition, and solar radiation all connect to remote monitoring systems to provide real-time updates.

Data from the sensors is sent to a gateway through a wireless network. Then, it is passed to the cloud. From there, it can be used in Web or Mobile interface to send notifications, show real-time charts, etc. Agriculturalists can also use it to trigger automatic actions on HVAC, lighting, sprinkler, and spraying networks.

Hydroponic and non-hydroponic greenhouses

There are two types of greenhouses; hydroponic and non-hydroponic.

In its most basic definition, hydroponics is a production method where the plants are grown in a nutrient solution rather than in soil. Over the past few years, several variations to the basic system have been developed.

Non-hydroponic, on the other hand, is the traditional method where farmers plant crops in soil.

The greenhouse and its environmental control system are the same whether plants are grown conventionally or with hydroponics. The difference comes from the support system and the method of supplying water and nutrients.

Daytime and nighttime temperature inside and outside of greenhouses

Both day and night temperatures should be carefully monitored. High temperatures may cause damages such as inhibition of growth, fruit abortion, and even death. Temperatures lower than the optimum will alter plant metabolic systems to slow growth and, again, hinder fruit set.

Humidity, moisture, and CO2 levels

Excessive moisture causes high humidity levels inside the greenhouse. The most visible effect of high humidity is the condensation that forms on the plastic or structural surfaces inside the greenhouse. Leaf surfaces of the plant will also feel damp to the touch, which can lead to increased disease problems.

Moisture buildup can be controlled by improving ventilation. The drier and warmer the greenhouse, the less likely that disease problems will exist.

Light efficiency and sun radiation effect

Solar radiation provides heat, light, and energy necessary for all living organisms. Optimum lighting is critical for photosynthesis and respiration to take place. The use of LED lights in an automated greenhouse enables shaded plants to photosynthesize more and speed up the growing process than in a natural environment.

pH Level

Automated greenhouses can periodically test the acidity and alkalinity of the soil and irrigation water used. The greenhouse water and nutrients applied may change the media pH over time. Correct choices in fertilizers and management of the irrigation water can be implemented.

Soil, watering, and draining measurements

The system automatically regulates when there is a need for watering and controls excessive moisture that can cause harm to plants.

Plant health and maturity

Automated greenhouses enable a balanced flow of plant essential nutrients. If plants lack any of the nutrients required, the system automatically ensures that nutrients are supplemented through the fertigation process.

II. Recommended readings for teachers

Development of IoT Smart Greenhouse System for Hydroponic Gardens
https://arxiv.org/ftp/arxiv/papers/2305/2305.01189.pdf
Greenhouse Automation System
https://ijecscse.org/papers/SpecialIssue/EnTC/19.pdf
An Automated Greenhouse Monitoring and Controlling System using Sensors and Solar Power
https://www.researchgate.net/publication/341031255_An_Automated_Greenhouse_Monitoring_and_Controlling_System_using_Sensors_and_Solar_Power

III. Integrating science principles and STEM concepts

- Botany and Plant Science: A greenhouse project can focus on the growth and care of plants, including their anatomy, physiology, and life cycle. Students can learn about photosynthesis, plant nutrition, and the effects of environmental factors such as light, temperature, and humidity on plant growth.
- Ecology and Environmental Science: Greenhouse projects can also explore concepts related to ecology and environmental science, including photosynthesis, the carbon cycle, water cycle, and nutrient cycling.

Students can learn about the impact of human activities such as deforestation and pollution on the environment, and explore ways to reduce their impact.

- Chemistry: The chemistry of soil and fertilizers can also be explored in a greenhouse project. Students can learn about the chemical properties of soil, the role of nutrients in plant growth, and the effects of pH on plant growth.
- Physics: The physics of light and heat can be explored in a greenhouse project. Students can learn about the properties of light, including wavelength and intensity, and how these factors affect plant growth. They can also investigate the effects of temperature on plant growth and explore ways to control temperature in a greenhouse.
- Engineering and Control Systems: A greenhouse project can involve the design and construction of the greenhouse itself. Students can learn about the principles of structural engineering, including load bearing and stability, and explore different materials and construction techniques. The automation of the greenhouse involves designing and building automated systems to control temperature, humidity, lighting and watering, among other parameters, through sensors, actuators, controllers, feedback loops, and programming. Students have the opportunity to understand principles of engineering design such as identifying criteria, generating design alternatives, selecting the best design solutions and testing and refining the design.
- Computer Science: The automation of a greenhouse project involves programming and controlling automated systems. This requires an understanding of computer science principles such as programming languages, algorithms, and data structures.
- Electrical Engineering: The automation of a greenhouse project involves designing and building electrical circuits to control various systems. This requires an understanding of electrical engineering principles such as circuits, voltage, current, and resistance.
- Data Analytics: The automation of a greenhouse project involves collecting data on various environmental and plant growth parameters. This requires an understanding of data analytics principles such as data collection, data analysis, and data visualization.
- Mathematics: Mathematics can be used to analyze data collected from the greenhouse project, including plant growth rates, temperature and humidity measurements, and nutrient levels in the soil. Students can learn about statistical analysis and data visualization to better understand their results.
- Economics: The global smart greenhouse market, which was valued at US$680.3 million in 2016, may reach US$1.31 Billion by 2022, growing at a Compound Annual Growth Rate (CAGR) of around 14.12% between 2017 and 2022. This development results from the rapid increase in the adoption of the Internet of Things, artificial intelligence by farmers and agriculturalists, particularly in Europe.

Overall, a greenhouse project can provide a rich learning experience that integrates concepts from multiple STEM fields.

IV. Examples of activities that could be carried out throughout the project

Biology

These activities can engage students in hands-on exploration, observation, and analysis, allowing them to develop a deeper understanding of biological concepts and processes.

- *Plant Anatomy and Morphology.* Students can study the anatomy and morphology of plants by observing the different parts of the plants grown in the smart garden system. They can examine the roots, stems, leaves, flowers, and fruits to understand their structures and functions. This activity can help students develop a foundational understanding of plant biology.

- *Plant Growth and Development.* Students can monitor and record the growth and development of the plants over time. They can measure parameters such as height, leaf size, and flower development, and analyze the data to observe patterns and trends. This activity can provide insights into the life cycle of plants and the factors influencing their growth.
- *Seed Germination.* Students can investigate the process of seed germination within the smart garden system. They can set up experiments with different variables, such as light conditions, temperature, or moisture levels, to understand their impact on seed germination rates and timing. This activity can introduce students to the concept of plant reproduction and the conditions necessary for successful germination.
- *Pollination and Reproduction*. Students can study the process of pollination by observing the interactions between plants, insects, or other pollinators within the greenhouse. They can analyze the role of flowers, pollen, and nectar in attracting pollinators and facilitating reproduction. This activity can provide insights into the importance of pollination in plant reproduction and ecosystem dynamics.
- *Plant Nutrition and Photosynthesis.* Students can explore the relationship between plants, nutrients, and photosynthesis. They can investigate the effects of different nutrient levels or deficiencies on plant health and growth. Additionally, students can conduct experiments to measure the rate of photosynthesis under varying light conditions or carbon dioxide concentrations. This activity can deepen their understanding of plant nutrition and the role of photosynthesis in energy production.
- *Environmental Interactions.* Students can study the interactions between plants and their environment within the smart garden system. They can investigate concepts such as plant adaptation to environmental factors, responses to stimuli like light or gravity, or the influence of external factors on plant growth. This activity can highlight the dynamic relationship between plants and their surroundings.
- *Biodiversity and Ecosystems.* Students can explore the concept of biodiversity by examining the variety of plant species grown in the smart garden system. They can identify and classify different plant species and investigate their roles within the ecosystem. This activity can foster an appreciation for the diversity of life and the importance of maintaining healthy ecosystems.

Informatics/Robotics

By engaging in these activities, students in the informatics/robotics class can contribute to the automation and optimization of the smart garden system, allowing them to apply their programming and technical skills in a real-world context. They will gain practical experience in working with sensors, actuators, data analysis, and software development, fostering their understanding of the integration between technology and agriculture.

- ✓ *Sensor Integration.* Students can work on integrating various sensors into the smart garden system. They can explore different types of sensors such as temperature sensors, humidity sensors, soil moisture sensors, or light sensors. They will learn how to connect these sensors to a microcontroller or a computer system to gather data about the environmental conditions in the greenhouse.

- ✓ *Data Logging and Analysis.* Students can develop software or programming scripts to log and analyze the data collected from the sensors in the smart garden system. They can create algorithms to process the data, detect patterns, and generate reports or visualizations that provide insights into the growth and health of the plants. This activity will allow students to develop skills in data analysis and visualization.
- ✓ *Automated Irrigation System.* Students can design and build an automated irrigation system for the smart garden. They can develop a system that utilizes sensors to monitor soil moisture levels and triggers the irrigation process when necessary. This activity will involve programming microcontrollers or using IoT platforms to control valves or pumps for water distribution.

- ✓ *Environmental Control.* Students can work on automating the control of environmental factors within the greenhouse, such as temperature and humidity. They can design and implement a system that regulates these parameters based on predefined thresholds or desired setpoints. This activity may involve programming actuators, such as fans or heaters, and integrating them with sensors and control algorithms.
- ✓ *Remote Monitoring and Control.* Students can develop a web or mobile application to remotely monitor and control the smart garden system. This application can provide real-time data visualization, allow users to adjust environmental parameters, or receive notifications/alerts about critical conditions. This activity will give students hands-on experience in developing user interfaces and working with networked systems.
- ✓ *Robotics and Automation.* Students can explore the use of robotics in the smart garden system. They can develop robotic mechanisms for tasks such as plant watering, seed planting, or pest control. This activity will involve designing and programming robots, integrating them with the overall automation system, and optimizing their performance.
- ✓ *Machine Learning and AI*. Students can delve into machine learning and artificial intelligence techniques to enhance the smart garden system. They can develop algorithms to predict plant growth, detect diseases or pests, or optimize resource allocation based on historical data and environmental factors. This activity will provide an introduction to advanced technologies and their applications in agriculture.

Economics

- ❖ An important lesson can involve tracking expenditures associated with greenhouse operations.
- ❖ In the classroom, there could be treasurers for periods so that students have the opportunity to be involved in the finances of running and maintaining the greenhouse.
- ❖ It is important to keep track of expenditures in order to effectively document/quantify the success of the harvest and sales, and to evaluate the benefits and costs of the greenhouse program.

- Documenting expenditures also allows classes to work toward making the greenhouse programming self-sustaining and potentially profitable in order to fund future projects.

Chemistry

These activities can not only deepen students' understanding of chemistry concepts but also foster their curiosity, critical thinking, and scientific inquiry skills.

- *Soil Analysis.* Students can collect soil samples from different areas of the greenhouse and perform chemical tests to determine the pH level, nutrient content, and composition of the soil. This activity can help them understand the importance of soil quality for plant growth and the role of different chemical elements in the soil.
- *Nutrient Analysis.* Students can analyze the nutrient levels in the soil and monitor how they change over time. They can measure the concentration of essential nutrients like nitrogen, phosphorus, and potassium using appropriate chemical tests. This activity can provide insights into the nutrient requirements of plants and the impact of fertilizers on plant growth.
- *Water Quality Assessment.* Students can investigate the quality of water used for irrigation in the smart garden system. They can perform chemical tests to analyze parameters such as pH, dissolved oxygen, and the presence of contaminants like heavy metals or pesticides. This activity can raise awareness about the importance of water quality for plant health and environmental sustainability.
- *Photosynthesis Experiments*. Students can design experiments to investigate the process of photosynthesis in plants. They can vary factors such as light intensity, temperature, or carbon dioxide levels and observe their impact on the rate of photosynthesis. This activity can help students understand the chemical reactions involved in plant metabolism and the factors influencing plant growth.
- *Plant Pigment Extraction.* Students can extract plant pigments, such as chlorophyll, from leaves or flowers grown in the smart garden system. They can use chemical solvents and techniques like chromatography to separate and analyze different pigments. This activity can provide insights into the role of pigments in photosynthesis and the diversity of plant colors.
- *Composting and Decomposition.* Students can set up composting systems within the greenhouse to observe the process of organic matter decomposition. They can analyze chemical changes in the compost pile, measure temperature, monitor pH levels, and assess the breakdown of organic compounds. This activity can highlight the chemical transformations that occur during decomposition and the importance of recycling organic waste.

Physics

These activities can not only deepen students' understanding of physics principles but also foster their problem-solving skills, data analysis, and critical thinking abilities in real-world applications.

- *Light and Photosynthesis*. Students can explore the relationship between light and photosynthesis by investigating the effects of different light wavelengths or intensities on plant growth. They can set up experiments using light filters or varying distances between plants and light sources to observe the impact on plant development. This activity can help students understand the role of light energy in the process of photosynthesis and the concept of light absorption.

- *Temperature and Plant Growth.* Students can monitor and analyze the impact of temperature on plant growth within the smart garden system. They can measure and record the temperature in different areas of the greenhouse and observe how it affects the rate of plant growth, germination, or flowering. This activity can provide insights into the concept of thermal energy transfer and its influence on biological processes.
- *Environmental Monitoring*. Students can use sensors and data loggers to monitor various environmental parameters within the greenhouse, such as temperature, humidity, and carbon dioxide levels. They can collect and analyze the data over time to observe patterns and correlations. This activity can introduce students to the concept of data collection, analysis, and interpretation in the context of environmental physics.
- *Watering Systems and Hydraulics.* Students can design and construct watering systems for the smart garden, considering factors such as water pressure, flow rate, and irrigation efficiency. They can experiment with different nozzle designs or valve settings to optimize water distribution and minimize wastage. This activity can provide hands-on experience with principles of fluid dynamics and the application of hydraulics in irrigation systems.
- *Energy Efficiency*. Students can assess and compare the energy consumption of different components within the smart garden system, such as lighting systems, pumps, or ventilation systems. They can explore ways to optimize energy usage, such as using energy-efficient bulbs or implementing smart control systems. This activity can raise awareness about energy conservation and sustainable practices in the context of technology and agriculture.
- *Structural Stability and Support.* Students can analyze the structural integrity of the greenhouse and design support structures for the plants. They can explore concepts such as load distribution, stability, and the effects of external forces like wind or weight. This activity can introduce students to principles of statics and mechanics while emphasizing the importance of robust structural design.

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