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

Intellectual Output 4

Extended report

Pilot studies with smart IoT planters in learning spaces

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Project information

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Project e-mail address:	teaspils.euproject@gmail.com
Twitter:	@eu_teaspils
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Project manager:	Dr. Bernardo Tabuenca
Project coordinator organisation:	Universidad Politécnica de Madrid (UPM)
Consortium Partners	Doukas school (DOU) Hochschule für Agrar und Umweltpädagogik (HAUP) Open University of Cyprus (OUC) Pädagogische Hochschule Wien (PHW) Universidad Pompeu Fabra (UPF)
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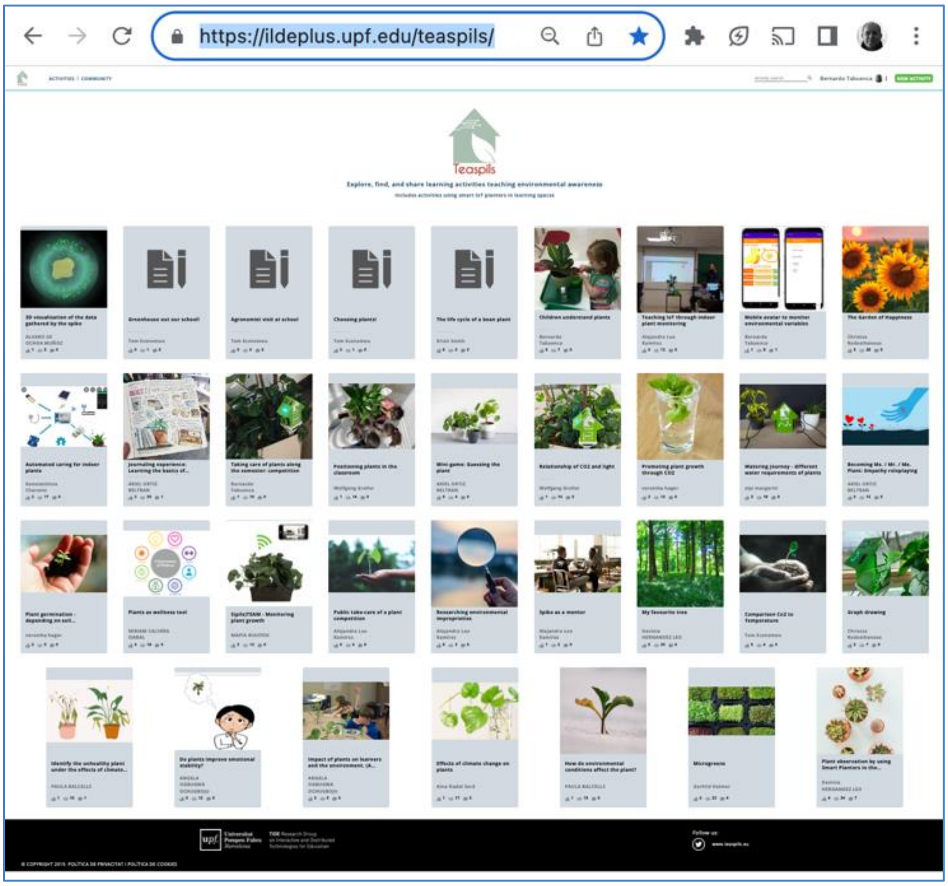
Pilot studies with smart IoT planters in learning spaces

Executive summary

This Intelectual Output aimed to explore innovative approaches to education by integrating Internet of Things (IoT) technology with plant-based learning activities.

In response to the growing demand for experiential and multidisciplinary learning, the project focused on designing and piloting 34 learning activities that harnessed the potential of IoT devices in conjunction with plant-based curricula. The activities were documented on the ILDE+ platform[1], fostering collaboration and enabling insightful data collection.

Methodologically, the project followed a participatory approach, involving diverse age groups and educational settings. These activities were thoughtfully designed to intertwine IoT concepts with botany, environmental science, and technology, enhancing students' understanding of both domains. The ILDE+ platform played a pivotal role in tracking progress, offering real-time feedback, and facilitating meaningful interactions among participants.



[1] Repository of learning activities: https://ildeplus.upf.edu/teaspils/

The outcomes of the piloted activities were nothing short of remarkable. Qualitative and quantitative data indicated heightened student engagement, improved comprehension of IoT principles, and increased enthusiasm for plant-based learning. The integration of real-time data from IoT sensors into the learning process allowed students to witness firsthand the intricate relationship between technology and the natural world.

The project also encountered challenges, providing valuable lessons for future endeavors. Addressing technological limitations and ensuring uniform access to IoT devices emerged as critical considerations. However, these challenges served to underscore the importance of adaptability and innovative problem-solving within educational contexts.

The broader impact of the project extended beyond the immediate participants. The successful integration of IoT and plant-based learning models showcased the potential for enriching educational experiences, inspiring other institutions to explore similar approaches. Strategies for sustainability, including curriculum integration and ongoing teacher training, were devised to ensure the longevity of the project's impact.

The dissemination efforts of the project resulted in a ripple effect across educational communities, sparking dialogues on the potential of IoT-integrated learning and fostering cross-disciplinary collaborations. Looking ahead, the project's success serves as a foundation for future developments, including expanded learning modules and continued engagement with emerging technologies.

In conclusion, the "Piloting an IoT Ecosystem using Plants in Educational Contexts" project not only accomplished its goals of merging IoT technology with plant-based learning but also illuminated a path towards holistic, interactive, and forward-looking educational practices. By nurturing curiosity, critical thinking, and collaboration, the project has set a precedent for transformative learning experiences that bridge the gap between the digital and natural realms.

1. Introduction

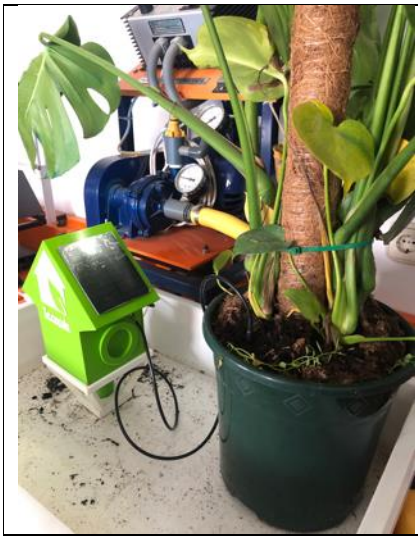
The integration of cutting-edge technologies into educational environments has become a pivotal avenue for fostering innovative and engaging learning experiences. The pilots were a cross-border endeavor that explored the intersection of Internet of Things (IoT) technology and plant-based learning within the educational landscapes of Greece, Spain, and Austria.

In the ever-evolving realm of education, the project sought to bridge the gap between technological advancements and ecological awareness by capitalizing on the potential of IoT ecosystems and plant-based activities. The aim was to offer students a unique opportunity to engage with both digital tools and the natural world, enriching their learning journeys while nurturing a deeper understanding of interconnectedness and sustainable practices.

The project unfolded against the backdrop of diverse educational settings encompassing primary schools, secondary institutes, and universities. Spanning three countries—Greece, Spain, and Austria—the project acknowledged the importance of cultural diversity and contextual relevance in shaping effective learning methodologies. By integrating IoT technology and plant-focused curricula into these institutions, the project sought to demonstrate the universality of its concepts and their adaptability across varying educational contexts.

The piloting phase, conducted during the project's latter stages, was strategically timed to leverage the cumulative insights and expertise accumulated throughout the earlier phases. This allowed for the seamless integration of IoT principles and plant-based learning activities into existing curricula, maximizing the potential for meaningful and sustainable impact on student learning outcomes.

By fostering cross-disciplinary collaboration, technological literacy, and ecological awareness, IO4 aimed to create a blueprint for educators and institutions seeking to modernize their approaches to teaching and learning. The following sections of this report delve into the methodology, implementation, outcomes, challenges, and implications of this ambitious initiative, shedding light on the transformative potential of merging IoT innovation with the natural world within the realm of education.



2. Methodology

The methodology employed in IO4 was carefully crafted to ensure effective integration of Internet of Things (IoT) technology and plant-based learning across diverse educational institutions in Greece, Spain, and Austria.

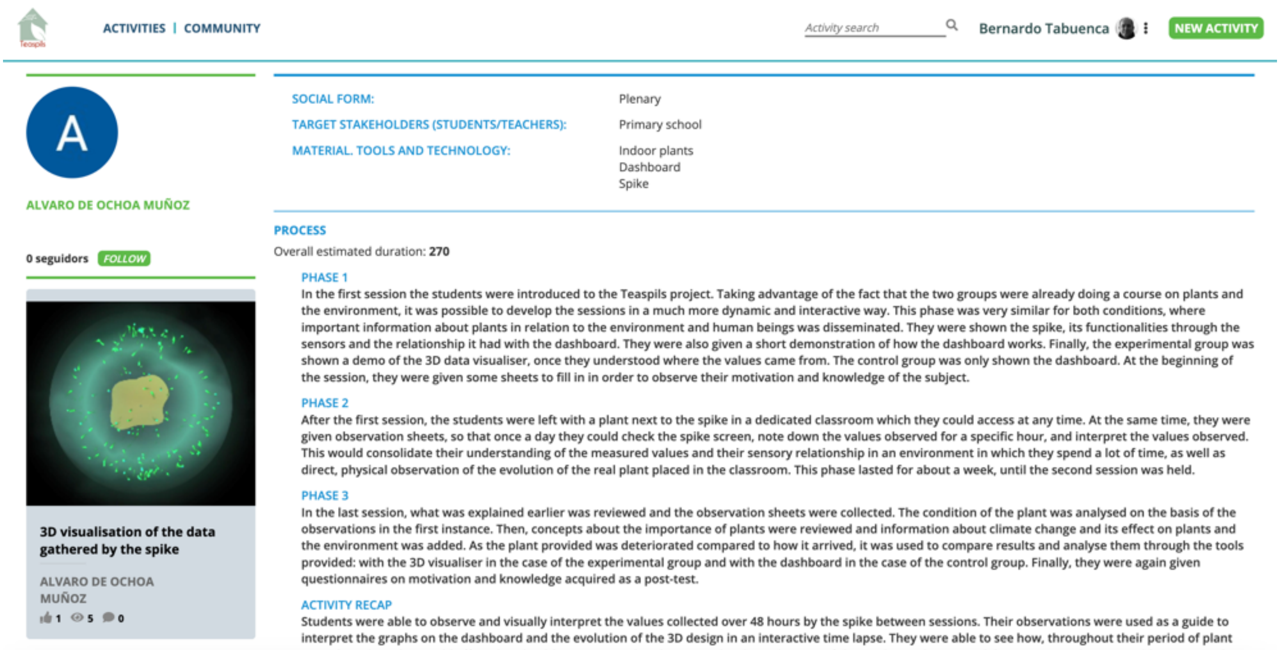
Before embarking on the piloting phase, a comprehensive training session known as Learning, Teaching, and Training (LTT) was conducted for each participating teacher. This session aimed to familiarize educators with the project's technological tools and methodologies. Additionally, a meticulously curated documentation package was provided to educators, serving as a guide to navigate the intricacies of IoT technology and plant-based curricula integration.

Learning, training and teaching seession. Train the trainers session

Throughout the piloting activities, teachers received unwavering support from all project partners. This collaborative approach ensured that educators felt equipped to effectively execute the learning activities within their respective classrooms. Despite the provision of guidelines and recommendations, the project recognized the importance of granting educators pedagogical autonomy to tailor the sessions to their unique teaching styles and students' needs.

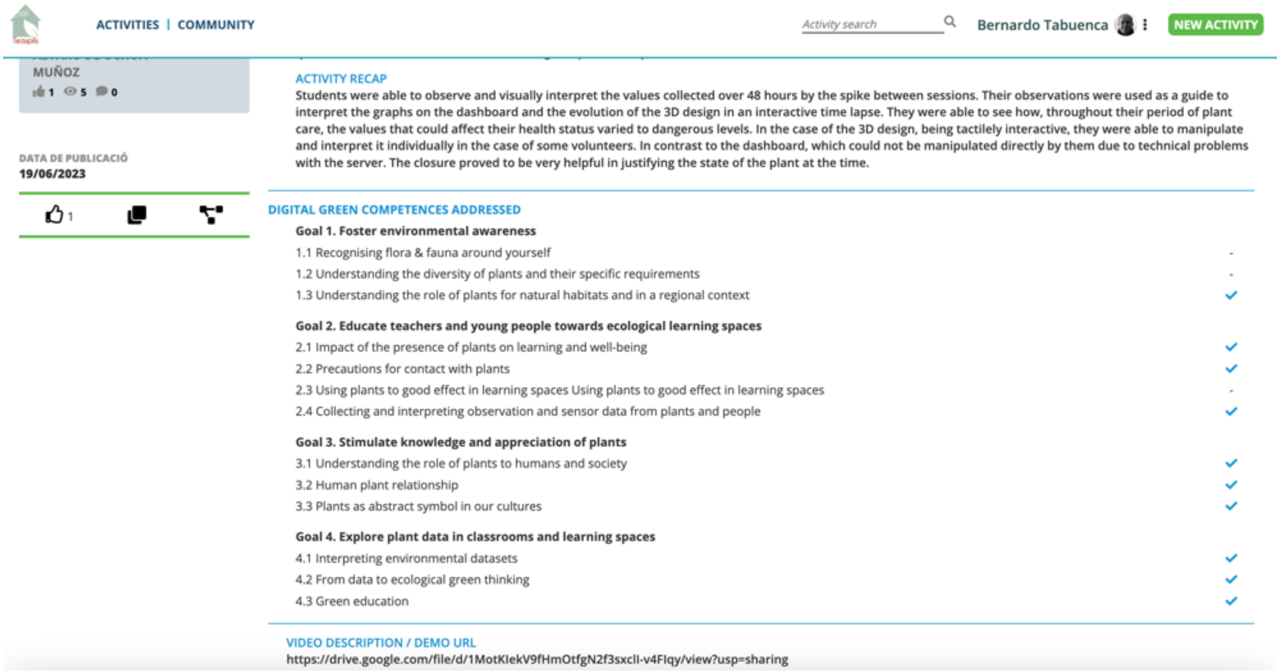
Teachers and trainers participating at the LTT event

The principle of Inquiry-Based Learning (IBL) was proposed as a guiding pedagogical framework for educators. This methodology encouraged students to actively explore and construct knowledge, fostering curiosity and critical thinking. By adopting an IBL approach, educators were poised to create interactive and engaging learning experiences that synergistically integrated IoT principles and plant-related subjects. A key aspect of the methodology involved the utilization of the ILDE+ platform. Teachers were encouraged to document their learning activities on this platform, offering a structured framework for presenting their initiatives. Within the platform, educators were prompted to specify the target age group, the distribution of the activity over time, and the learning objectives associated with each session. This documentation not only facilitated sharing of best practices but also contributed to the broader dissemination of project outcomes.



Learning activity definition in phases in ILDE+

Furthermore, educators were guided to align their activities with the overarching goals of the project—developing digital green competences. By focusing on digital skills intertwined with ecological awareness, educators aimed to cultivate a generation of learners equipped to address contemporary challenges through sustainable and technology-enabled solutions.



Learning goals within the activity targeting the goals of the project

In conclusion, the methodology adopted for the piloting phase was characterized by its collaborative nature, flexibility, and emphasis on innovative pedagogies. By combining comprehensive training, educator autonomy, IBL methodology, and documentation on the ILDE+ platform, the project succeeded in not only guiding educators through the integration of IoT and plant-based learning but also in fostering a network of educators committed to digital green competences[2].

Digital Green Competences Framework. TEASPILS project

[2] Generating an environmental awareness system for learning using IoT technology. https://www.sciencedirect.com/science/article/pii/S2542660523000793

3. Implementation of Learning Activities

The successful execution of IO4 involved the careful design and implementation of a range of learning activities. These activities were thoughtfully crafted to bridge the realms of IoT technology and plant-based learning while catering to diverse age groups within primary, secondary, and tertiary education settings. The activities were focused on fostering a deep appreciation for plants, ecology, and technology while addressing various aspects of the digital green competences framework.

1. Recognizing Flora and Fauna Around Yourself: Students engaged in hands-on exploration of their immediate environment to identify local plant species. IoT sensors were utilized to collect data, encouraging students to connect technology with real-world observations.

2. Understanding Diversity of Plants and Their Requirements: Students delved into the diverse world of plants, exploring their unique requirements for growth and survival. Students connected IoT data collection to monitor and optimize plant growth conditions.

3. Exploring the Role of Plants in Natural Habitats: Students investigated the pivotal role of plants in regional ecosystems. By integrating IoT sensors, students tracked environmental changes and plant responses, highlighting the interdependence of organisms and their surroundings.

4. Impact of Plants on Learning and Well-being: Students explored how the presence of plants in learning spaces influenced their cognitive well-being. IoT data collection showcased the positive impact of greenery on concentration and mood.

5. Precautions for Contact with Plants: Students learned about safe interactions with plants. IoT technology was integrated to monitor environmental factors that might influence plant toxicity.

6. Utilizing Plants in Learning Spaces: Students transformed their classrooms by integrating plants. IoT sensors facilitated data collection, allowing students to observe the effects of plants on the learning environment.

7. Collecting and Interpreting Observation and Sensor Data: Students engaged in data collection from both plants and human subjects. IoT sensors were used to gather information, fostering connections between digital data and ecological understanding.

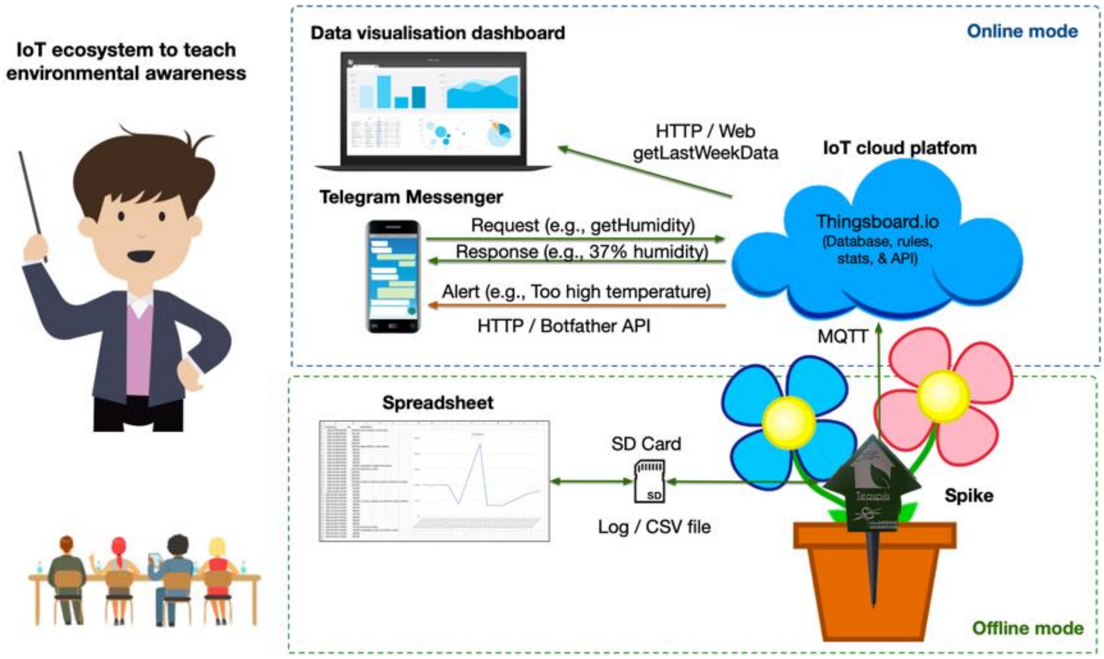
8. Exploring the Human-Plant Relationship: Students across age groups examined the intricate relationship between humans and plants, incorporating IoT technology to highlight symbiotic connections.

9. Plants as Symbols in Culture: Students explored the symbolism of plants in various cultures. IoT data presentation highlighted the cultural significance of different plant species.

10. Interpreting Environmental Datasets: Students analyzed complex environmental datasets, integrating IoT-collected information to develop critical analytical skills.

11. From Data to Ecological Green Thinking: Students traced the journey from IoT data collection to ecological awareness, fostering green thinking and understanding.

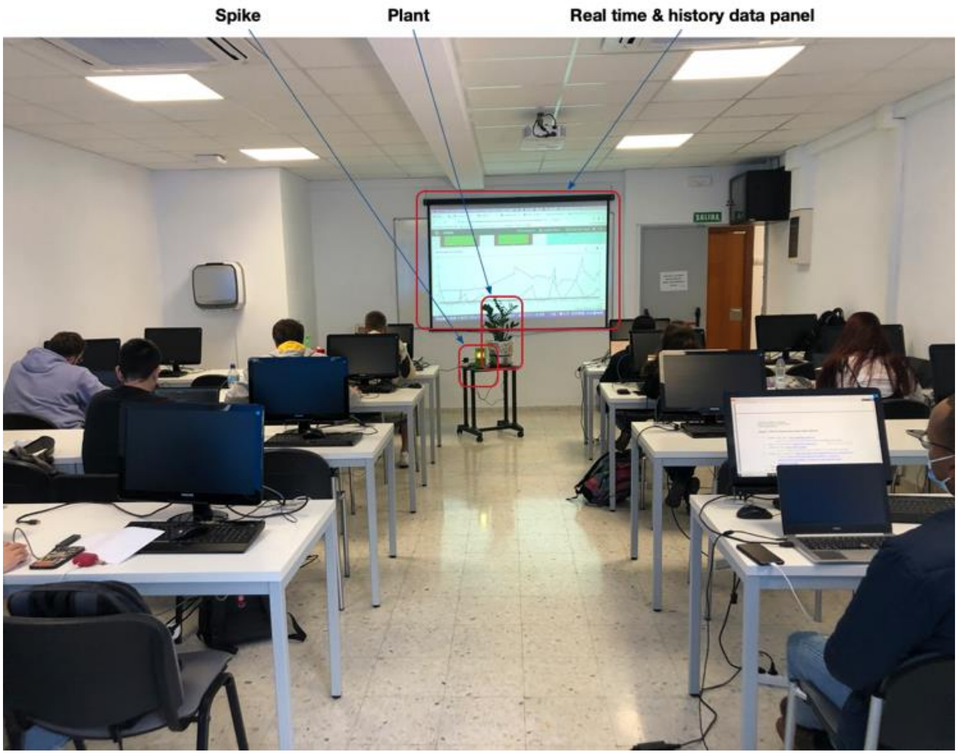
12. Green Education: Students engaged in meta-analysis of the project's outcomes, investigating the potential for scalable green education models supported by IoT technology.



TEASPILS's IoT ecosystem for teaching environmental awareness

5. Outcomes and Results

The 34 documented learning activities were piloted by teachers across primary, secondary, and tertiary educational settings in Greece, Spain, and Austria. By weaving IoT technology and plant-based curricula, these activities promoted holistic understanding and inspired students to recognize the importance of digital green competences in addressing contemporary environmental challenges. The dynamic connection between technology, ecology, and culture was underscored, nurturing a generation of learners equipped to thrive in a digitally-connected and environmentally-conscious world.



Pilot at Master classroom in UPM

The successful results are evaluated, reported, and presented with empirical findings as reported in the following final degree projects, Masters's final projects, and academic publications.

Final Degree Projects

Bautista Santos-Olmo, Antonio (2022). **Smartceta: sistema de medición de valores básicos de una planta utilizando IoT.** Proyecto Fin de Carrera / Trabajo Fin de Grado, E.T.S.I. de Sistemas Informáticos (UPM), Madrid. https://oa.upm.es/70371/

Arquero Gallego, Juan (2022). **Diseño y construcción de módulo IoT para la monitorización de la calidad del agua de riego.** Proyecto Fin de Carrera / Trabajo Fin de Grado, E.T.S.I. de Sistemas Informáticos (UPM), Madrid. https://oa.upm.es/71917/

Gschwandtl, K. (2022). Lernförderliche Auswirkungen durch Begrünung von Lernräumenauf Studierende der Hochschule für Agrar-und Umweltpädagogik Wien (Bachelorarbeit) – **Effects of greening learning spaces on students at the University of Agricultural and Environmental Education,** Vienna (English). https://www.haup.ac.at/wp-content/uploads/2023/06/Bacc-Arbeit_Lernfoerderliche-Auswirkungen-durch-Begruenung-von-Lernraeumen.pdf

Xie, Hongyan and Shen, Dina (2023). **Asistente de voz para la monitorización del estado de una planta mediante un sistema basado en IoT.** Proyecto Fin de Carrera / Trabajo Fin de Grado, E.T.S.I. de Sistemas Informáticos (UPM), Madrid. https://oa.upm.es/73427/

Master's Final Projects

Balcells Falgueras, Paula. **Dashboard for Environmental Awareness Education** (2022). Trabajo Fin de Master, Master thesis on Cognitive Systems and Interactive Media, Universidad Pompeu Fabra (UPF), Barcelona. http://hdl.handle.net/10230/54300

Ochoa Muñoz, Alvaro. **3D Digital Interaction for Environmental Awareness Education** (2023). Trabajo Fin de Master, Master thesis on Cognitive Systems and Interactive Media, Universidad Pompeu Fabra (UPF), Barcelona. https://drive.google.com/file/d/1xVtvCdWZ1srxI1gTDRB-66DHDt0pOieJ/view?usp=share_link

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Journal articles

Tabuenca, B., Serrano-Iglesias, S., Martin, A. C., Villa-Torrano, C., Dimitriadis, Y., Asensio-Pérez, J. I., ... & Kloos, C. D. (2021). Affordances and core functions of smart learning environments: A systematic literature review. IEEE Transactions on Learning Technologies, 14(2), 129-145. https://ieeexplore.ieee.org/document/9384279

Tabuenca, B., Greller, W., & Verpoorten, D. (2022). Mind the gap: smoothing the transition to higher education fostering time management skills. Universal Access in the Information Society, 21(2), 367-379. https://link.springer.com/article/10.1007/s10209-021-00833-z

Tabuenca, B., Moreno-Sancho, J. L., Arquero-Gallego, J., Greller, W., & Hernández-Leo, D. (2023). Generating an environmental awareness system for learning using IoT technology. Internet of Things, 22, 100756. https://www.sciencedirect.com/science/article/pii/S2542660523000793

Leo-Ramírez, A., Alvarez, J., Pérez, M., Greller, W., & Tabuenca, B. (2023). Learning Activities with Plants and Technology: A Systematic Literature Review. Applied Sciences, 13(6), 3377. https://www.mdpi.com/2076-3417/13/6/3377

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Leo-Ramírez, A., Tabuenca, B., García-Alcántara, V., Tovar, E., Greller, W., & Gilarranz-Casado, C. (2021, July). Solutions to ventilate learning spaces: a review of current CO2 sensors for IoT systems. In 2021 IEEE 45th Annual Computers, Software, and Applications Conference (COMPSAC) (pp. 1544-1551). IEEE. https://ieeexplore.ieee.org/abstract/document/9529390

Tabuenca, B., García-Alcántara, V., Gilarranz-Casado, C., Leo-Ramírez, A., Arquero-Gallego, J., & Tovar, E. (2022, March). Engineering IoT systems in the convergence between agronomic and computer sciences. In 2022 IEEE Global Engineering Education Conference (EDUCON) (pp. 2084-2087). IEEE. https://ieeexplore.ieee.org/abstract/document/9766773

Rodosthenous, C., Mavrotheris, E., Greller, W., & Tabuenca, B (2022). Creating Environmental Awareness in Education through IoT and Gamification. In Proceedings of the 25th International Conference on Interactive Collaborative Learning (ICL 2022); 27-30 September 2022, Vienna, Austria. Best paper award. https://link.springer.com/chapter/10.1007/978-3-031-26190-9_69

Rodosthenous, C., & Mavrotheris, E. (2022). Applying Gamification Mechanics in an Environmental Education SPOC. In Proceeding of 14th International Conference on Education and

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Tovar, E., Tabuenca, B., Greller, W., Piedra, N., & Friesel, A. (2023, May). Recognizing lifelong learning competences: a report of two cases. In 2023 IEEE Global Engineering Education Conference (EDUCON) (pp. 1-6). IEEE. https://ieeexplore.ieee.org/document/10125240

Tabuenca, B., Leo-Ramirez, A., Uche-Soria, M., Tovar, E., Greller, W., Rodosthenous, C., Mavrotheris, E., (2023). Unlocking the potential of IoT for interactive and collaborative learning: Case studies in higher education, In: International Conference on Interactive Collaborative Learning 2023, Springer. In Press (Seot 2023).

Workshops
Hernández-Leo, D., Ortiz-Beltrán, A., Balcells, P., (2022) TEASPILS: Plantes i tecnologia.Creació d'activitats d'aprenentatge. Presentation at Maker Faire Barcelona, on July 2, 2022, Barcelona, Spain.
https://docs.google.com/presentation/d/1wpr6tN-jOcBkYitUXOrWgtmYRomYaWWi1W9MKaAZLmk/edit#slide=id.p

Hernández-Leo, D., Ortiz-Beltrán, A., Balcells, P., (2022) Sensors, IoT per l'aprenentatge STEAM i el desenvolupament de consciència mediambiental. Presentation at Maker Faire Barcelona, on July 1, 2022, Barcelona, Spain.
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6. Challenges and Lessons Learned

The implementation of IO4 was not without its challenges, which provided valuable insights and opportunities for growth. This section outlines the key challenges encountered during the project's execution and the lessons gleaned from navigating these hurdles.

Pilot at Bachelor classroom in UPM

1. Technological Accessibility and Equity: Ensuring uniform access to IoT devices and technology across diverse educational settings proved to be a challenge. Variations in resources and technological infrastructure posed barriers to seamless implementation. The lesson learned here was the importance of strategic planning to accommodate technological disparities and create an inclusive learning environment for all participants.

2. Integrating IoT and Plant Learning: Merging IoT technology with plant-based curricula required careful balance. Some educators found it challenging to effectively intertwine these seemingly disparate concepts. The lesson learned was the significance of providing educators with comprehensive training that bridges the gap between these domains, enabling them to seamlessly integrate technology and plant-focused content.

3. Data Interpretation Complexity: Interpreting data collected from IoT sensors posed a challenge, particularly for younger students. The complexity of data analysis and its translation into meaningful ecological insights required creative teaching approaches. The lesson learned was the need for scaffolding data interpretation skills, ensuring students could extract meaningful conclusions from the collected data.

4. Cultural and Regional Variations: Educational contexts across Greece, Spain, and Austria exhibited cultural and regional differences that influenced the implementation of learning activities. Adapting activities to align with local contexts while retaining the project's core objectives was a balancing act. The lesson learned was the value of flexible curricular design that respects cultural nuances while maintaining a cohesive project framework.

5. Pedagogical Autonomy vs. Project Objectives: Granting educators pedagogical autonomy while ensuring alignment with project objectives required careful communication. Some educators diverged significantly from the recommended methodologies, impacting the project's intended

outcomes. The lesson learned was the importance of clear communication and ongoing support to strike a balance between teacher creativity and project cohesion.

6. Sustainability Beyond the Project: Ensuring the sustainability of the IoT ecosystem and plant-based learning initiatives after the project's conclusion presented a challenge. Establishing mechanisms for ongoing training, support, and integration of these methodologies into broader curricula was a complex endeavor. The lesson learned was the necessity of proactive planning for sustaining the project's impact beyond its duration.

7. Student Engagement and Assessment: Assessing student engagement and learning outcomes across diverse age groups and activities posed challenges. Measuring the effectiveness of the project's multidisciplinary approach required tailored assessment strategies. The lesson learned was the importance of formative assessment methods that capture the holistic development of digital green competences.

8. Interdisciplinary Collaboration: Collaboration among educators from different subject areas required careful coordination. Interdisciplinary collaboration was essential for successful implementation, but it required educators to bridge gaps in knowledge and approach. The lesson learned was the value of facilitating regular communication and fostering a collaborative spirit among educators to create a cohesive learning experience.

In conclusion, the challenges faced during IO4 provided valuable opportunities for growth and refinement. Each challenge was met with a corresponding lesson that contributed to the project's ongoing evolution. The project's adaptability, commitment to equity, and dedication to fostering innovative educational practices were reaffirmed through the process of addressing these challenges.