Teaching Environmental Awareness with Smart IoT Planters in Learning Spaces [TEASPILS]

Intellectual Output 2

Extended report

Smart IoT planters to collect data in learning spaces

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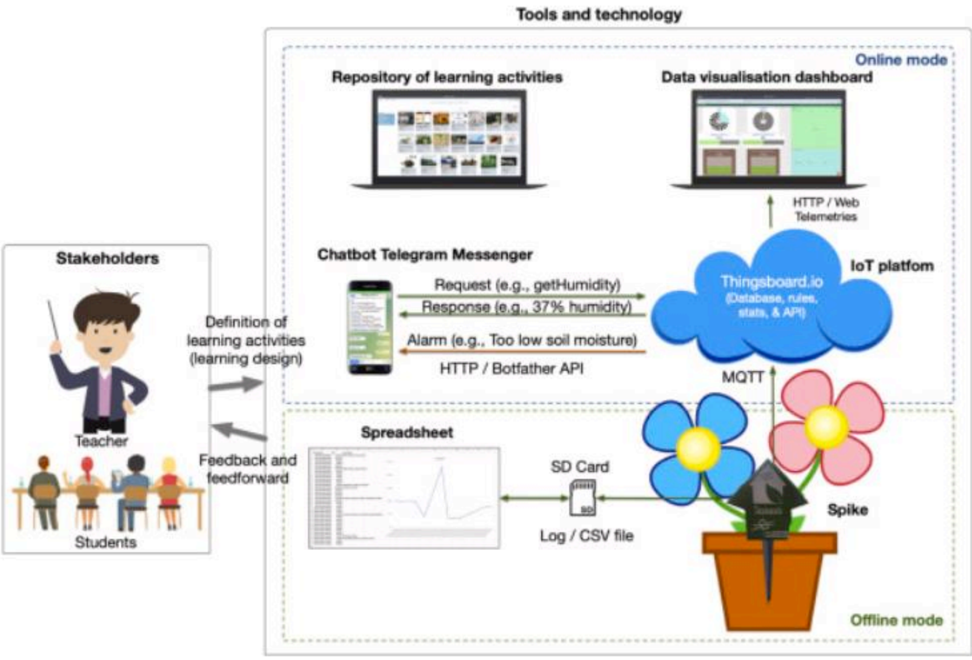
Smart IoT planters to collect data in learning spaces

The IoT system implemented in this IO has been designed to explore variables affecting plants and the environment in which they are located. It intends to support teachers in the creation of learning activities (i.e., learning designs) using IoT technology and indoor plants to train the digital green competences mentioned above. The interaction between stakeholders and the IoT system aims to inspire authentic learning experiences (i.e., feedback and feedforward) to promote awareness on the benefits of using plants in learning spaces. The overall setup if the IoT system comprises the following tools:

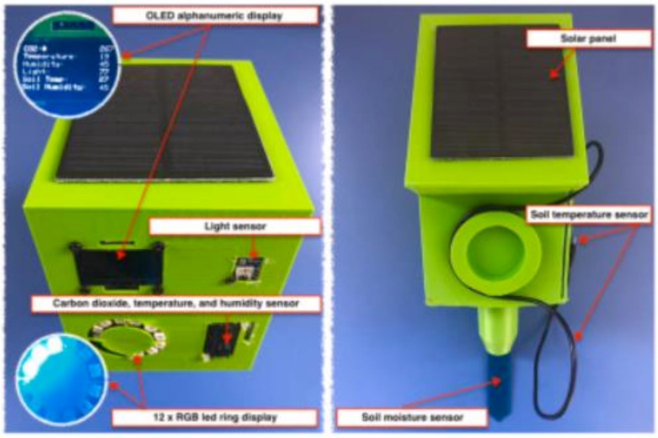


Spike

The Spike is the core of the system. It is responsible for collecting data (sensors), storing it (internal and remote), and offering real-time feedback on it (actuators). All system components are orchestrated by an ESP32 micro-controller with Wi-Fi and Bluetooth connectivity. The case of the Spike was designed with a 3D printer. The upper part is shaped like a house and the microelectronics are isolated inside. The lower part is shaped like a stake to be able to insert it into a planter and obtain measurements about the soil of the plant. As illustrated in Fig. 3b, the roof is divided into two sides: the first side has a solar panel installed to recharge the batteries (inside the casing) that operate the entire system. Alternatively, the Spike can be powered using a micro-usb cable (5 V) if there is not enough charge. The other side of the roof is equipped with sensors and actuators. Here we describe the variables measured by these sensors and the arguments considered to install them in the Spike:

- Carbon dioxide. As students and teachers exhale carbon dioxide (CO_2) when they breathe, the concentration of this gas is an objective measure to determine if the air in the classroom is clean. High CO_2 levels increase the chances to breathe air that was previously exhaled by another person. Therefore, the system makes it possible to observe how plants moderate CO_2 levels and consequently apply the existing recommendations/regulations to ventilate classrooms.

- Light. Plants need light to carry out photosynthesis. Natural photosynthesis is the process of capturing CO_2 in the form of carbohydrate and releasing O_2 using light as the energy source.
- Ambient temperature. Humans and plants carry out their vital functions in a more efficient way within certain ambient temperature ranges. The Sensirion-SCD30 sensor of the Spike monitors ambient temperature levels in Celsius degrees (°C) to optimise the well-being of plants and stakeholders in the classroom.
- Ambient humidity. Humidity is a key variable to consider for obtaining a healthy environment for humans and plants. The Sensirion-SCD30 sensor of the Spike monitors relative humidity levels in percentage (%) to optimise the well-being of plants and stakeholders.
- Soil moisture. This variable must be optimised considering the composition, the texture of the soil (clay, sandy) and the type of plant. Soil texture determines water filtration. The seed-studio capacitive soil moisture sensor of the Spike monitors soil humidity to automatise plant watering and to optimise plant growth. The capacitive soil moisture sensor, compared with resistive sensors, does not require direct exposure of the metal electrodes which can significantly reduce the erosion of the electrodes.
- Soil temperature. Based on the scientific literature, the researchers of this work considered it interesting to empirically explore how soil temperature is correlated with the rest of the variables measured by the Spike (C02, humidity, etc.) in a learning context.

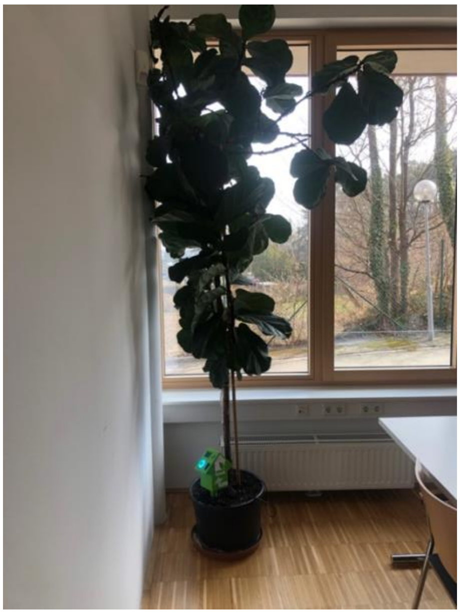


The system allows to configure how often the data is read from the sensors. The Spike stores the data collected from sensors on a memory SD-card in spreadsheet format (i.e., Excel and CSV file). The SD-card can be ejected from the Spike to insert in a computer to analyse the data. When working in online mode, the Spike also uploads the data to the cloud. The system is equipped with two displays (actuators) to present the data. The 1.3-inch OLED is used to display alphanumeric data with the measurements collected by the sensors in real-time. In addition, the 12 multicoloured LED ring is using a traffic light metaphor to indicate the gradient for the monitored variable. The system represents a moment in which the CO_2 variable is monitored (see asterisk on the OLED display). Three blue leds indicate optimum levels in the variable. Table 1 shows the correspondence between the configured thresholds and the feedback colour on the ring for the variables measured.

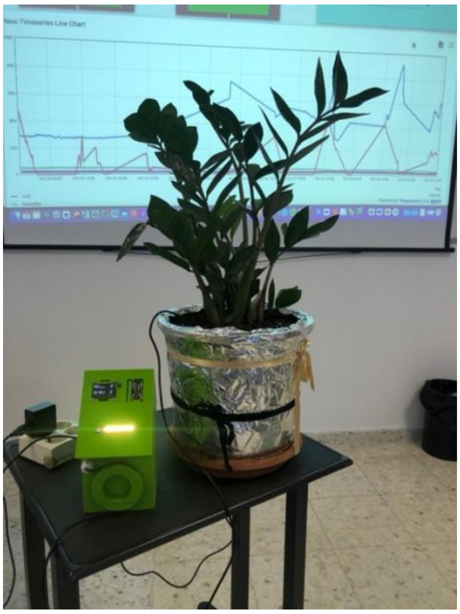
The system has evolved throughout the project in three different versions:

Spike version 1

This IoT system contains all the elements described above and was designed to be embedded in the soil of the planter itself.

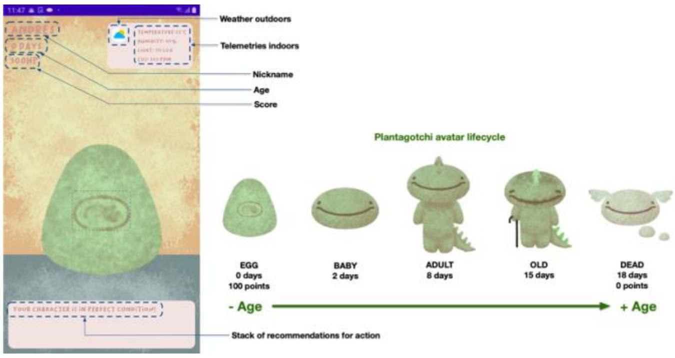


Spike version 2
This IoT system improves the previous version by incorporating actuators (OLED RGB progressive bar) adapted to improve feedback usability in colorblind people. In addition, two temperature probes have been incorporated to be able to compare/contrast the measurements between two different plants. The system includes a chatbot to interact with the plant via text messages via Telegram. Unlike the previous version, this system was designed to be physically installed next to the pot as the dimensions of the spike could damage small potted plants.



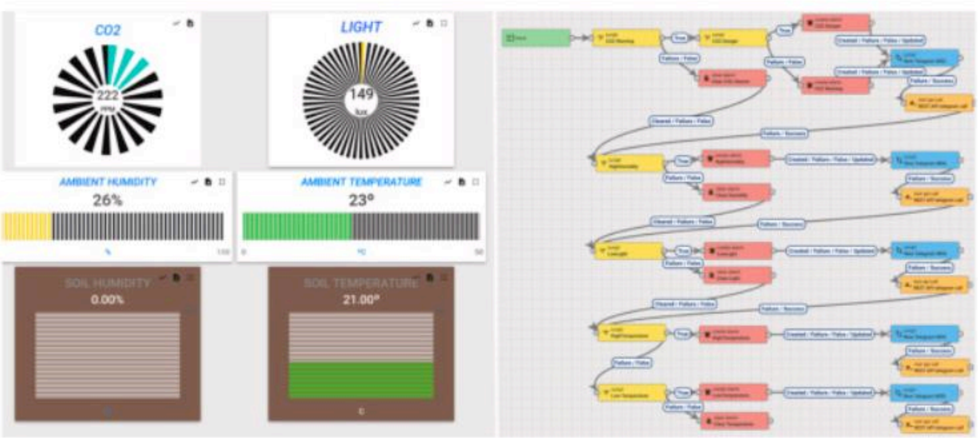
Spike version 3
This IoT system includes functionalities that allow exploring learning activities related to the Internet of Things and artificial intelligence. These functionalities are: 1) a voice assistant that allows you to interact with the system through voice dialogues; 2) a mobile avatar (Plantagotchi) that allows the gardener to be given a virtual entity that allows illustrating how the plant reacts to different environmental conditions that may occur in the classroom; 3) an electrical differential

meter that allows exploring how the plant reacts to different stimuli (for example: presence of people, music, noise, irrigation of the plant, or extreme variations of light or temperature).



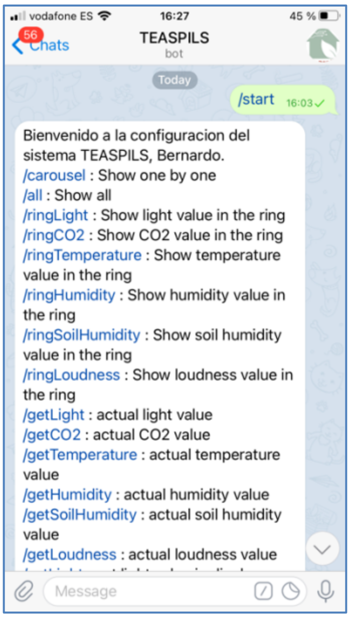
IoT cloud platform

The platform is an online service that allows hosting the data collected by the Spike when working in online mode. This service includes a data panel to remotely display the information collected by the sensors. The visualisation includes an individual panel for each variable collected in real-time, and also a representation of historical data with a line chart. The timeline representation allows stakeholders to download the database for a given time/date range in a spreadsheet for exhaustive analysis. The platform includes a web service that facilitates the programming of additional applications to access and represent data. In addition, the platform features rules configuration to identify specific scenarios and to activate additional alarms (e.g., the need for watering the plant in case of extremely low soil moisture). The system is configured to trigger alerts whenever the red thresholds are reached. The figure illustrates alarm messages due to extremely low ambient light.



Mobile messaging application

Interactions between humans and plants are highly complex and are to a large extent based on an intrinsic intuition toward nature. Many aspects of plants are hidden from fact-based measurements with technical instruments and rely on observation and experiential estimation, such as judging the state of health of a plant organism, or when a plant is about to bloom. Similarly, the effects plants have on humans are equally difficult to evidence with hard data. However, in our approach, we aim to use technology as a mediator between these to agents to arrive at a better understanding of what the interrelationship entails. From this combination, we investigate two research questions: 1) We have investigated what measurements are relevant to explore in the care for a plant towards promoting awareness about the impact of nature on healthy learning environments.SLEs collect data, analyze data, and react considering the results of analyzing the data, for example with machine learning algorithms or natural language processing; 2) We have investigated what kind of plant-human interactions might help to scaffold learning activities towards promoting awareness about the impact of nature on healthy learning environments. These questions call for innovative solutions that bind IoT technologies and pedagogies using learning analytics. In this paper, we present a prototype system called Smart Spike as a key enabler to scaffold learning activities in SLEs.



The system architecture includes a mobile chatbot which is based on the Telegram instant messenger. This system has been configured with a series of commands that allow interaction between stakeholders and the system. The application features two types of interactions considering the actor initiating the communication:

- Stakeholder-initiated interactions. Teachers and students can use the chatbot to find the last measurement made by any of the sensors installed in the system.
- System-initiated interactions. Teacher and students remotely receive alerts when specific scenarios occur (See configured rules in previous section). These notifications can be configured to be sent to one person or to a group.

This feature was designed to refine the developments and perceived usefulness of the Spike to enhance human-2-plant interaction in smart learning environments, and to stimulate environmental awareness using plants and IoT technology. One insight we took from the bulk of feedback was that there are a complex number of potential variables involved. It may prove to be difficult to prioritize various indicators delivered by the sensors over others. For some parameters very little is known regarding their impact on plant life, e.g., noise level.
A further challenge was the triangulation of different ambient measurements that are mutually reinforcing: air quality, state of soil, and internal plant health. Since the aim of the study is learner-focused, a simple gathering of environmental data will not be comprehensive enough to fully fathom the impact on students' well-being and productivity. The responses we received in the evaluation exercise partly suggest to combine physical measurements with immeasurable subjective input by individuals (e.g., what do you feel when looking at me?). This can be achieved via the "plant diary" as envisaged in part (c) of our learning analytics lens. However, this might

require the development of a shared vocabulary.
These forthcoming challenges aside, the results obtained indicate that the data that can be automatically collected by the sensors encapsulated in the Spike may be relevant and valid to support interesting learning activities. Results also show that the potential of the Smart Spike device goes beyond its current design, as additional sensors have been proposed by participants to extend the device. Moreover, the responses stressed the role of human annotations as complementary data to extend the depth and breadth of the learning opportunities that can be envisaged. Among the independent variables are threshold levels arising from the analysis of the data and the reactions they trigger. Different plant species operate under different conditions. Therefore, critical conditions arise under different circumstances. Learning activities will be created to define user control mechanisms to configure thresholds for warning levels to take care of the plant. These mechanisms will be combined with botanical advice to customize the initial plant-specific settings of the Spike. Interaction triggers can then be introduced on the basis of LA interaction patterns collected in learning activities.
The general idea and objective of the Spike was received very positively by the participants, as they see great opportunity and potential for integration into classroom life and teaching. The active engagement of students is perceived to lead to experiential learning with options for some inquiry-based learning activities. It will be an interesting experiment to evaluate the individual relationships emerging between plant and student caretaker. Our learning analytics approach will monitor this relationship and detect potential changes in behavior and attitude. A variety of mutual attachment levels are foreseeable, but it can be hoped that all students will benefit and internalize a higher appreciation and awareness of plant surroundings.
The current state of the art of plant-supported pedagogy is still rudimentary. Involving technology as a mediator in a participatory learning design, could meet objections by some people or contravene health and safety policies. Using mobile interfaces for interaction, for example, could be prevented by school policies restricting mobile phone use.
In future work, we intend to investigate suitable machine learning algorithms to chat with plants with the aim to support specific dialogues for improved well-being of plants, students, and teachers in learning spaces.

Dissemination and academic results

The success of this IO is contrasted with the following tangible results:
- 4 final degree projects, 2 final master's projects, and 1 doctoral thesis (in progress) presented throughout the project.
- 4 Articles in international impact journals
- 3 Articles in international conferences.
- More than 30 learning activities features piloting the system